Appendix B-10: Alternative 11

Summer Rainfall

HEC-ResSim Initial Alternative Assessment

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1. Alternative Description & Objective

The objective of Alternative 11 is to analyze different operating options during the summer months in order to mitigate flooding from large summer rainfall events. In this case, summer was defined as May 15th to September 1st. For this alternative, no operational changes were made outside the summer months.

This alternative was divided into two variants. The first variant, Alternative 11a, created a summer surcharge level (SSL) at Rafferty Reservoir of 1809.4 ft (551.5 m). This elevation is equivalent to the Inflow Design Flood Storage Level (IDFSL) defined by the reservoir's Reservoir Management Manual. Once the reservoir exceeds its SSL during summer, it makes largely unconstrained releases until its pool returns to SSL, its only rules being a rate of increase (ROI) and a rate of decrease (ROD) rule during that time. At Grant Devine Reservoir, no SSL was added; however, the reservoir was allowed to make unconstrained releases from May 15th to June 1st to bring the pool down to FSL by June 1st.

Alternative 11a also increased downstream flow constraints at Rafferty, Grant Devine and Lake Darling reservoirs during the summer months. At Rafferty, flow constraints were increased when the reservoir's pool elevation was between Full Supply Level (FSL) and SSL. At Grant Devine and Lake Darling, flow constraints were increased whenever the reservoir's pool elevation was above FSL. Table 1, Table 2, and Table 3 show the adopted downstream maximum rules for Rafferty, Grant Devine and Lake Darling, respectively, during the summer months. No modifications were made to the operation of Boundary Reservoir.

Table 1. Alternative 11a, Rafferty Reservoir maximum release rule (May 15-Sep 1)

Rafferty Reservoir (May 15th – Sep 1st)			
Baseline		Alternative 11a	
Elevation (ft)	**Downstream Constraint (ft^3/s)**	**Elevation (ft)**	**Downstream Constraint (ft^3/s)**
1763.45	706	1763.45	706
1808.1	883	1806.4	1,236
1809.1	1,236	1807.7	1,942
1810.1	1,942	1809.4	3,531
1817.59	1,942		

Table 2. Alternative 11a, Grant Devine Reservoir maximum release rule (Jun 1-Sep 1)

Grant Devine Reservoir (Jun 1st – Sep 1st)			
Baseline		Alternative 11a	
Elevation (ft)	**Downstream Constraint (ft^3/s)**	**Elevation (ft)**	**Downstream Constraint (ft^3/s)**
1800	706	1800	706
1844.83	706	1844.5	883
1850.51	1,236	1845.5	1,236
1853	1,413	1846.5	3,178
1857.5	1,765	1847.1	11,300
1859	11,300		
1865	11,300		

*Note: From May 15th to Jun 1st, no downstream release constraints were applied to Grant Devine.

Table 3. Alternative 11a, Lake Darling maximum release rule (May 15-Sep 1)

Lake Darling (May 15th – Sep 1st)			
Baseline		Alternative 11a	
Elevation (ft)	**Downstream Constraint (ft^3/s)**	**Elevation (ft)**	**Downstream Constraint (ft^3/s)**
1598	500	1598	1,000
1599	1,000	1599	2,500
1600	2,500	1600	5,000

The second variant, Alternative 11b, added an SSL to both Rafferty and Grant Devine and lowered the Lake Darling FSL by 1 ft (0.3 m) to 1597 ft. Like 11a, when a reservoir exceeds SSL, it makes nearly unconstrained releases until its pool returns to FSL, with its only rules being an ROI and an ROD rule during that time. Unlike Alternative 11a, all downstream constraint rules were kept the same as the baseline model whenever the pool was below SSL.

1.1 Alternative Development

Alternative 11 was developed after receiving input from Elizabeth Nelsen (U.S. Army Corps of Engineers), and Curtis Hallborg (Water Security Agency) following the May PAG/RAAG workshop in Minot, ND (personal communications, May 2019). Suggested downstream constraints for Rafferty and Grant Devine reservoirs were provided by Curtis Hallborg, and suggested downstream constraints for Lake Darling were provided by Liz Nelsen. This alternative was modeled based on the preliminary Plan of Study HEC-ResSim model.

1.2 Alternative Fine Tuning

To prevent unrealistic changes in reservoir releases during May, rate of increase and rate of decrease rules were developed and added to Rafferty and Grant Devine reservoirs. These rules are directly related to the maximum flows that can be expected during a flood event. The main assumptions when developing these ROD and ROI rules were (1) flows can only increase up to 100% in a single time step, and (2) there is no need to ramp up outflows quickly as during real flood operation. Figure 1 illustrates the rate of increase and decreased used for both reservoirs as a function of existing releases. If Alternative 11 is carried forward in Phase 3, these ROD and ROI rules should be refined to better represent actual reservoir operation.

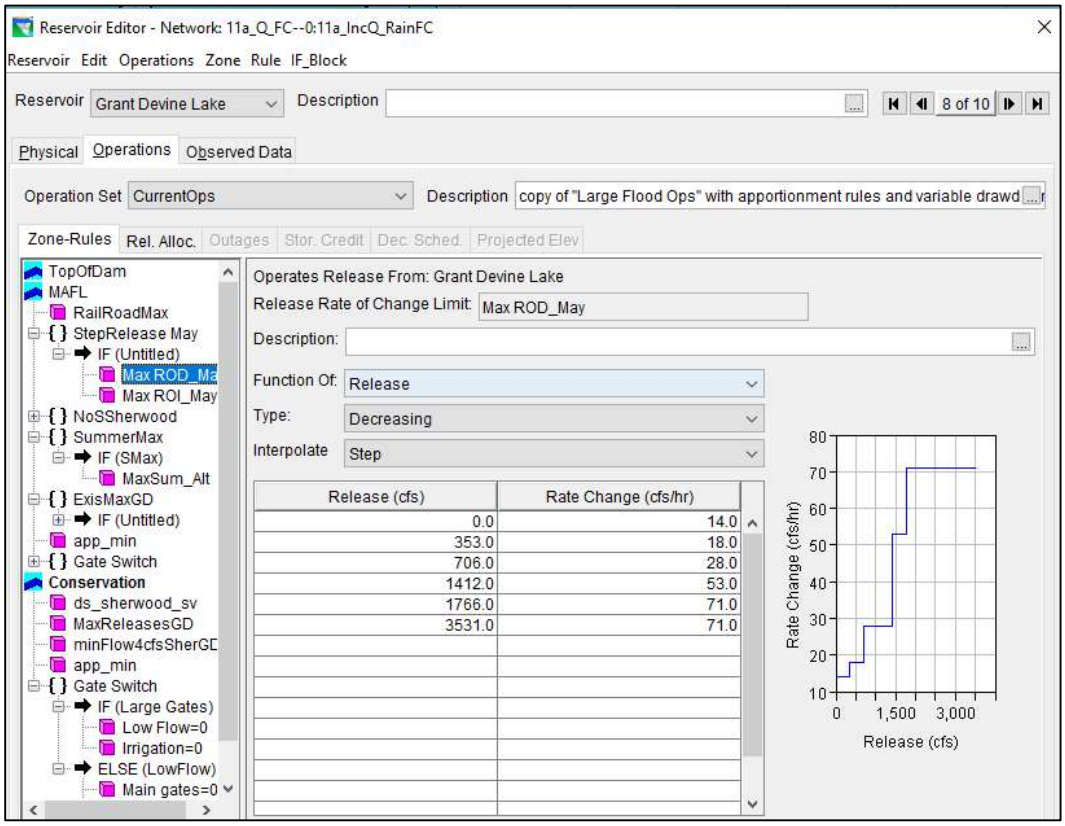


Figure 1. Rate of Decrease (ROD) release rate change rule

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 networks, alternatives and simulations used to model both baseline and alternative operations are listed in

Table 4.

Table 4. Model nomenclature

Scenario	Time Window	ResSIM Model Name	Network Name	Alternative Name	Simulation Name
Baseline	1946-2017	SourisRiver PoS	cal2Fsl	Base	00_BL_AnxA_46_17
Increased Downstream Constraints (11a)	1946-2017	SourisRiverPoS	11a_Q_FC	Summer Flood Ops	11a_IncQ_RainFC
Lower Darling FSL (11b)	1946-2017	SourisRiverPoS	11b_FSL_F	11b Summer Flood Ops	11b_LwrFSL_RainFC_SY_EY

2. Operational Rules

2.1 Alternative 11a

Table 5 presents the operational rules that were added to the base HEC-ResSim model alternative to specifically reflect the changes required in support of the Summer Rainfall Operations Alternative 11a.

Table 5. Operation rules added specific to alternative 11a

Name of Dam	Name of Rule, Outlet or IF Statement or State Variable Element	Rule Description
Rafferty Reservoir	If Block: StepReleases_May	Ensures releases are staged according to the ROD/ROI defined for a May drawdown (i.e. 2011)
	Max ROD/ROI	Rate of increase and decrease developed by USACE based on observed during 2011
	If Block: SQincrea	Contains a conditional for that applies the summer max flows between May 15 and Sep 1
	If Block: exisEstMax/NoSSherwood	Applies the max flow constraints for Estevan and Sherwood when no summer ops
	Rule: AltMaxEstevan	Summer maximum constraints for Estevan
	Note that a new zone was define for Rafferty (SSurcharge)	
Grant Devine Reservoir	Rule: RailRoadMax	Rule to limit releases based on the Railroad crossing capacity downstream of Grant Devine
	If block: SummerMax	Contains the new maximum summer constraints for Grant Devine as a function of pool elevation
	Rule: MaxSum_Alt	New summer max constraints for

Name of Dam	Name of Rule, Outlet or IF Statement or State Variable Element	Rule Description
		this alternative
	If block: ExisMaxGD/NoSSherwood	Applies the existing max flow constraints for Estevan and Sherwood when no summer ops
	If Block: StepRelease May	It makes sure that the releases are staged according to the rod/roi defined for a May drawdown (i.e. 2011)
Lake Darling Reservoir	If block: SummerAlt	Applies the rule for the summer ops period (may 15-sep1)
	Rule: AltMaxMinot	New summer max constraints for Minot based on water level
	If block: Minot	Applies the existing rules when no summer ops

Table 6 presents the operational rules that were changed from the base HEC-ResSim model to specifically reflect the changes required in support of the Summer Rainfall Operations Alternative 11a.

Table 6. Operation rules modified specific to Alternative 11a

Name of Dam	Name of Rule, Outlet or IF Statement or State Variable Element	Rule Description
Rafferty Reservoir	If Block: exisEstMax/NoSSherwood	Applies the max flow constraints for Estevan and Sherwood when no summer ops
Grant Devine Reservoir	If block: ExisMaxGD/NoSSherwood	Applies the existing max flow constraints for Estevan and Sherwood when no summer ops
Lake Darling Reservoir	If block: Minot	Applies the existing constraints when no summer ops

The maximum rate of increase/decrease was added into the MAFL zone of both Canadian reservoirs to ensure releases weren't being increased or decreased at an unreasonable rate. Conditions were applied to the if blocks created in order to apply the rules seasonally. For example, all the maximum flows rules created for this alternative were applied for the summer ops period that was defined from May 15th to September 1st with the exception of Grant Devine, where no rules were applied from May 15th to June 1st in order to allow the reservoir to get back down to FSL by June 1st.

For Rafferty Reservoir, a new reservoir zone was defined named SSurcharge. This new zone allows elevations at Rafferty to surcharge by 3 ft (1 m) during the summer before the downstream constraints are removed. Downstream flow constraints were modified within this zone.

The maximum flow constraints for Grant Devine were also increased by the specified amount during summer operations. These downstream constraints were the only constraints that were applied during this period of time. A similar approach was applied to Lake Darling where max flow constraints were increased as a function of pool elevation.

The figures below illustrate where a rule/if statement was inserted into the ResSim model user interface for each reservoir. The relevant model feature is indicated by a red box. Figures Figure 2 through Figure 9 show the changes to Rafferty, Figures Figure 10 through Figure 14 illustrate the additions to Grant Devine and Figures Figure 15 through Figure 17 show changes made to Lake Darling.

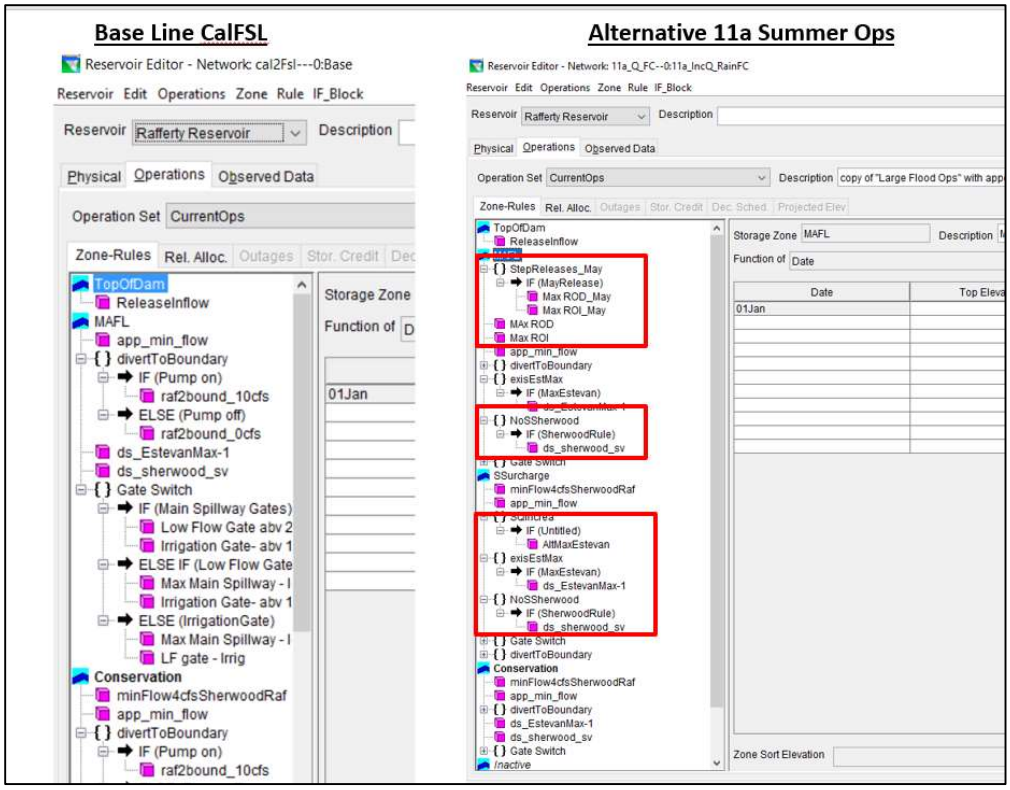


Figure 2. Overview of changes made to Rafferty

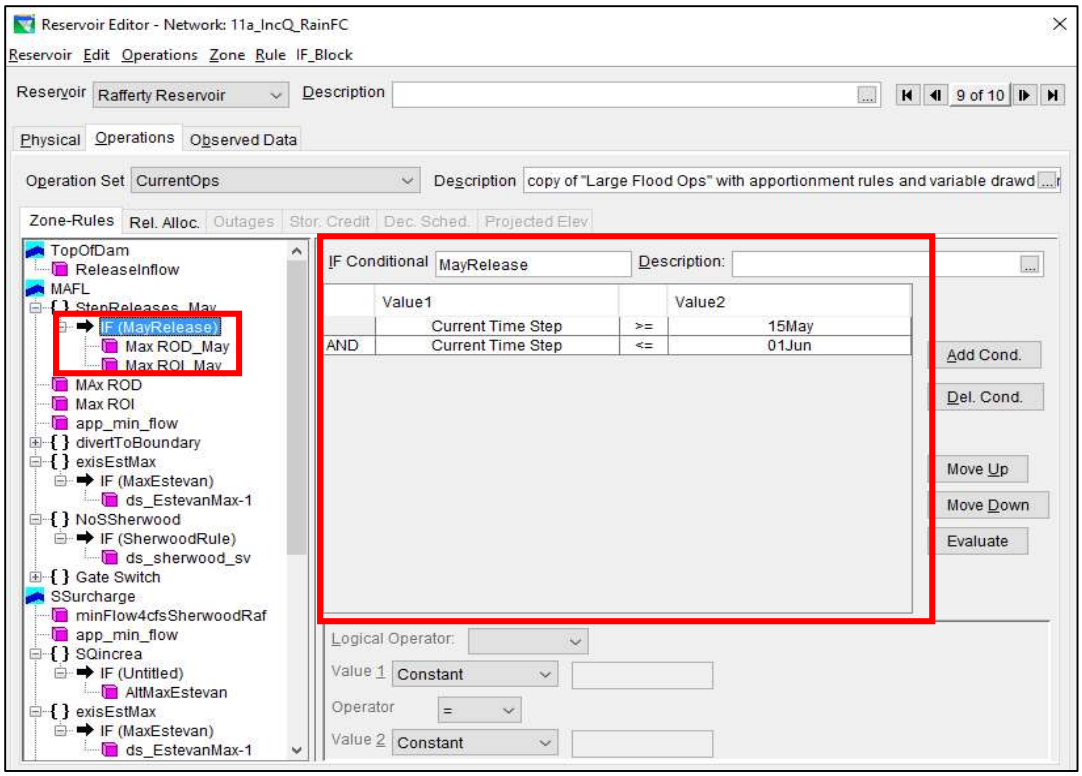


Figure 3. Changes made to Rafferty – If Block: StepReleases_May

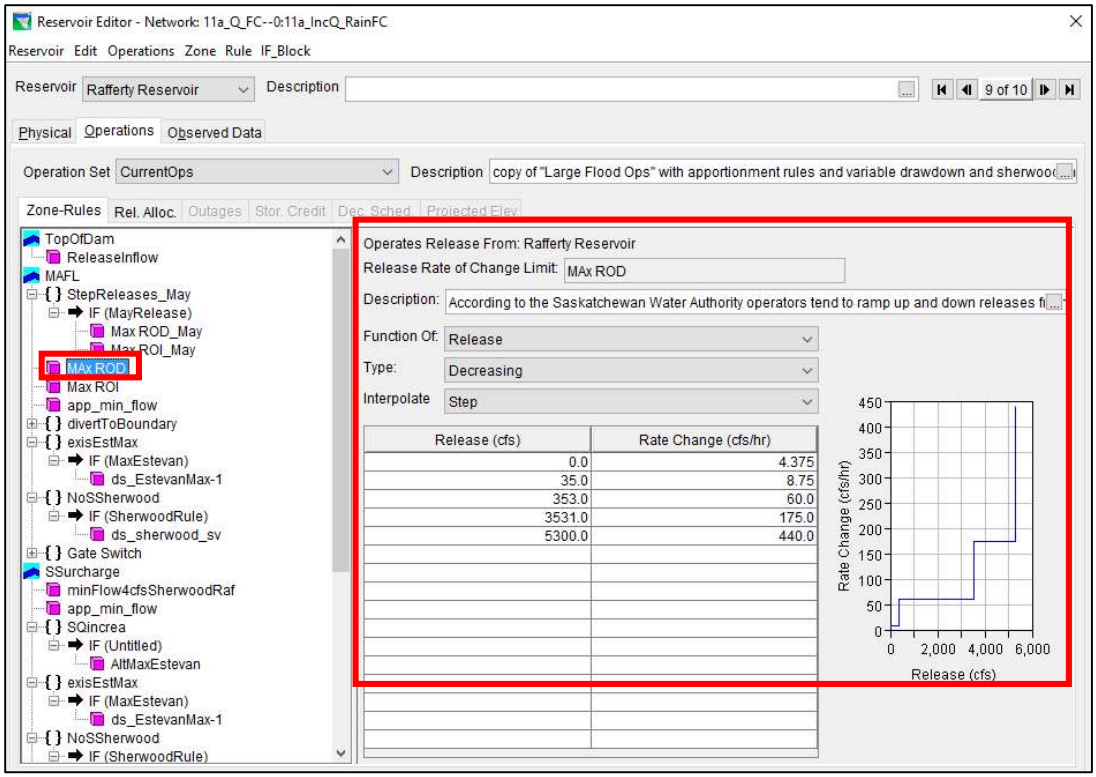


Figure 4. Changes made to Rafferty – Max ROD

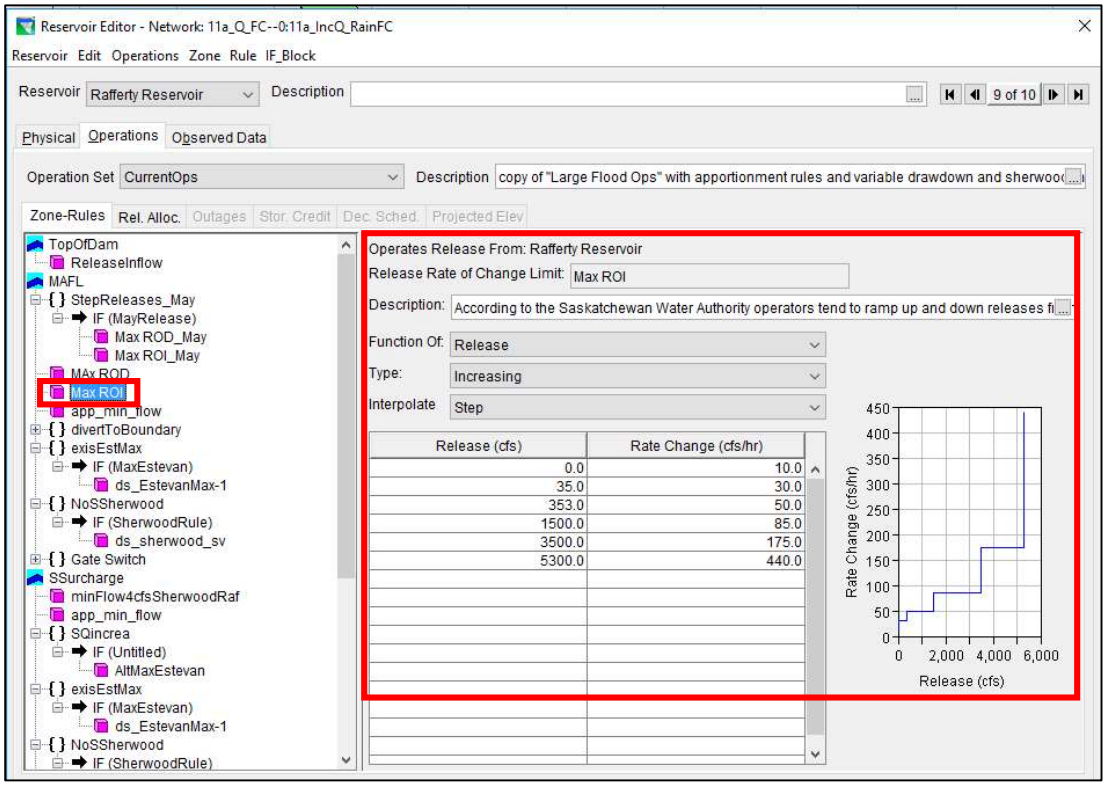


Figure 5. Changes made to Rafferty – Max ROI

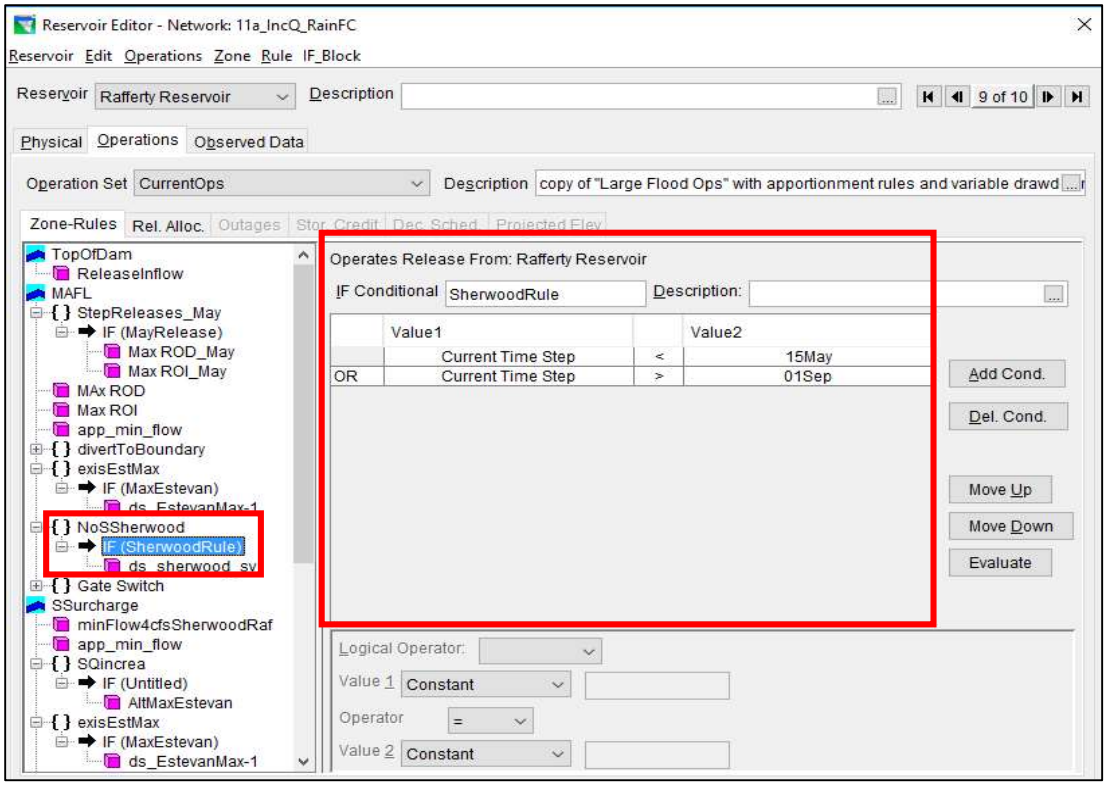


Figure 6. Changes made to Rafferty – If Block: NOSSherwood

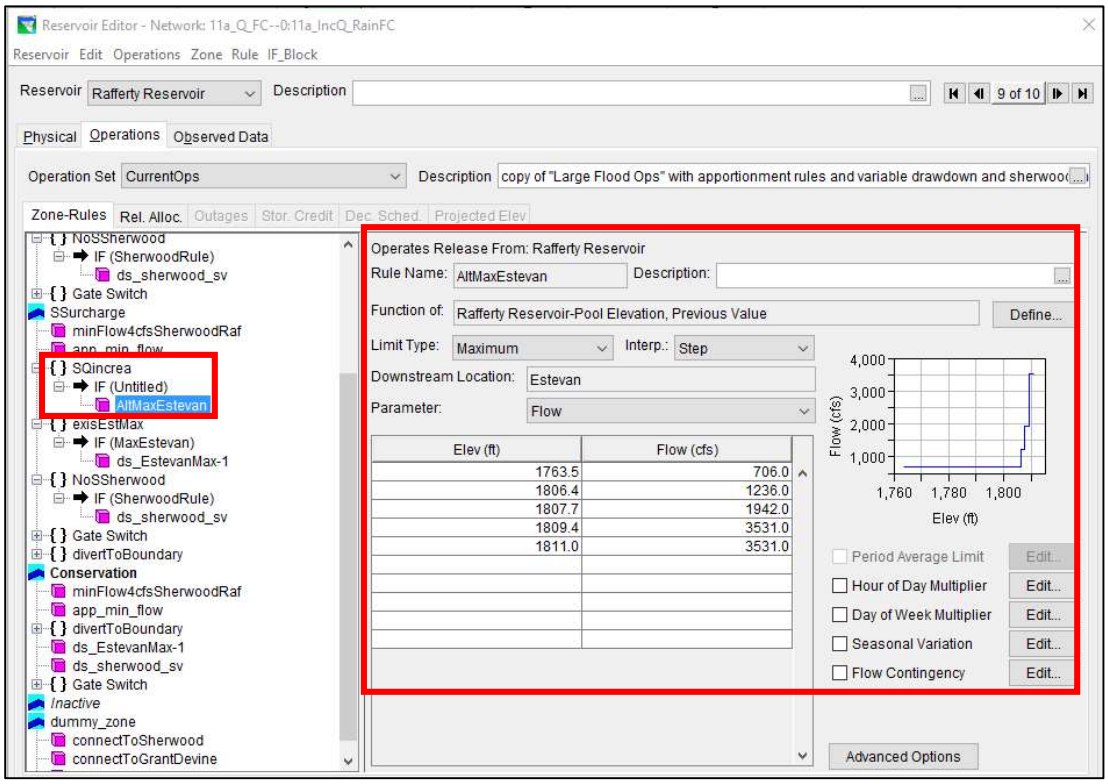


Figure 7. Changes made to Rafferty – If Block: SQincrea

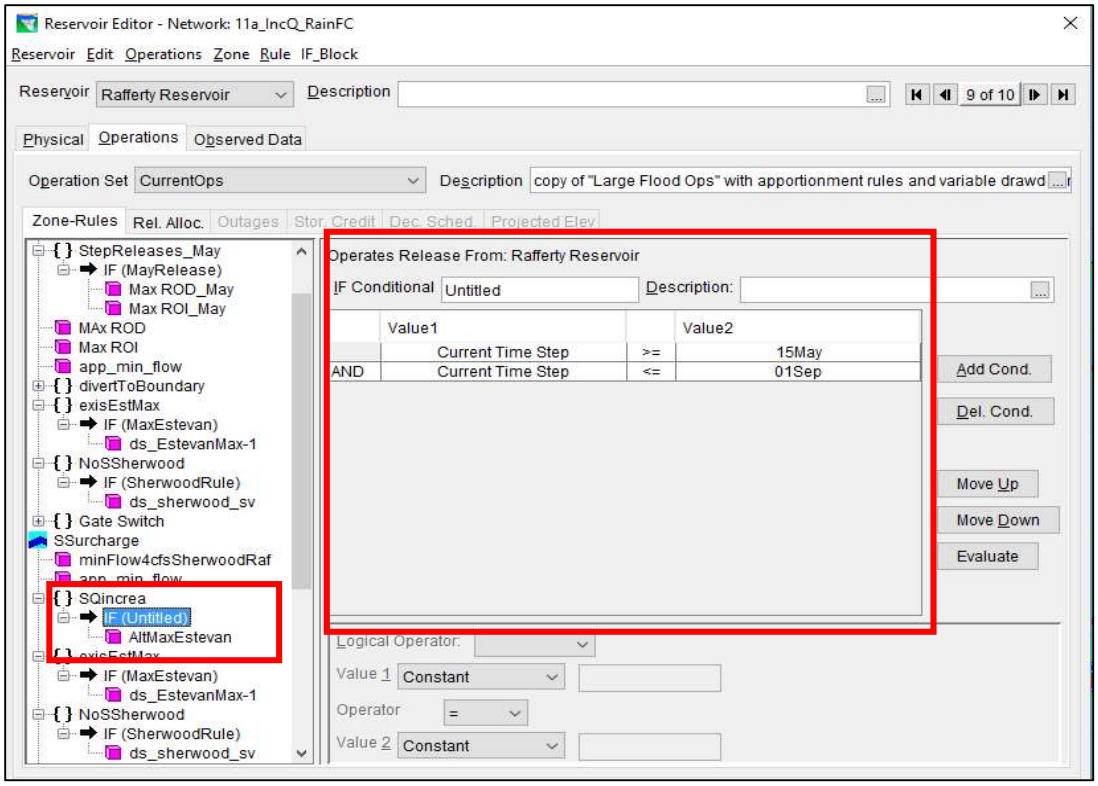


Figure 8. Changes made to Rafferty – If Block: SQincrea

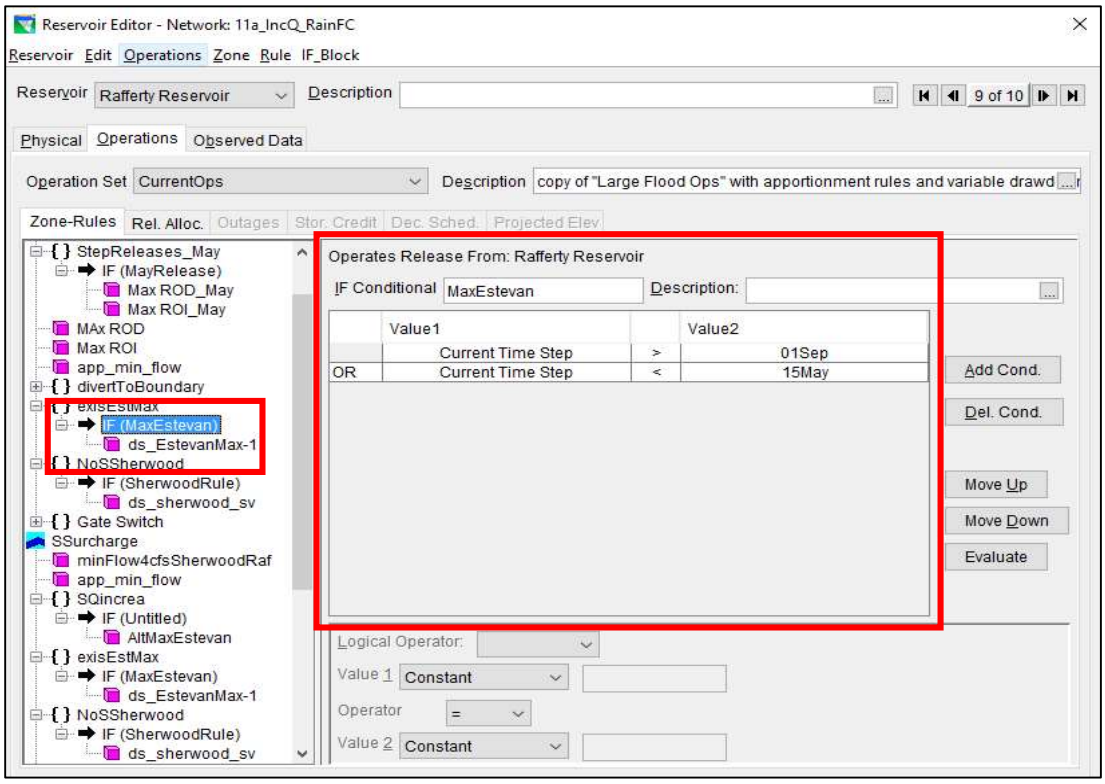


Figure 9. Changes made to Rafferty – If Block: exisEstMax

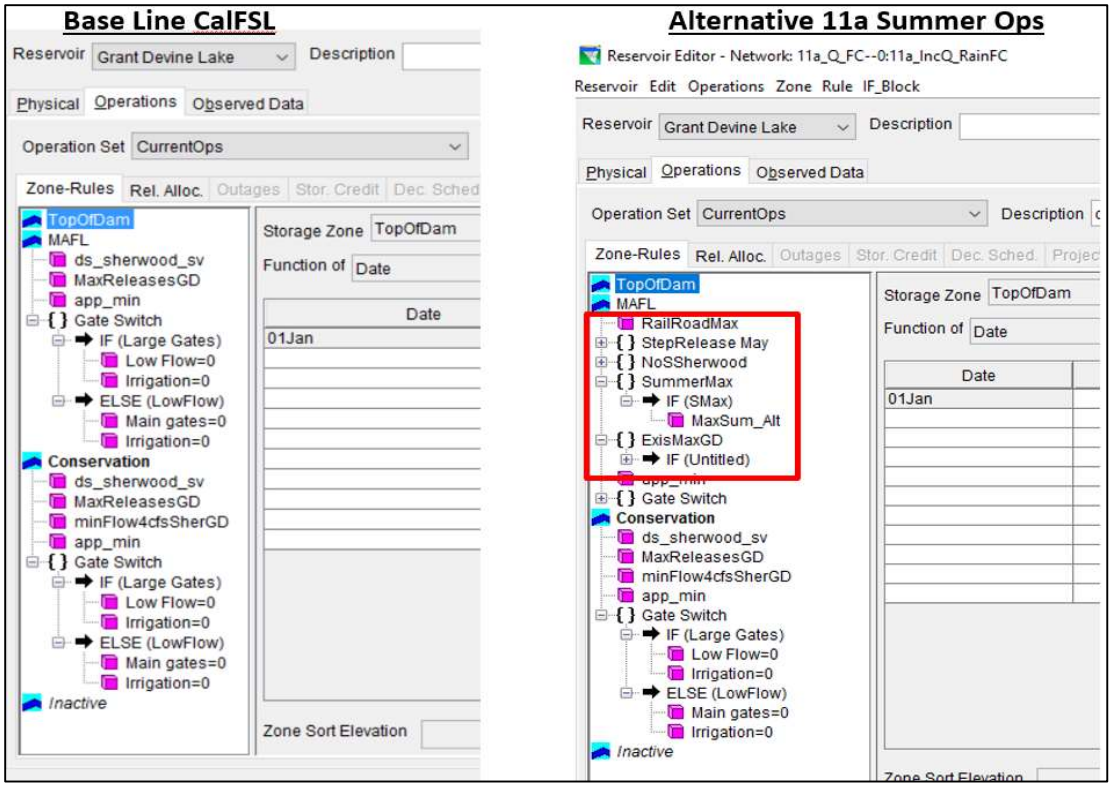


Figure 10. Overview of changes made to Grant Devine

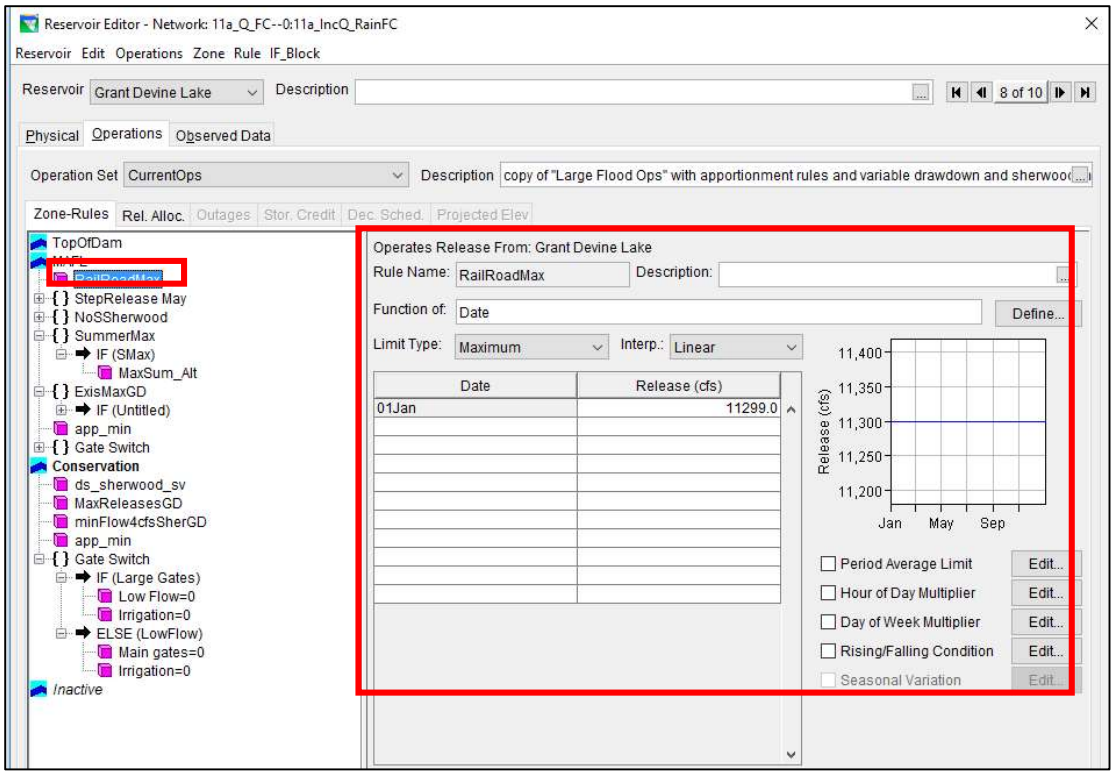


Figure 11. Changes made to Grant Devine – Rule:RailroadMax

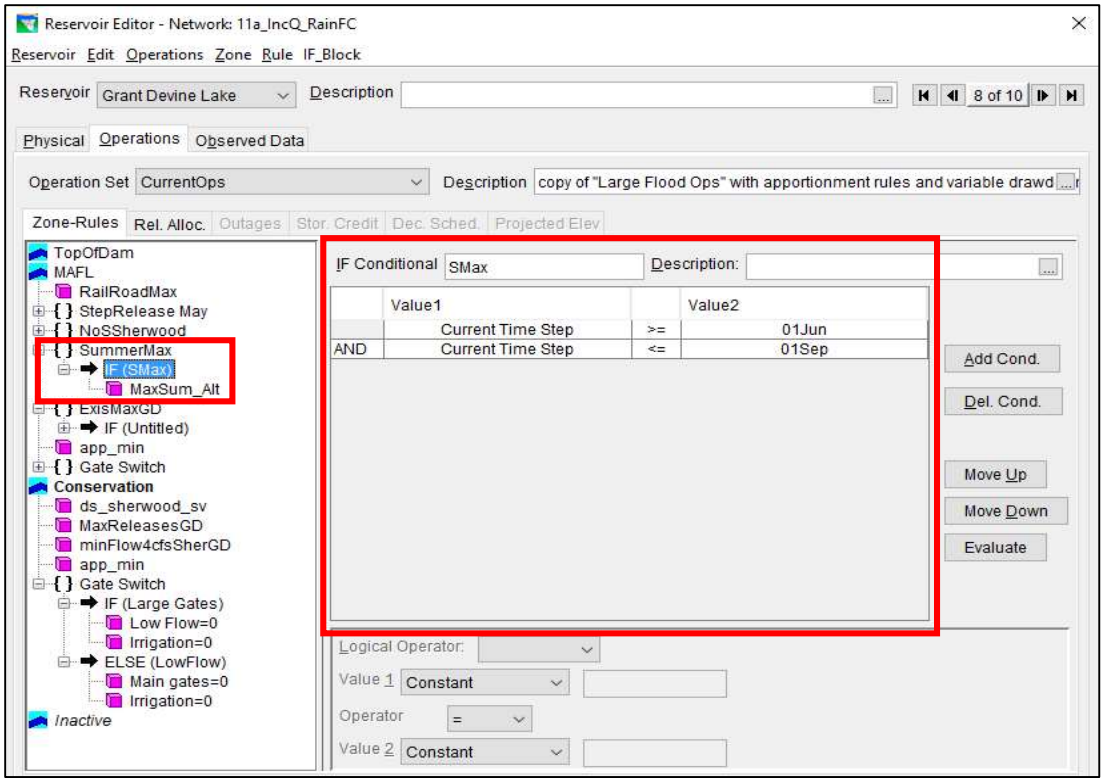


Figure 12. Changes made to Grant Devine – If Block: SummerMax

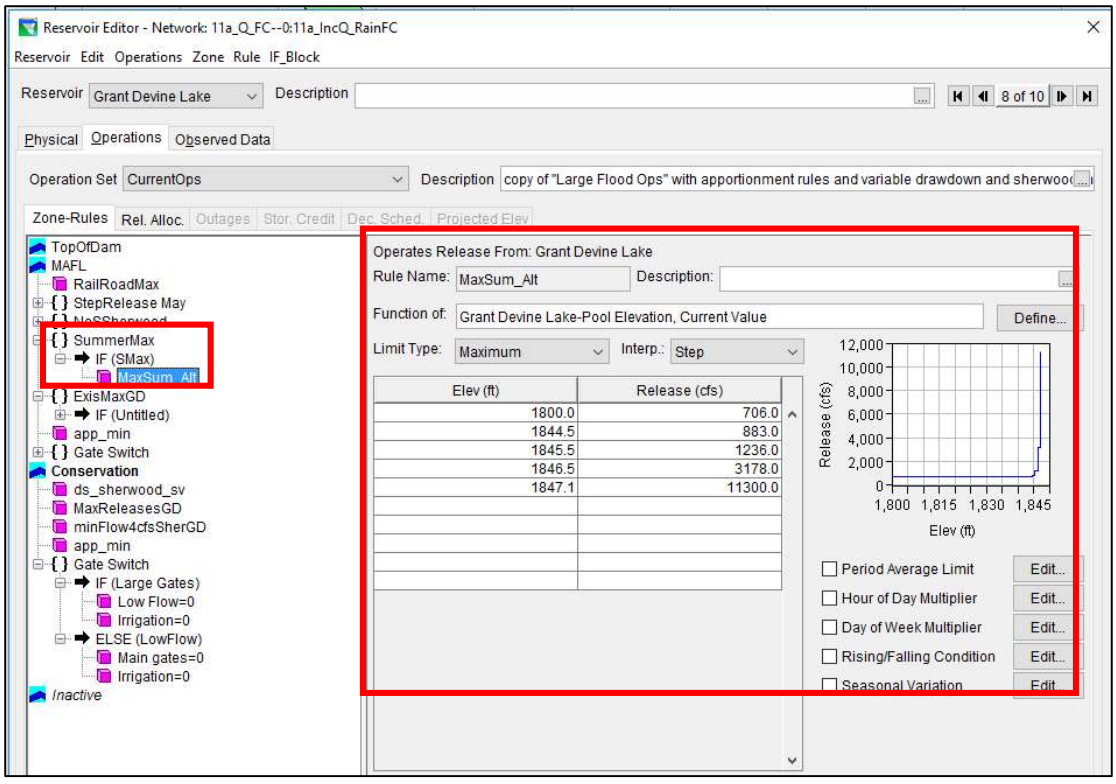


Figure 13. Changes made to Grant Devine – Rule MaxSum_Alt

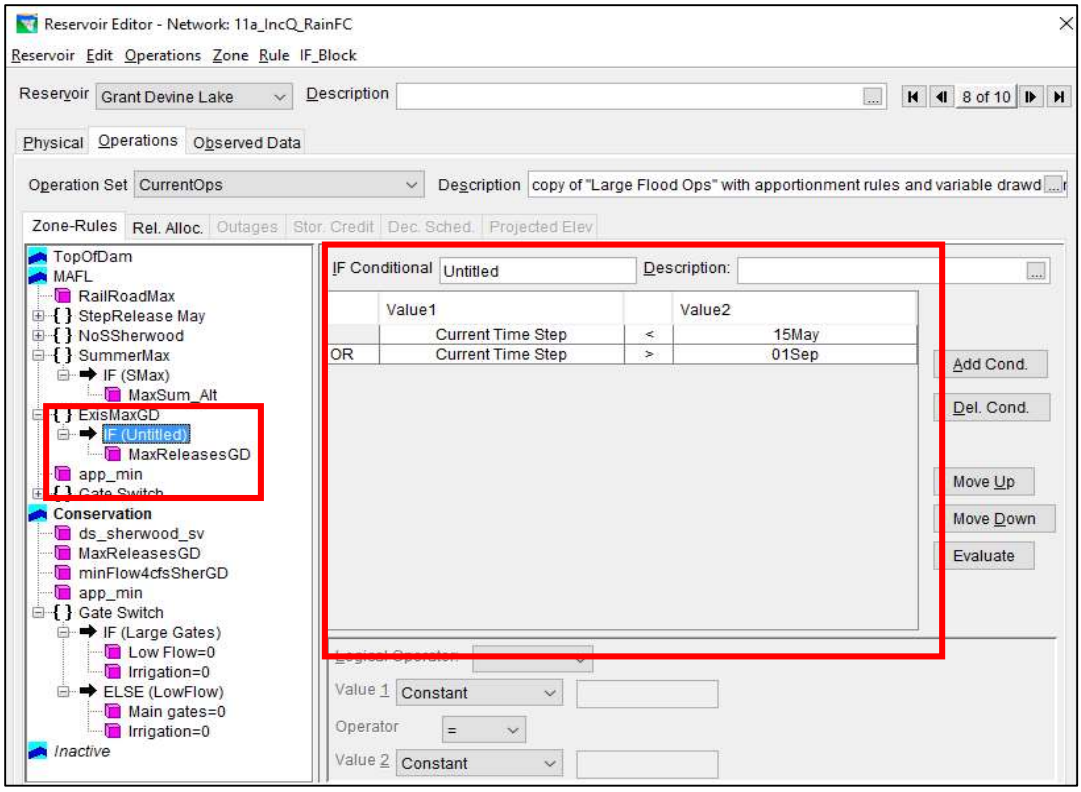


Figure 14. Changes made to Grant Devine – If Block: ExisMaxGD

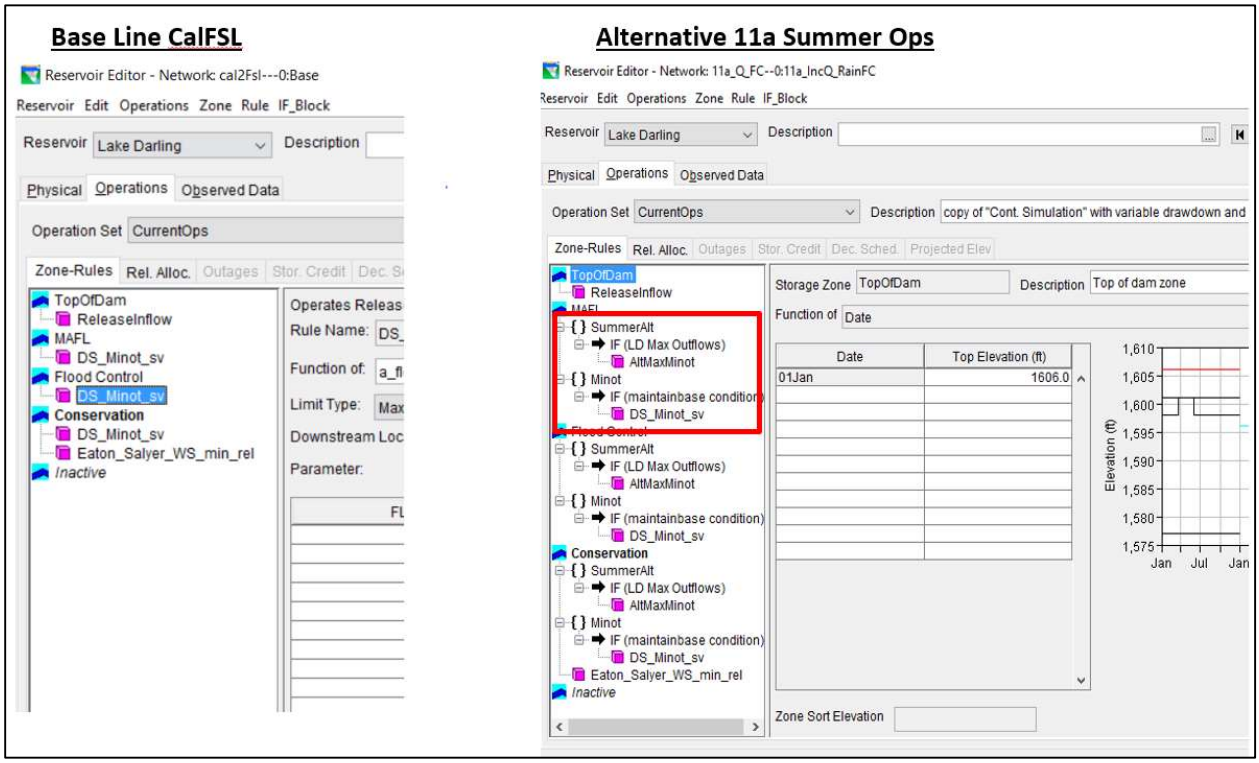


Figure 15. Overview of changes made to Lake Darling

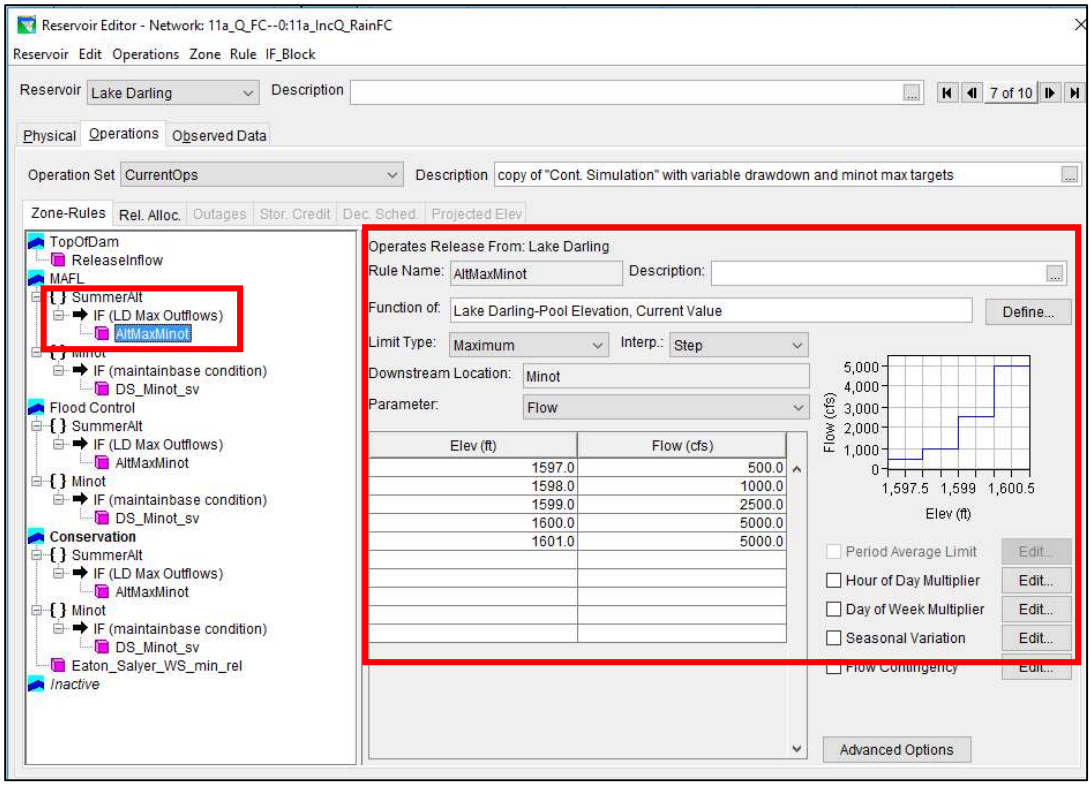


Figure 16. Changes made to Lake Darling – If Block: SummerAlt & Rule: AltMaxMinot

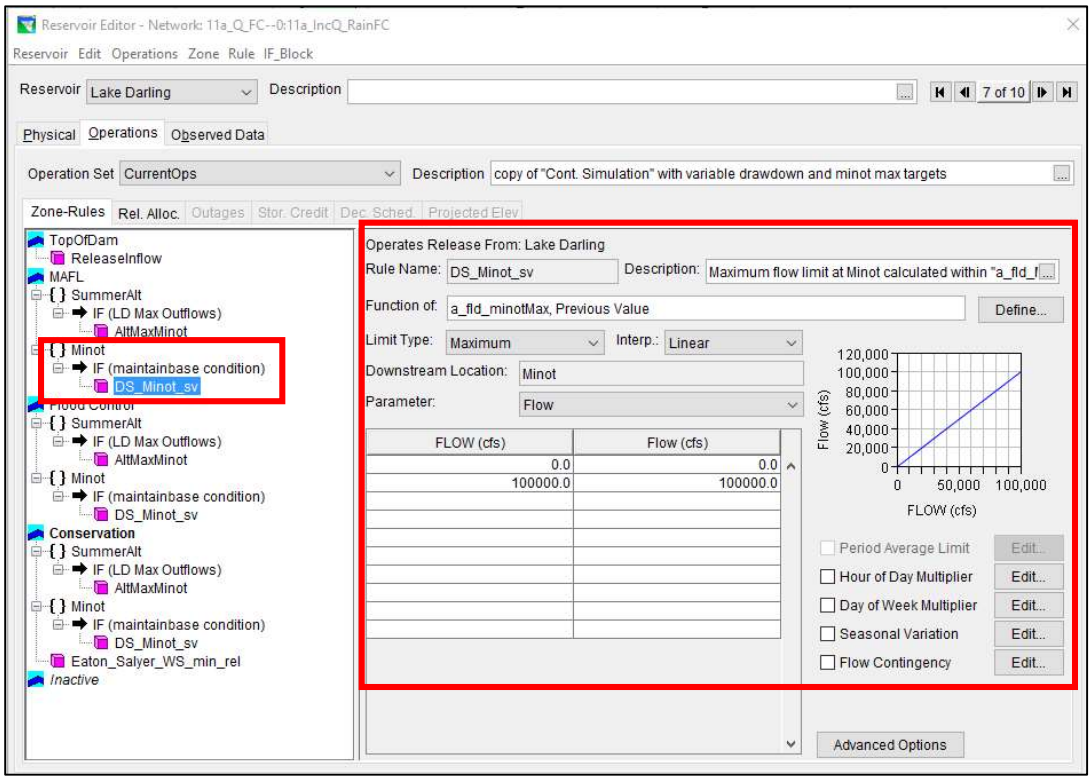


Figure 17. Changes made to Lake Darling – If Block: Minot

2.2 Alternative 11b

Table 7 presents the operational rules that were included in the base HEC-ResSim model to specifically reflect the changes required in support of the Summer Rainfall Operations Alternative 11b.

Table 7. Operation rules added specific to alternative 11b

Name of Dam	Name of Rule, Outlet or IF Statement or State Variable Element	Rule Description
Rafferty Reservoir	If Block: StepRelease_May	Ensures releases are staged according to the ROD/ROI defined for a May drawdown (i.e. 2011)
	Max ROD/ROI_May	Rate of increase and decrease developed to stage up and down May releases when the reservoir is above ssurcharge zone
	If Block: exisEstMax/NoSSherwood	Applies the max flow constraints for Estevan and Sherwood when no summer ops
	If Block: SQincrea	Contains a conditional for that applies the summer max flows between May 15 and Sep 1
	Rule: SQInc_Alt	
	Note that a new zone was define for Rafferty (SSurcharge); same rules as the Conservation zone apply with the additional rules/if blocks added as stated above	
Grant Devine Reservoir	If Block: StageMayRelease	Ensures releases are staged according to the ROD/ROI defined for a May drawdown (i.e. 2011)
	Max ROD/ROI_May	Rate of increase and decrease developed to stage up and down May releases when the reservoir is above ssurcharge zone
	If Block: NoSummerConst	Applies the max flow constraints for Estevan and Sherwood when no summer ops
	Rule: RailRoadMax	Rule to limit releases based on the Rail Road crossing capacity downstream of Grant Devine
	Note that a new zone was define for Grant Devine (SSurcharge); same rules as the Conservation zone apply with the additional rules/if blocks added as stated above	
Lake Darling Reservoir	State variable: darNormPool value	The Lake Darling normal pool value was modified in the state variable from 1597 to 1596 ft as required for this alternative

Table 8 presents the operational rules that were removed from the base HEC-ResSim model to specifically reflect the changes required in support of the Summer Rainfall Operations 11b.

Table 8. Operation rules removed specific to alternative 11b

Name of Dam	Name of Rule, Outlet or IF Statement or State Variable Element	Rule Description
Rafferty Reservoir	No rules were removed for this alternative, however, some of the existing rules were limited to the no summer flood ops period by using the if statements described previously	
Grant Devine Reservoir	MaxReleasesGD	This rule was removed from the MAFL zone. The alternative is only using the rail road crossing as max constraint

The maximum rate of increase/decrease was added into the MAFL zone of Rafferty and Grant Devine reservoirs to ensure releases weren't increased or decreased at an unreasonable rate. Conditions were applied to the if blocks created in order to apply the rules seasonally. For example, all the maximum flows rules created for this alternative were applied for the summer ops period that was defined from May 15th to September 1st. Outside of this time frame, the baseline conditions were applied.

This alternative required both Rafferty and Grant Devine to have an additional zone added above the conservation zone called SSurcharge. This new zone allows elevations at Rafferty to surcharge by 3 ft (1 m), and Grant Devine by 0.3 ft (0.1 m) during the summer before the downstream constraints are not applied. For Lake Darling, FSL was lowered using the state variable.

The following figures display where the rule/if statement was inserted into the ResSim model user interface for each reservoir. The relevant model feature is indicated by the red box. Figures Figure 18 through Figure 26 illustrate the additions that were made to Rafferty and Figures Figure 27 through Figure 30 show the changes made to Grand Devine that were necessary for this alternative. Figure 31 provides a screenshot of where the state variable script was modified to model the Lake Darling portion of this alternative. Relevant lines of the state variable script are indicated by the red box.

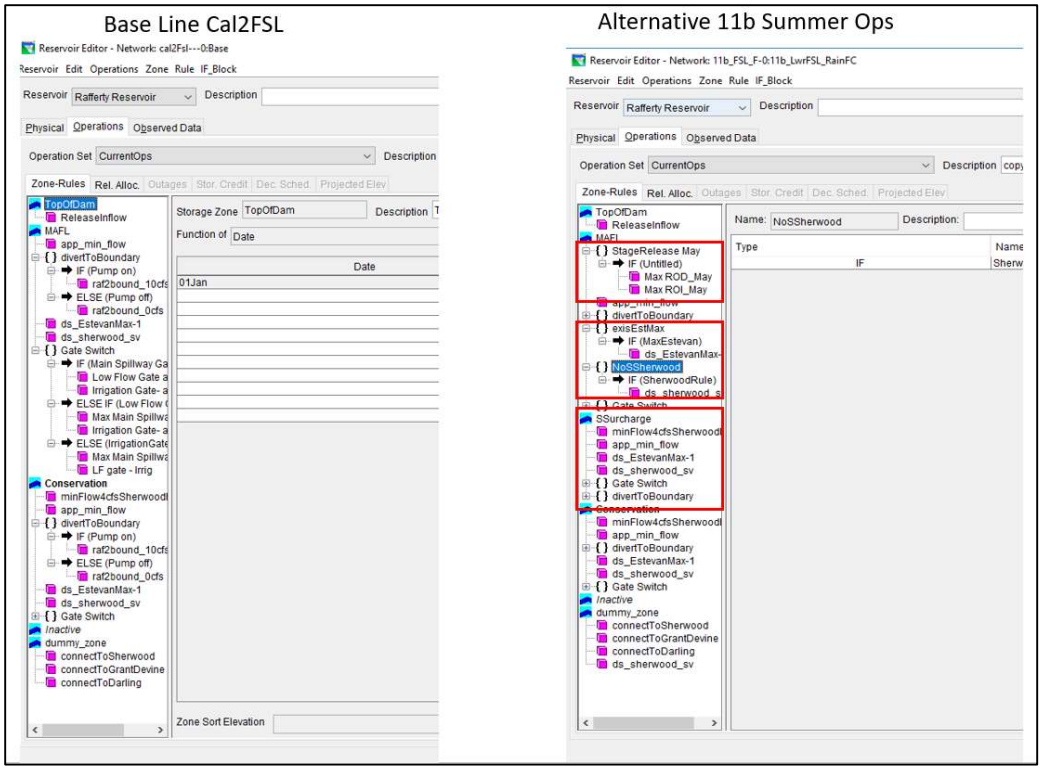


Figure 18. Overview of changes Made to Rafferty

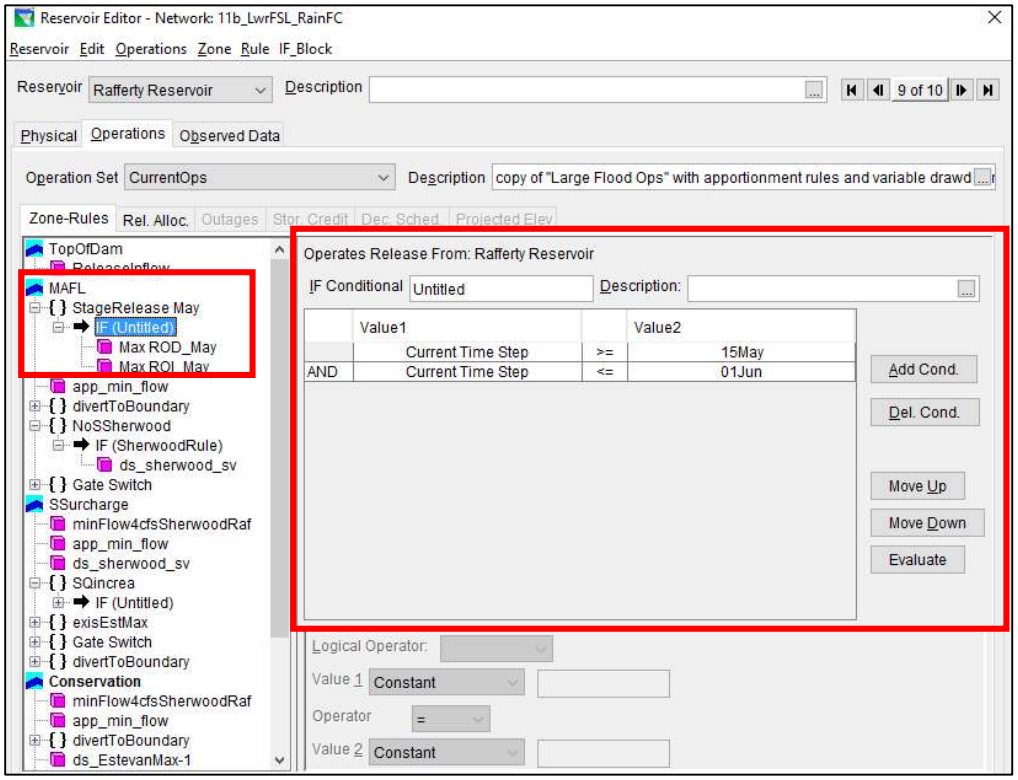


Figure 19. Changes made to Rafferty – IF Block: StageRelease_May

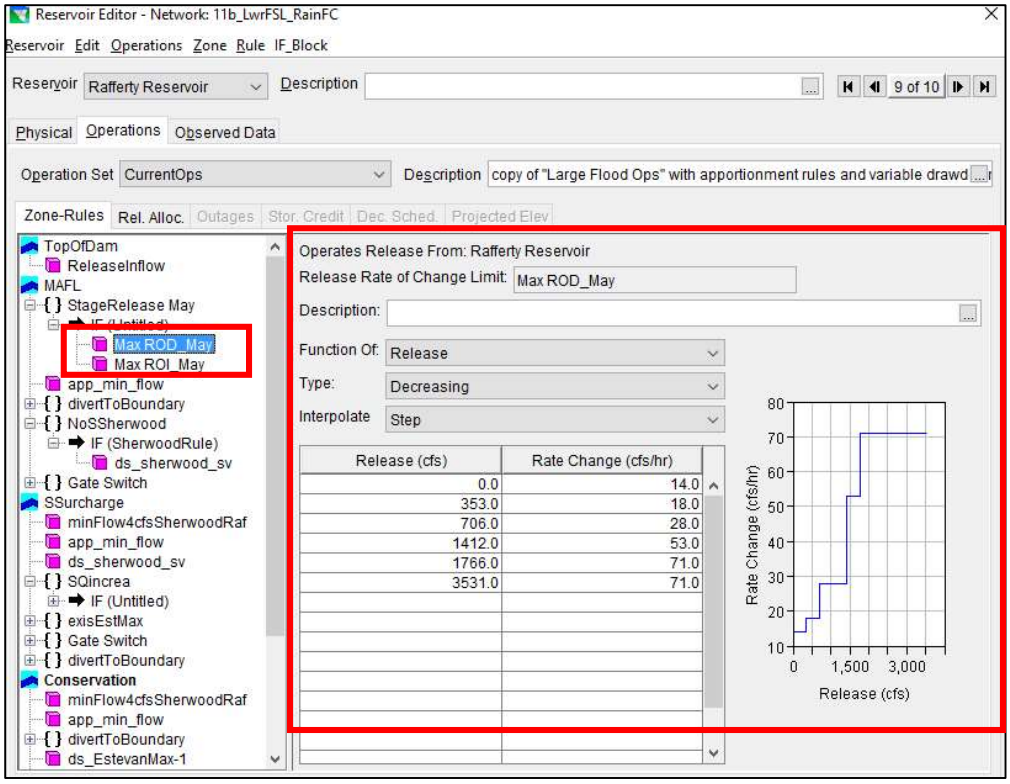


Figure 20. Changes made to Rafferty – MaxROD_May

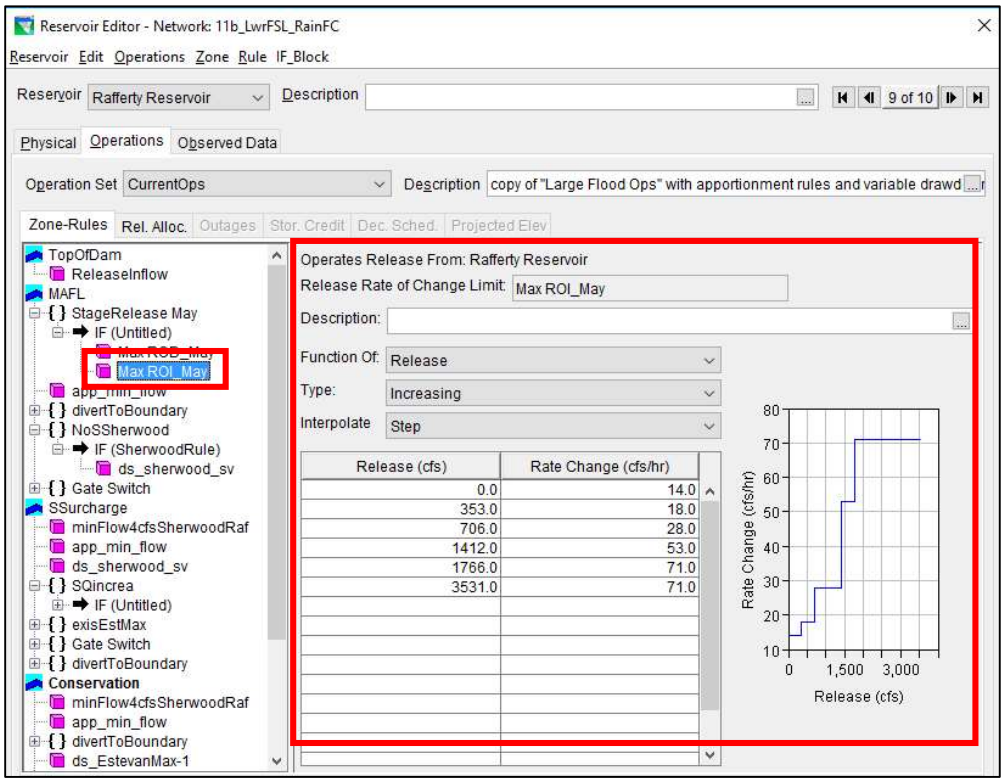


Figure 21. Changes made to Rafferty – MaxROI_May

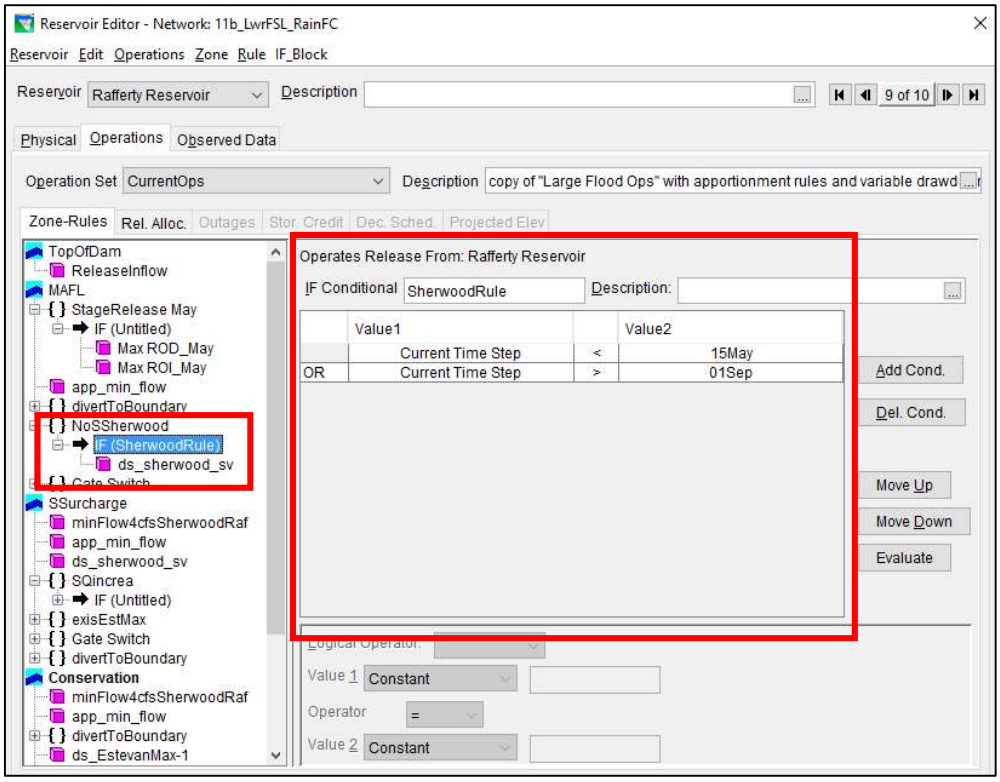


Figure 22. Changes made to Rafferty – If Block: NoSSherwood

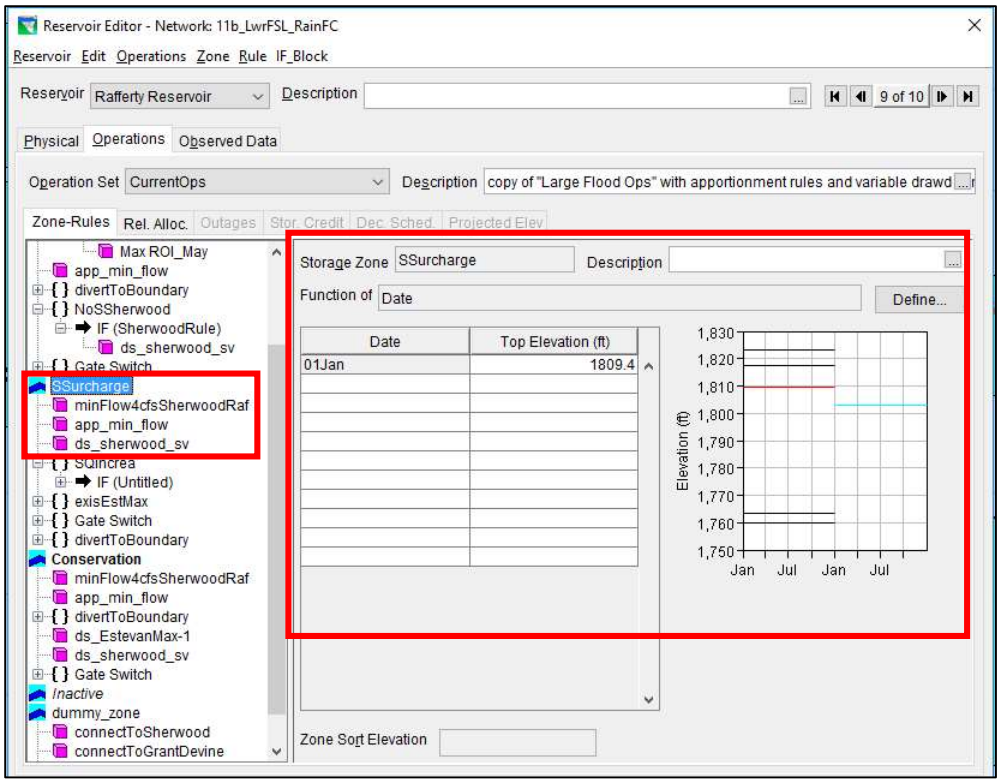


Figure 23. Changes made to Rafferty – New SSurcharge Zone

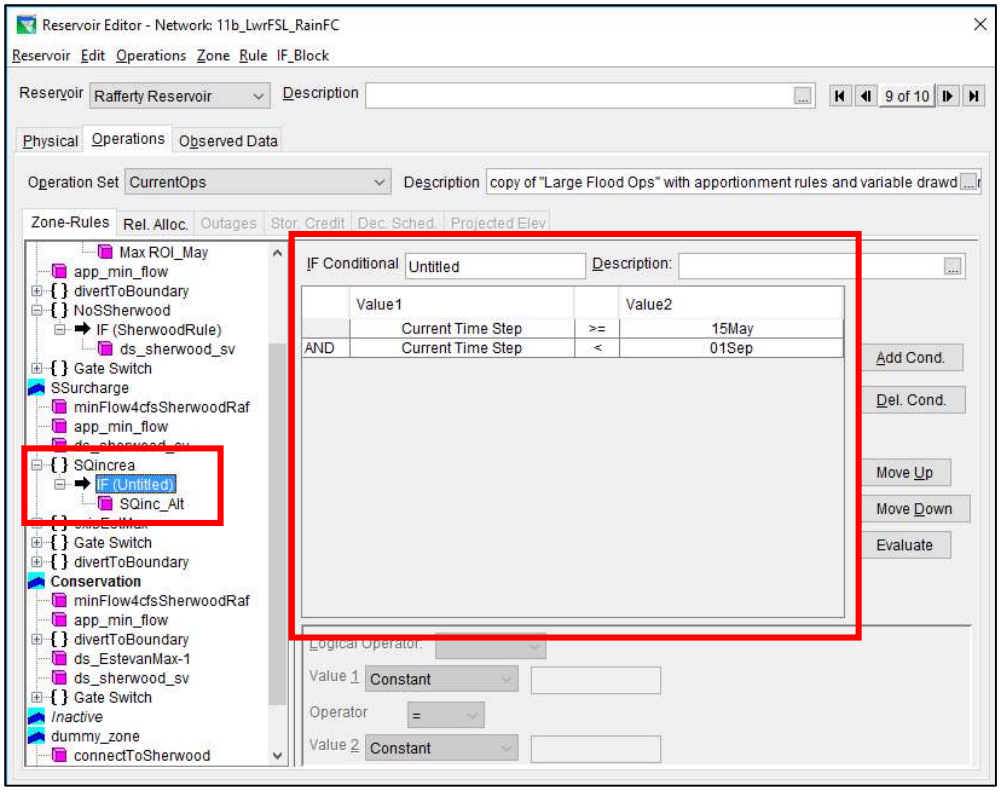


Figure 24. Changes made to Rafferty – If Block: SQincrea

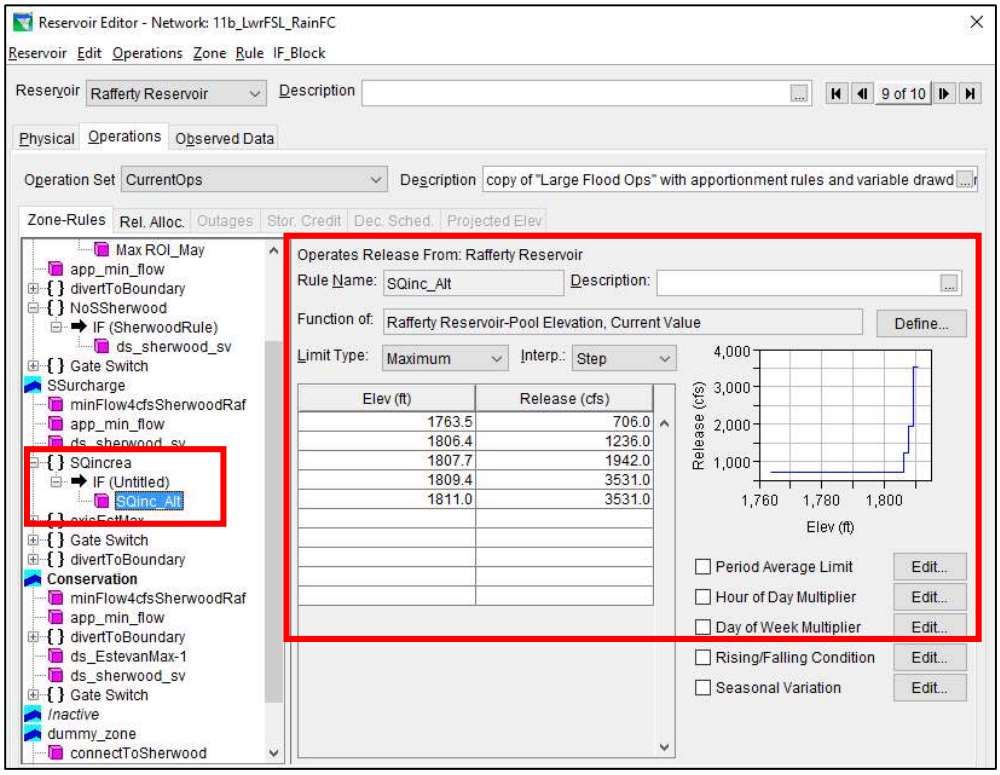


Figure 25. Changes made to Rafferty – New Rule: SQinc_Alt

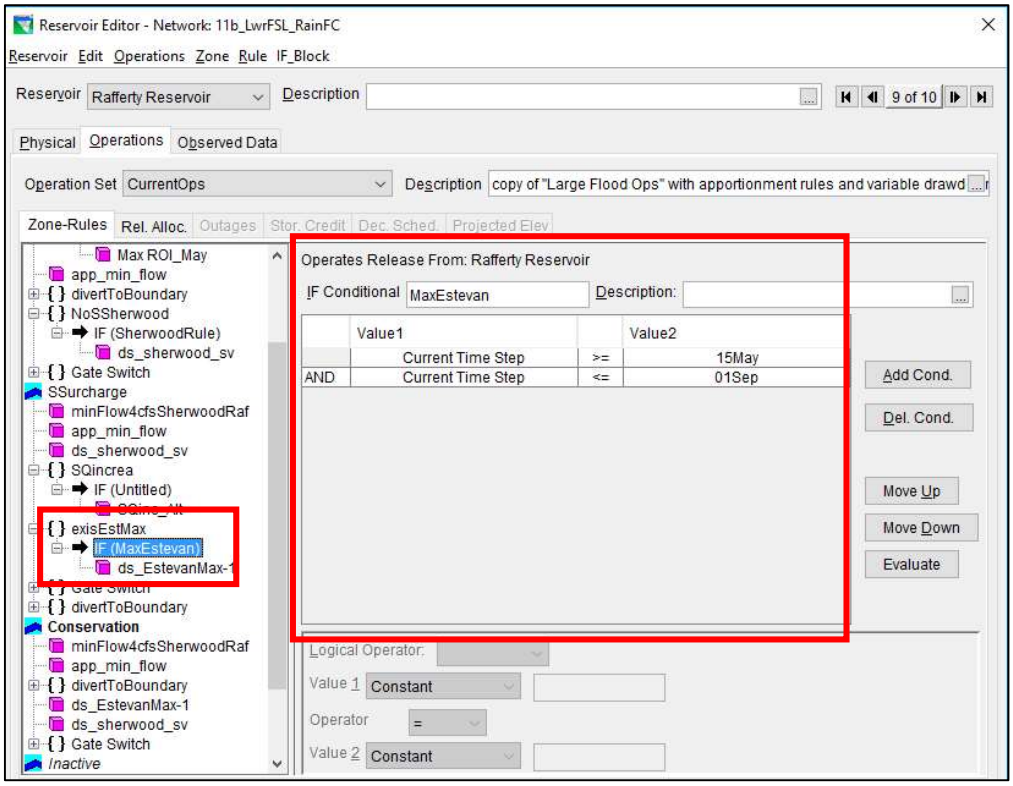


Figure 26. Changes made to Rafferty – If Block: exisEstMax

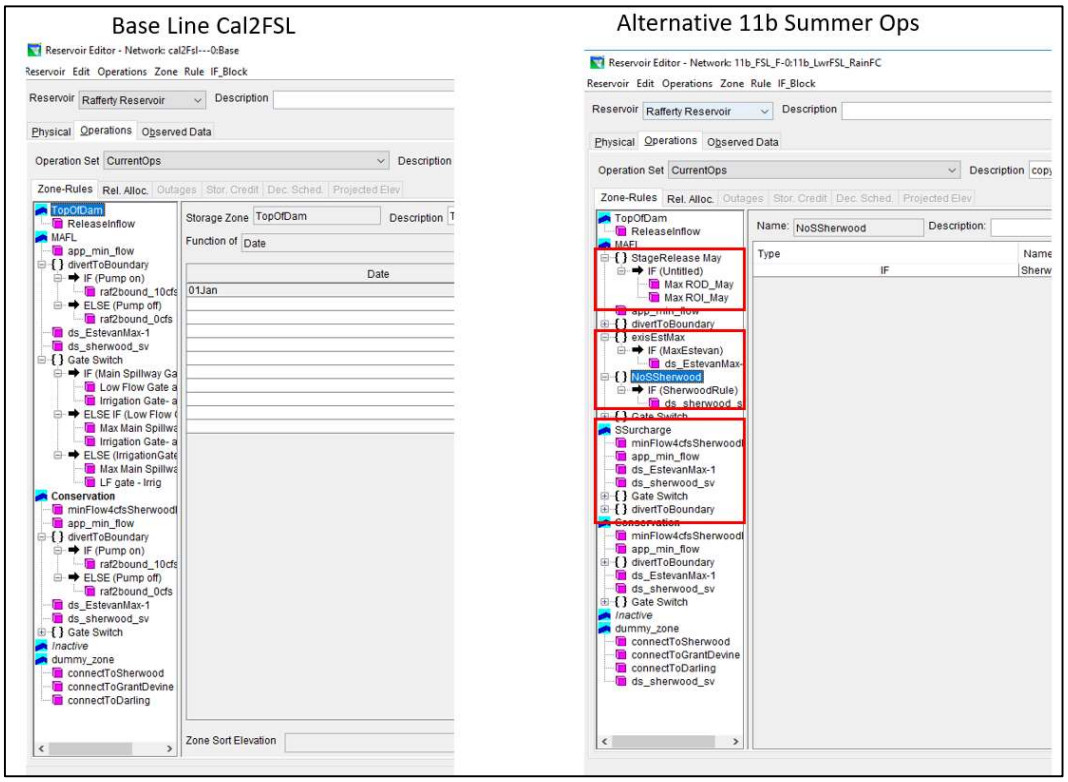


Figure 27. Overview of changes made to Grant Devine

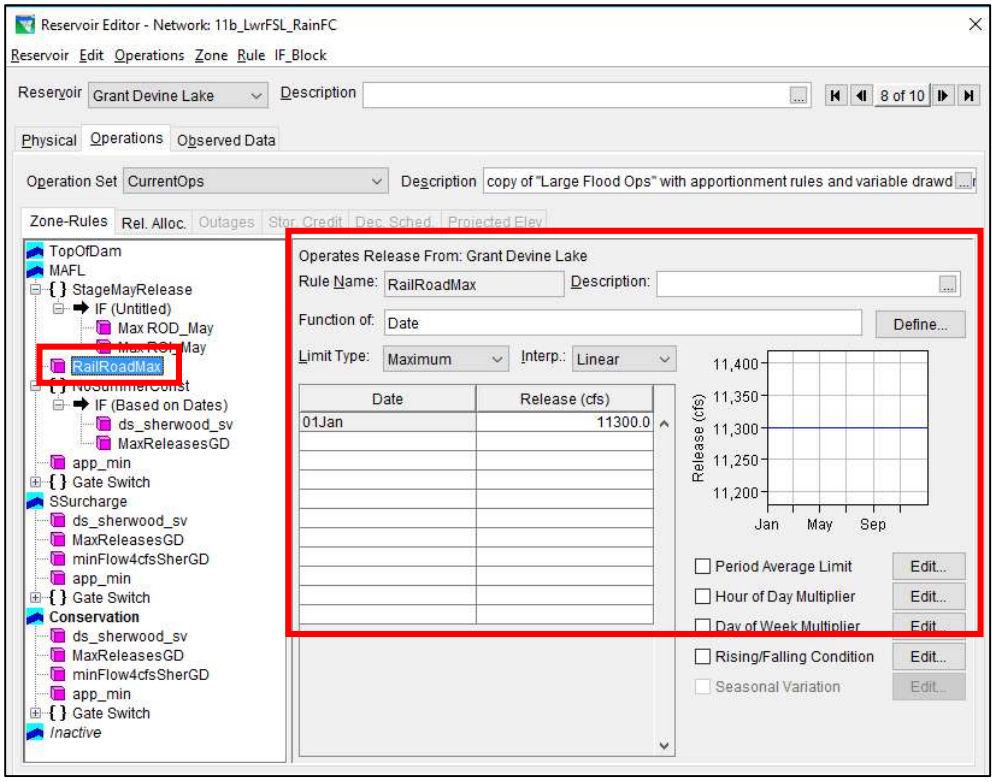


Figure 28. Changes made to Grant Devine – Rule: RailRoadMax

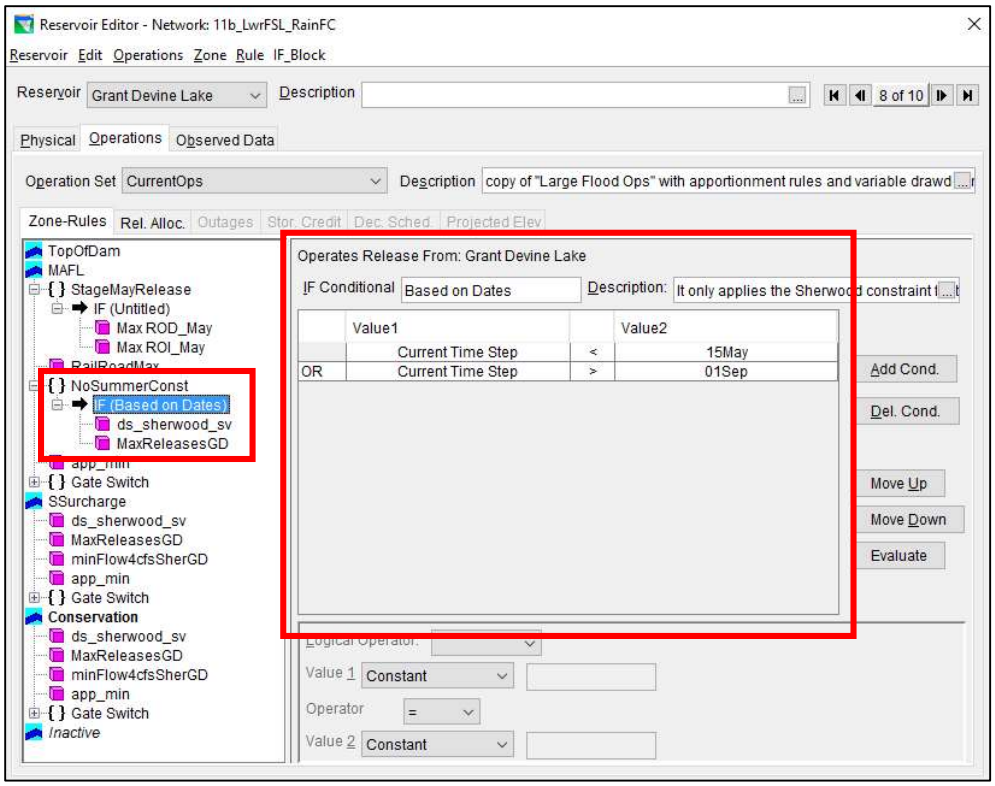


Figure 29. Changes made to Grant Devine – If Block: NoSummerConst

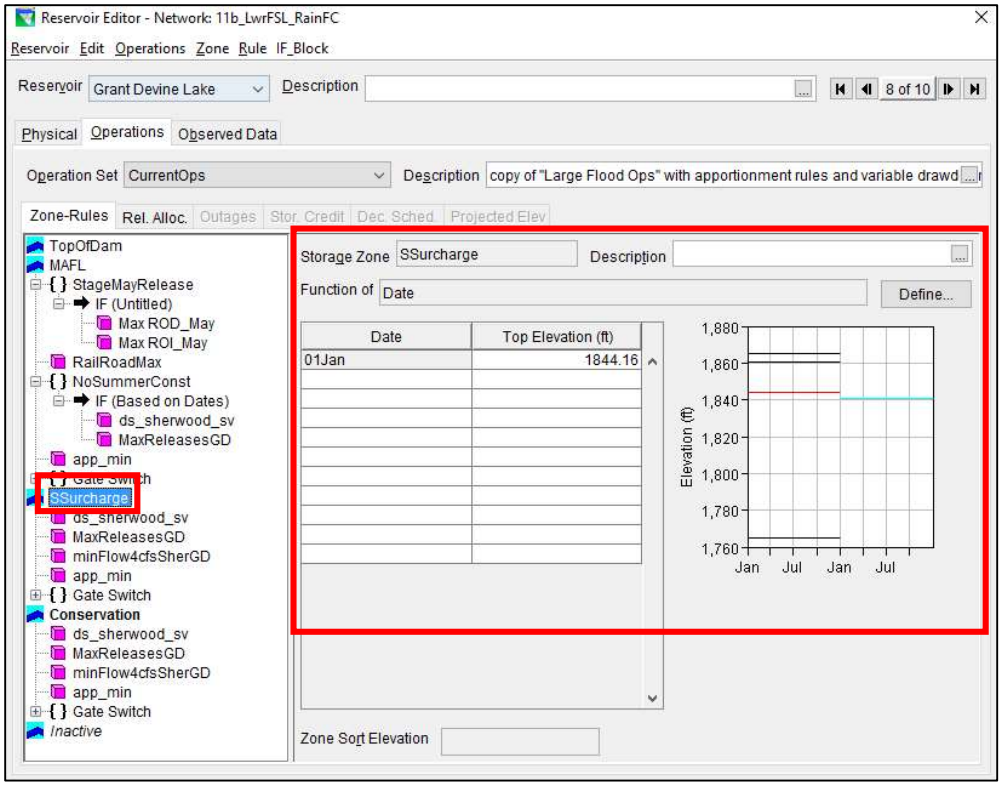


Figure 30. Changes made to Grant Devine – New Zone SSurcharge

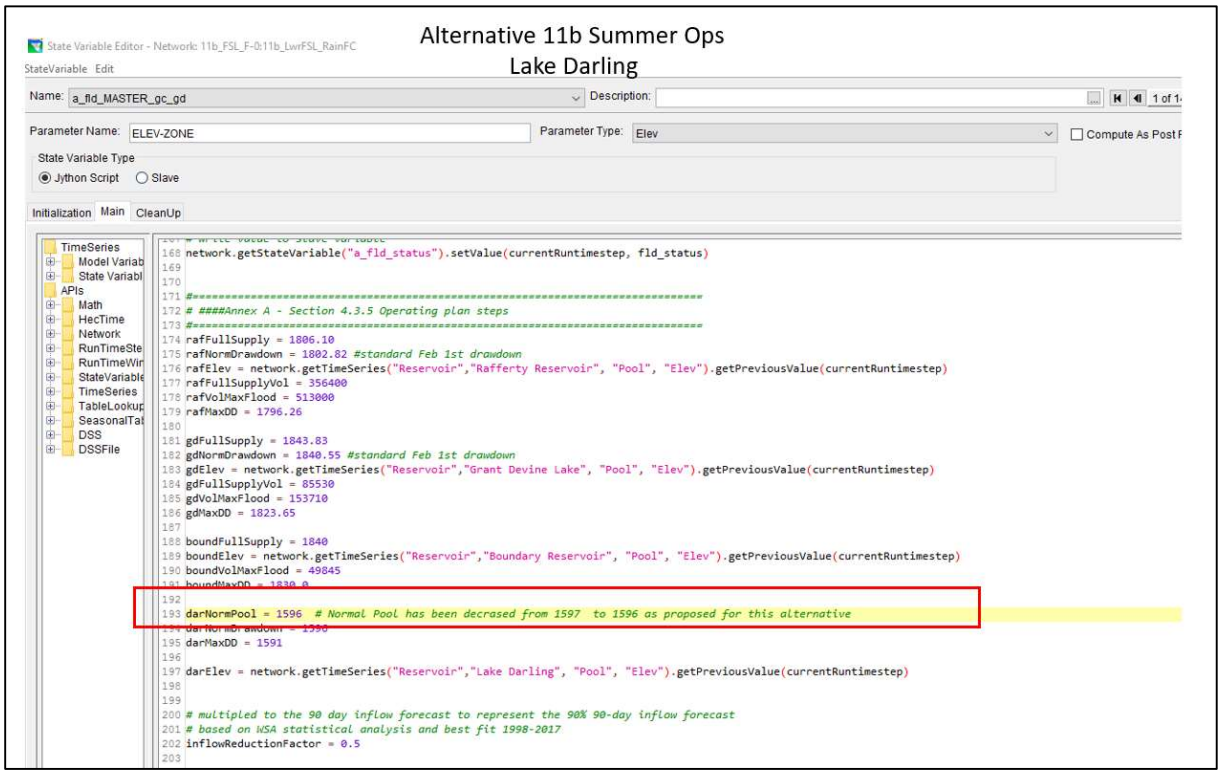


Figure 31. Changes made to Lake Darling State Variable

3. Alternative vs Baseline Condition Results

Plates 01-08 and 10-17 show hydrographs detailing the results of Alternative 11 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 11, only the high flow years (1969, 1975, 1976 and 2011) are plotted for each alternative variant, since the operational changes made for this alternative only affect large floods.

Plates 09 and 18 display performance indicator results for all study reaches over the entire simulation (1946-2017) for each alternative variant. 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 general, both alternative variants, 11a and 11b, show similar changes from baseline as those seen in the Dam Safety scenario (Alternative 9). During large flood years in both alternatives, releases from Rafferty and Grant Devine substantially increase during May as the reservoirs initiate a summer drawdown. This increases storage for a summer rainfall event but can increase downstream flooding by either increasing the flood peak, as in 1975, or causing flooding much earlier in the year, as in 2011. In all cases, Rafferty and Grant Devine reservoirs return to FSL faster during the summer months.

4.1 11a (Increasing Downstream Constraints)

In Alternative 11a, Rafferty and Grant Devine make large releases on May 15th in 1975, 1976 and 2011, which cause the flow at Sherwood to exceed its maximum limit. In 1975, May 15th discharges occur at the same time as the natural flood peak, increasing the peak flow by approximately 60% at Sherwood. In 1976, May discharges are smaller, since the natural flood peak occurred in April that year, and contribute less to flooding downstream. However, since Rafferty is allowed to make larger releases during the summer months in this scenario, the peak flow that occurs downstream as a result of the moderate 1976 summer rainfall event is increased. In both 1975 and 1976, the changes made to Lake Darling did not have a large effect on flows downstream of the reservoir.

In 2011, both Rafferty and Grant Devine enter the summer period significantly above SSL and FSL, respectively. Therefore, large releases are made to return to summer operating levels during May. These releases significantly increase flows relative to the baseline scenario during May, causing large scale flooding basin-wide. Then, since there is slightly more storage available during June, the summer rainfall peak is reduced at Sherwood by approximately 20%. At Lake Darling, releases from Rafferty and Grant Devine force Lake Darling to MAFL immediately following May 15th, and the reservoir releases inflows until the pool drops below MAFL in late June. Following the June peak at Rafferty, increased maximum releases allow the pool to return to FSL by August, much earlier than the baseline scenario.

4.2 11b (Lower Lake Darling FSL)

In Alternative 11b, results are very similar to 11a; however, in 2011, Rafferty does not return to FSL until October due to its maximum release rule being the same as the baseline scenario when the pool is below SSL. At Grant Devine, the pool remains at SSL (FSL) for the entire summer during 2011. The only other significant change from 11a occurs in 1976. Since the maximum release constraints are not increased at Rafferty, the peak from the 1976 summer rainfall event does not increase, and Lake Darling remains at FSL throughout the summer. It does not appear lowering FSL at Lake Darling without adding any additional rules has any significant impact on flows downstream of the reservoir.

4.3 Performance Indicators

4.3.1 Reservoirs

Neither 11a nor 11b significantly affect performance indicators for Rafferty and Grant Devine reservoirs. In 2011, Boundary Reservoir is able to return to MAFL faster in both 11a and 11b, resulting in benefits to the dam safety performance indicator. At Lake Darling, scenario 11a leads to higher inflows to the reservoir with no corresponding drawdown, resulting in negative impacts to Mouse River Park and the historic sites in the area. The lower FSL level of Lake Darling in scenario 11b largely mitigates the negative effects seen in 11a and results in improved flood control at Mouse River Park and reductions in flooding of cultural and boating access sites. However, the lower FSL level also reduces water supply and fish and wildlife habitat.

4.3.2 Riverine Reaches

Since both scenario 11a and 11b largely only affect flood years, most changes to performance indicators throughout the river are a result of changes to the hydrograph during floods. In both 11a and 11b, the 2011 event changes from a single peak event in June to a double peak event. The first peak occurs in May when summer operations take effect, and the second occurs in June. Since both peaks are still relatively high, flooding of railroads, bridges, and the City of Minot occurs earlier and for a greater duration than the Baseline scenario. In 1975, when the natural flood peak occurs in May, summer operations increase the flood peak, resulting in negative impacts to flood control and agricultural performance indicators upstream of Lake Darling. All in all, negative impacts generally outweigh positive impacts over the period of record, and most performance indicators have neutral or negative consequences.

5. Suggested Further Alternative Fine Tuning

The ROD and ROI rules added to Rafferty and Grant Devine should be discussed and possibly modified to limit releases from the reservoirs to more realistic levels. Further discussion should also take place regarding how fast the reservoirs should return to summer surcharge levels after May 15th. Longer, more drawn out releases may reduce the risk of additional downstream flooding during May. Different magnitudes for downstream constraints during summer, as well as dates of summer operations, should also be considered.

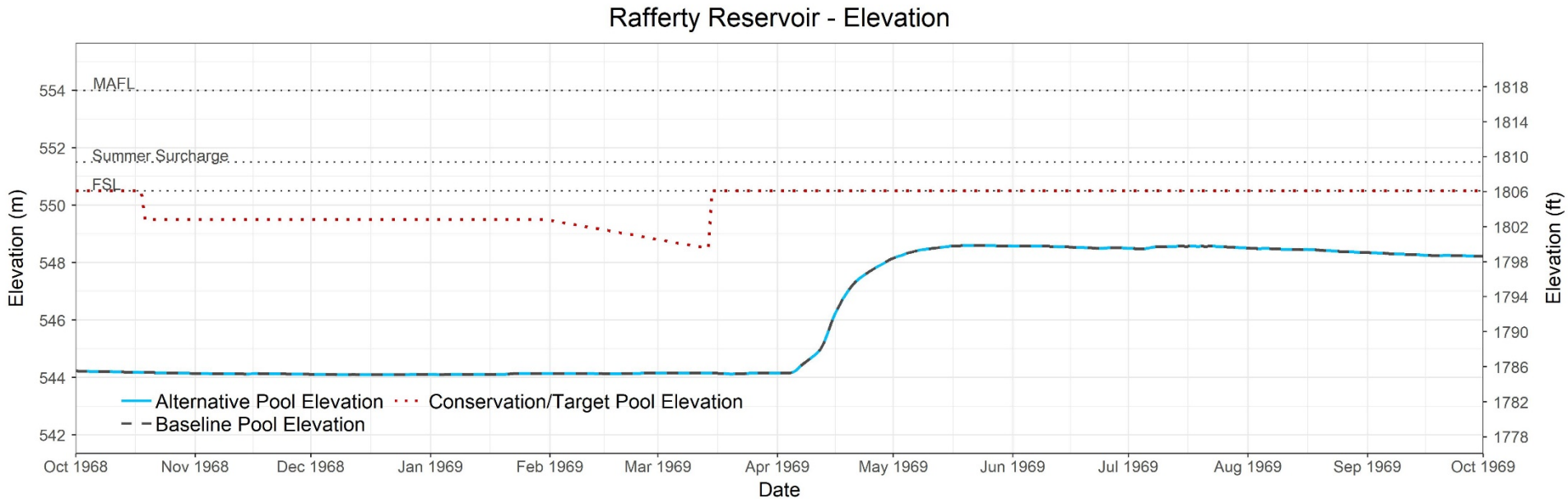
6. Path Forward

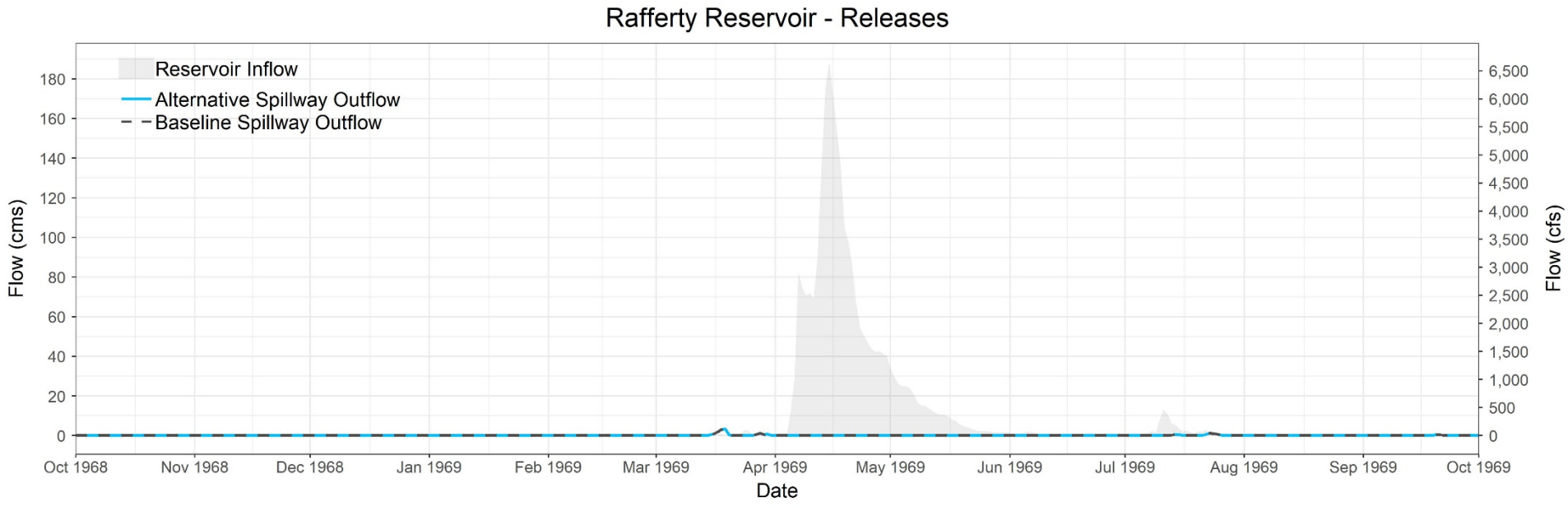
Since there is a desire to add a summer operating plan to the Agreement, further exploration of summer operating rules will be carried forward to Phase 3 in Alternative 305.

7. References

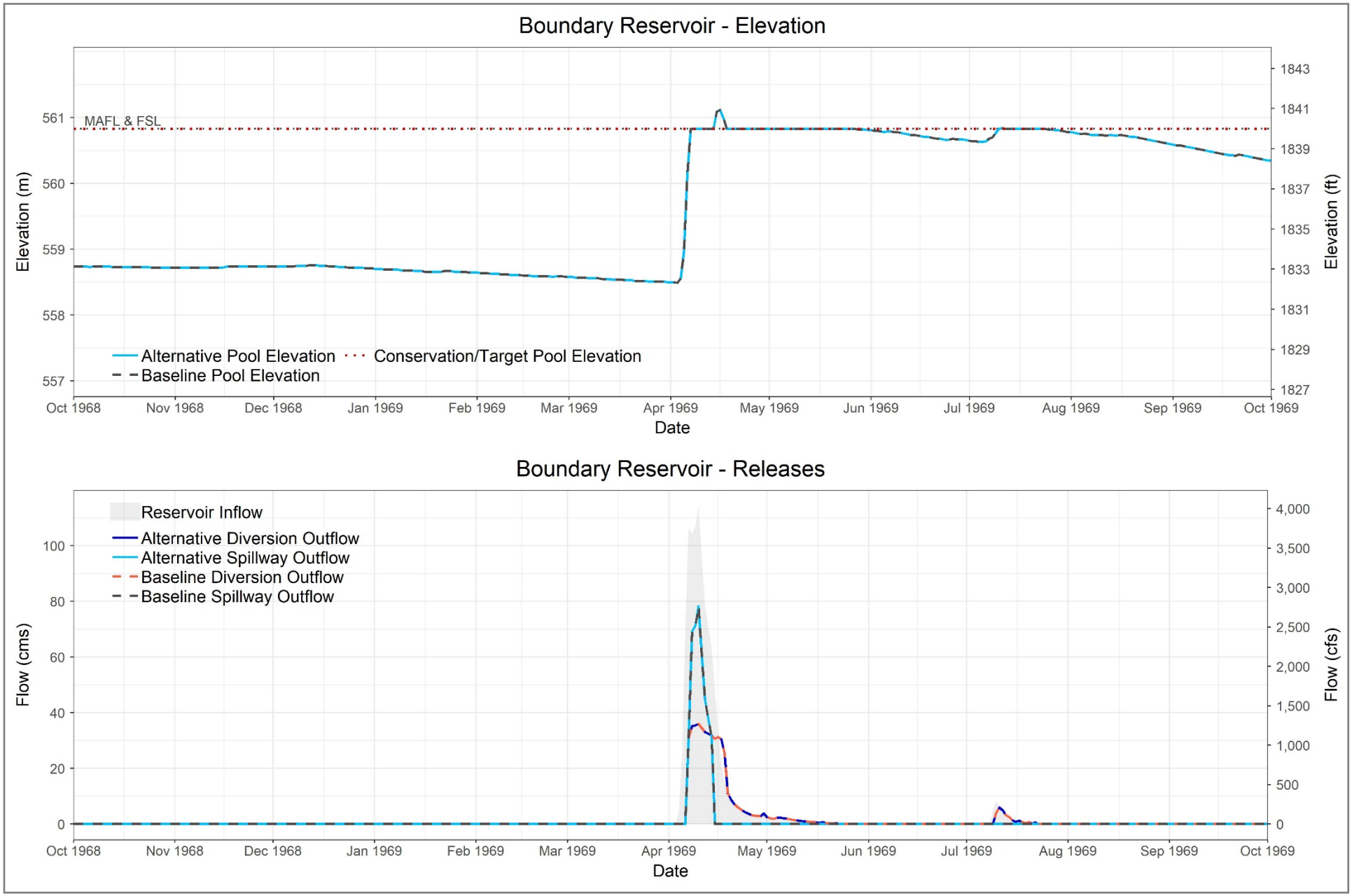
1. “HEC-DSSVue,” U.S Army Corps of Engineers, Hydraulic Engineering Center, February 2010.
2. “HEC-ResSim, Reservoir System Simulation, Version 3.3”, U.S Army Corps of Engineers, Hydraulic Engineering Center, December 2018.
3. Canada and USA, 1989. Agreement between the Government of Canada and the United 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. Hallborg, Curtis. (April 2019). E-mail dated April 19, 2019.
6. Nelsen, Elizabeth. (April 2019). E-mail dated April 20, 2019.

Plate 01	Reservoirs – 1969	Alternative 11a (Phase 2) Souris River Plan of Study

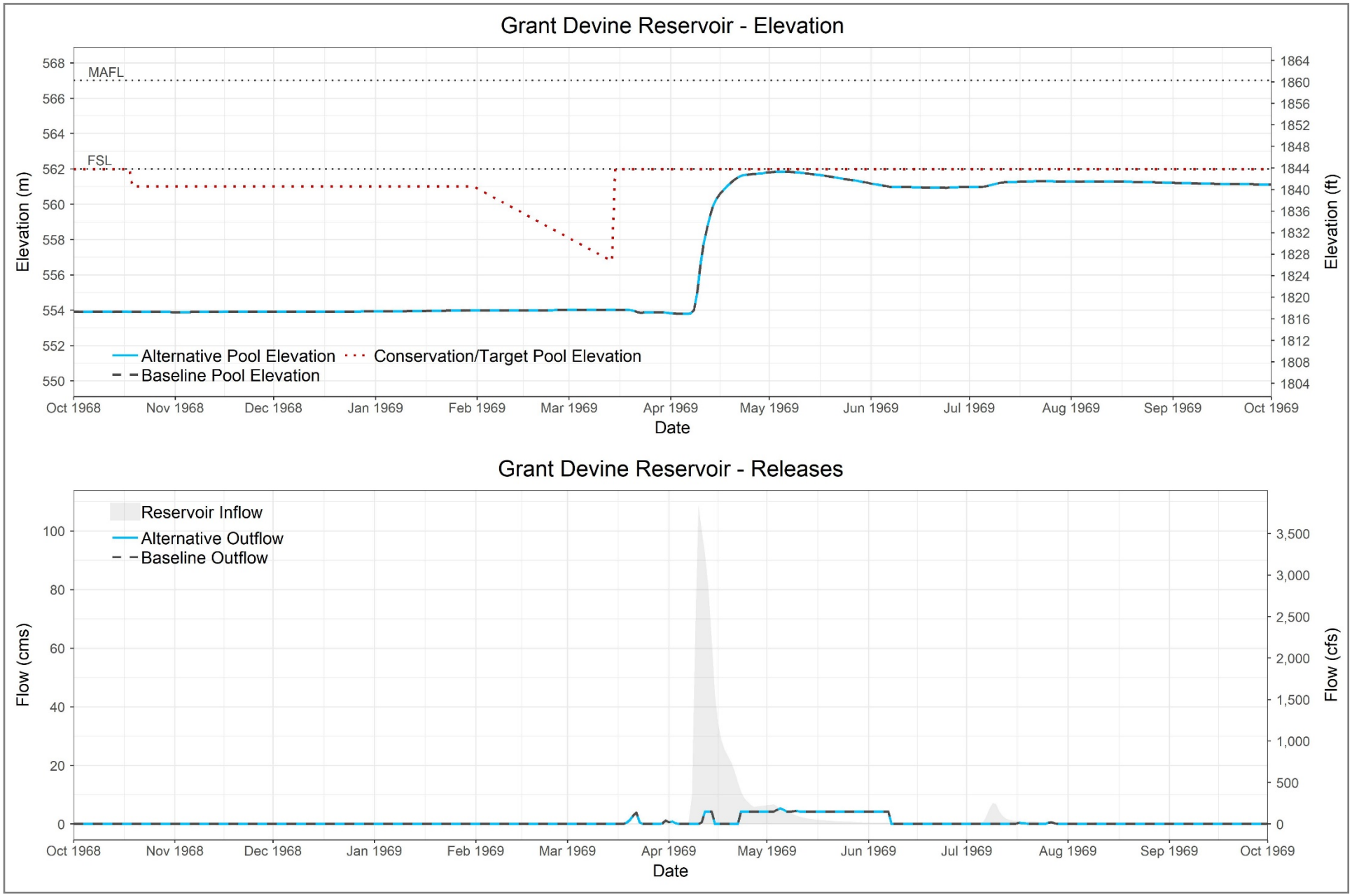




**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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

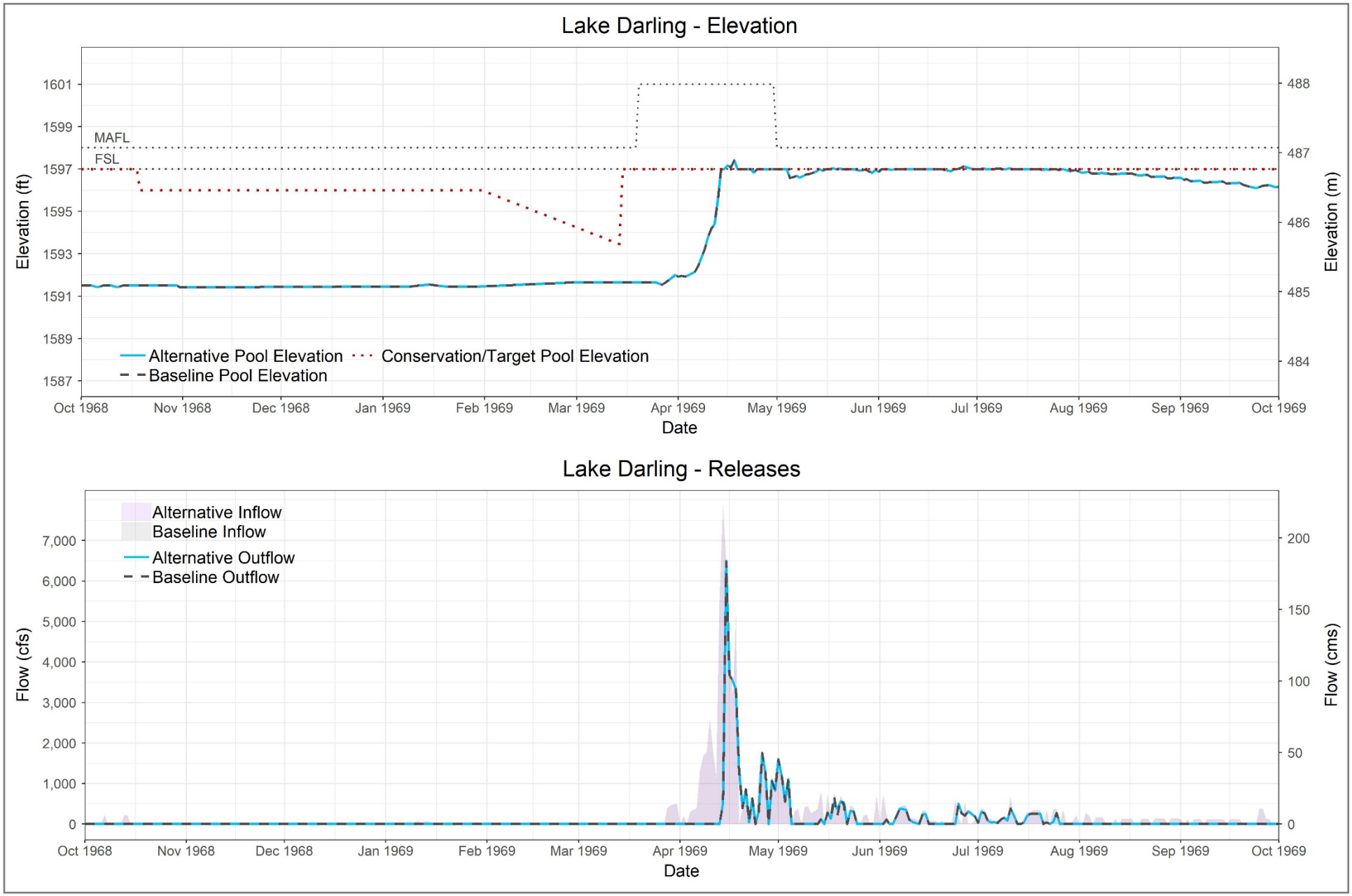
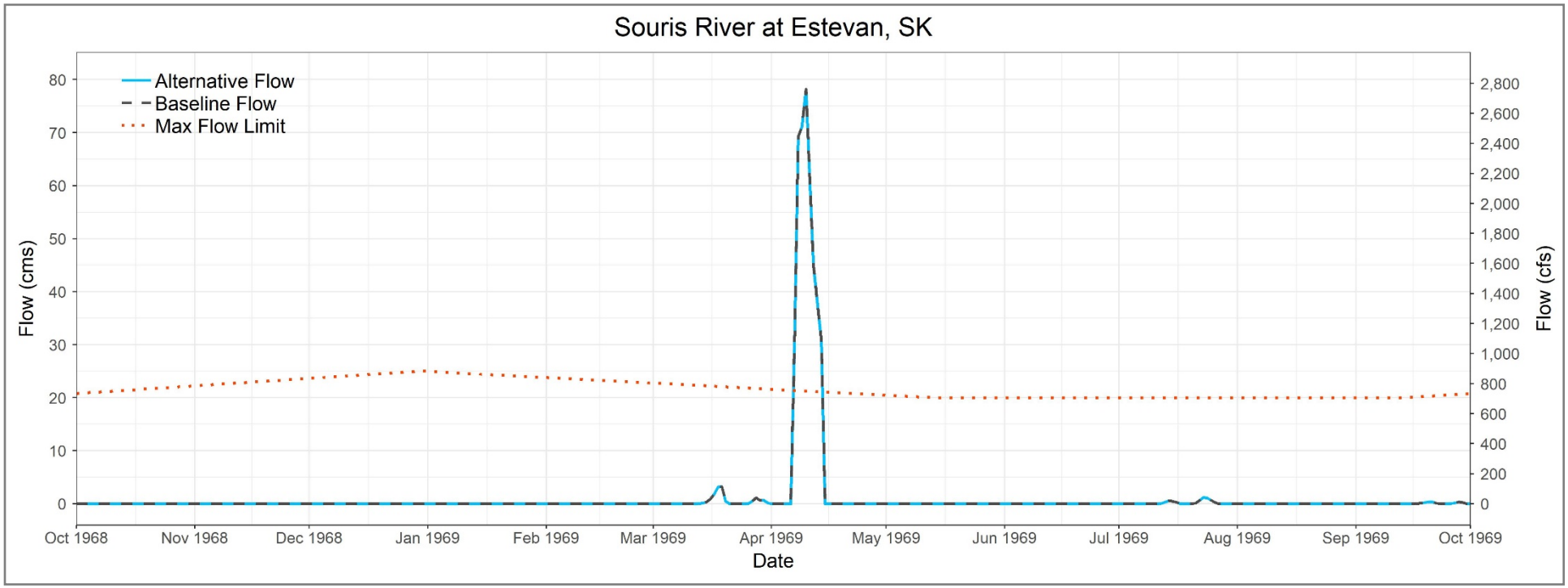

Lake Darling - Elevation
Elevation (ft)
Elevation (m)
1601
1599
1597
1595
1593
1591
1589
1587
488
487
486
485
484
MAFL
FSL
Alternative Pool Elevation
Conservation/Target Pool Elevation
Baseline Pool Elevation
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Date
Lake Darling - Releases
Flow (cfs)
Flow (cms)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
200
150
100
50
0
Alternative Inflow
Baseline Inflow
Alternative Outflow
Baseline Outflow
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Date

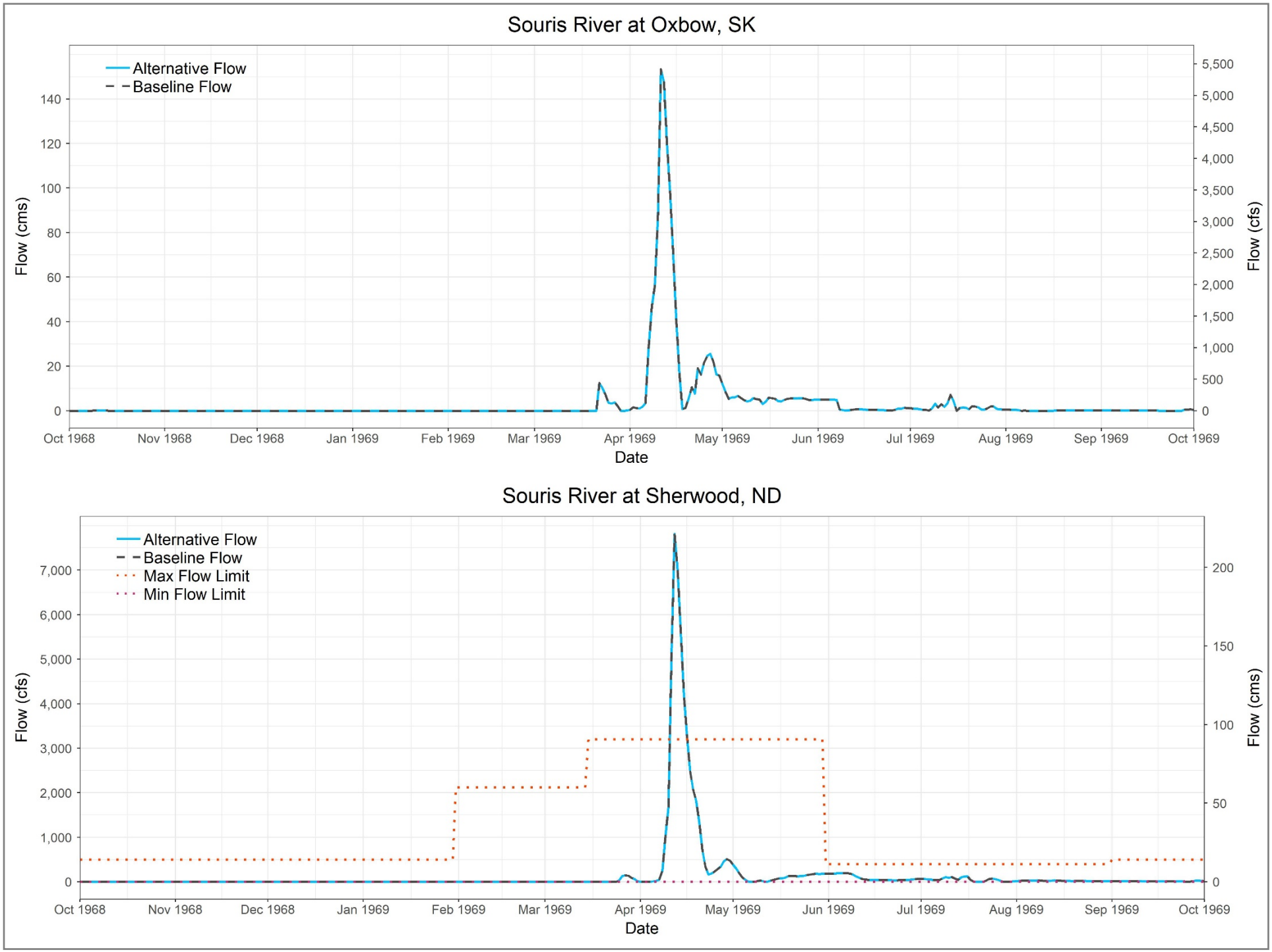
Plate 02

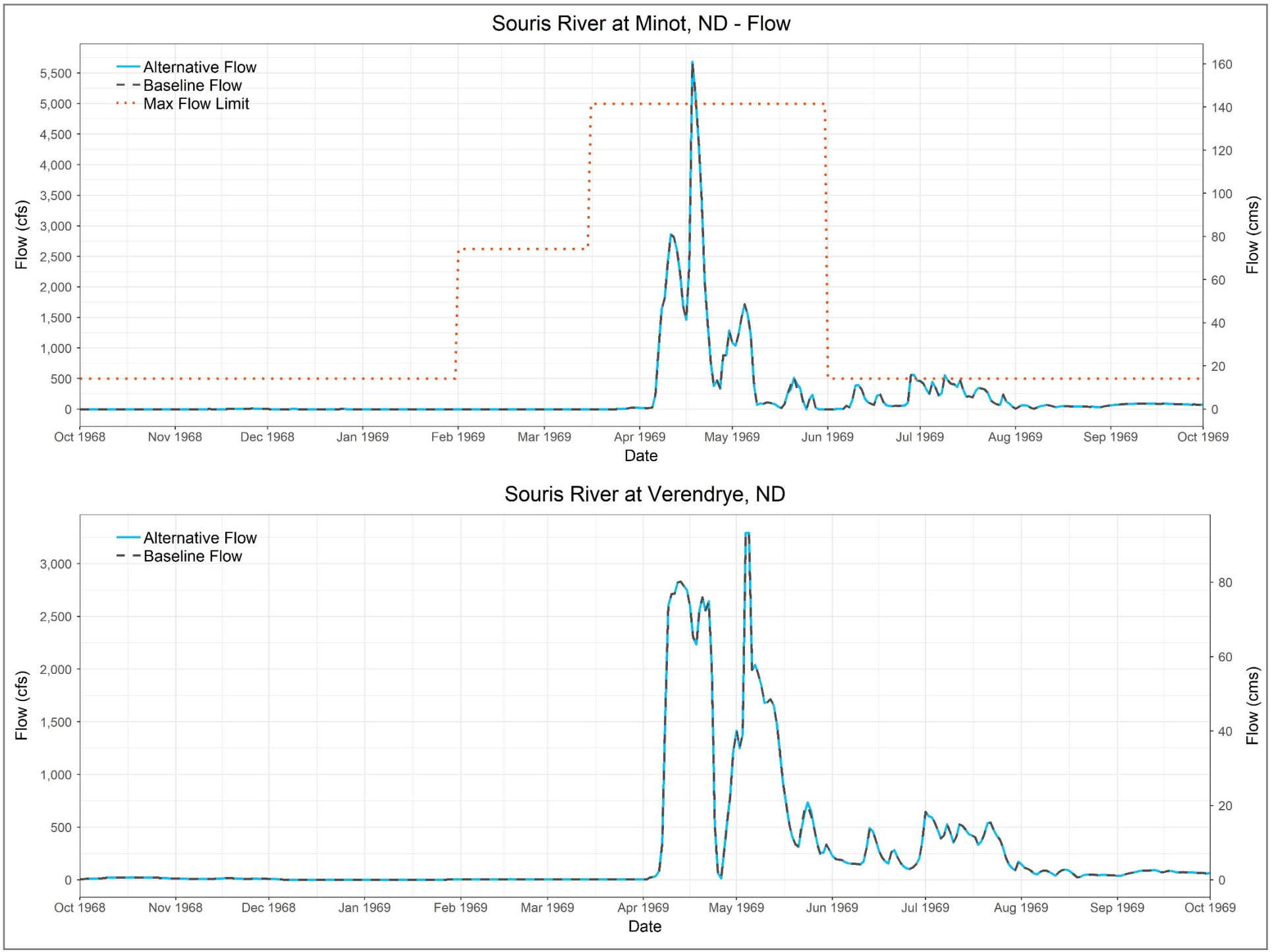
Critical Flow Locations – 1969

Alternative 11a (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date

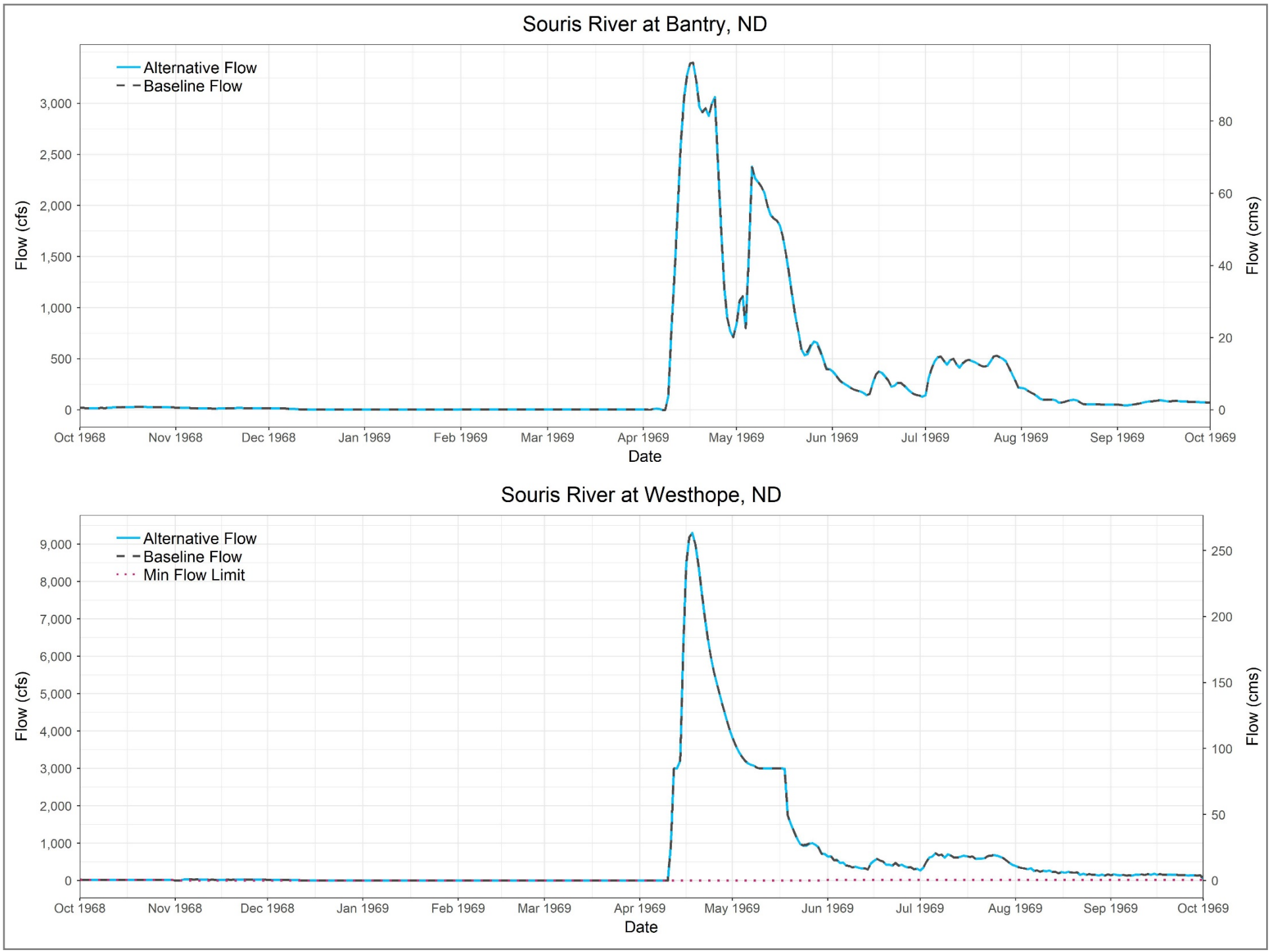
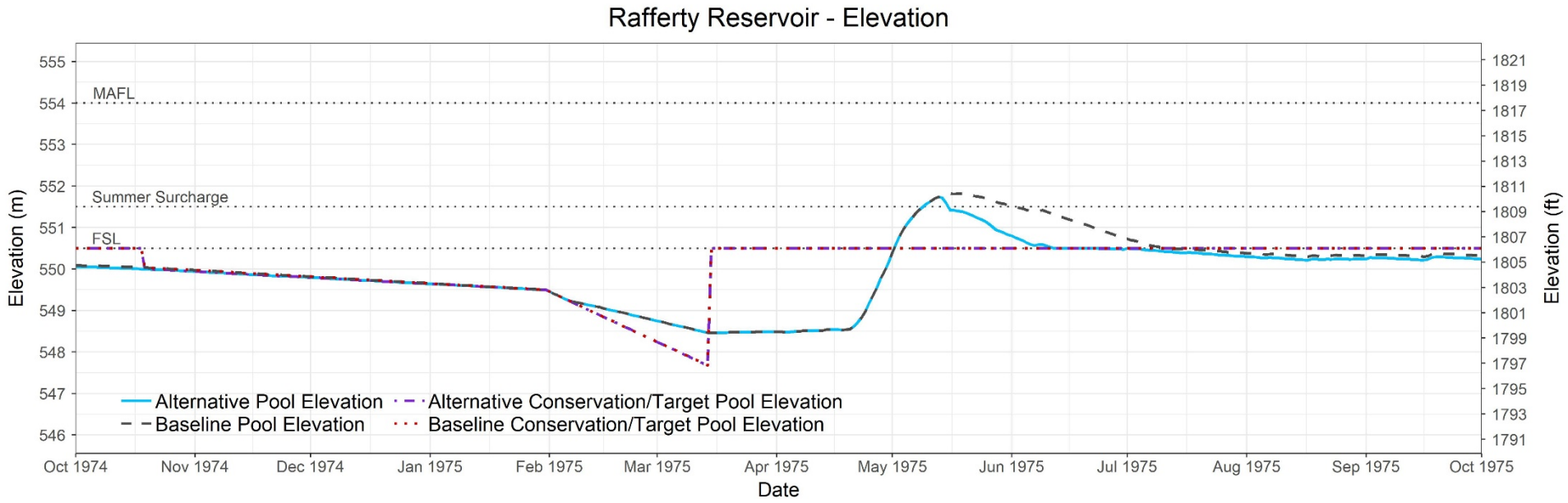
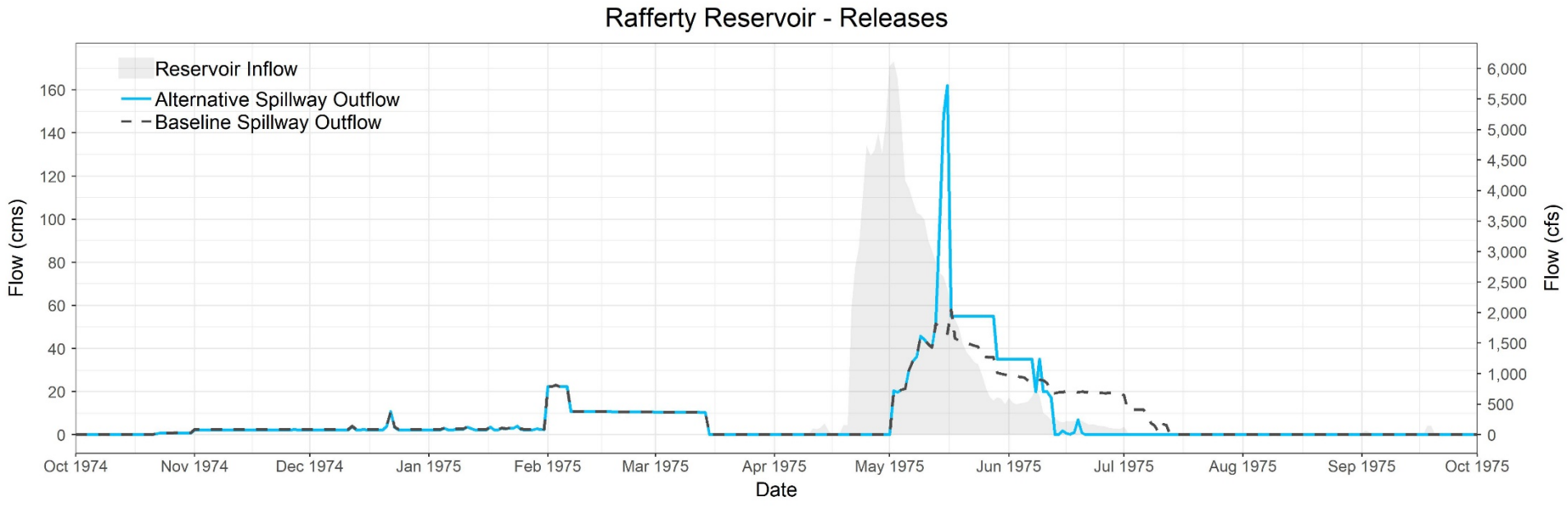
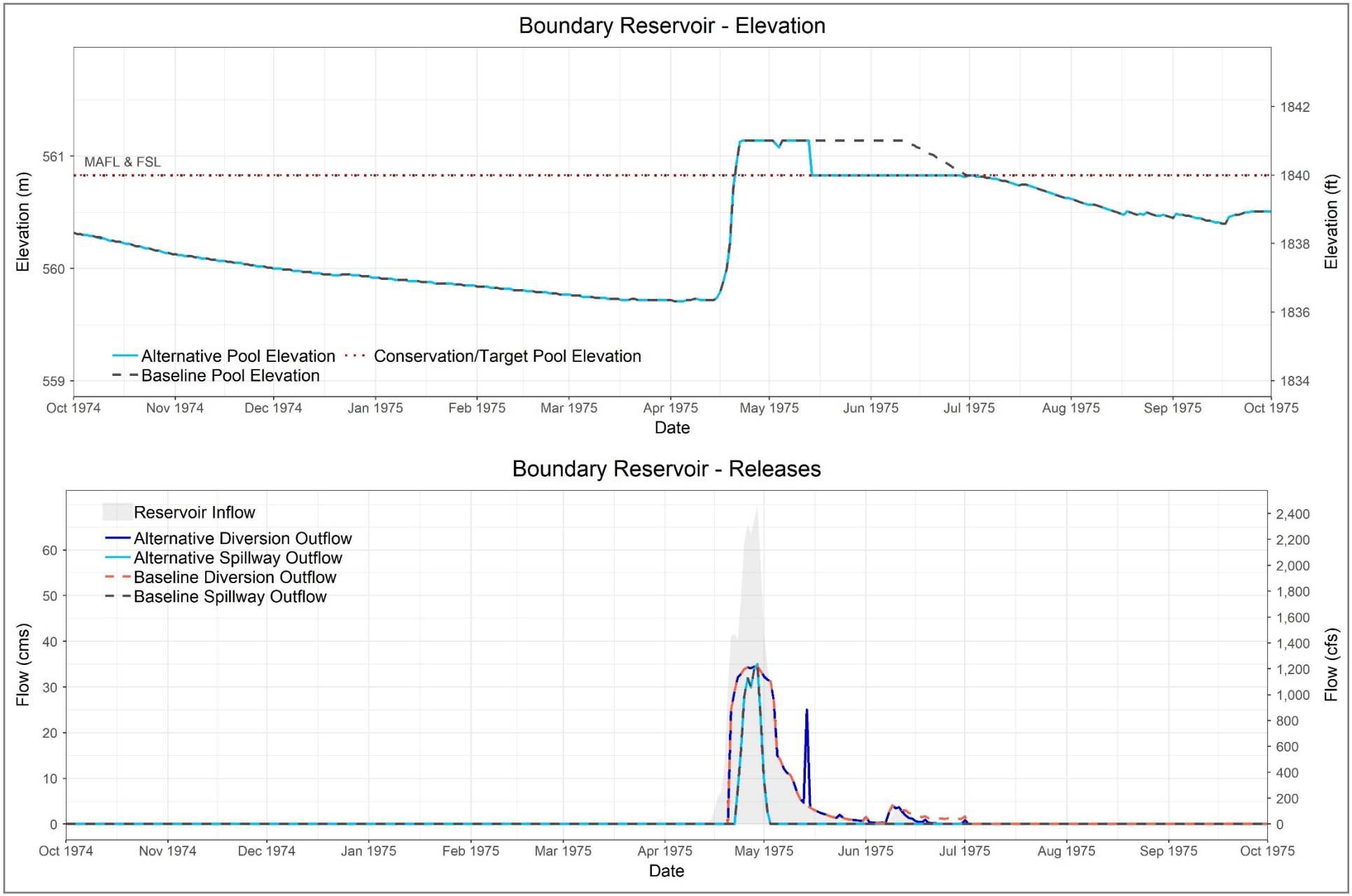

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
Date

Plate 03	Reservoirs – 1975	Alternative 11a (Phase 2) Souris River Plan of Study

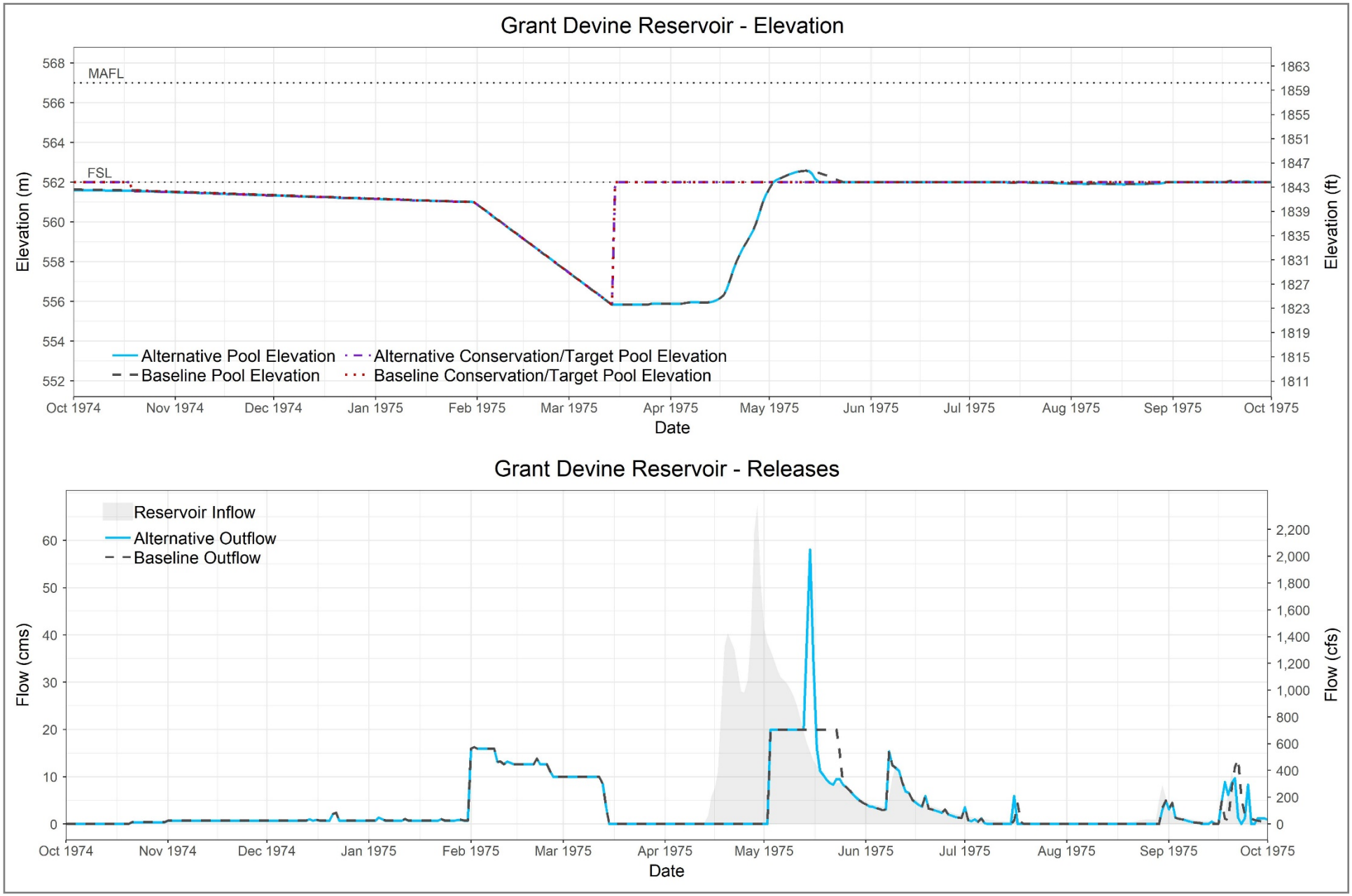




**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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

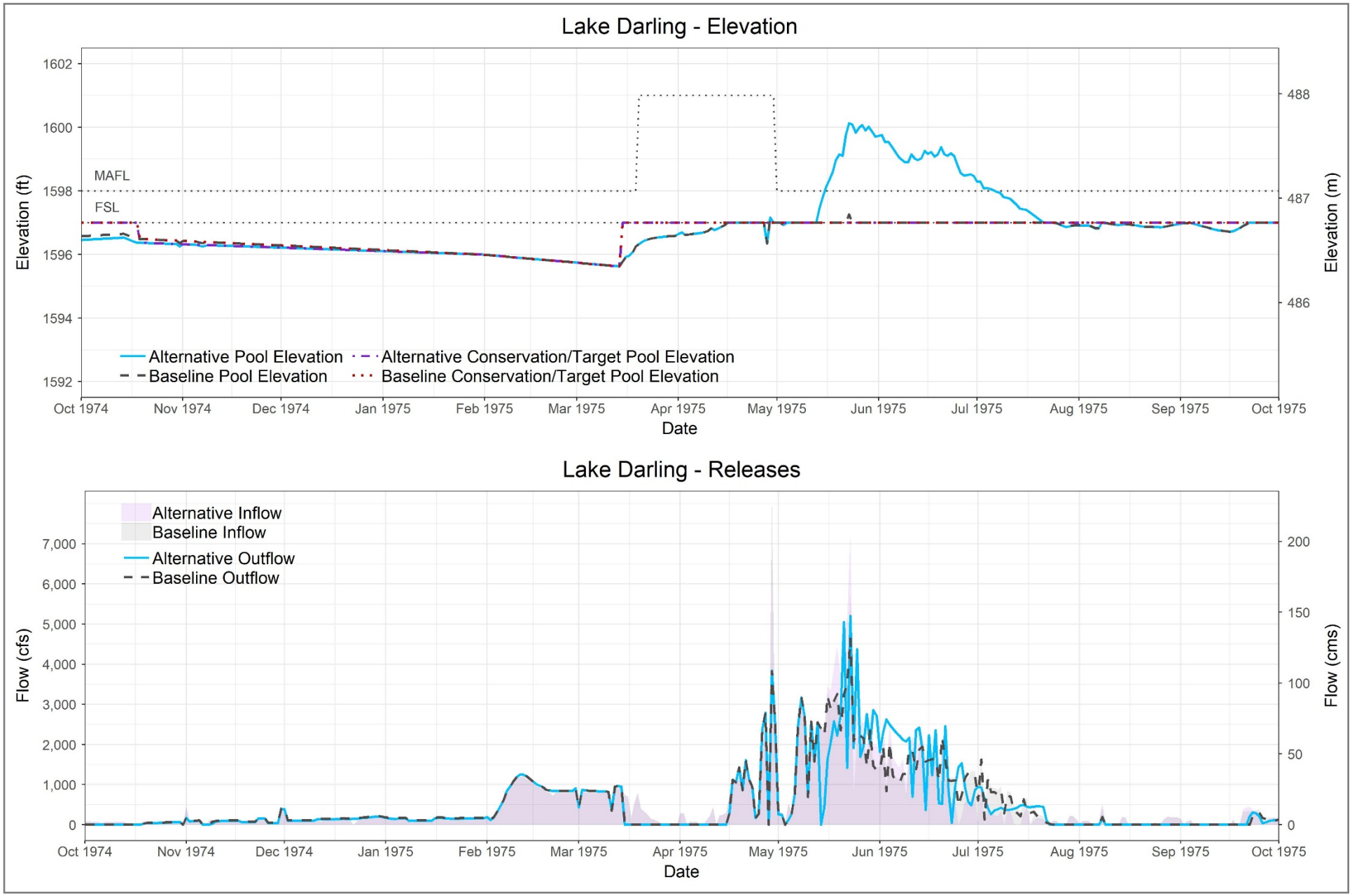
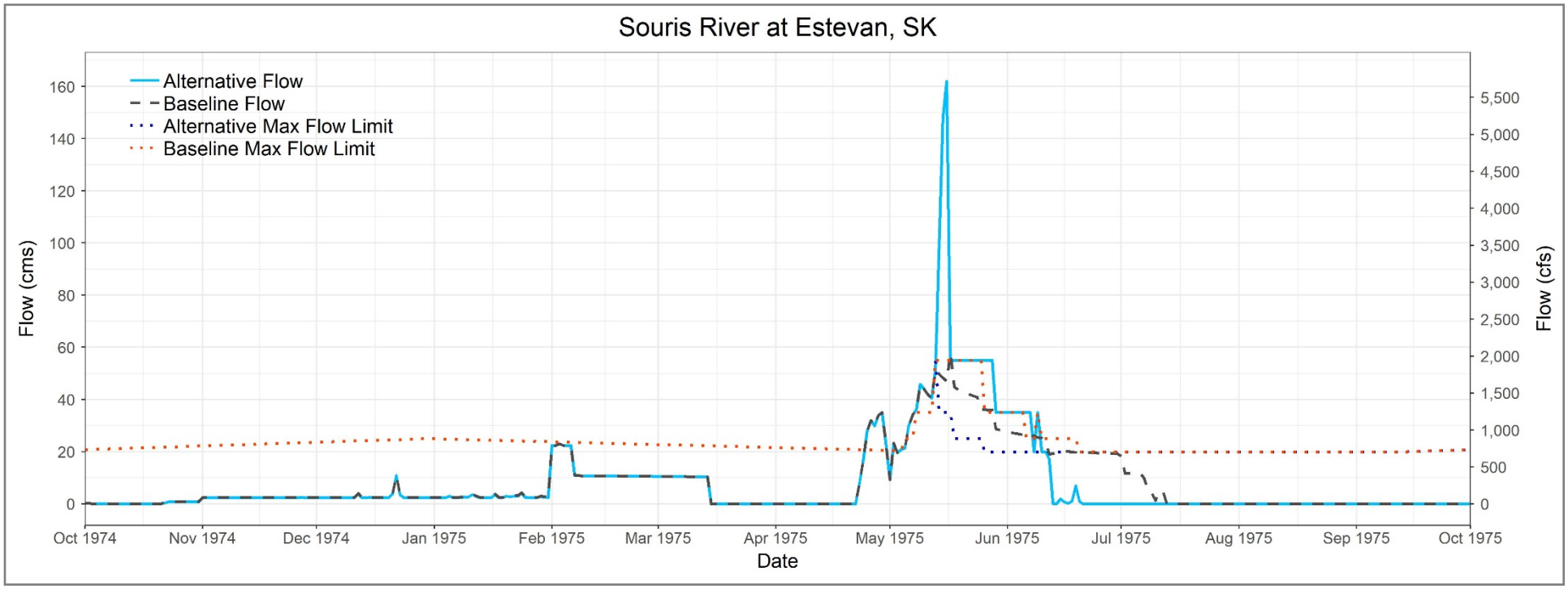

Lake Darling - Elevation
Elevation (ft)
Elevation (m)
1602
1600
1598
1596
1594
1592
488
487
486
MAFL
FSL
Alternative Pool Elevation
Alternative Conservation/Target Pool Elevation
Baseline Pool Elevation
Baseline Conservation/Target Pool Elevation
Oct 1974
Nov 1974
Dec 1974
Jan 1975
Feb 1975
Mar 1975
Apr 1975
May 1975
Jun 1975
Jul 1975
Aug 1975
Sep 1975
Oct 1975
Date
Lake Darling - Releases
Alternative Inflow
Baseline Inflow
Alternative Outflow
Baseline Outflow
Flow (cfs)
Flow (cms)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
200
150
100
50
0
Oct 1974
Nov 1974
Dec 1974
Jan 1975
Feb 1975
Mar 1975
Apr 1975
May 1975
Jun 1975
Jul 1975
Aug 1975
Sep 1975
Oct 1975
Date

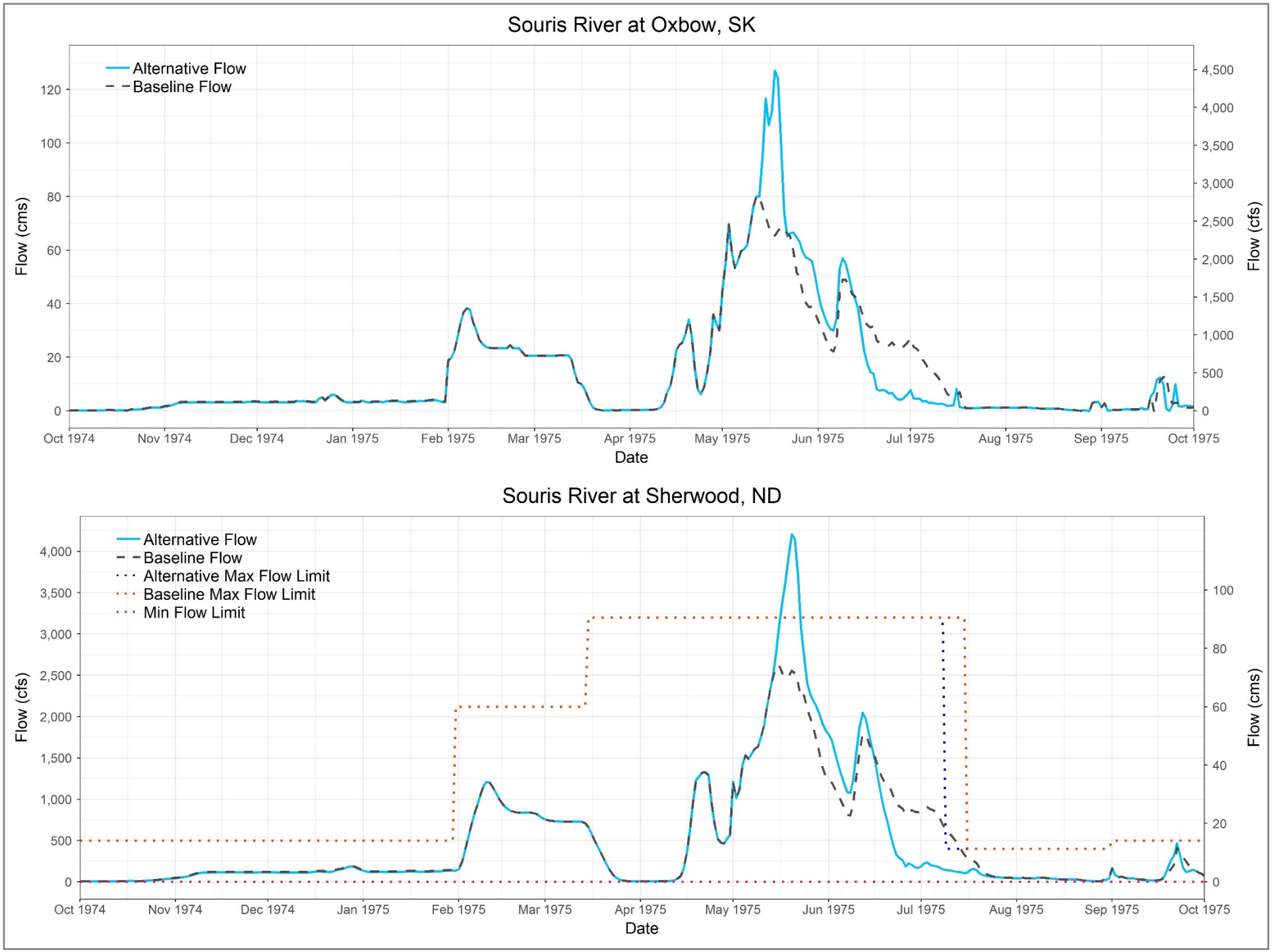
Plate 04

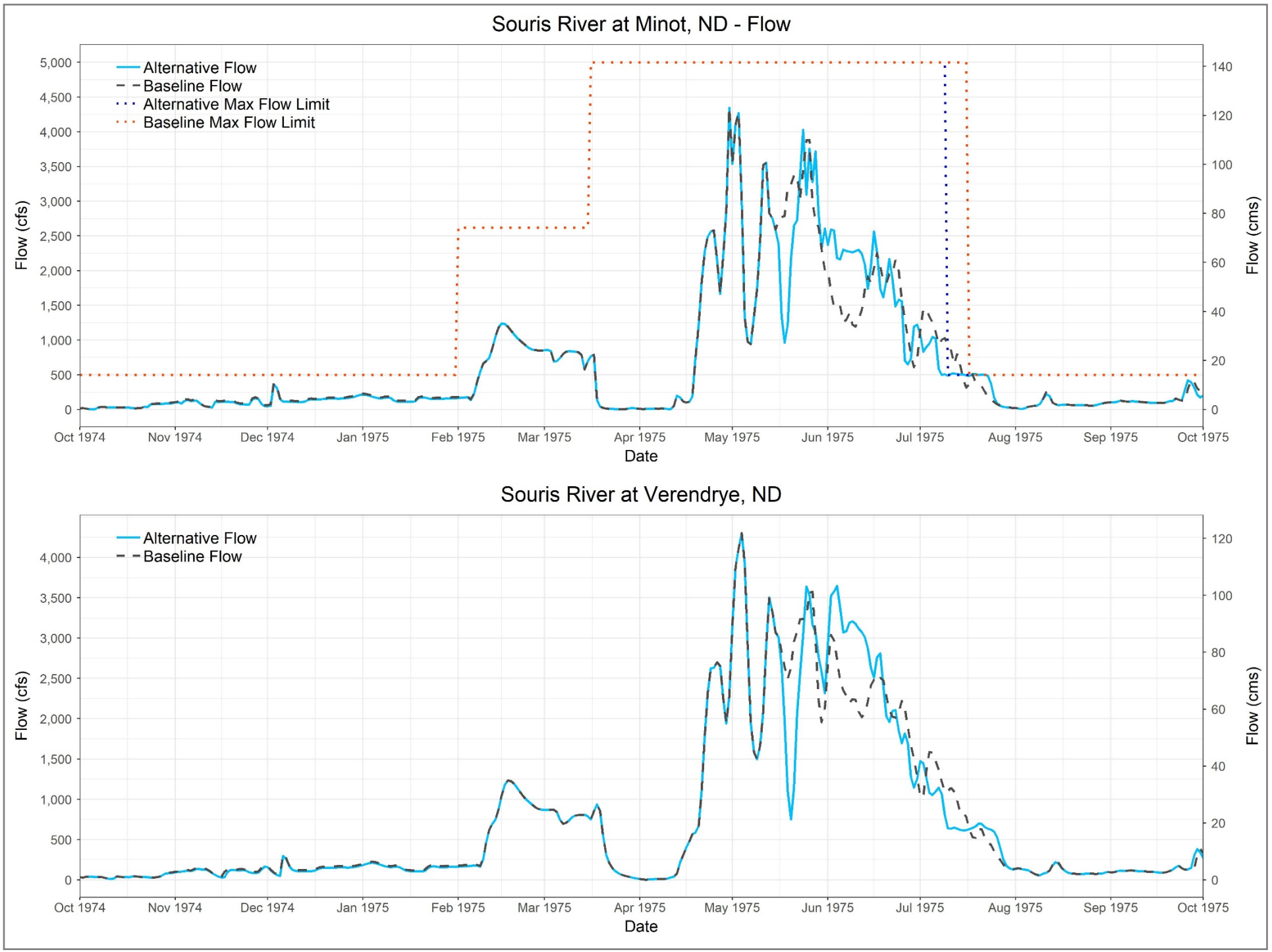
Critical Flow Locations – 1975

Alternative 11a (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 1974
Nov 1974
Dec 1974
Jan 1975
Feb 1975
Mar 1975
Apr 1975
May 1975
Jun 1975
Jul 1975
Aug 1975
Sep 1975
Oct 1975
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 1974
Nov 1974
Dec 1974
Jan 1975
Feb 1975
Mar 1975
Apr 1975
May 1975
Jun 1975
Jul 1975
Aug 1975
Sep 1975
Oct 1975
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date

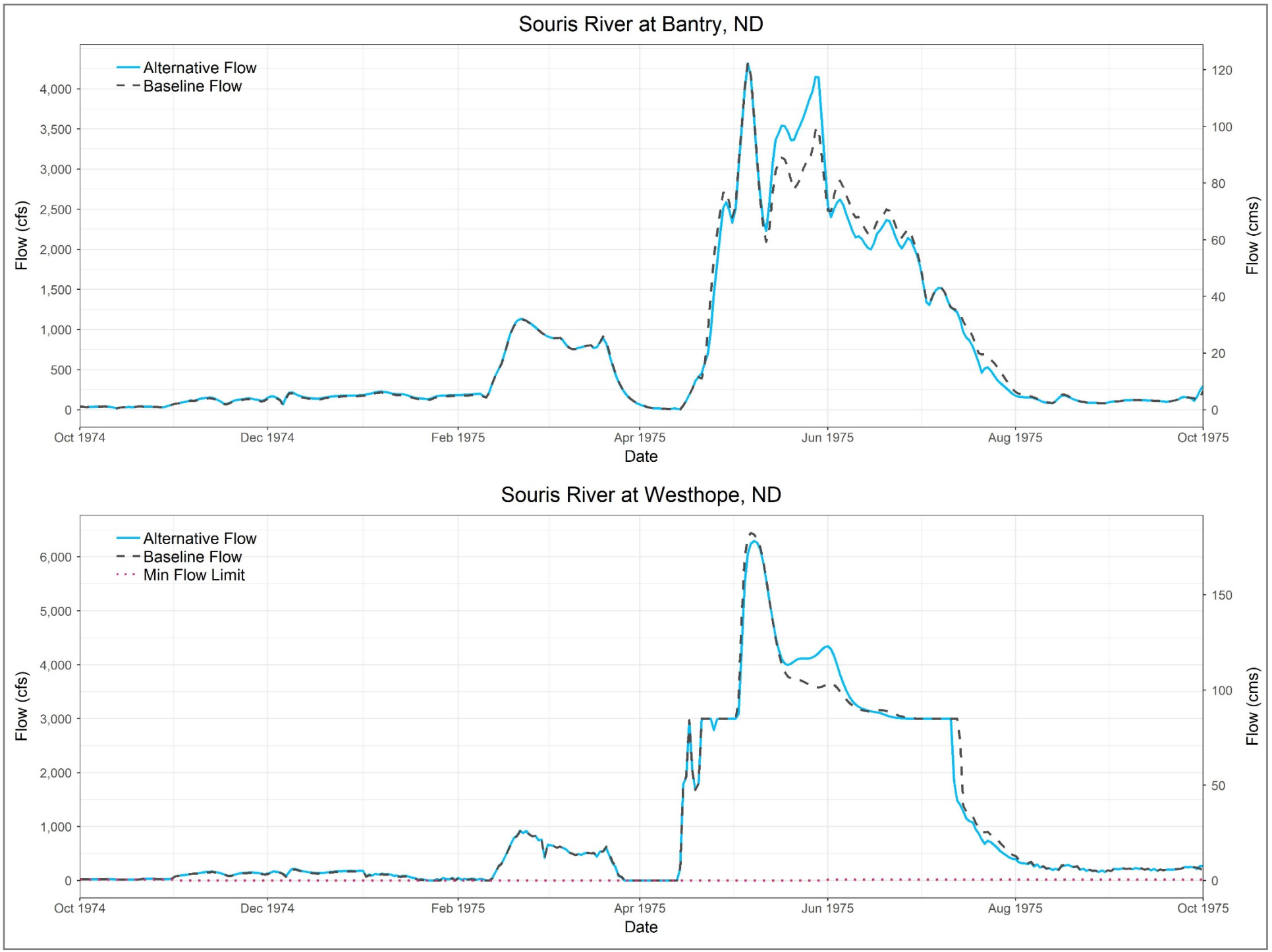
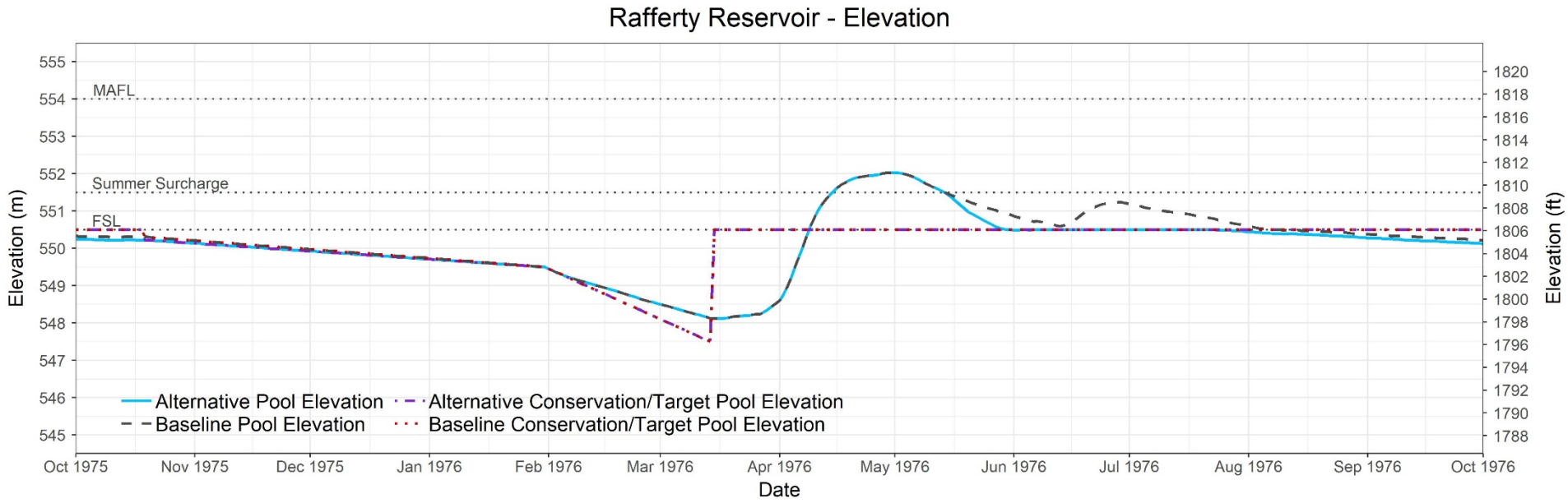
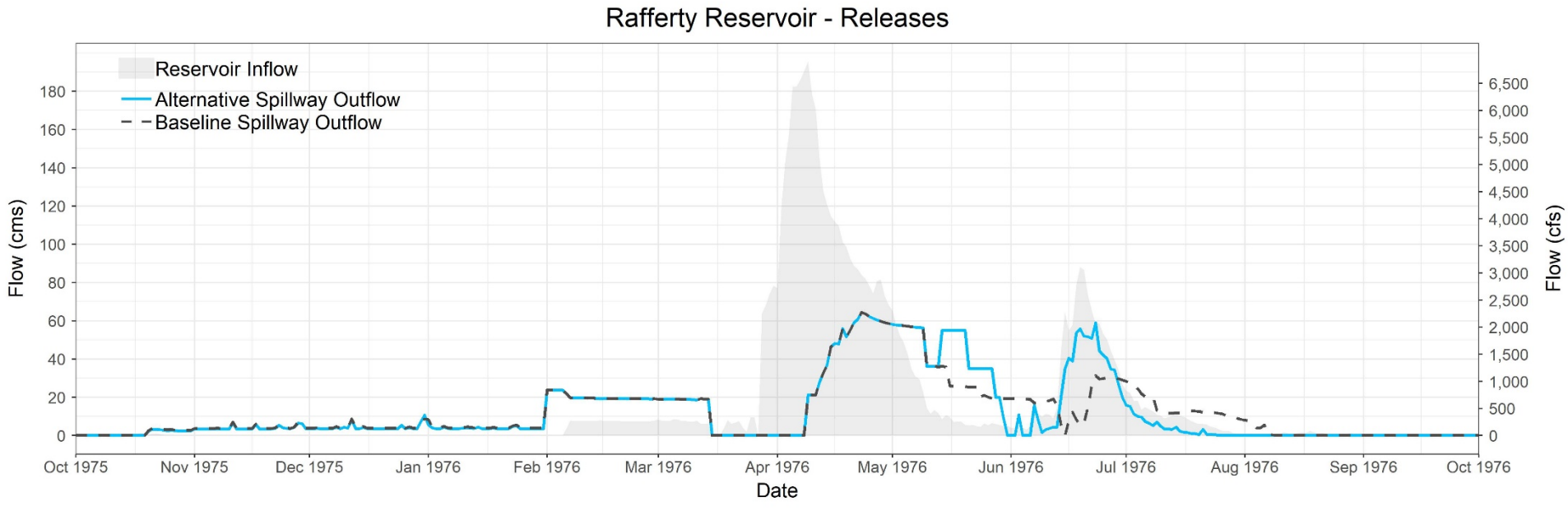
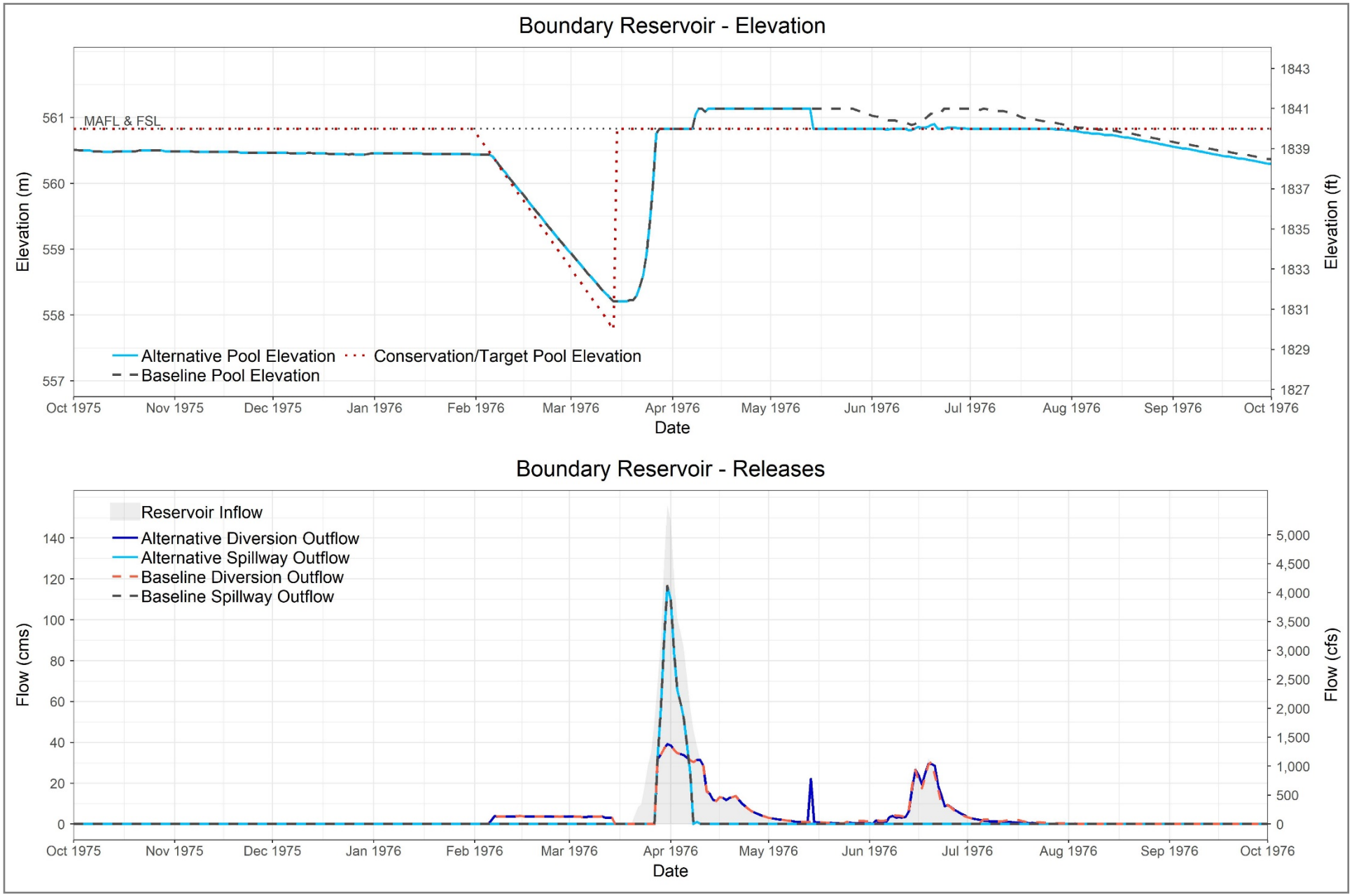

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date
Oct 1974
Dec 1974
Feb 1975
Apr 1975
Jun 1975
Aug 1975
Oct 1975
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
Date

Plate 05	Reservoirs – 1976	Alternative 11a (Phase 2) Souris River Plan of Study

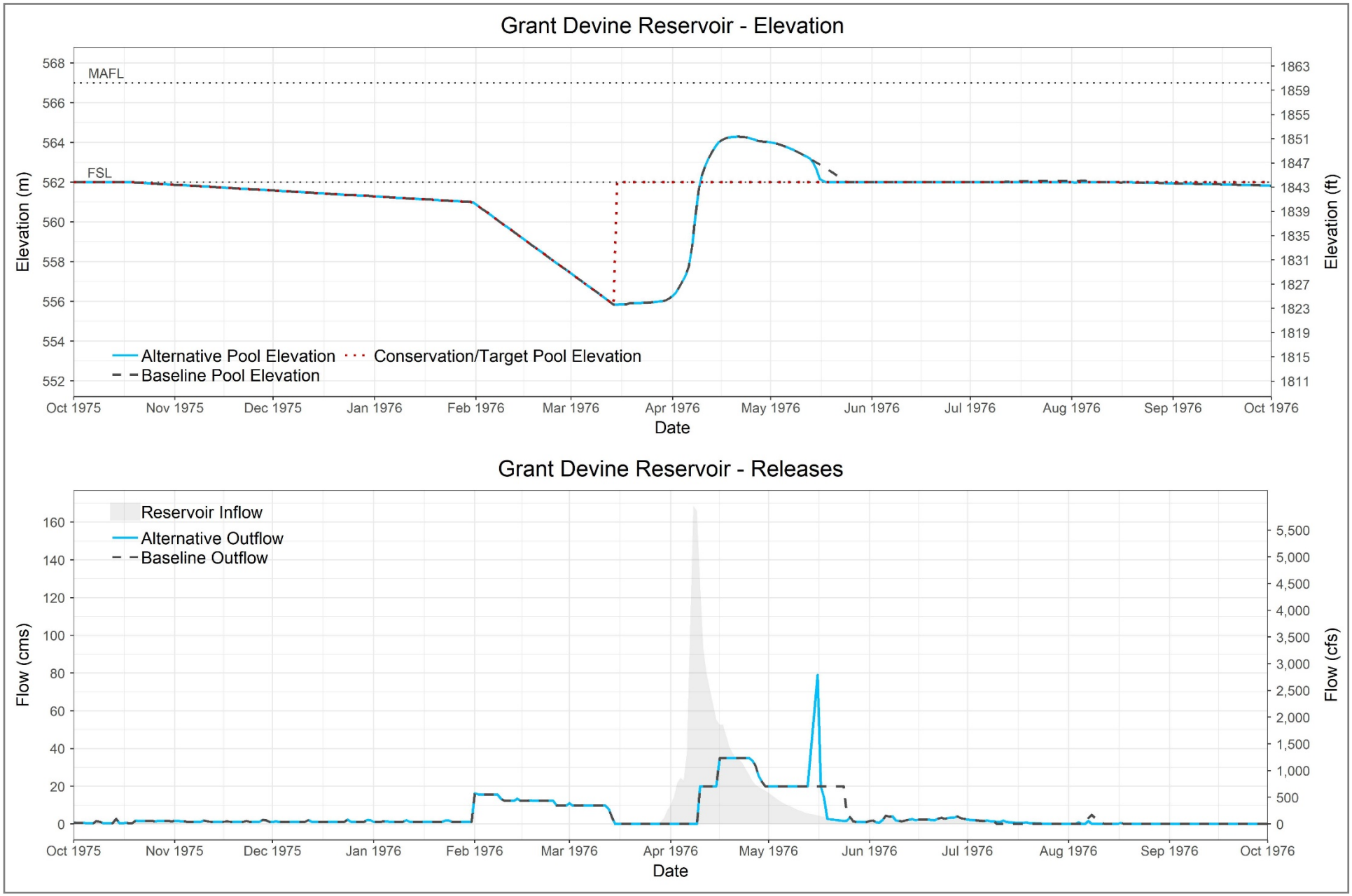




**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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

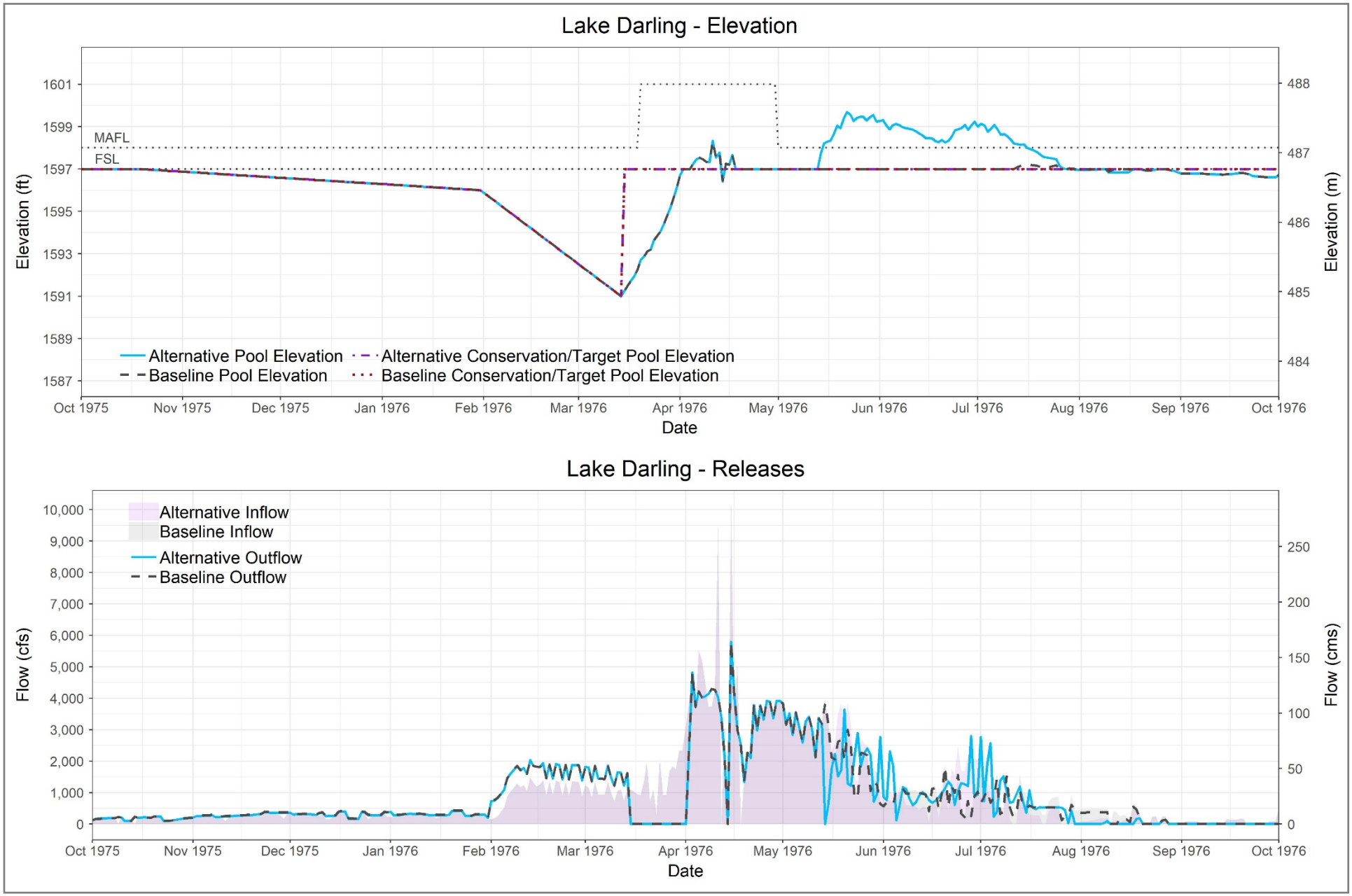
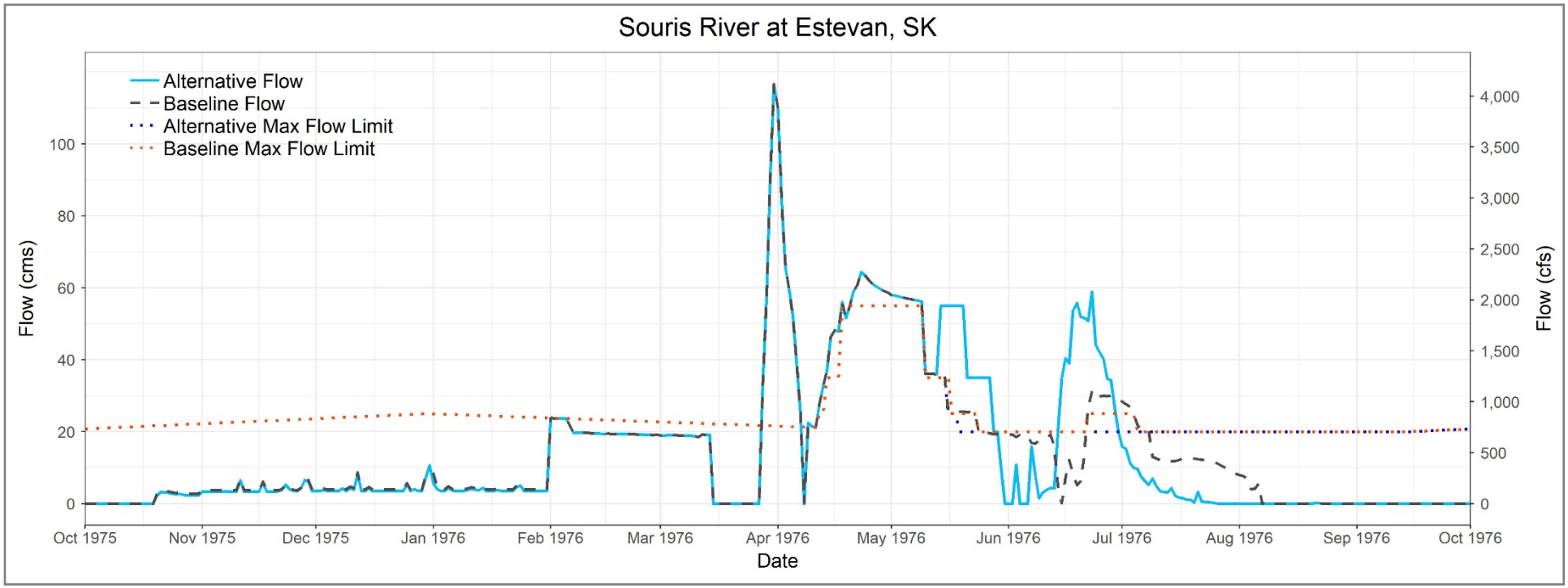

Lake Darling - Elevation
Elevation (ft)
Elevation (m)
MAFL
FSL
Alternative Pool Elevation
Alternative Conservation/Target Pool Elevation
Baseline Pool Elevation
Baseline Conservation/Target Pool Elevation
Date
Lake Darling - Releases
Alternative Inflow
Baseline Inflow
Alternative Outflow
Baseline Outflow
Flow (cfs)
Flow (cms)
Date

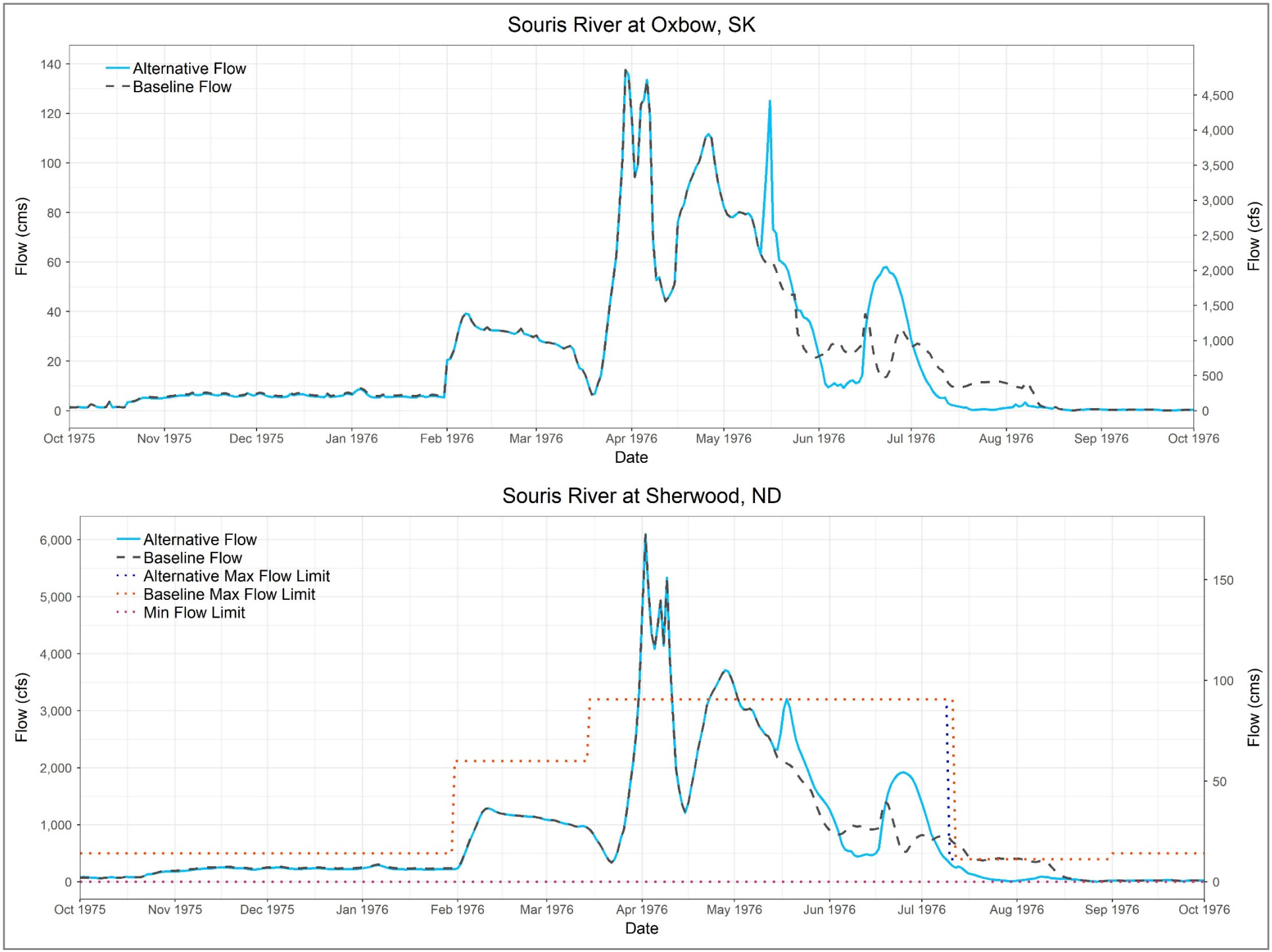
Plate 06

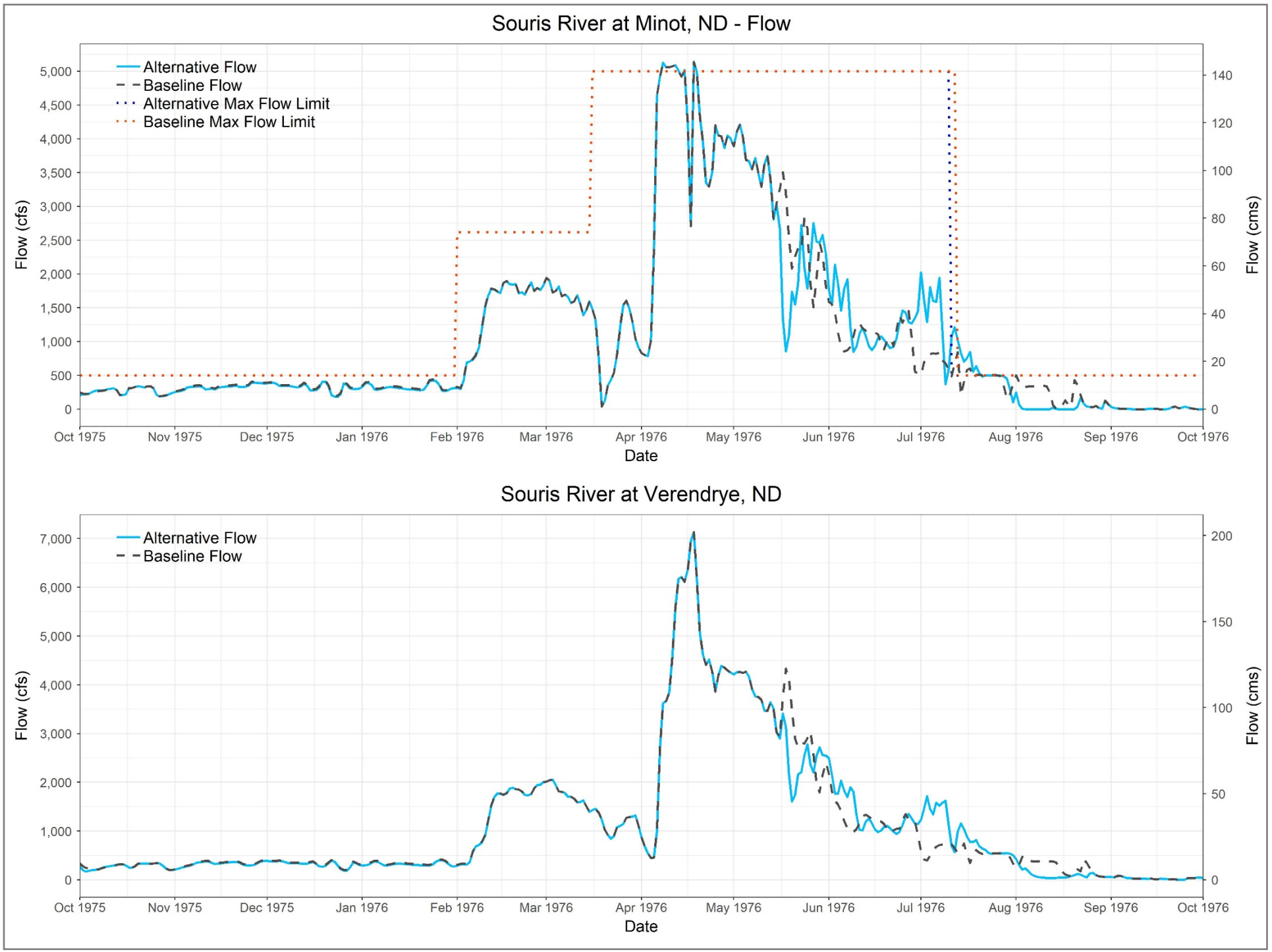
Critical Flow Locations – 1976

Alternative 11a (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 1975
Nov 1975
Dec 1975
Jan 1976
Feb 1976
Mar 1976
Apr 1976
May 1976
Jun 1976
Jul 1976
Aug 1976
Sep 1976
Oct 1976
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 1975
Nov 1975
Dec 1975
Jan 1976
Feb 1976
Mar 1976
Apr 1976
May 1976
Jun 1976
Jul 1976
Aug 1976
Sep 1976
Oct 1976
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date

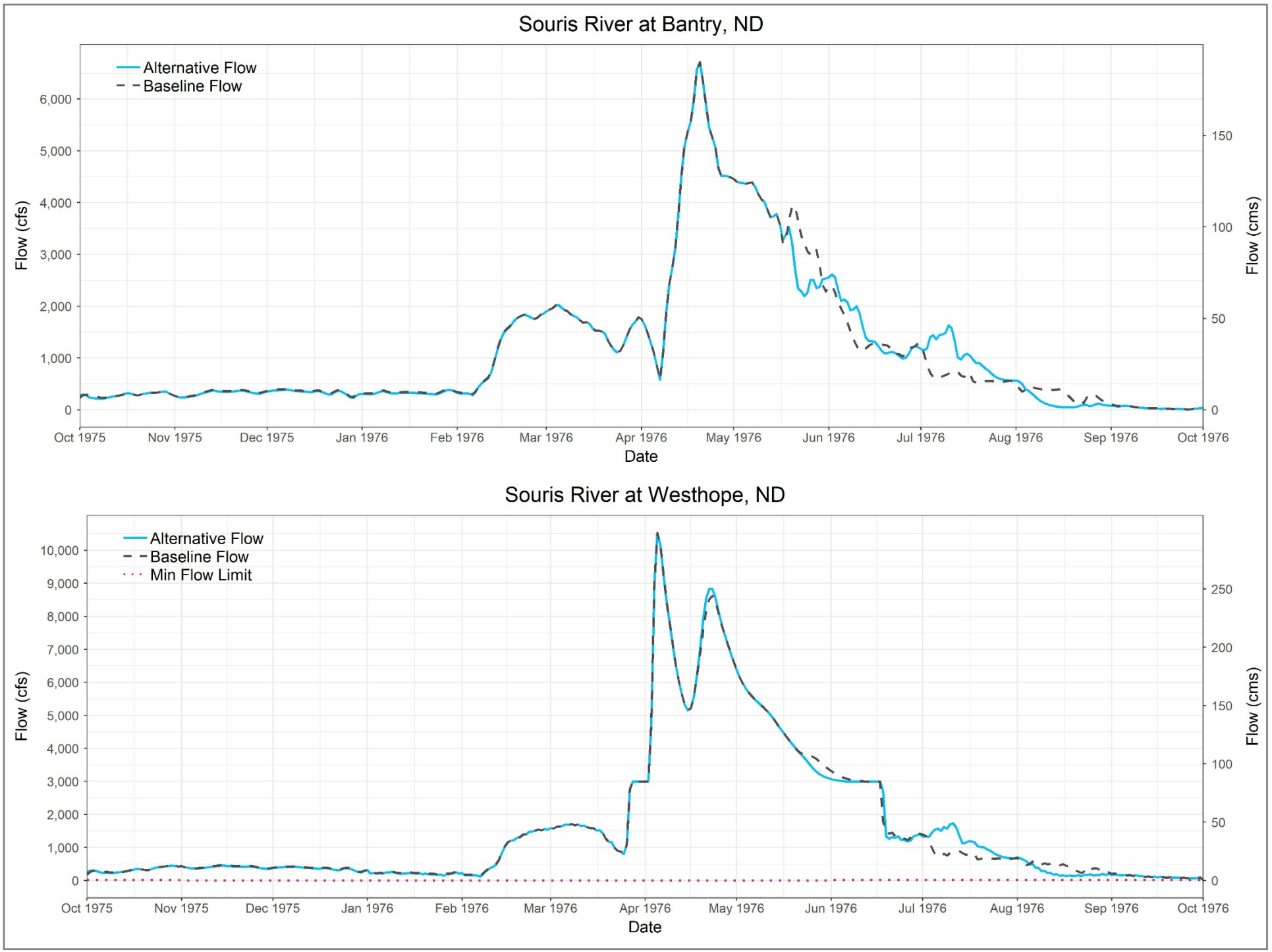
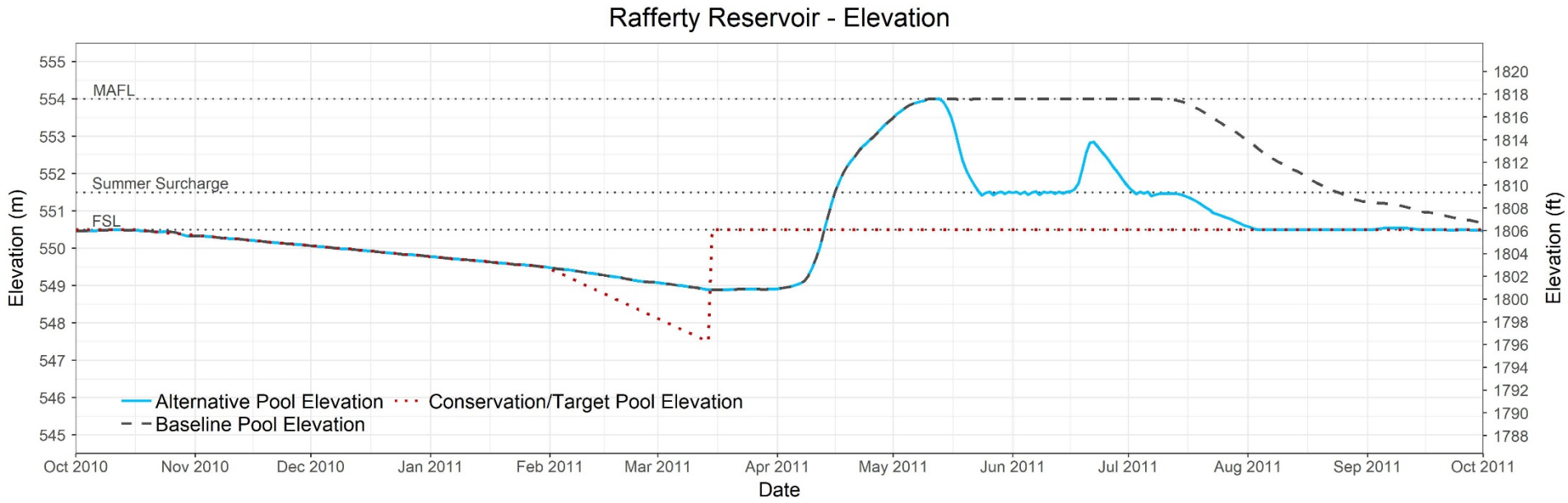
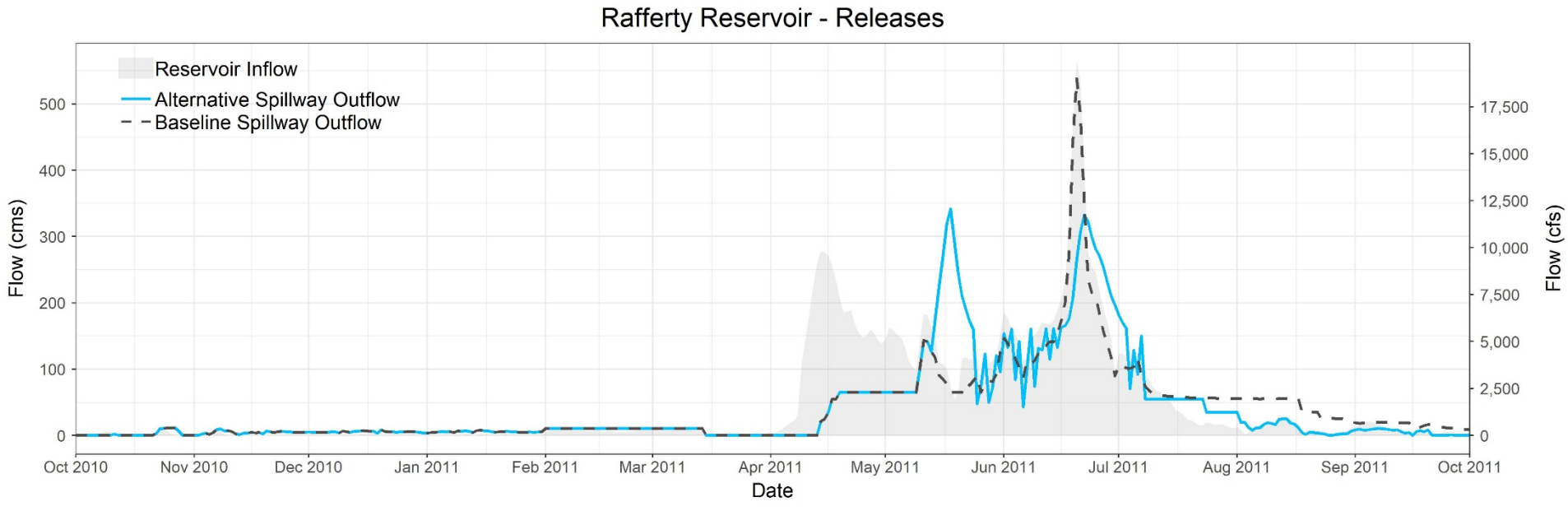
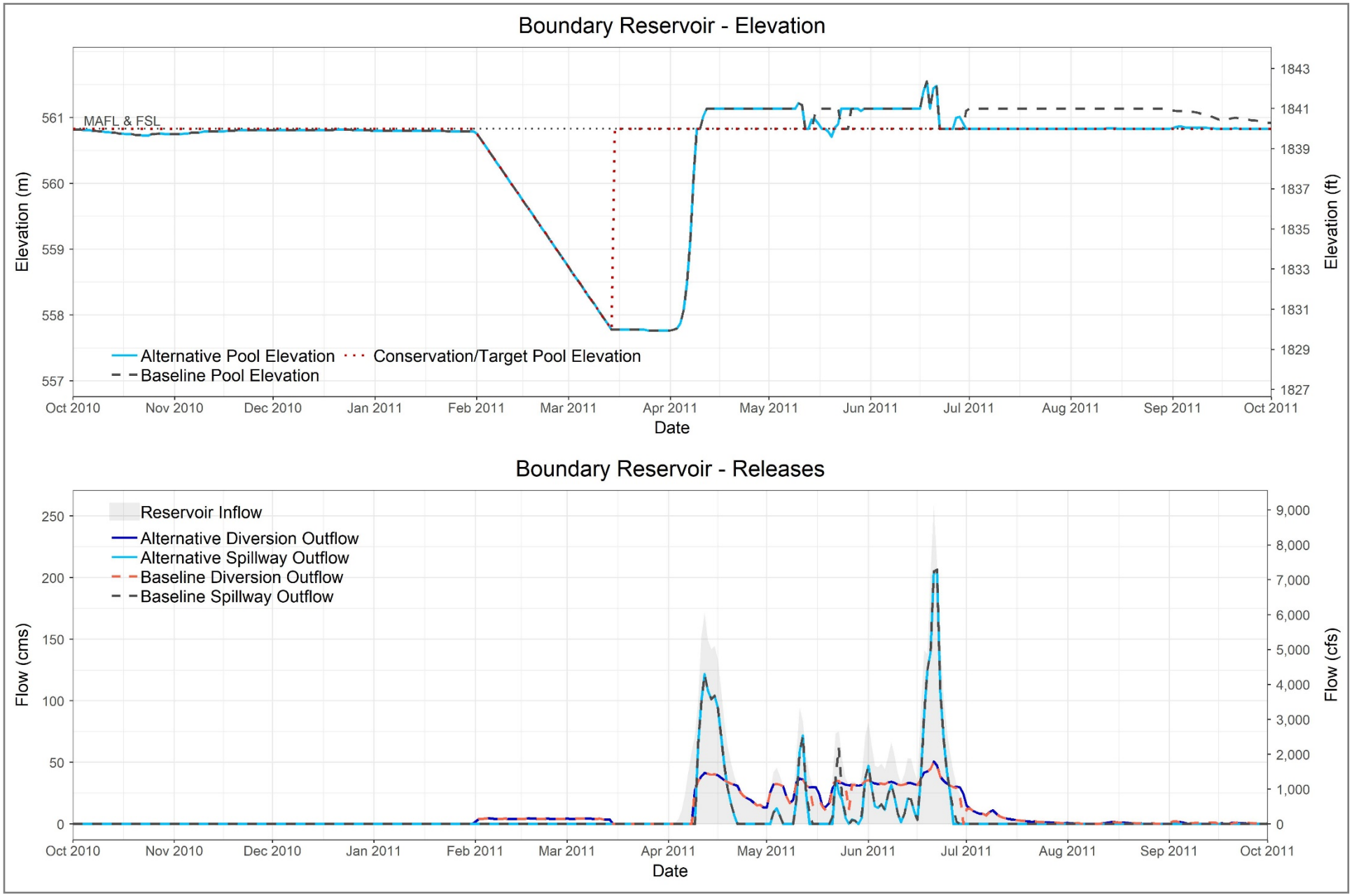

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date
Oct 1975
Nov 1975
Dec 1975
Jan 1976
Feb 1976
Mar 1976
Apr 1976
May 1976
Jun 1976
Jul 1976
Aug 1976
Sep 1976
Oct 1976
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
Date

Plate 07	Reservoirs – 2011	Alternative 11a (Phase 2) Souris River Plan of Study

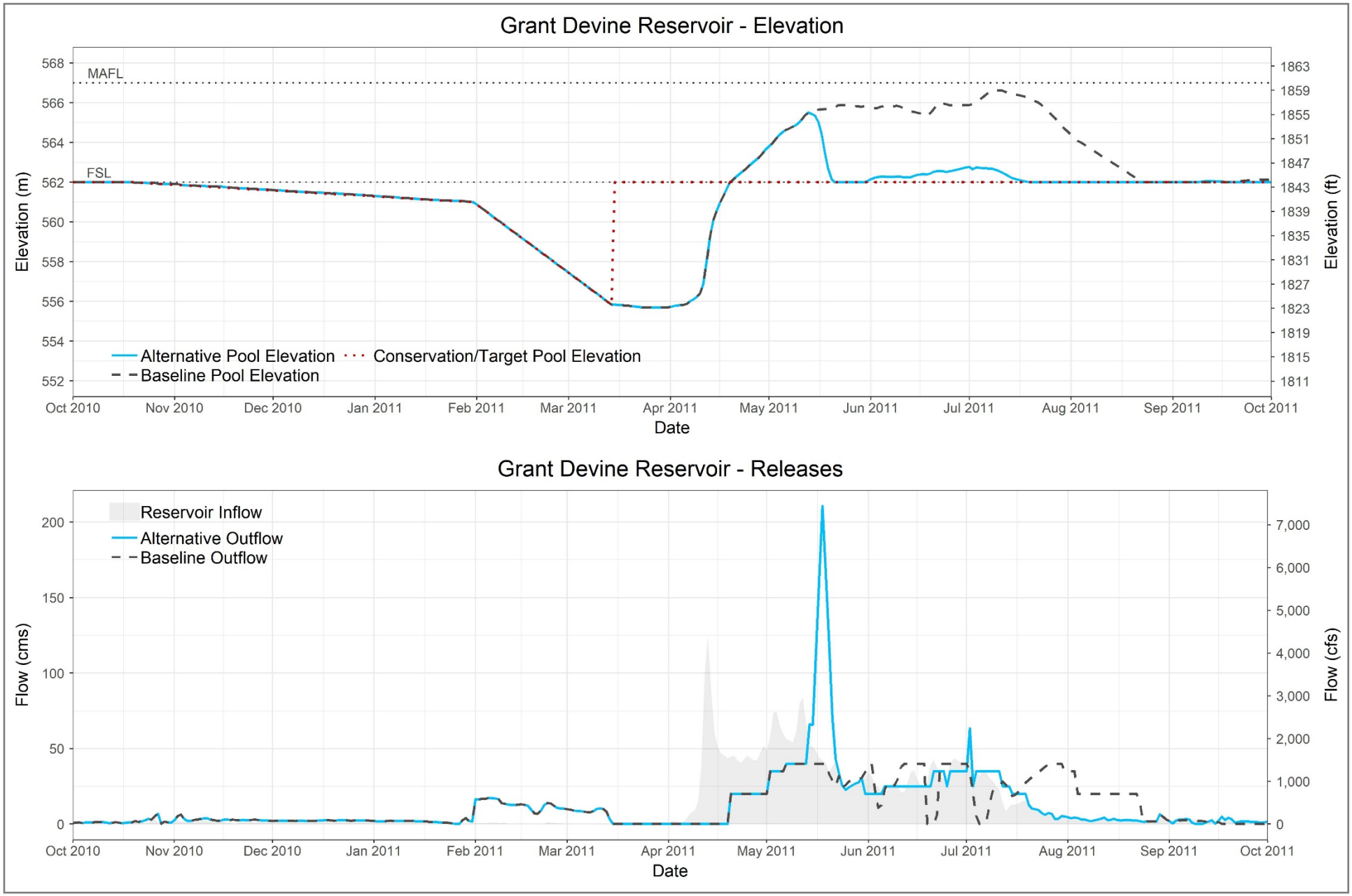




**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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

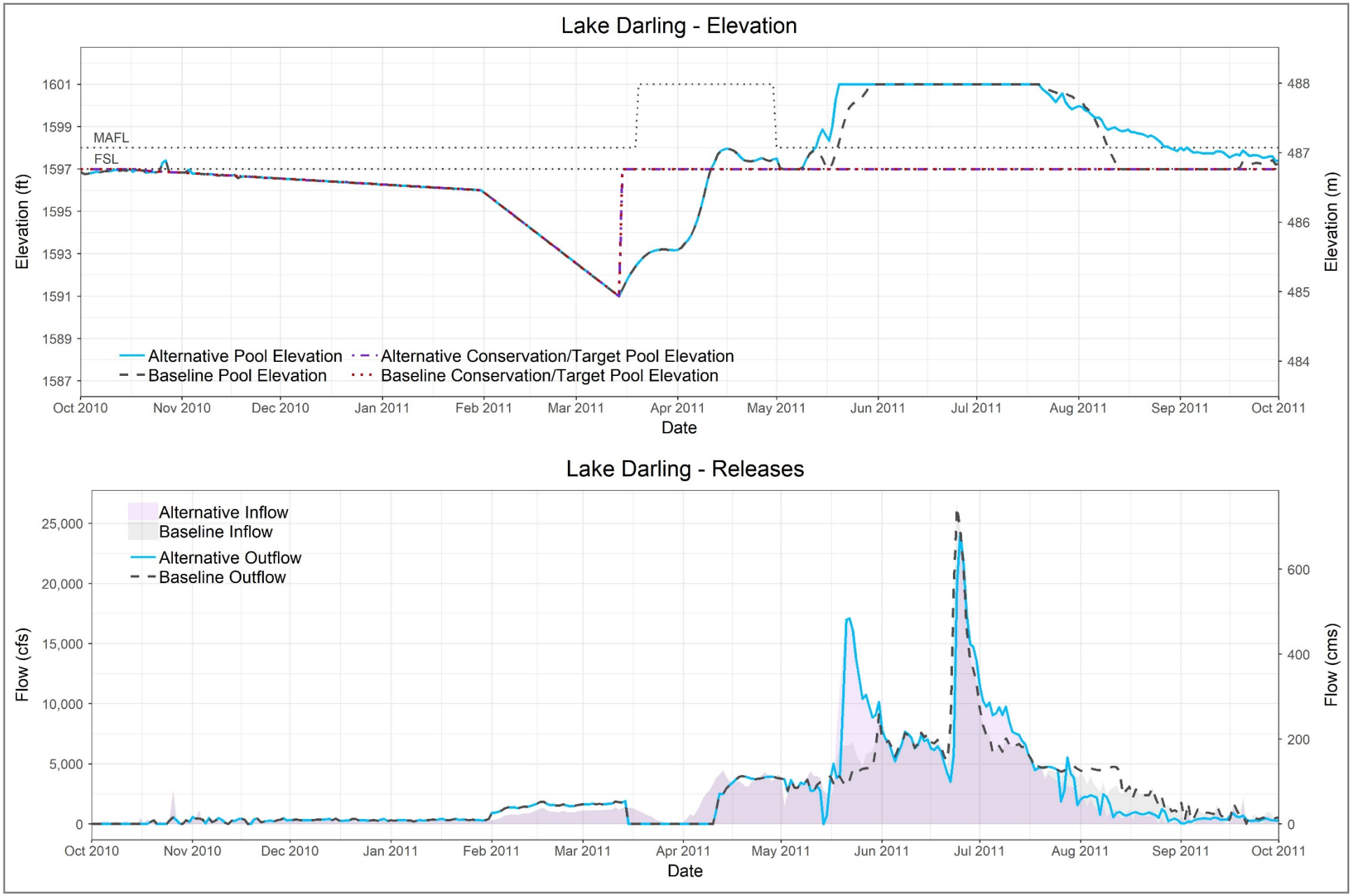
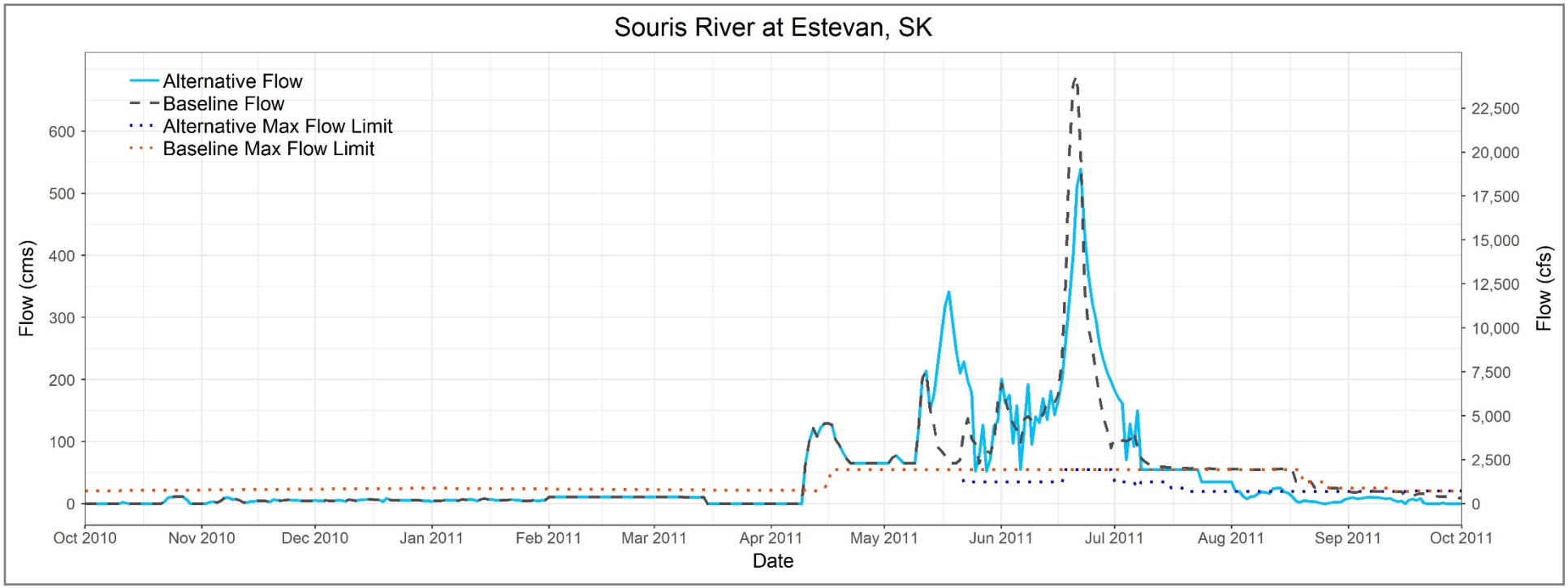

Lake Darling - Elevation
Elevation (ft)
Elevation (m)
1601
1599
1597
1595
1593
1591
1589
1587
488
487
486
485
484
MAFL
FSL
Alternative Pool Elevation
Baseline Pool Elevation
Alternative Conservation/Target Pool Elevation
Baseline Conservation/Target Pool Elevation
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Oct 2011
Date
Lake Darling - Releases
Flow (cfs)
Flow (cms)
25,000
20,000
15,000
10,000
5,000
0
600
400
200
0
Alternative Inflow
Baseline Inflow
Alternative Outflow
Baseline Outflow
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Oct 2011
Date

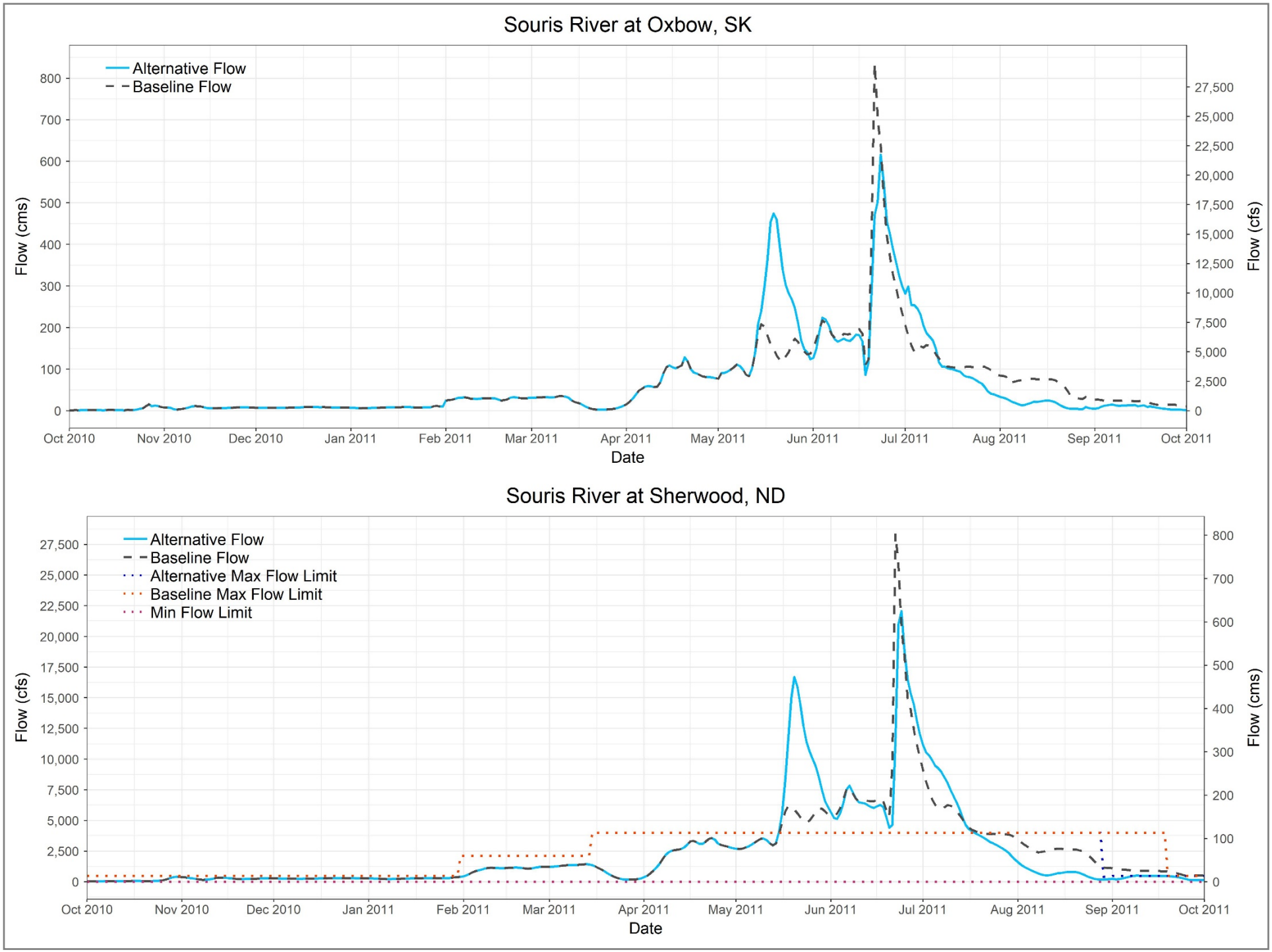
Plate 08

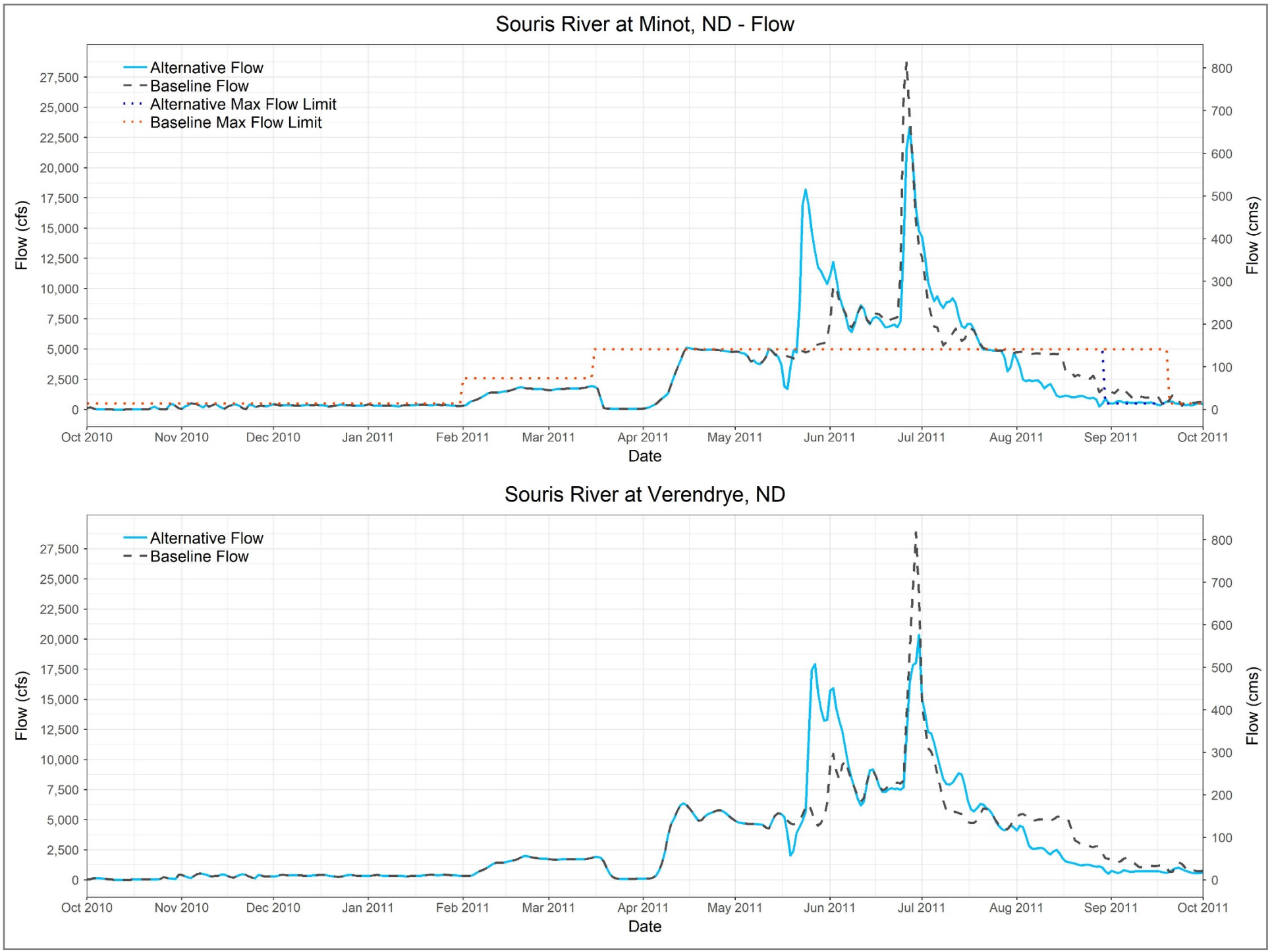
Critical Flow Locations – 2011

Alternative 11a (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Oct 2011
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Oct 2011
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date

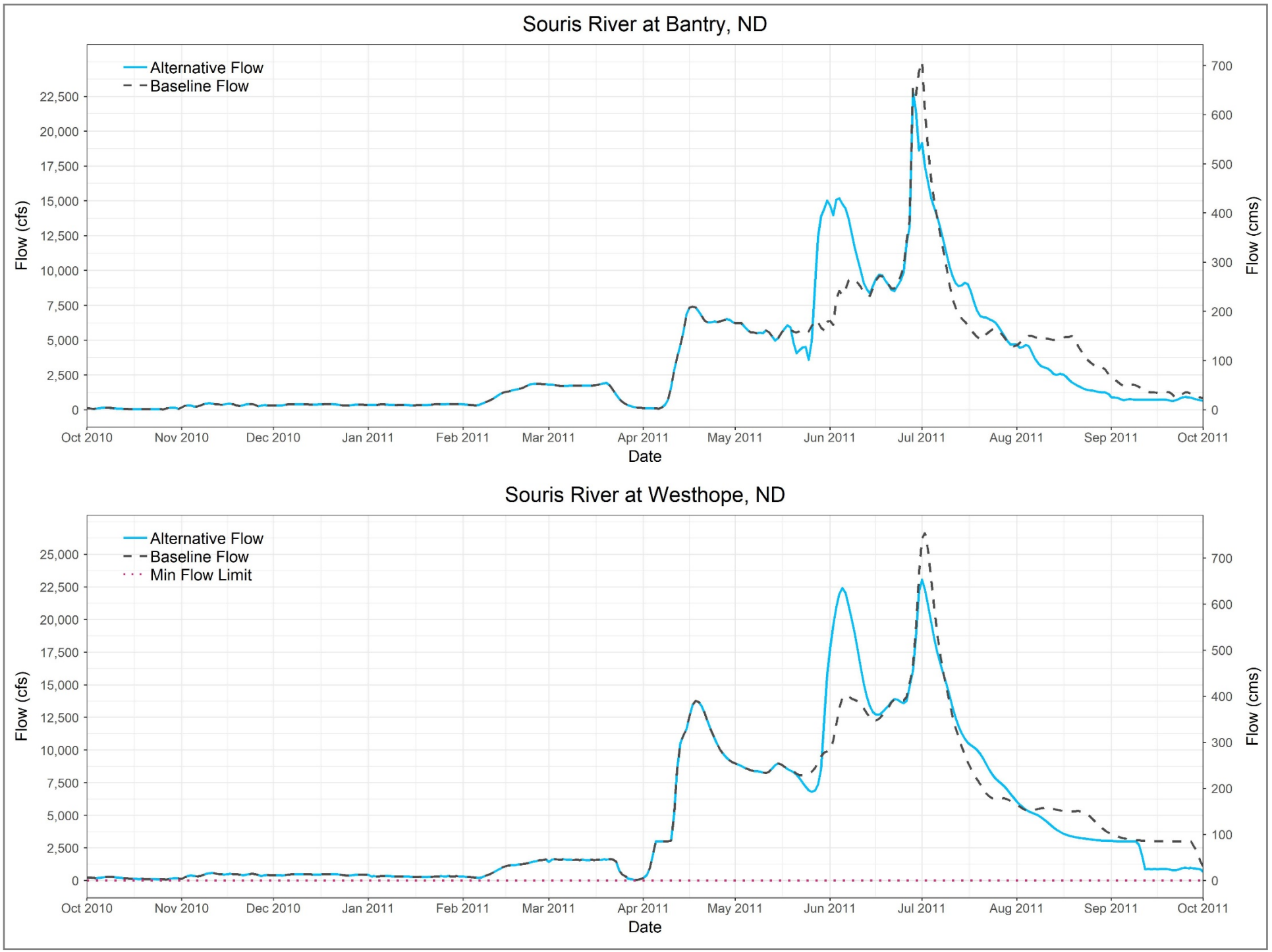
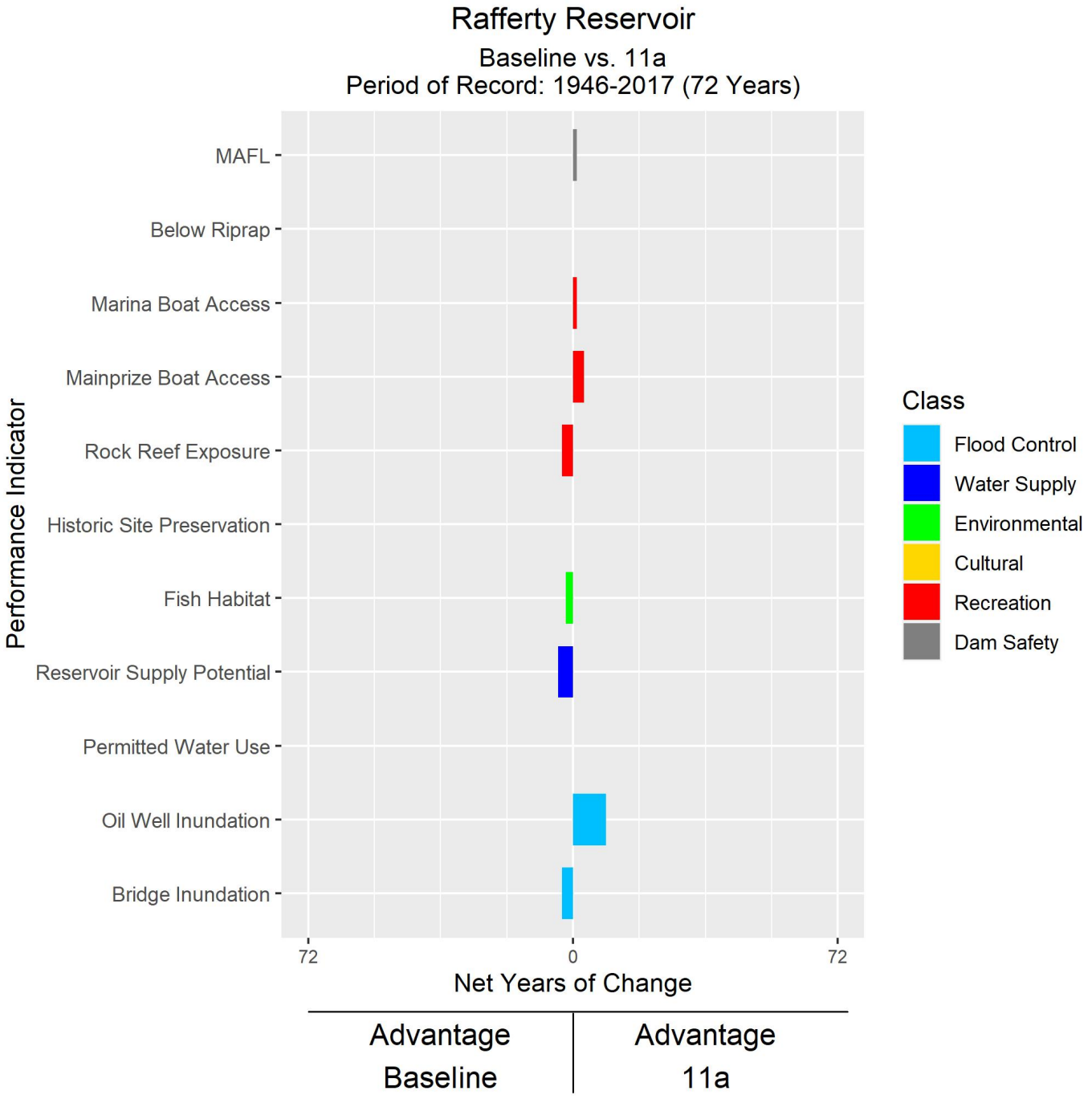
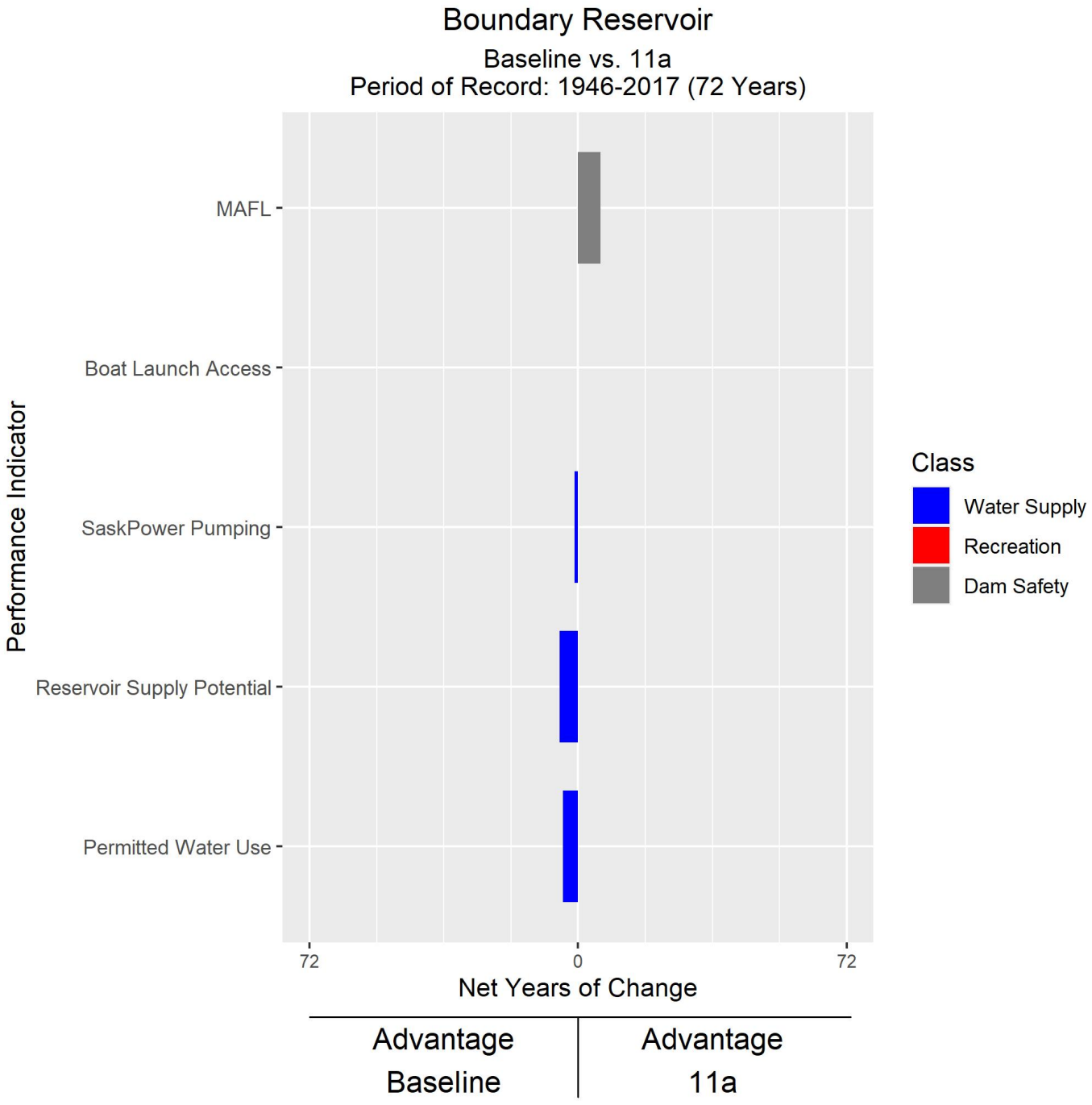
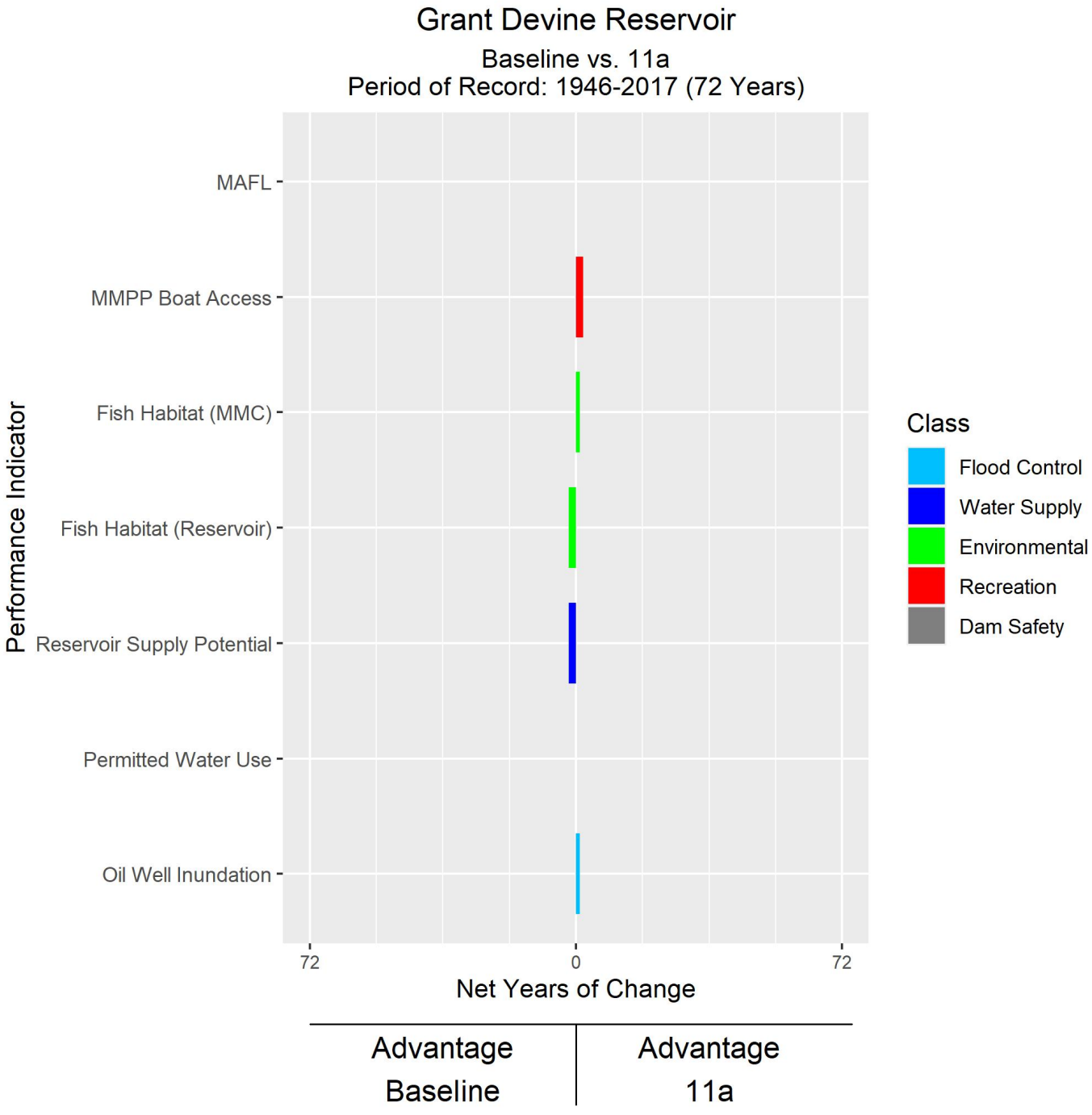
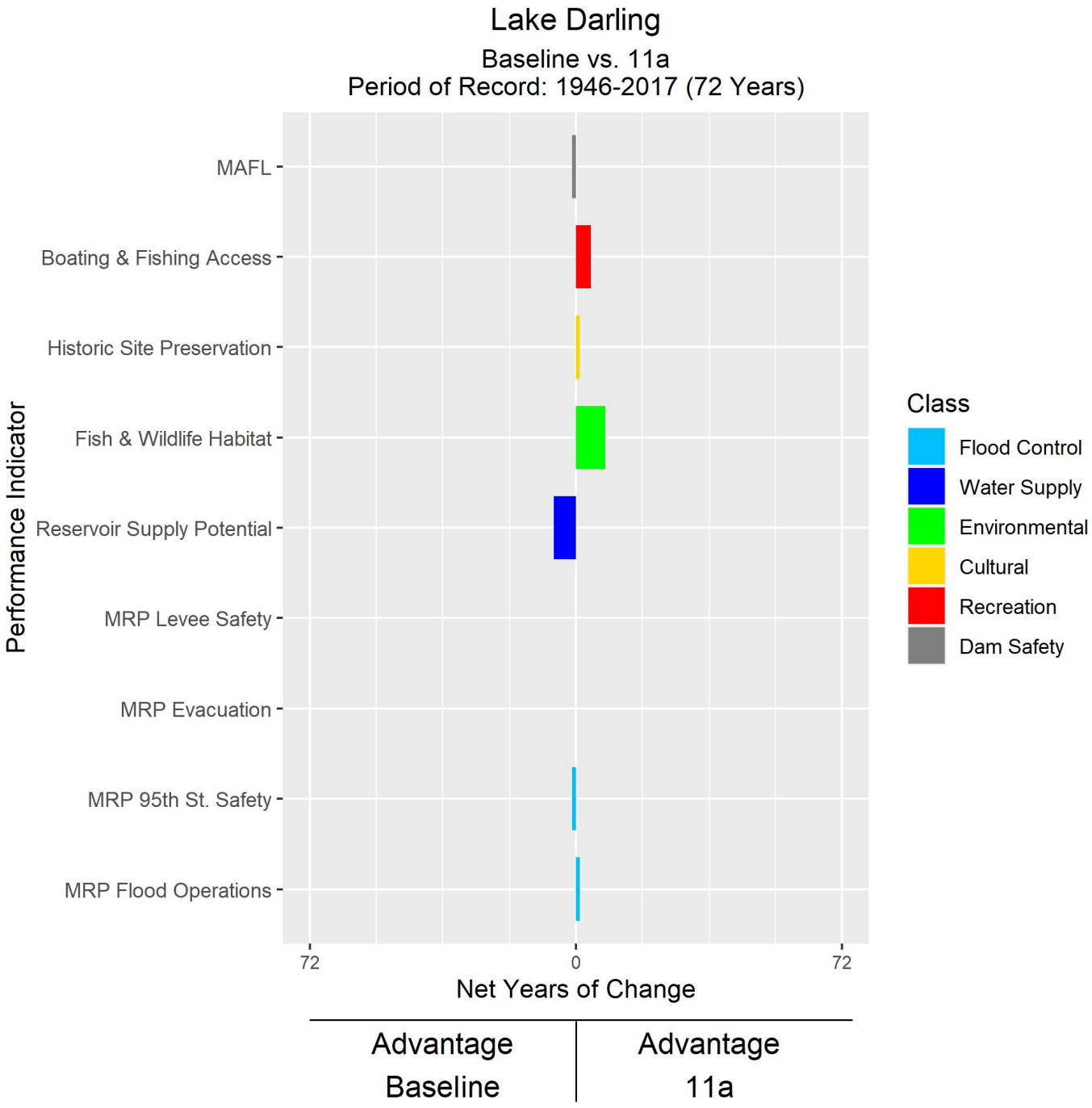

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Oct 2011
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
Date

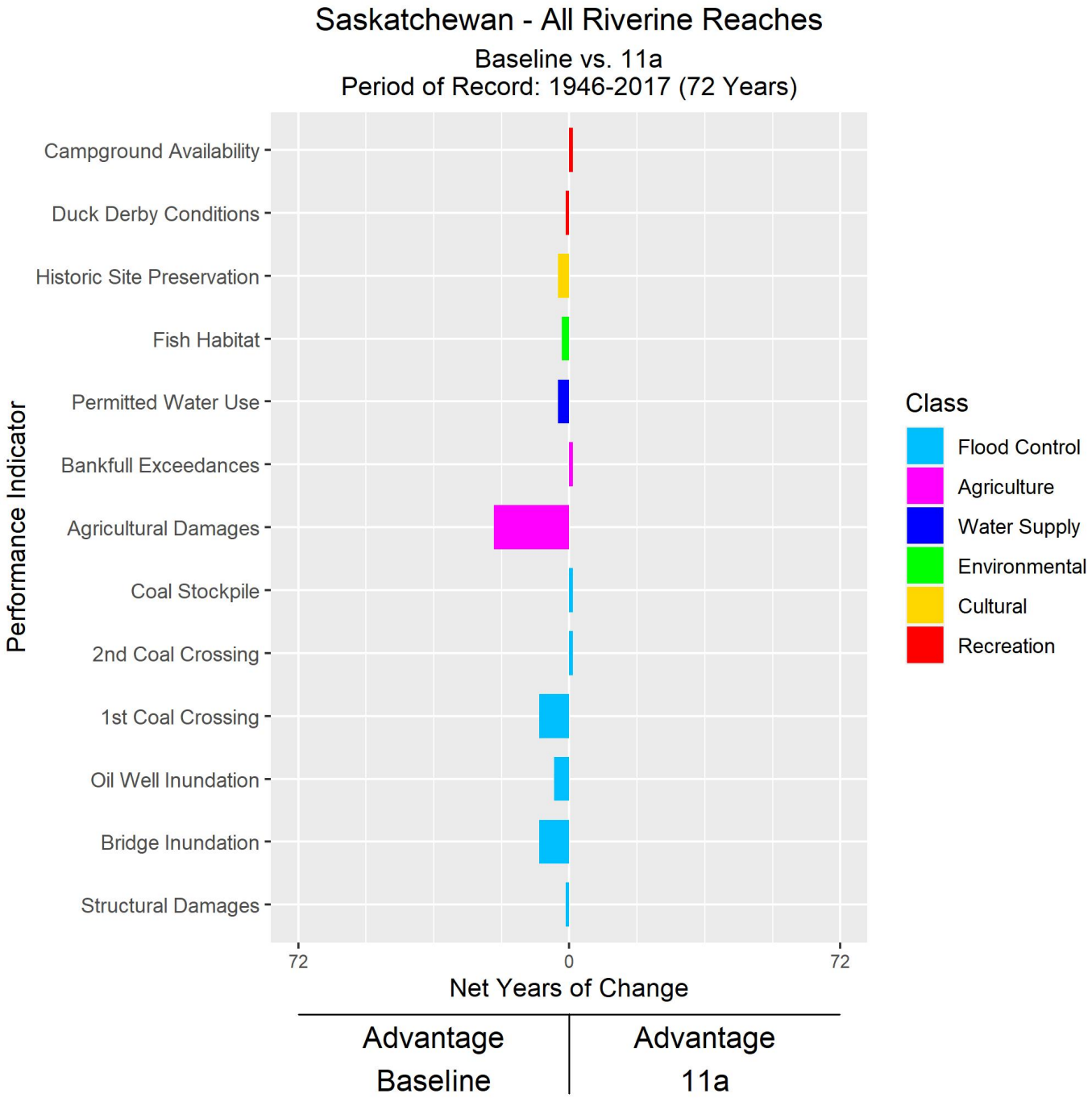
Plate 09	Performance Indicators 1946-2017 (72 years)	Alternative 11a vs. Baseline (Phase 2)

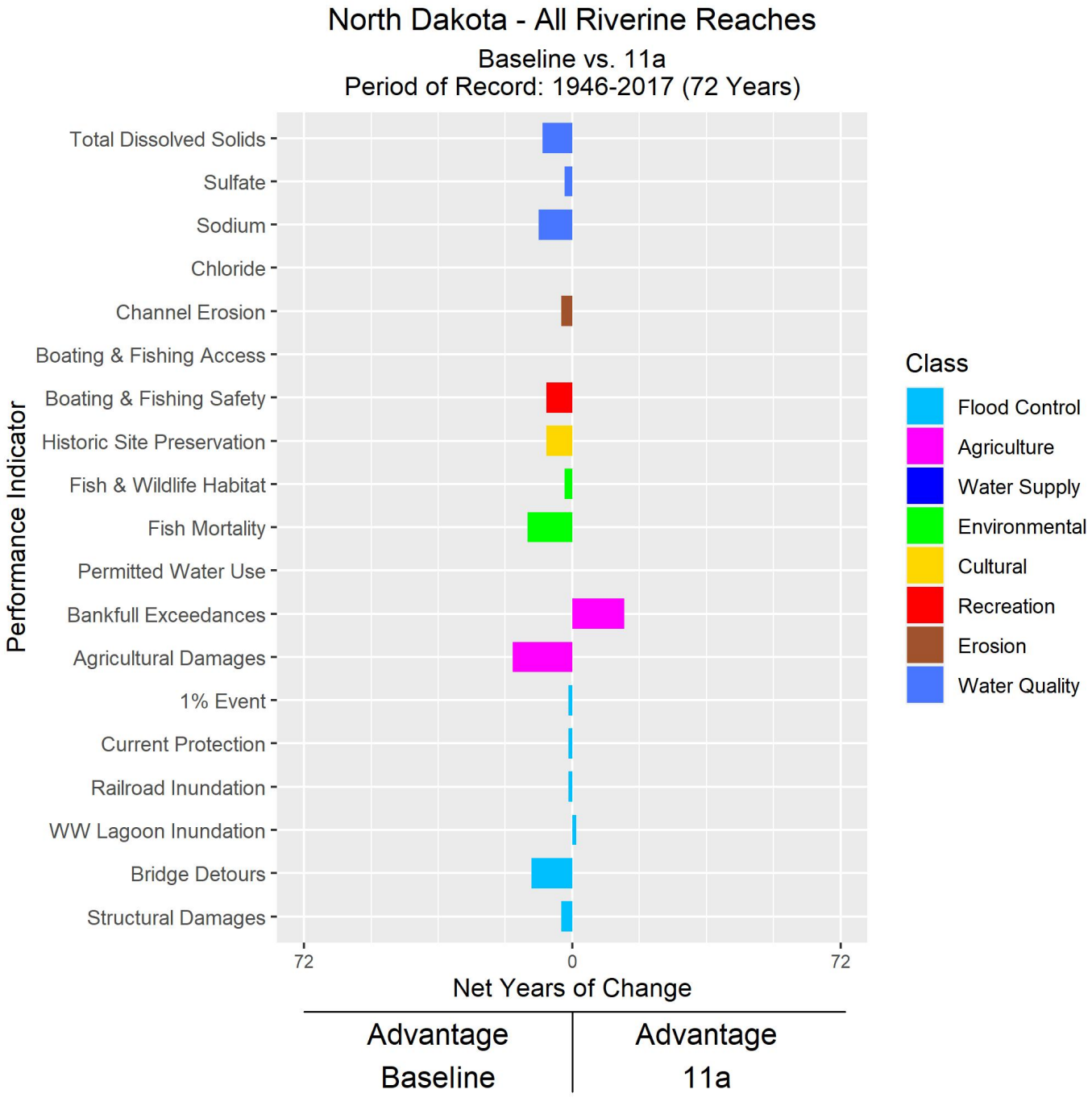


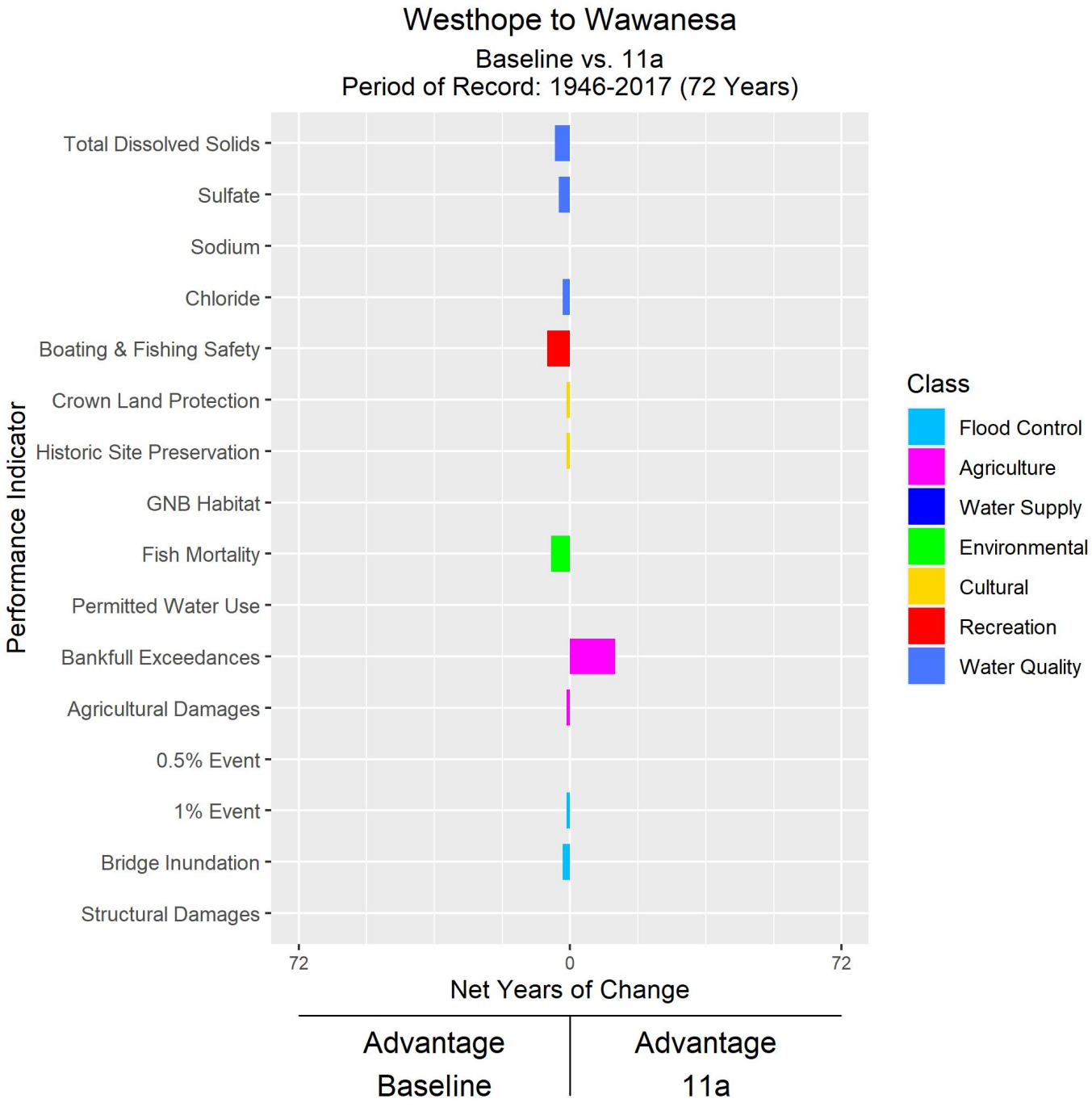

Boundary Reservoir
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
MAFL
Boat Launch Access
SaskPower Pumping
Reservoir Supply Potential
Permitted Water Use
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11a
Class
Water Supply
Recreation
Dam Safety

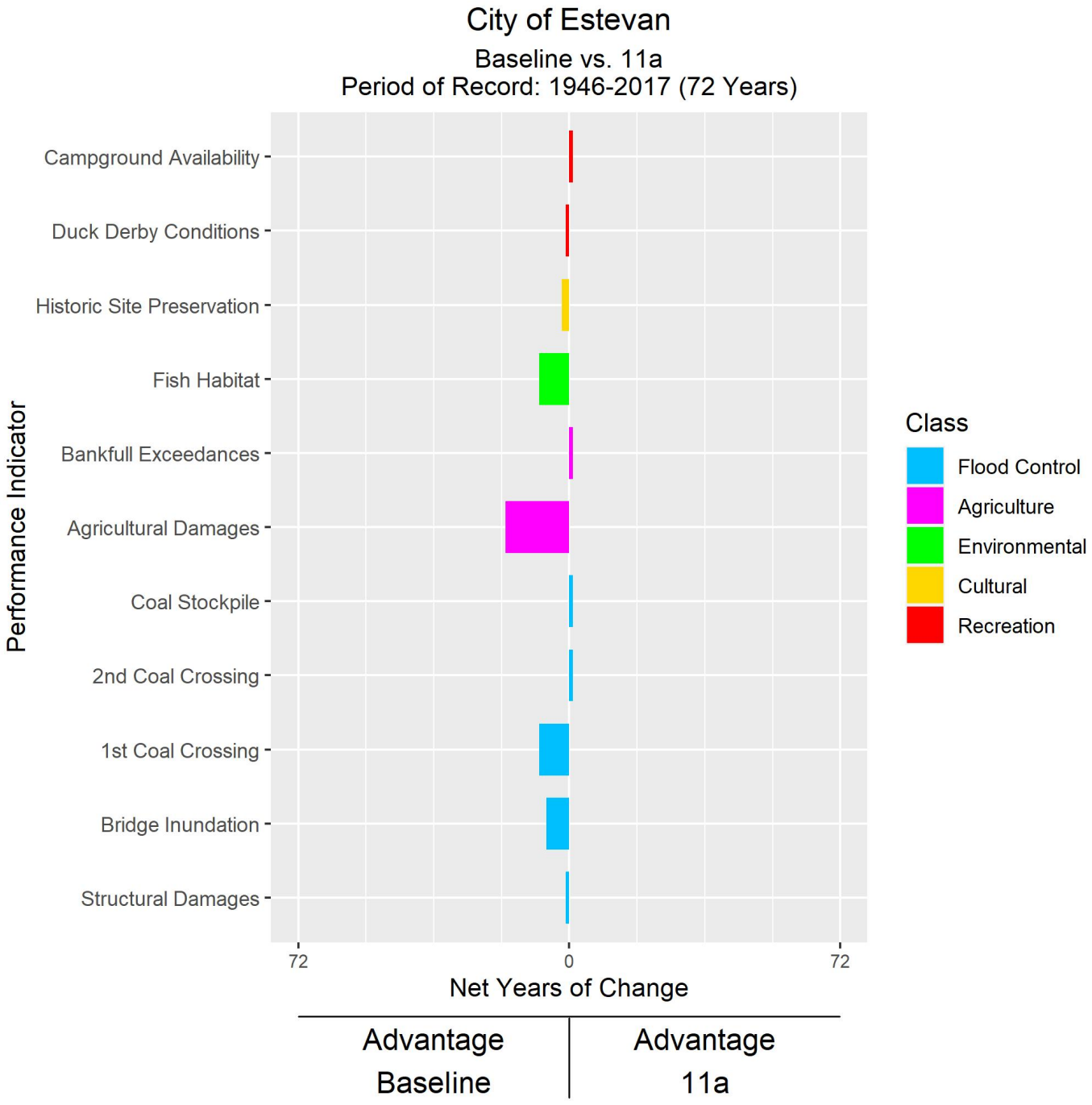

Grant Devine Reservoir
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
MAFL
MMPP Boat Access
Fish Habitat (MMC)
Fish Habitat (Reservoir)
Reservoir Supply Potential
Permitted Water Use
Oil Well Inundation
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11a
Class
Flood Control
Water Supply
Environmental
Recreation
Dam Safety

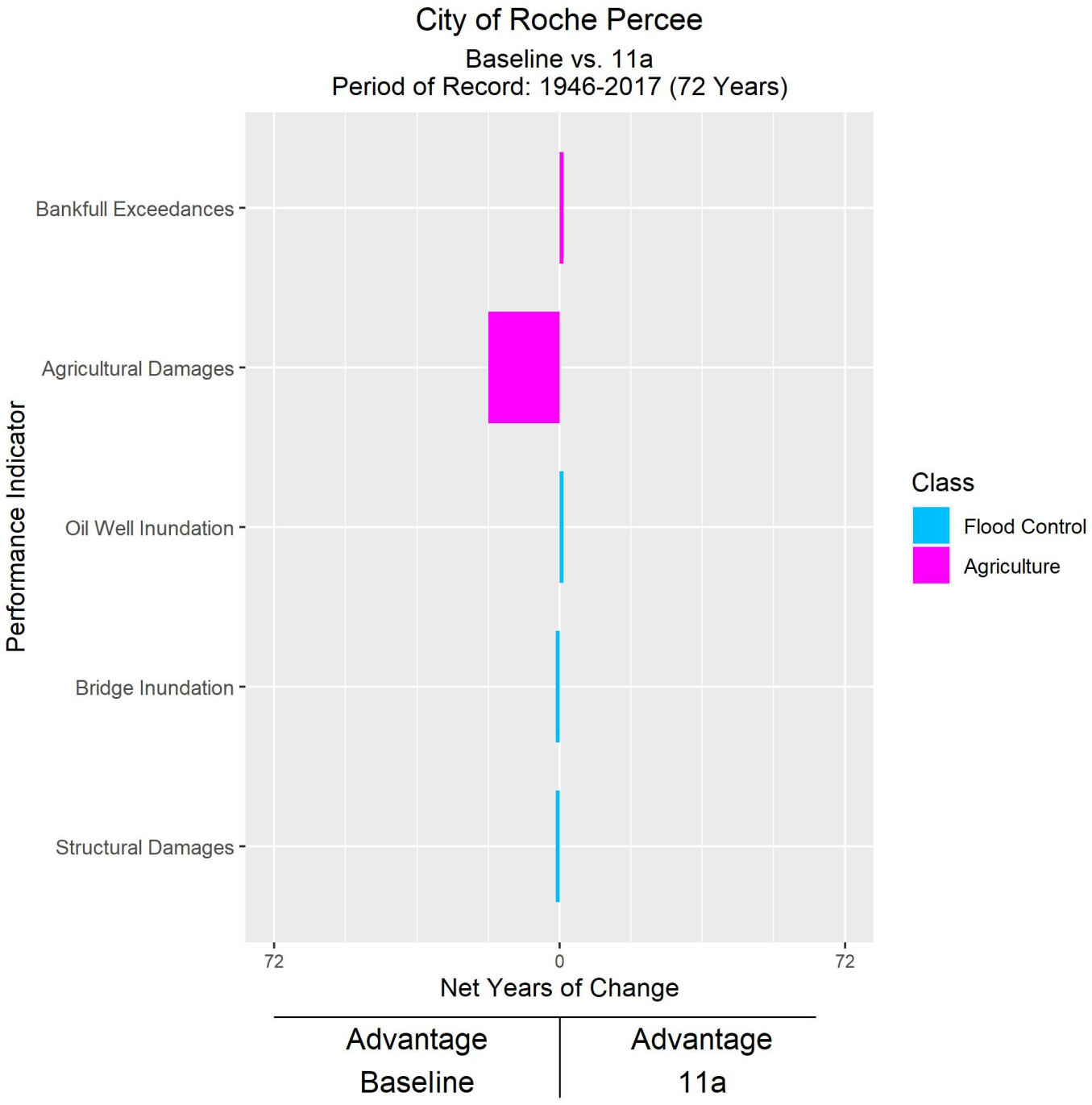

Lake Darling
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
MAFL
Boating & Fishing Access
Historic Site Preservation
Fish & Wildlife Habitat
Reservoir Supply Potential
MRP Levee Safety
MRP Evacuation
MRP 95th St. Safety
MRP Flood Operations
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Water Supply
Environmental
Cultural
Recreation
Dam Safety

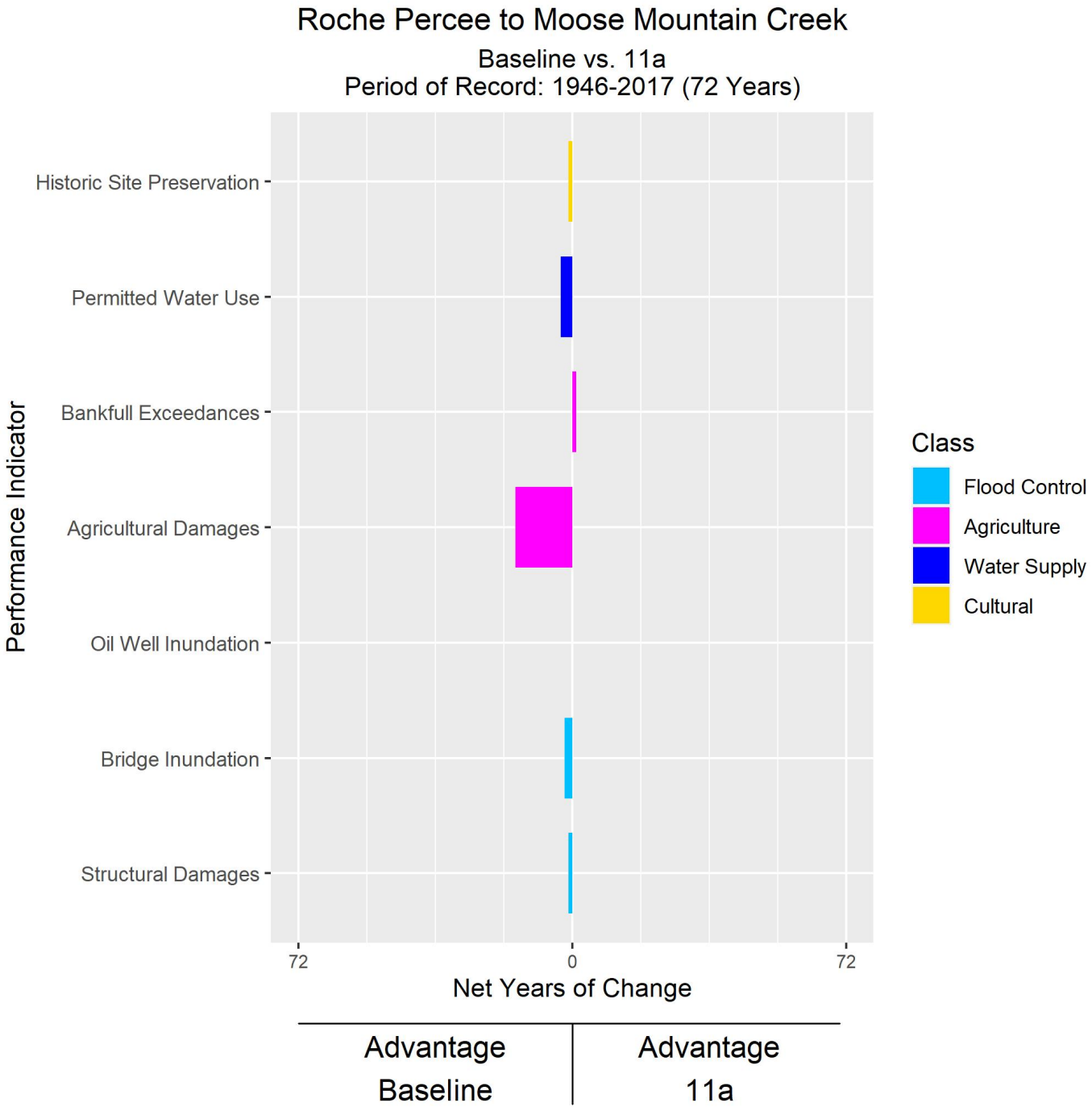

Saskatchewan - All Riverine Reaches
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Campground Availability
Duck Derby Conditions
Historic Site Preservation
Fish Habitat
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Coal Stockpile
2nd Coal Crossing
1st Coal Crossing
Oil Well Inundation
Bridge Inundation
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation

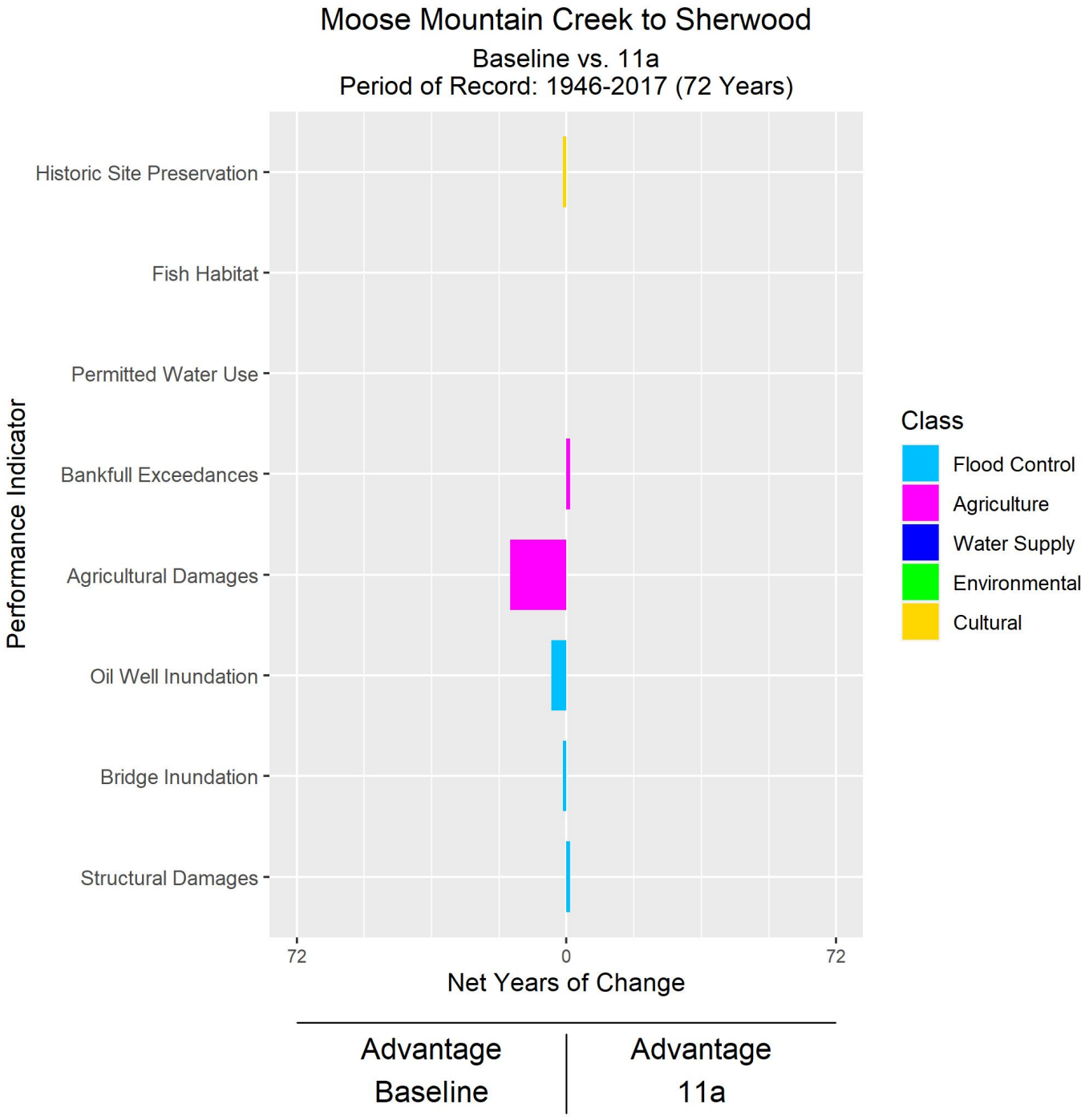

North Dakota - All Riverine Reaches
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Total Dissolved Solids
Sulfate
Sodium
Chloride
Channel Erosion
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
1% Event
Current Protection
Railroad Inundation
WW Lagoon Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion
Water Quality

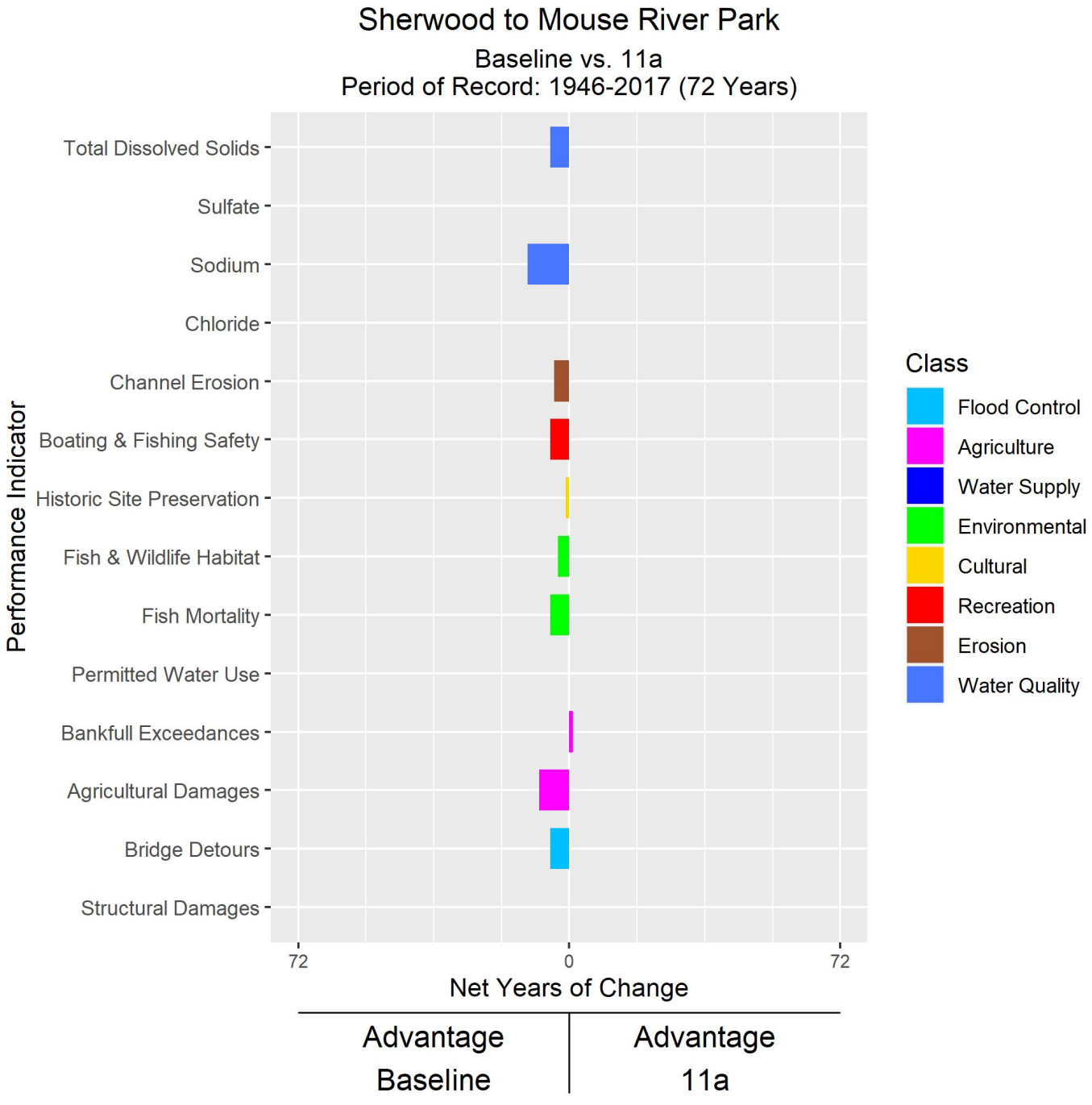

Westhope to Wawanesa
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Total Dissolved Solids
Sulfate
Sodium
Chloride
Boating & Fishing Safety
Crown Land Protection
Historic Site Preservation
GNB Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
0.5% Event
1% Event
Bridge Inundation
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Water Quality

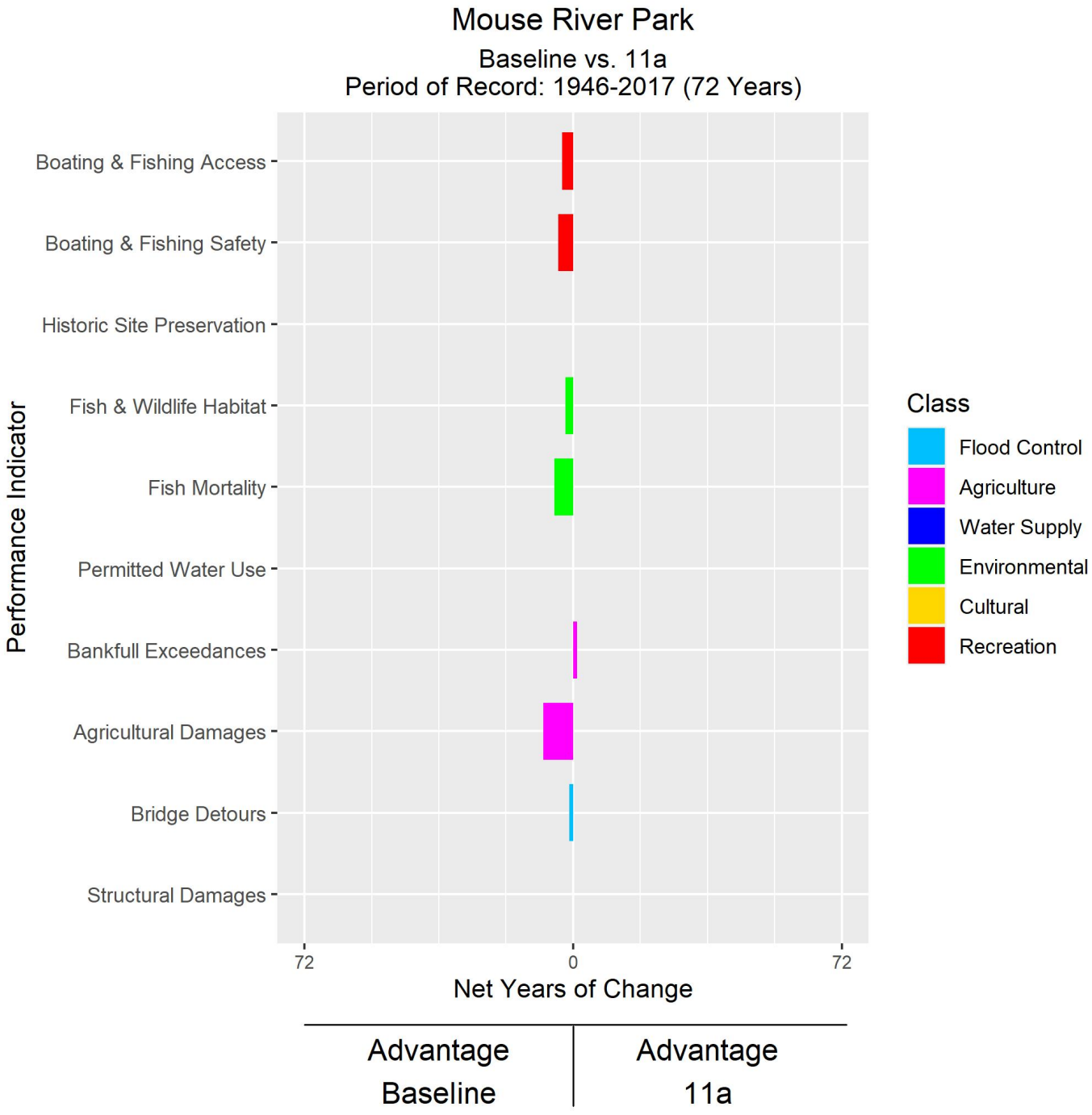

City of Estevan
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Campground Availability
Duck Derby Conditions
Historic Site Preservation
Fish Habitat
Bankfull Exceedances
Agricultural Damages
Coal Stockpile
2nd Coal Crossing
1st Coal Crossing
Bridge Inundation
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Environmental
Cultural
Recreation

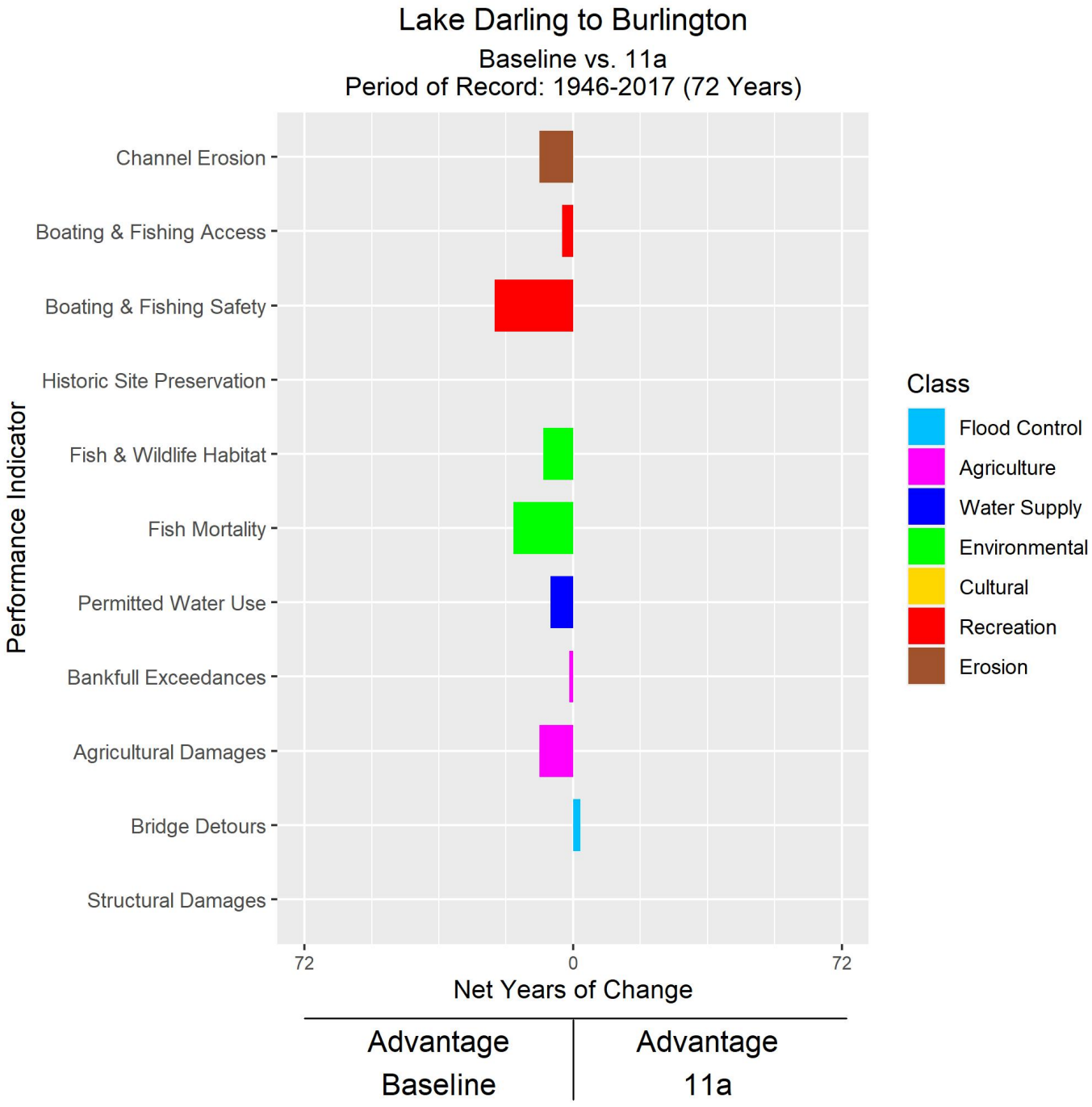

City of Roche Percee
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Bankfull Exceedances
Agricultural Damages
Oil Well Inundation
Bridge Inundation
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture

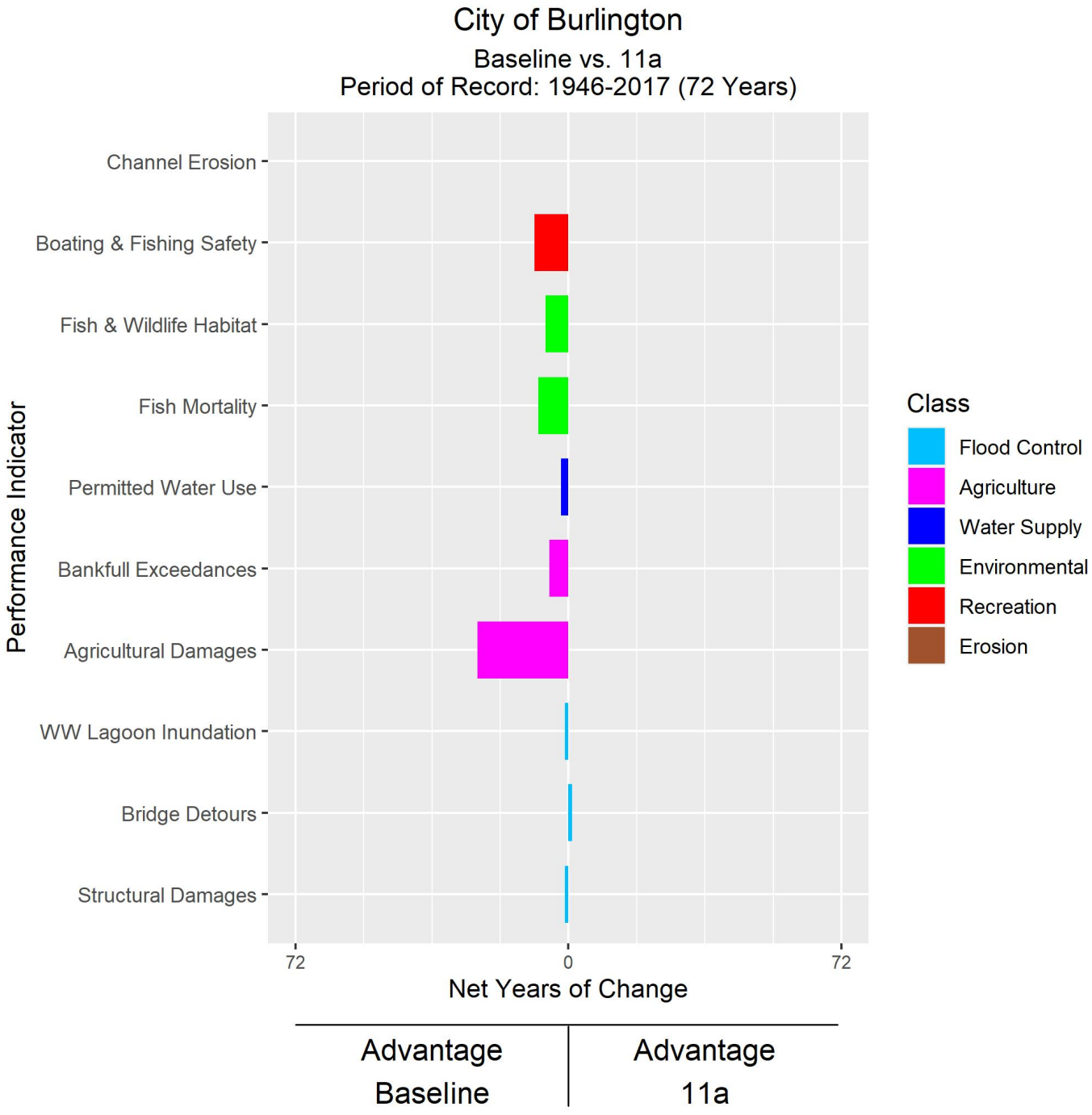

Roche Percee to Moose Mountain Creek
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Historic Site Preservation
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Oil Well Inundation
Bridge Inundation
Structural Damages
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11a
Class
Flood Control
Agriculture
Water Supply
Cultural

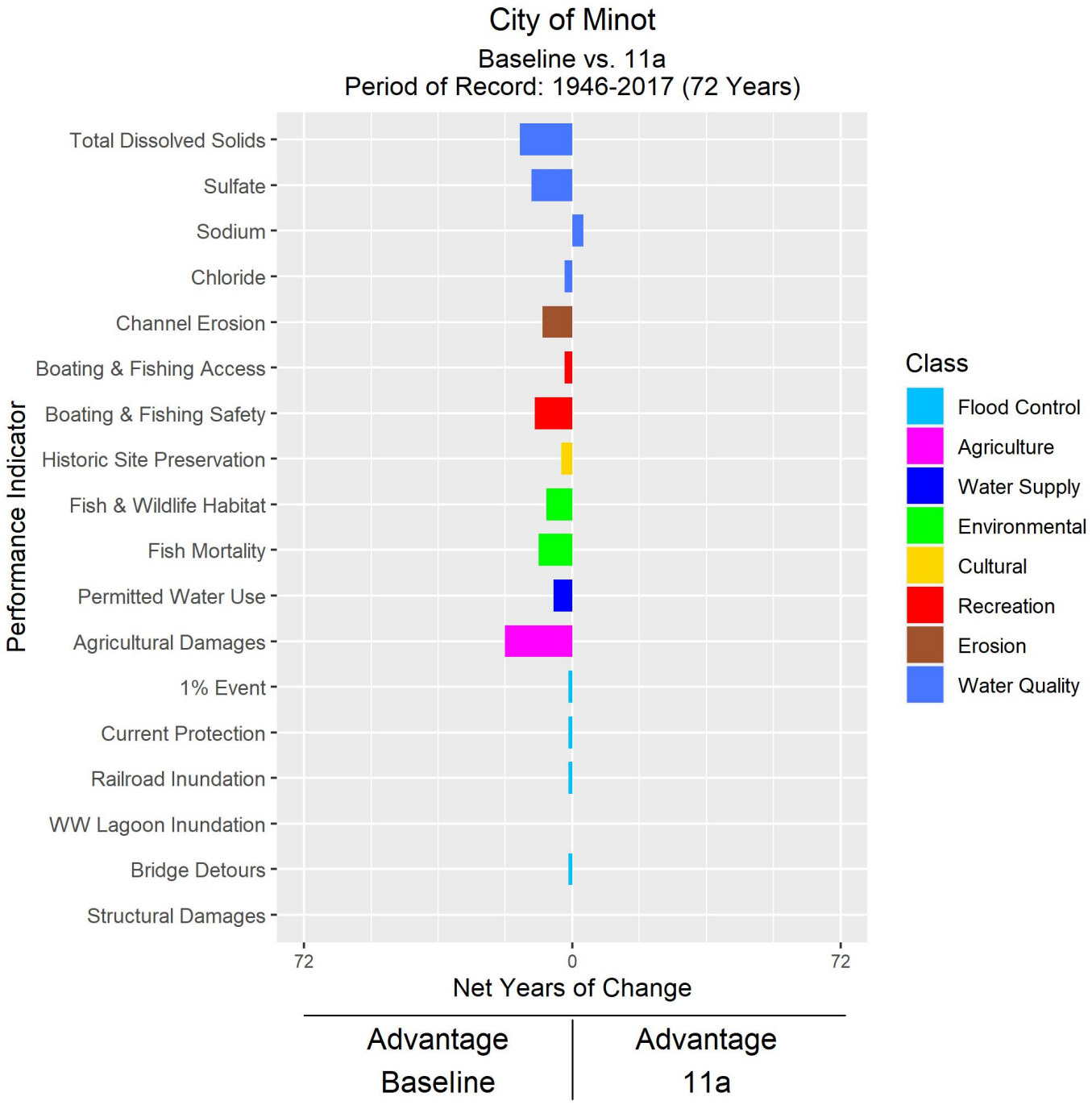

Moose Mountain Creek to Sherwood
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Historic Site Preservation
Fish Habitat
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Oil Well Inundation
Bridge Inundation
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural

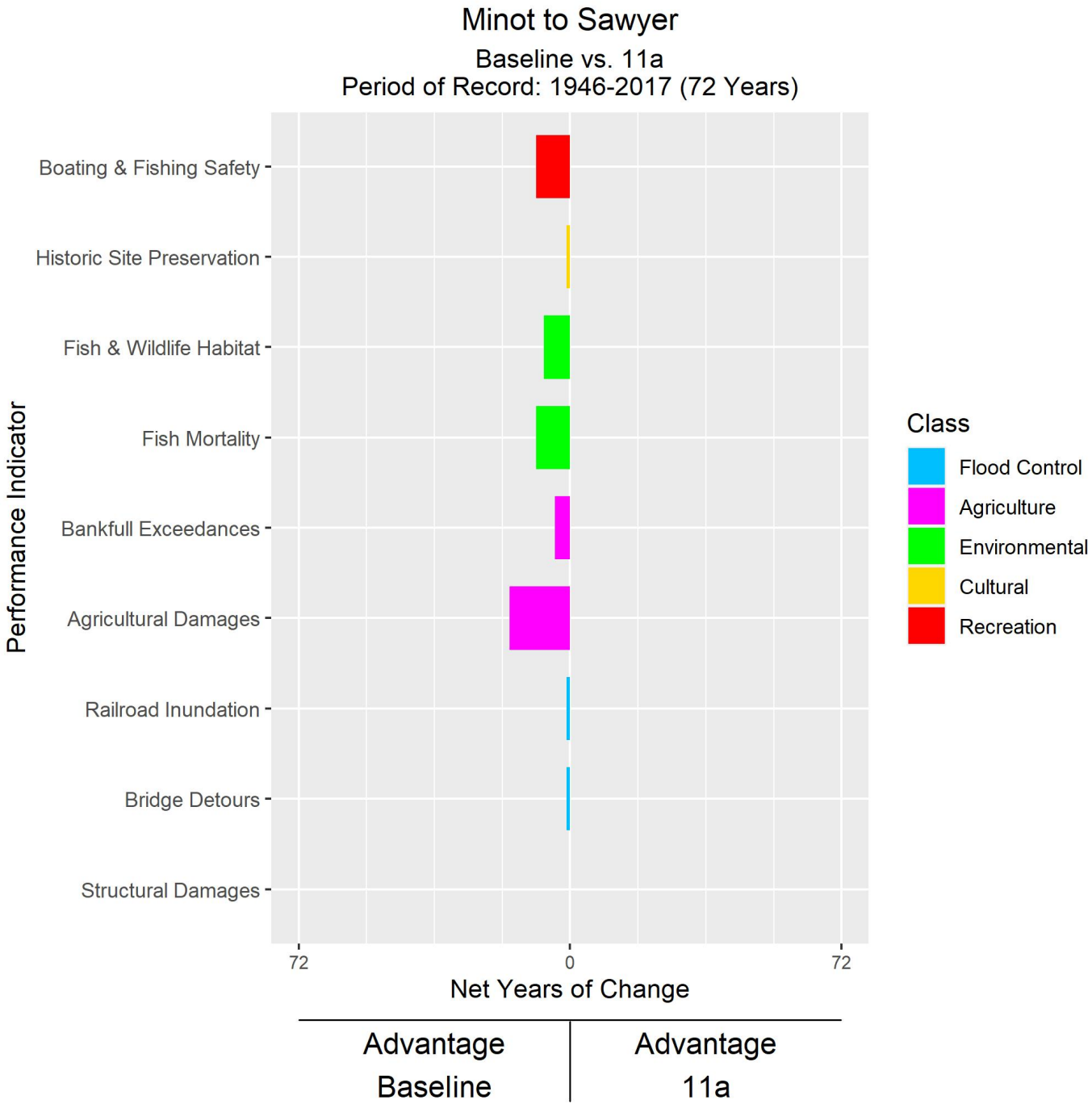

Sherwood to Mouse River Park
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Total Dissolved Solids
Sulfate
Sodium
Chloride
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion
Water Quality

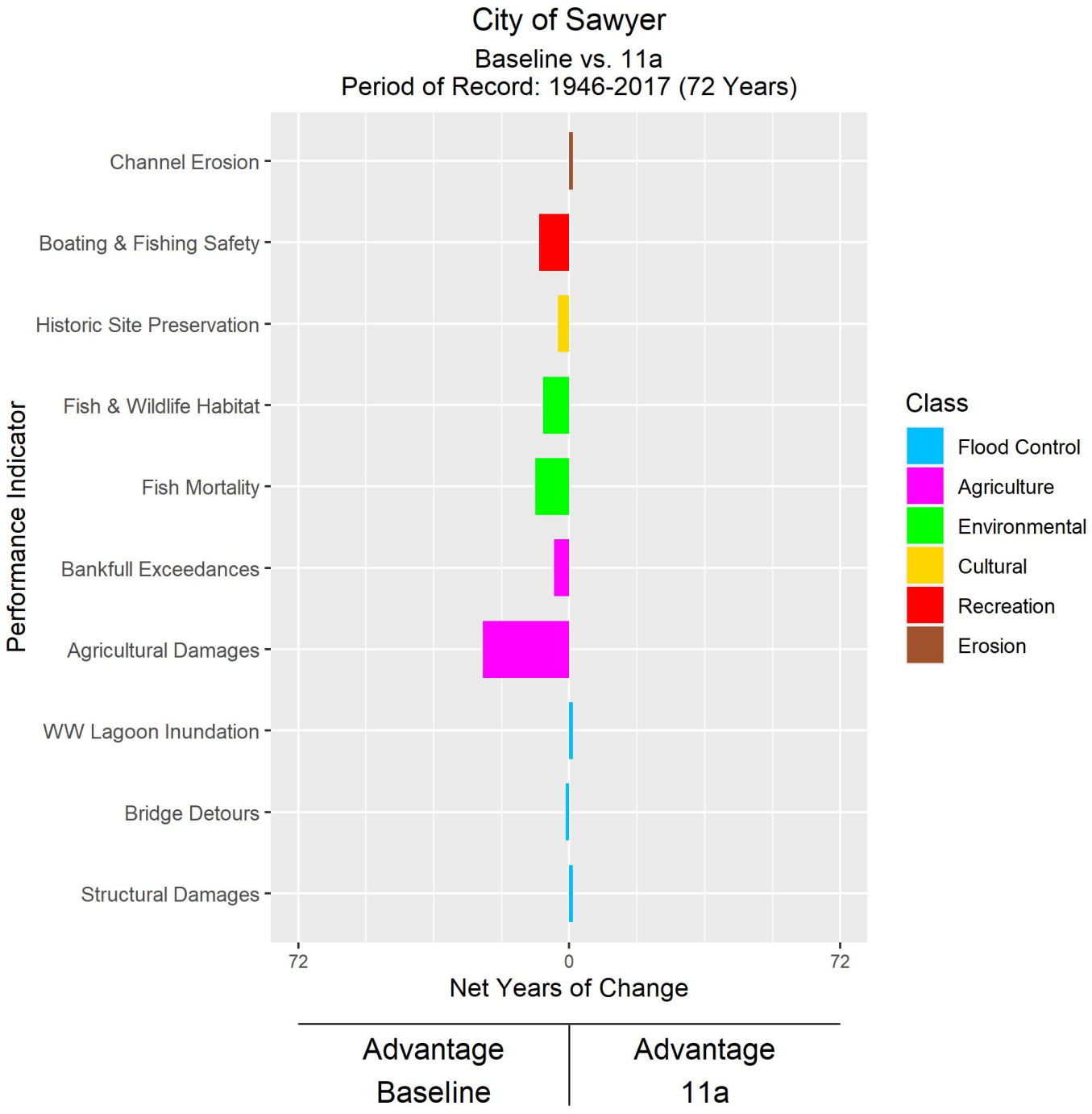

Mouse River Park
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation

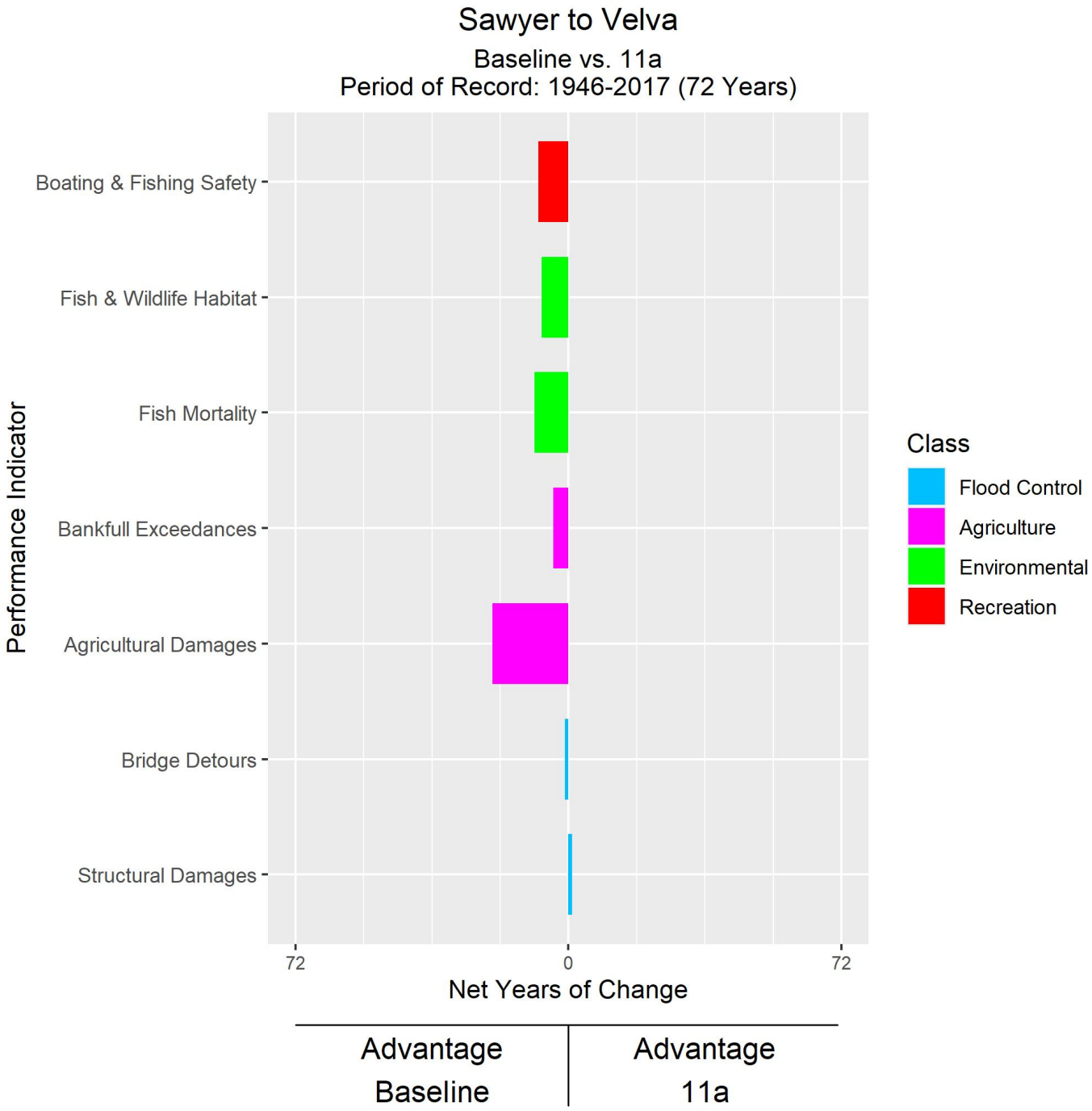

Lake Darling to Burlington
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion

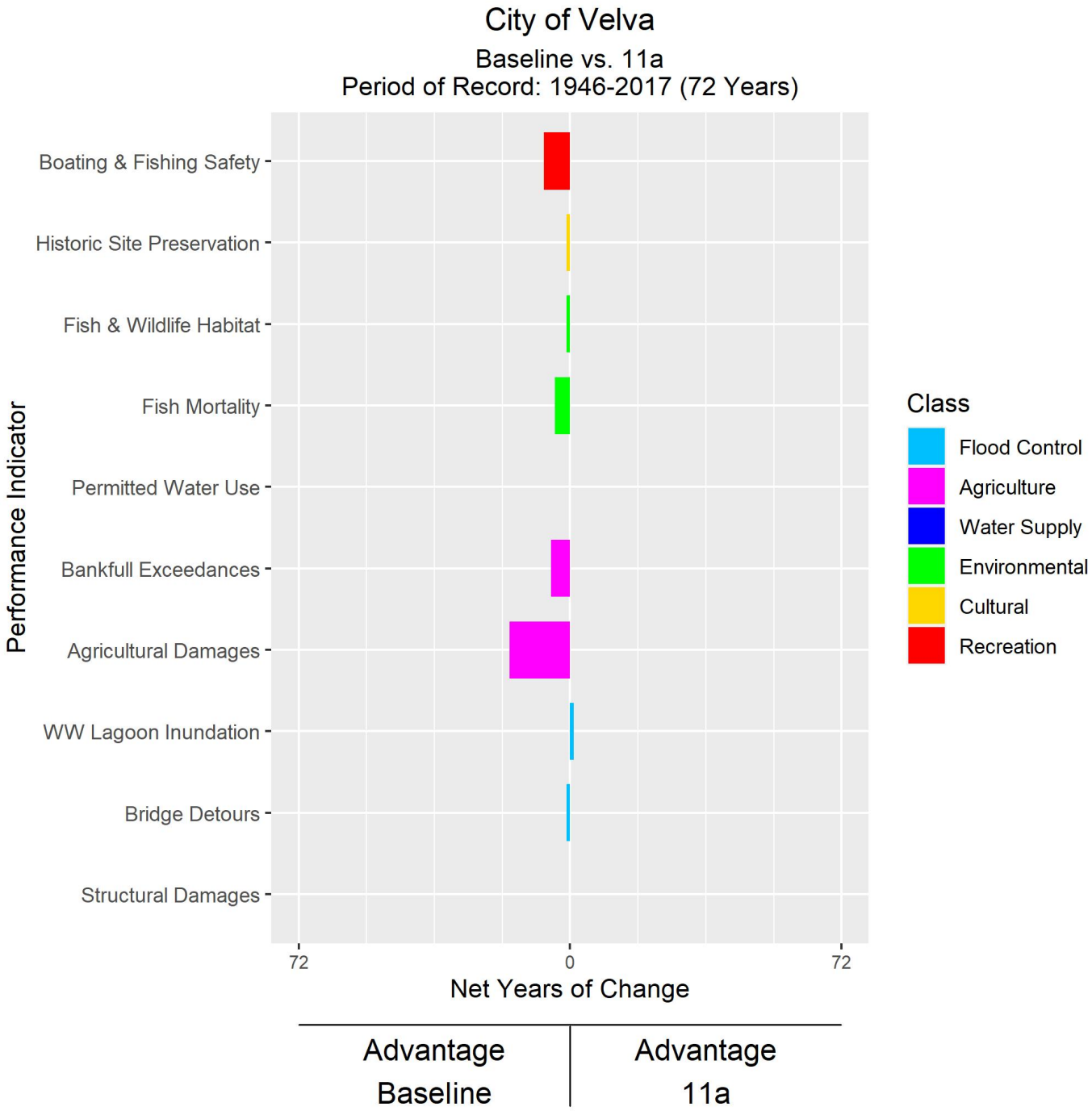

City of Burlington
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
WW Lagoon Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Recreation
Erosion

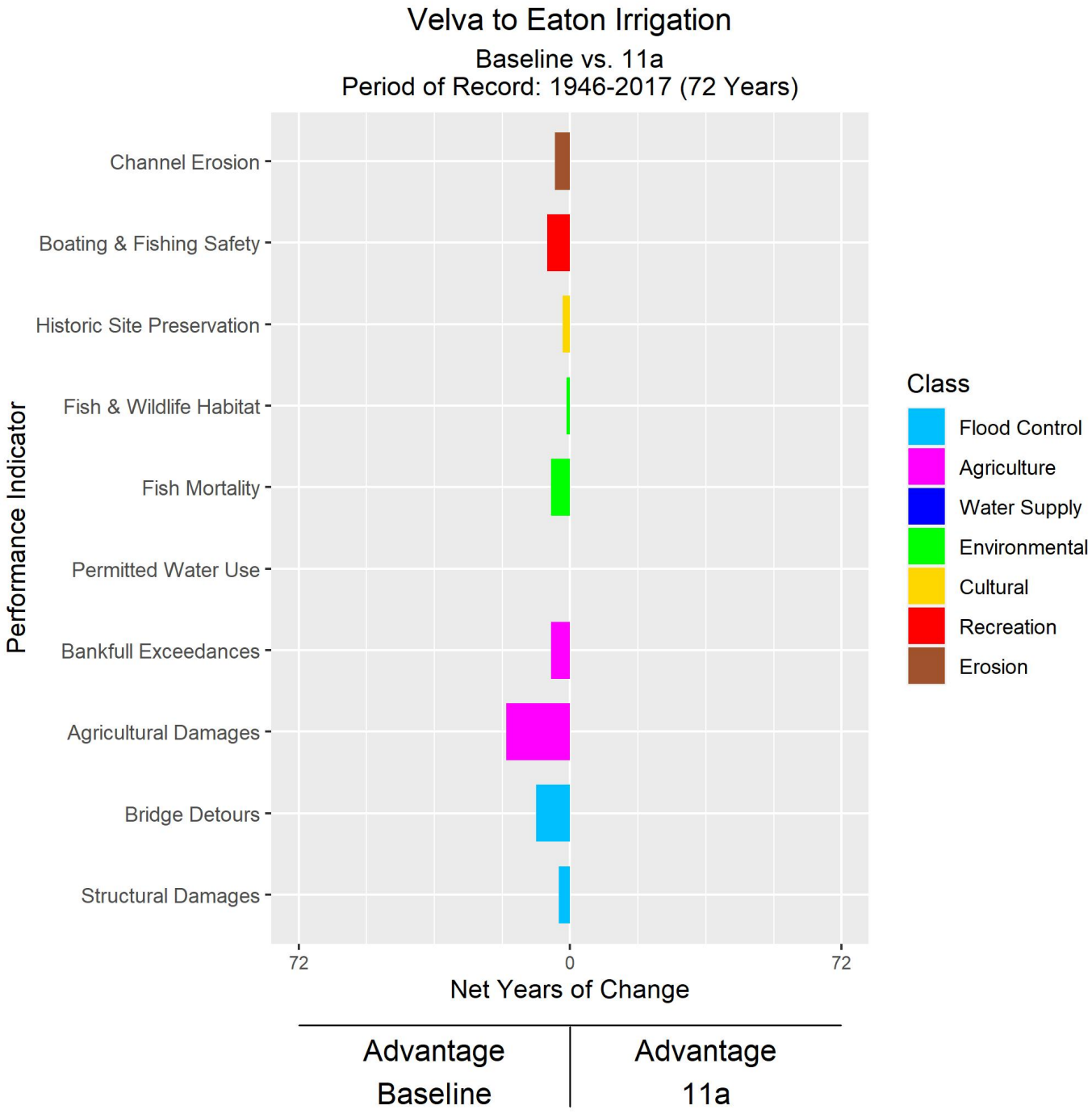

City of Minot
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Total Dissolved Solids
Sulfate
Sodium
Chloride
Channel Erosion
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Agricultural Damages
1% Event
Current Protection
Railroad Inundation
WW Lagoon Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion
Water Quality

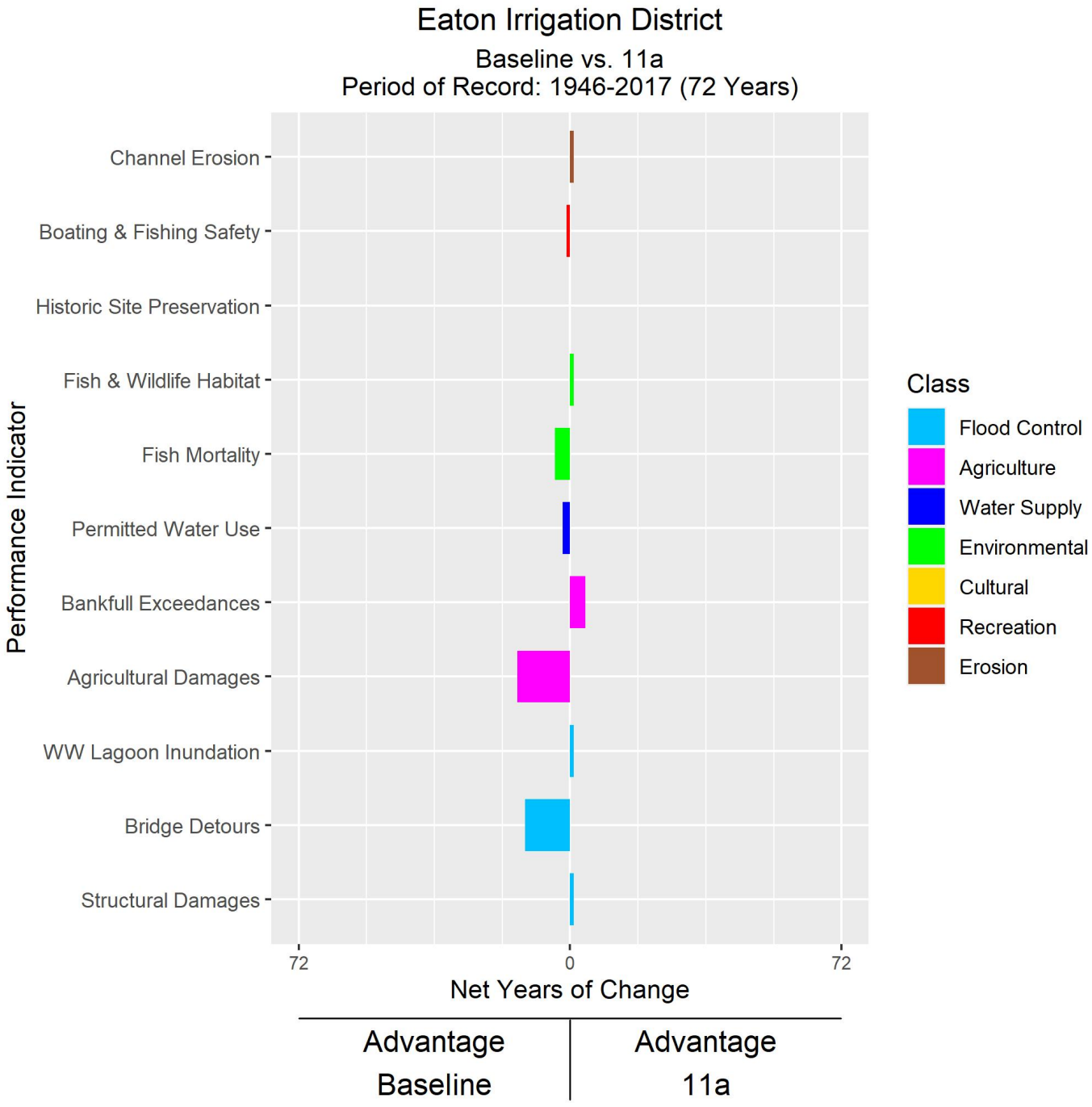

Minot to Sawyer
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Bankfull Exceedances
Agricultural Damages
Railroad Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Environmental
Cultural
Recreation

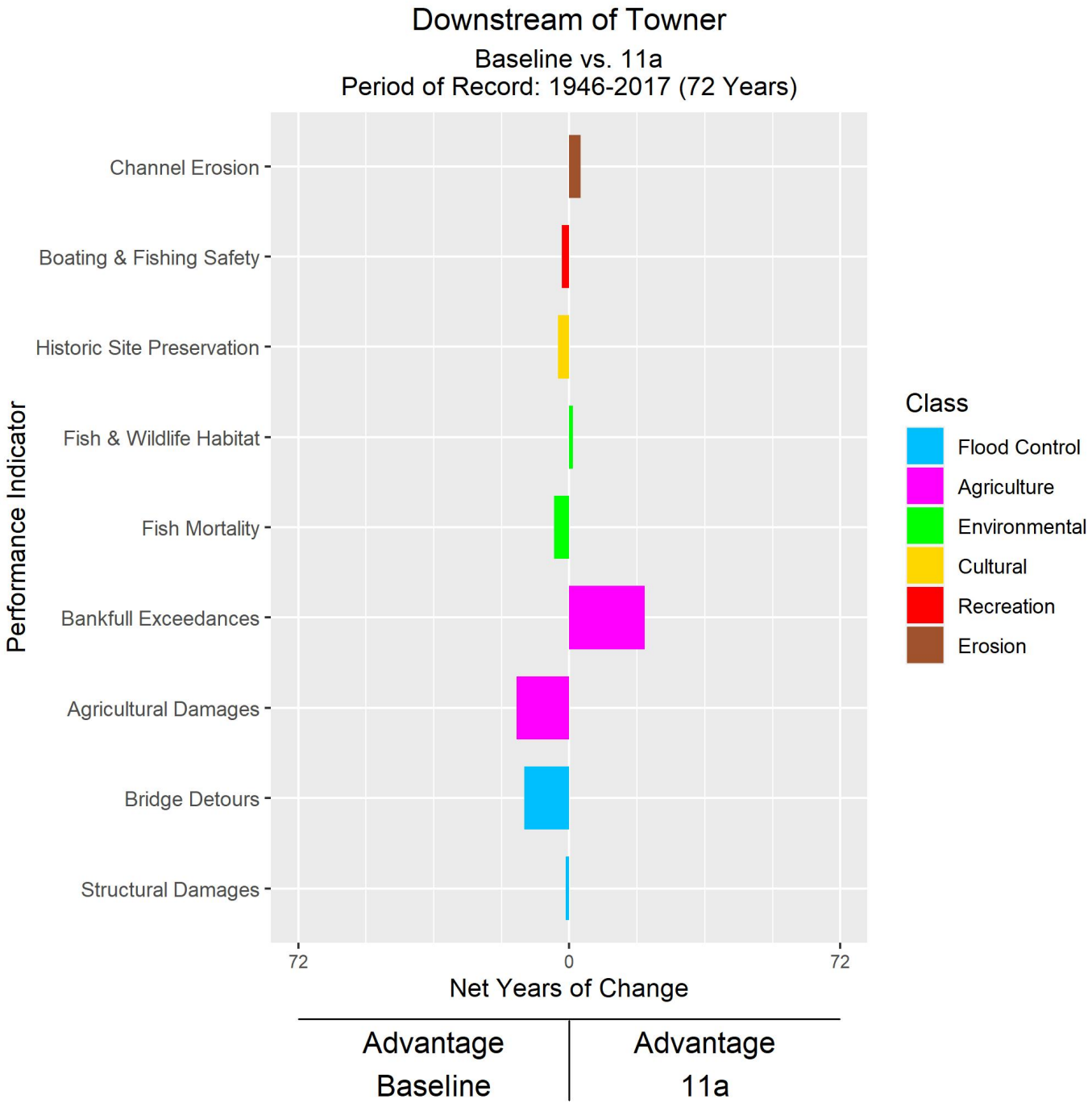

City of Sawyer
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Bankfull Exceedances
Agricultural Damages
WW Lagoon Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Environmental
Cultural
Recreation
Erosion


Sawyer to Velva
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Boating & Fishing Safety
Fish & Wildlife Habitat
Fish Mortality
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Environmental
Recreation


City of Velva
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
WW Lagoon Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation


Velva to Eaton Irrigation
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion


Eaton Irrigation District
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
WW Lagoon Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion


Downstream of Towner
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11a
Class
Flood Control
Agriculture
Environmental
Cultural
Recreation
Erosion

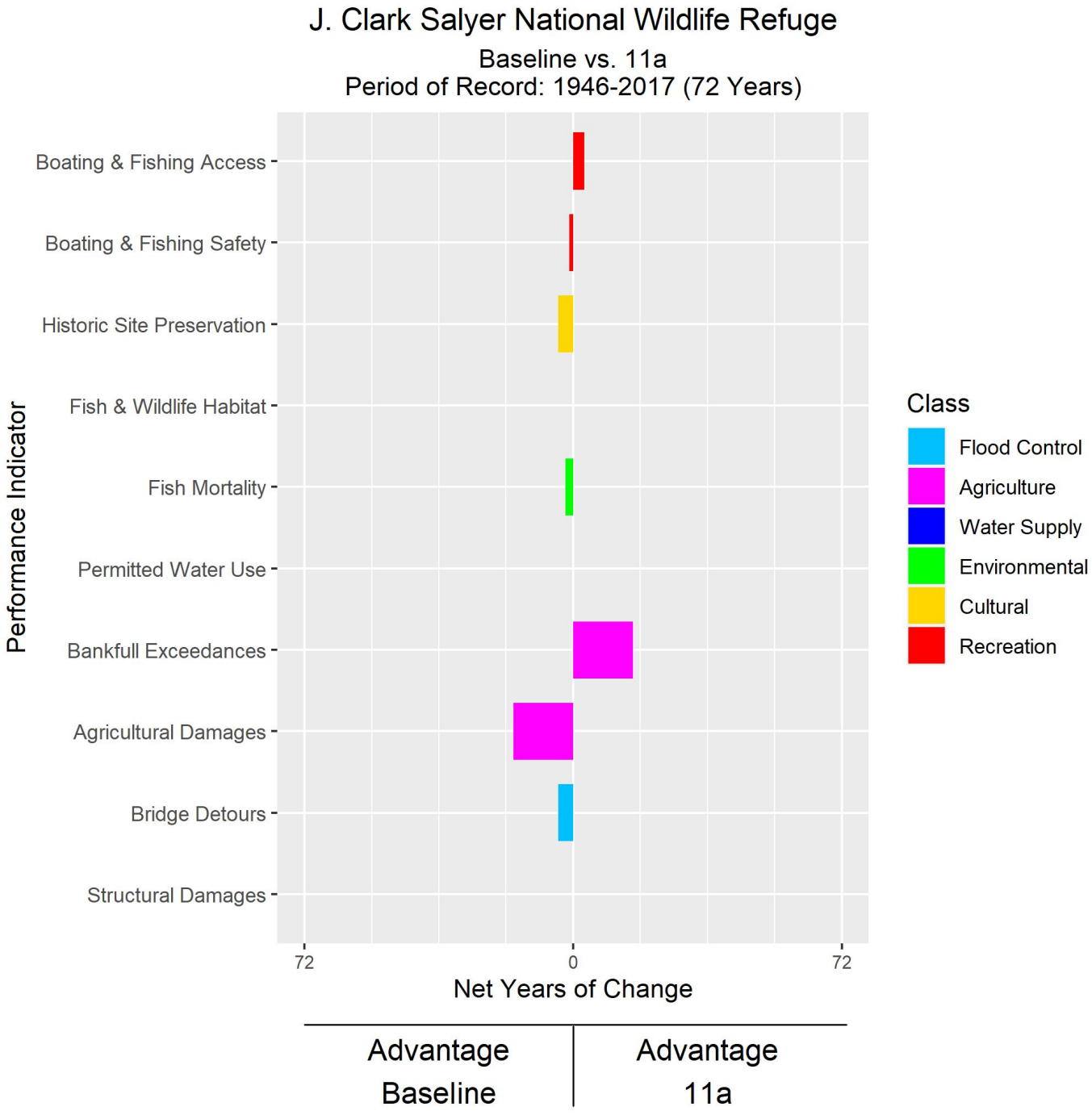
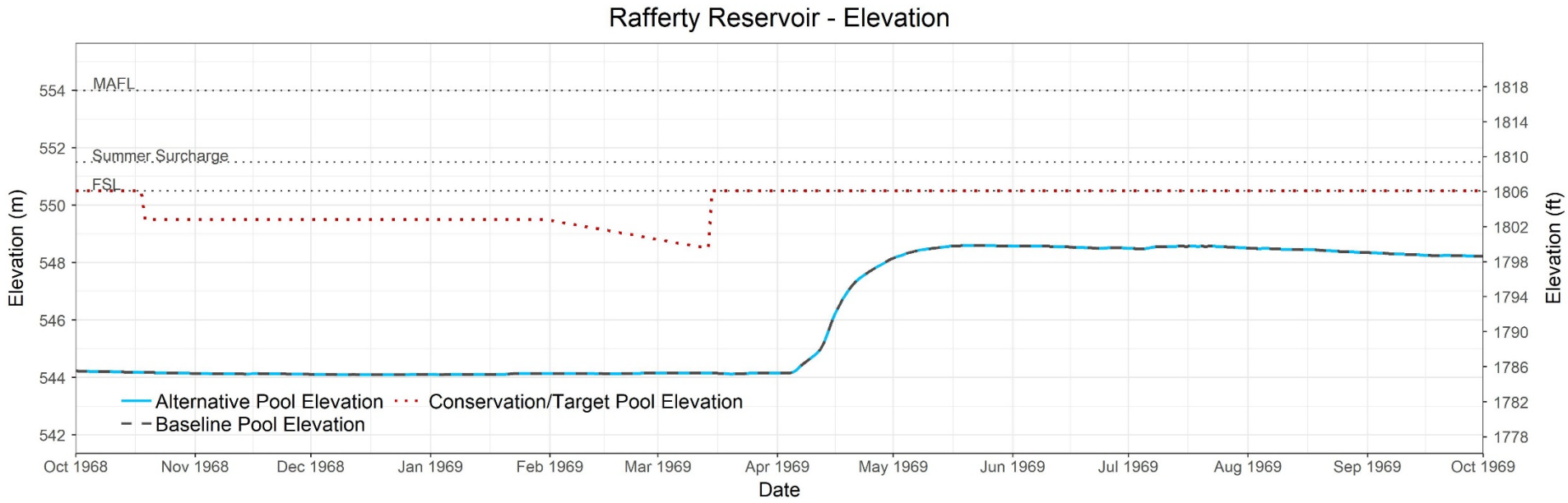
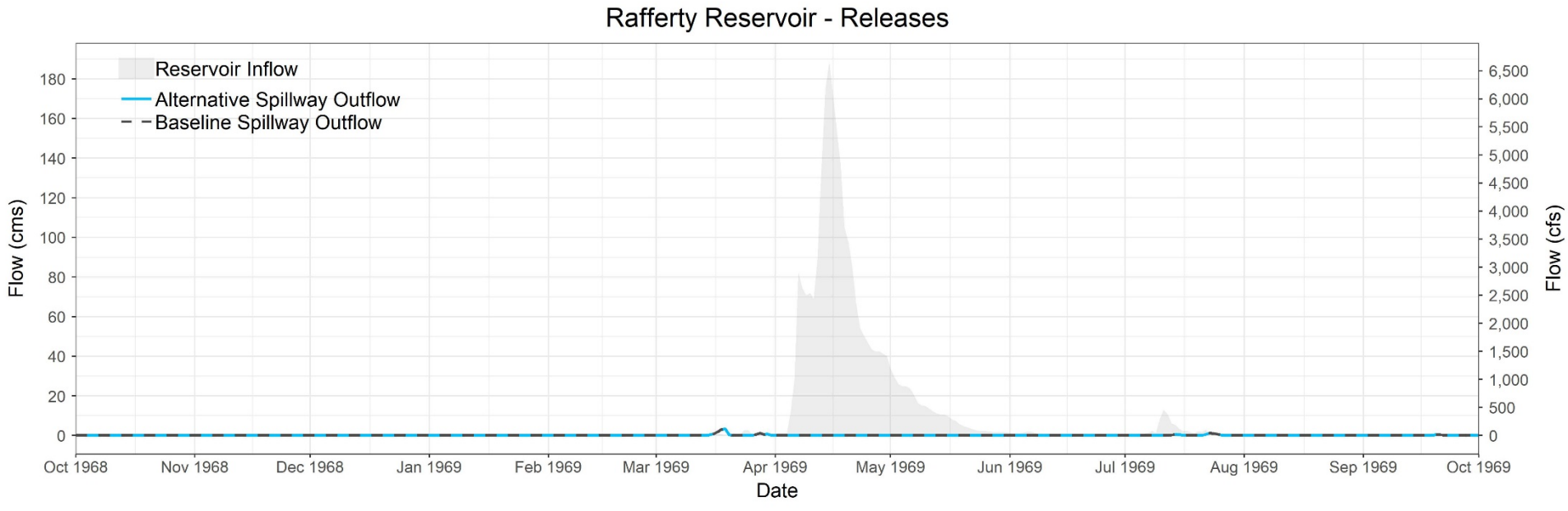
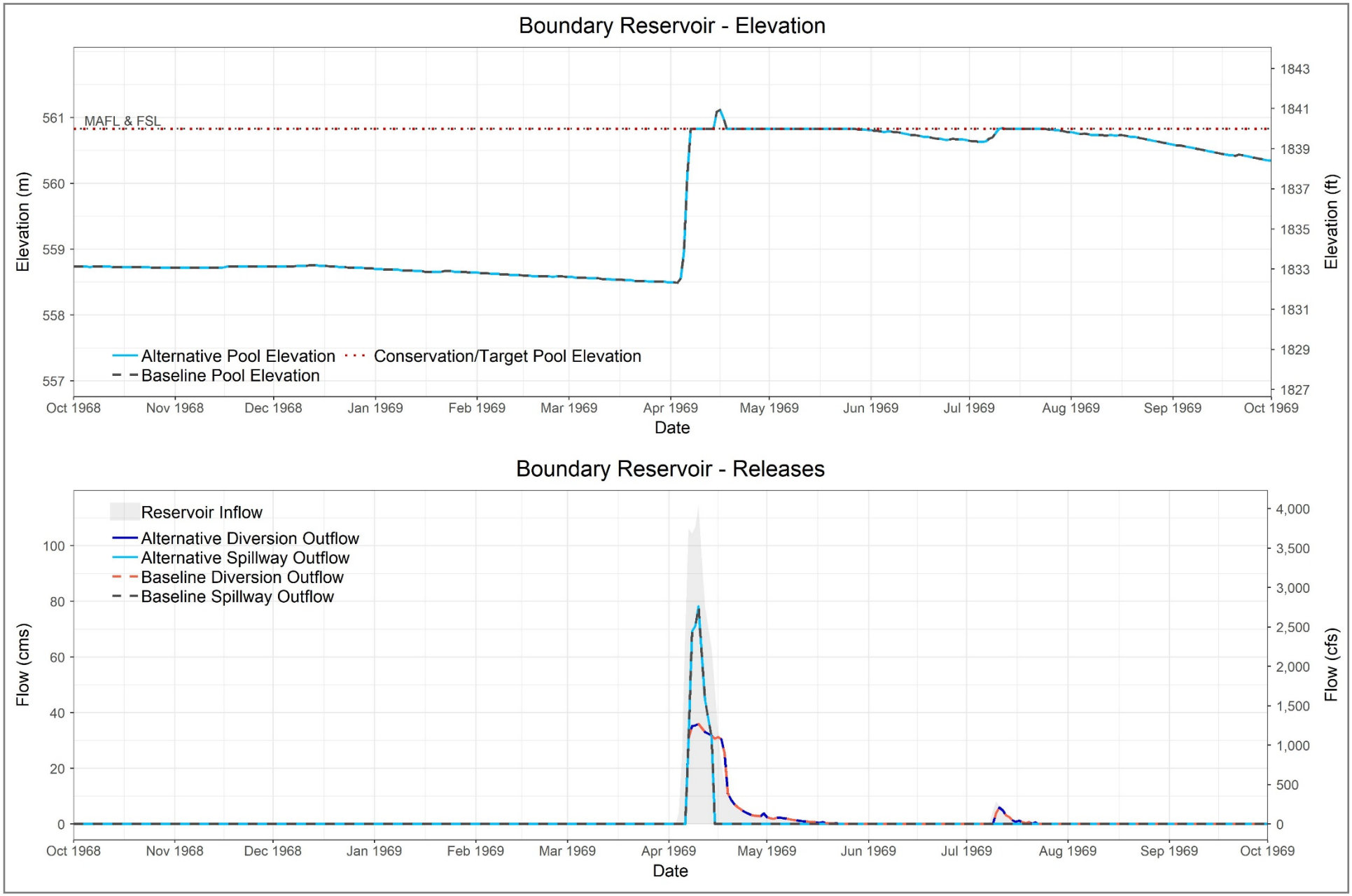

J. Clark Salyer National Wildlife Refuge
Baseline vs. 11a
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11a
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation

Plate 10	Reservoirs – 1969	Alternative 11b (Phase 2) Souris River Plan of Study

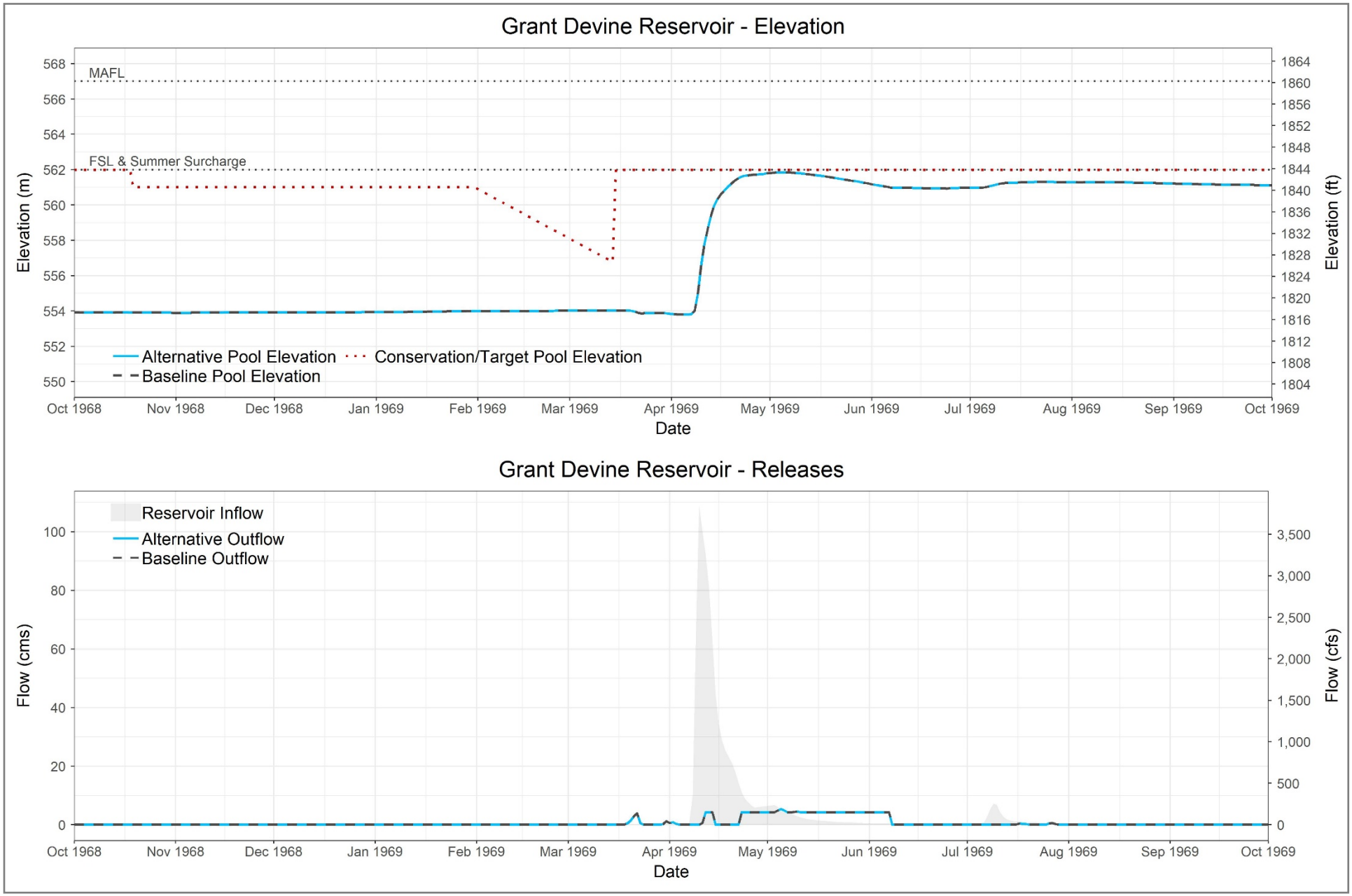




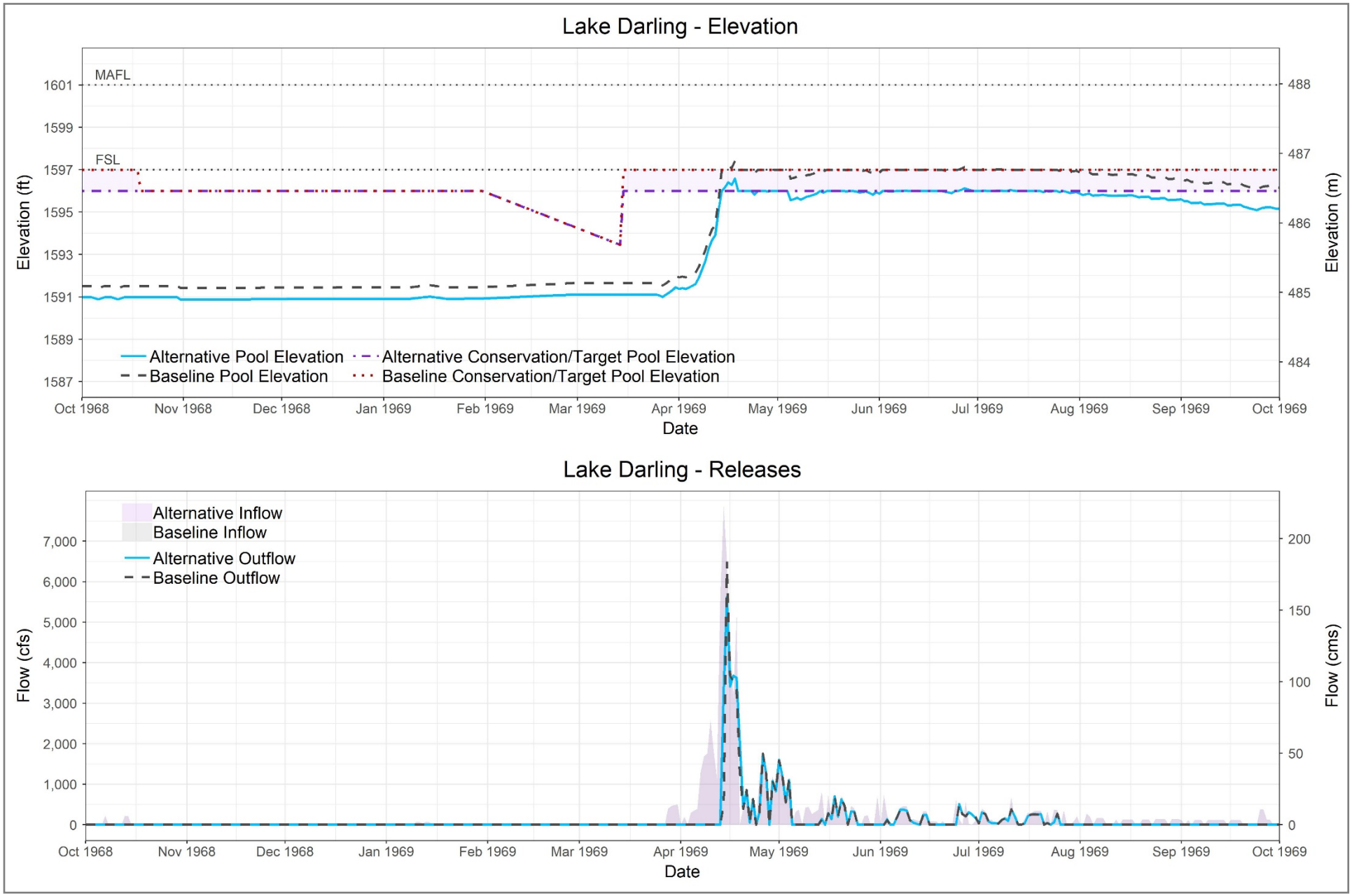
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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



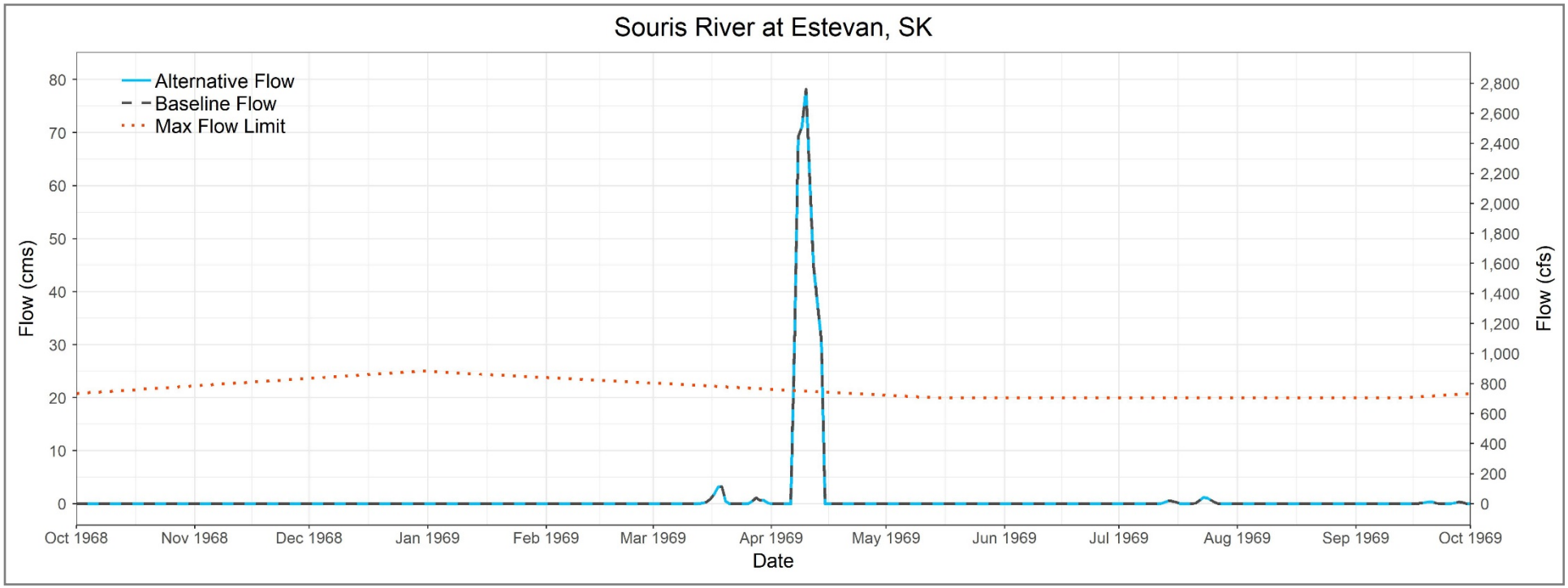
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*

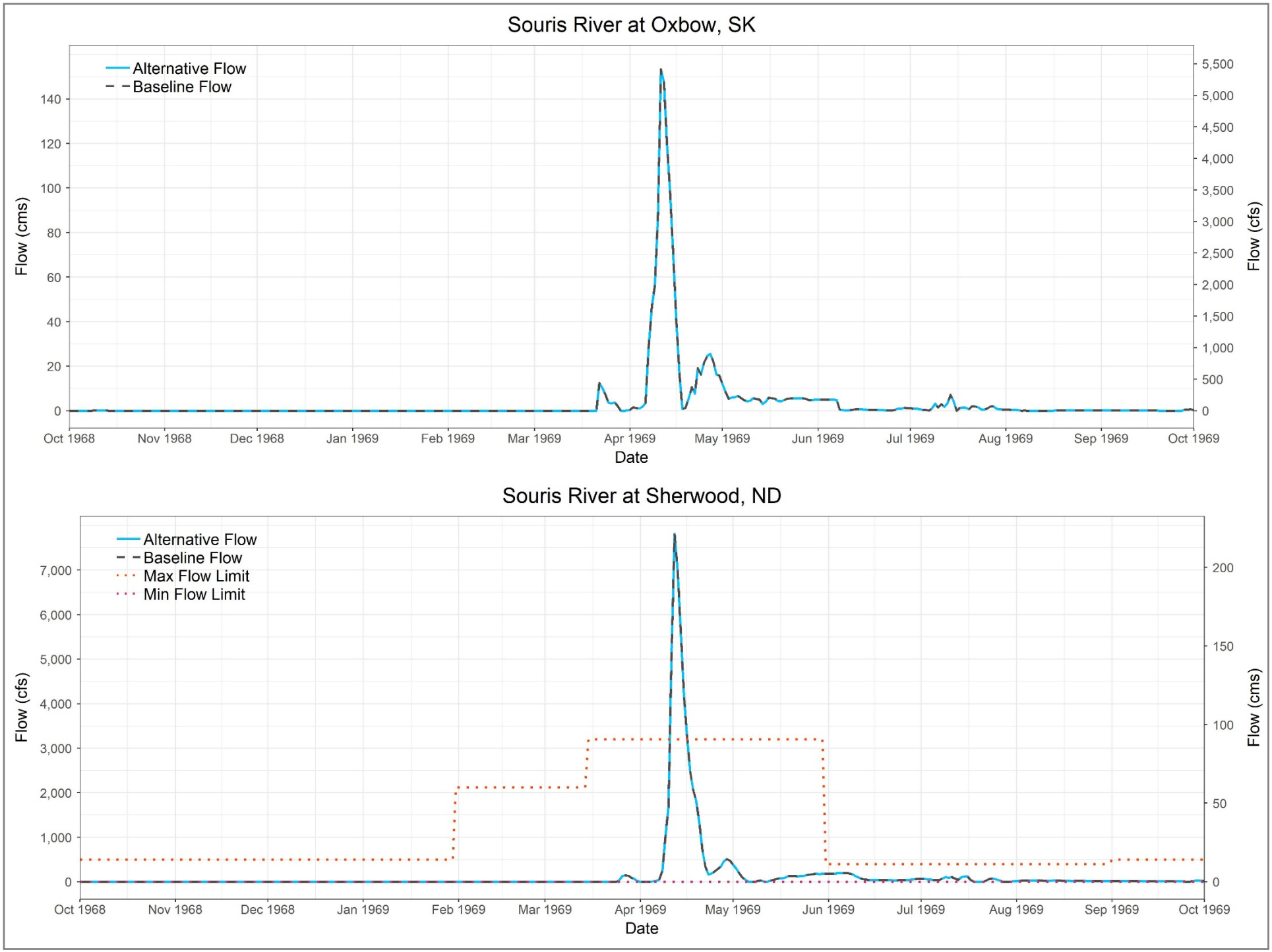
Plate 11

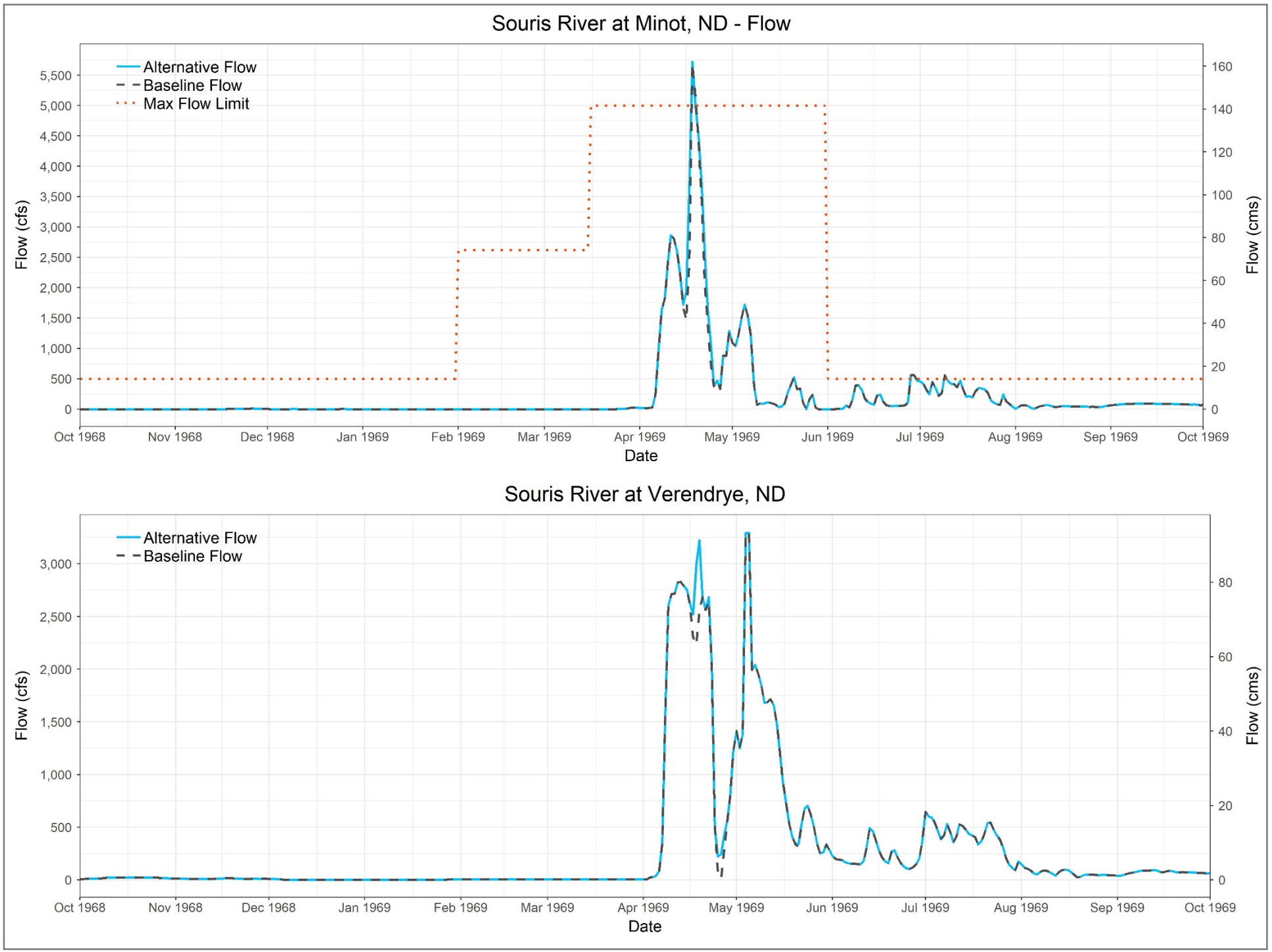
Critical Flow Locations – 1969

Alternative 11b (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Max Flow Limit
Flow (cfs)
Flow (cms)
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
160
140
120
100
80
60
40
20
0
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Date
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
3,000
2,500
2,000
1,500
1,000
500
0
80
60
40
20
0
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Date

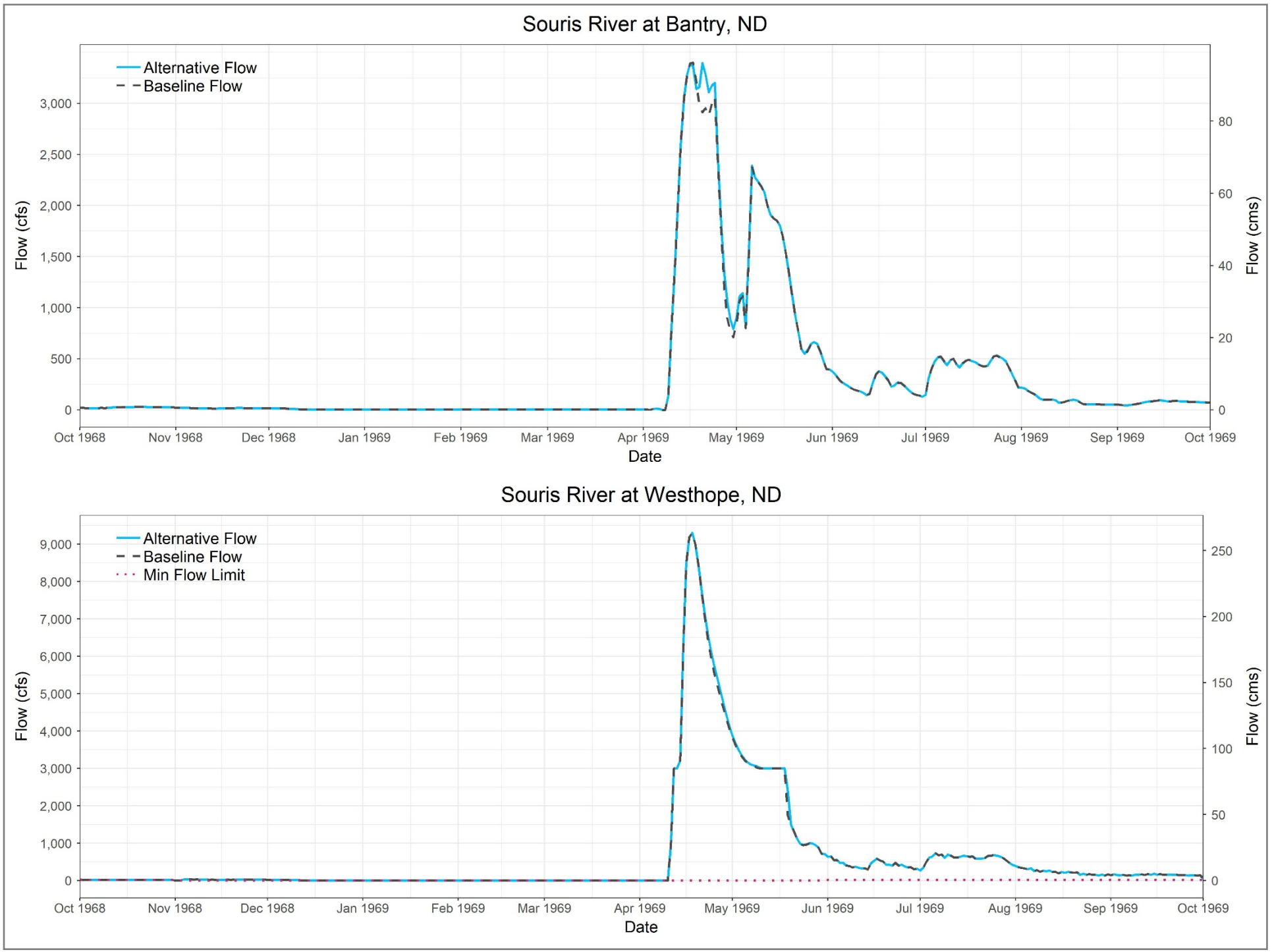
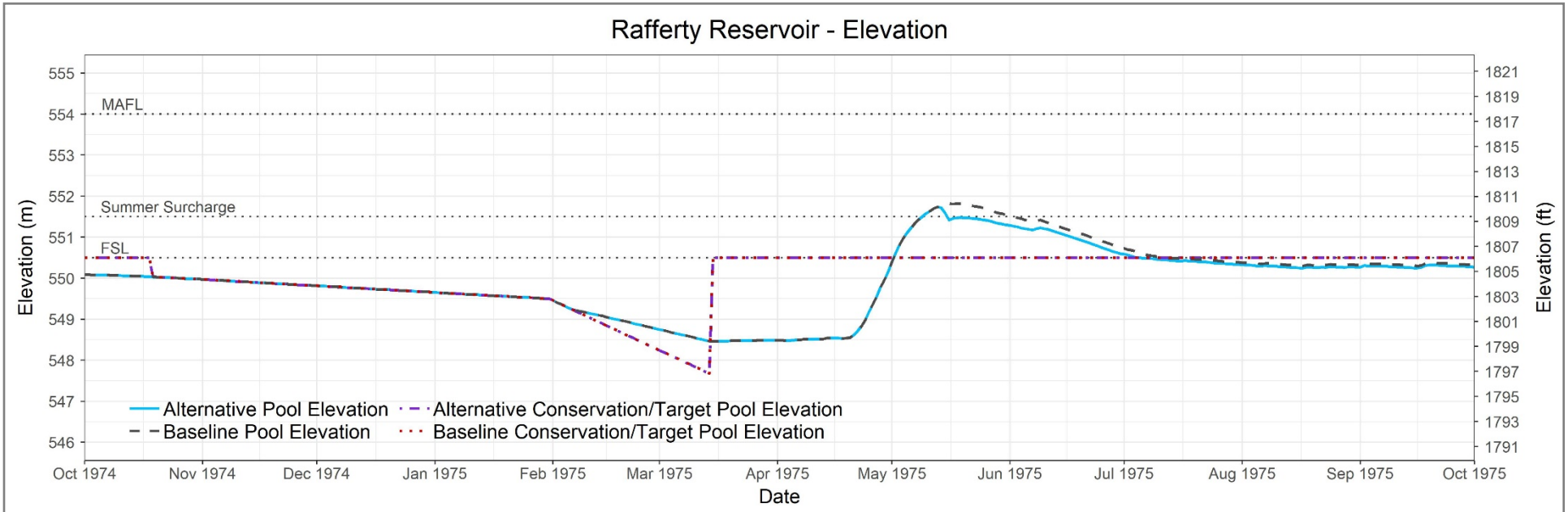
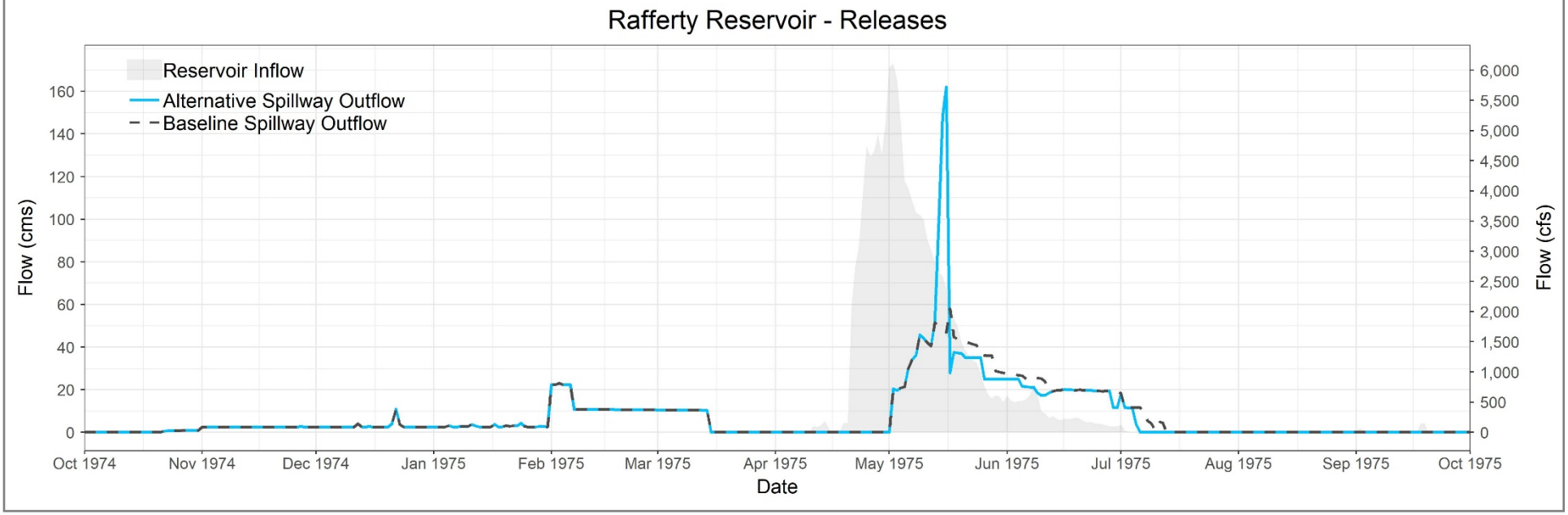
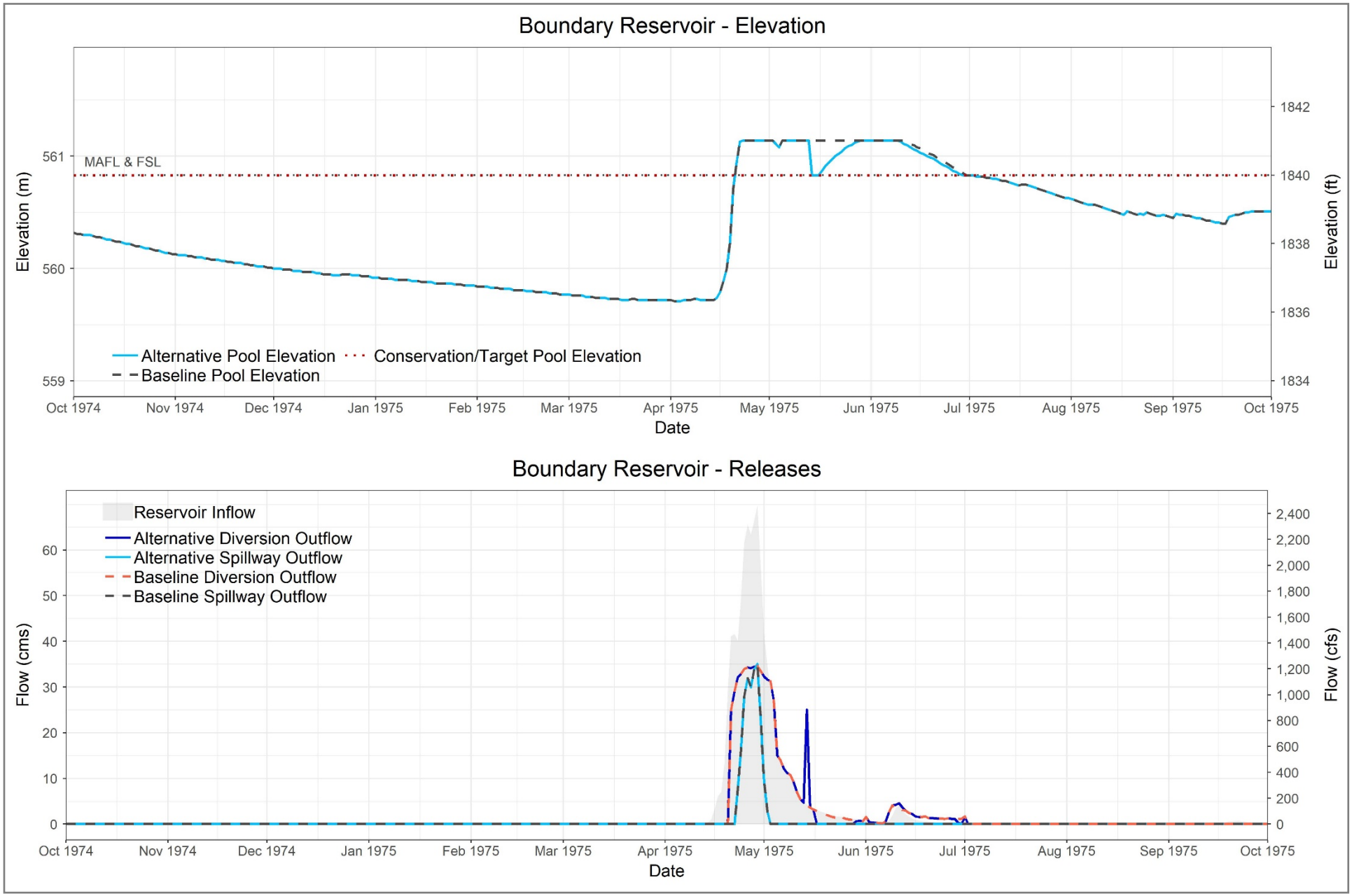

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
Date

Plate 12	Reservoirs – 1975	Alternative 11b (Phase 2) Souris River Plan of Study

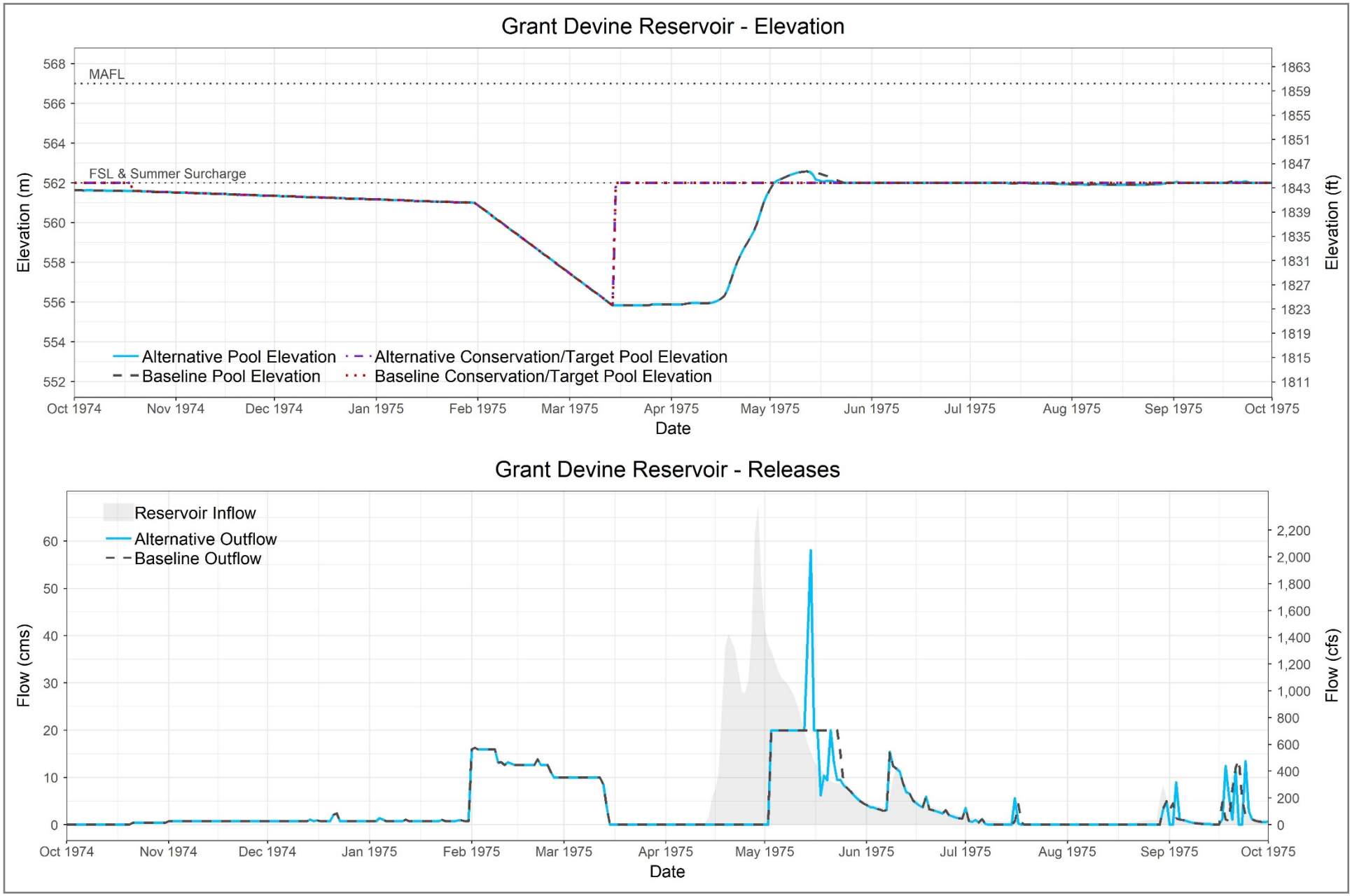




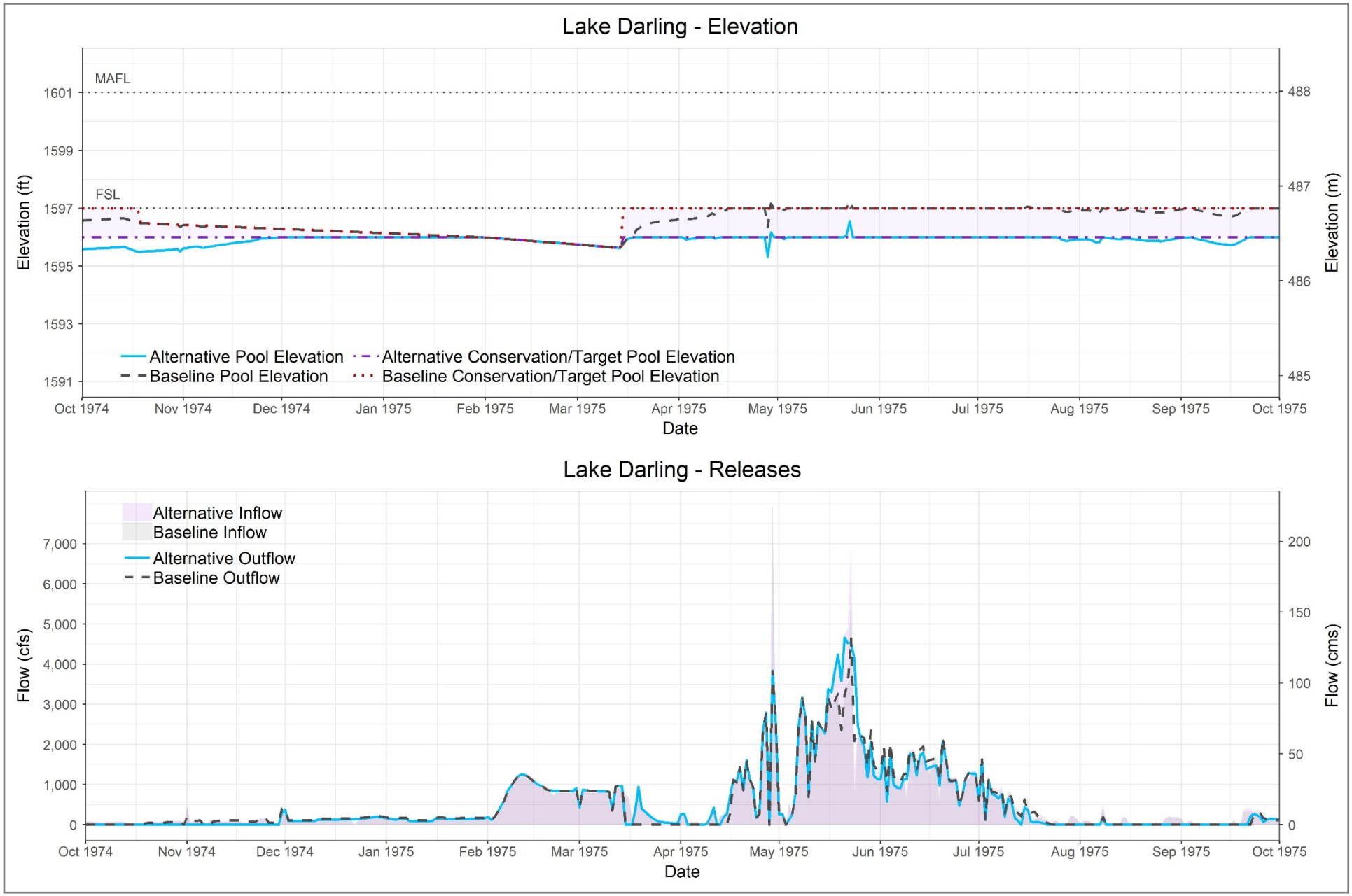
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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



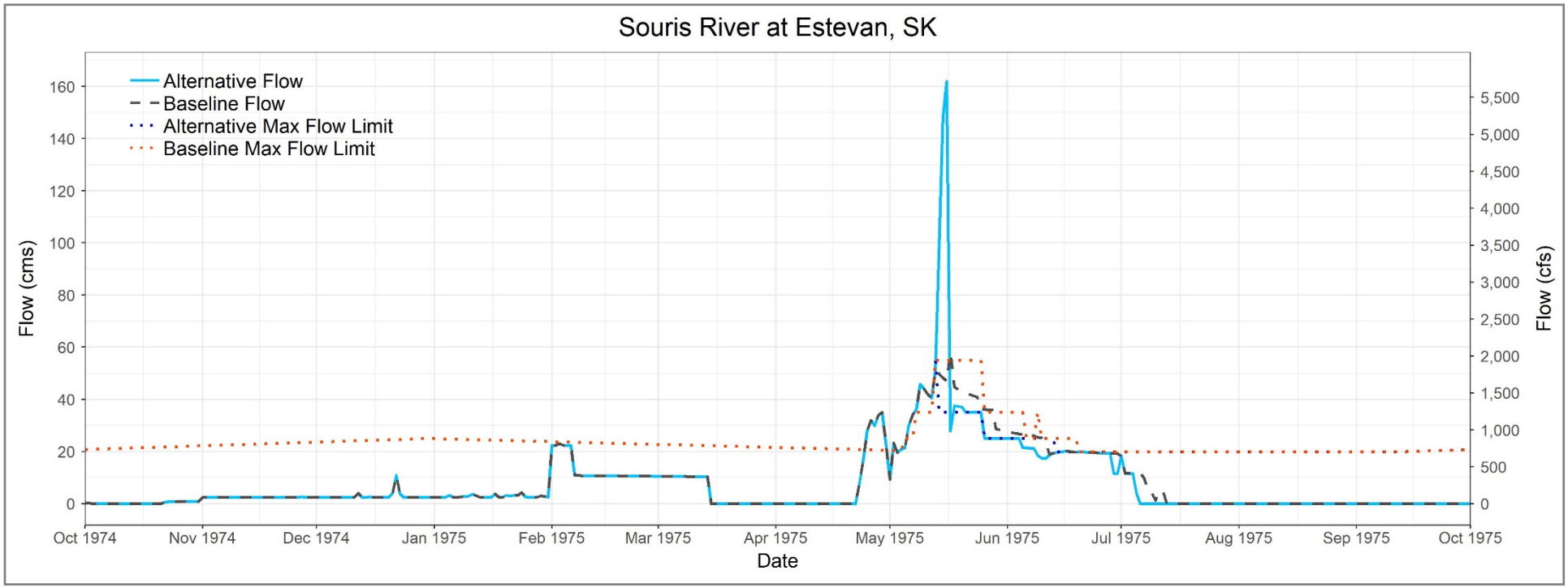
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*

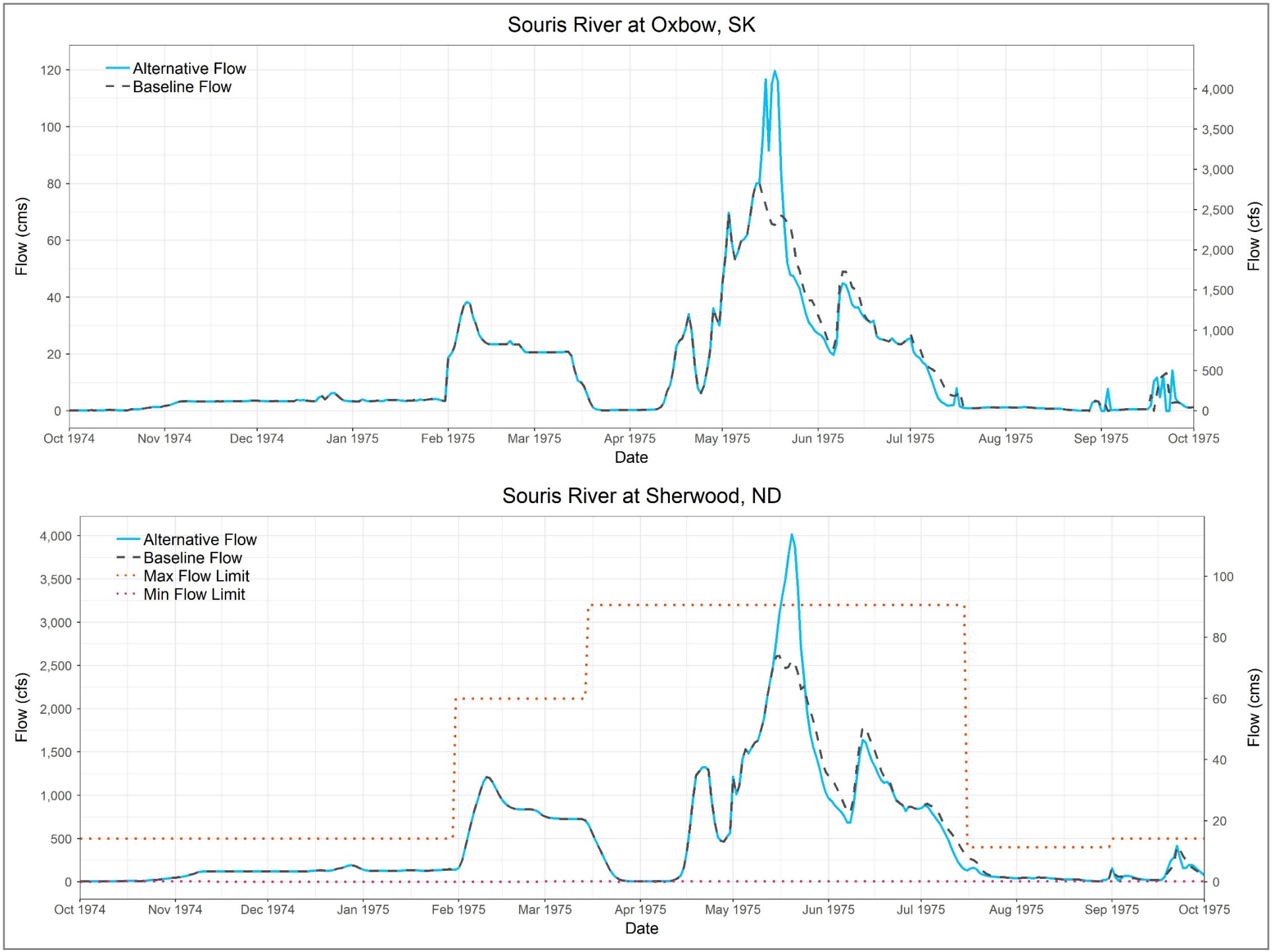
Plate 13

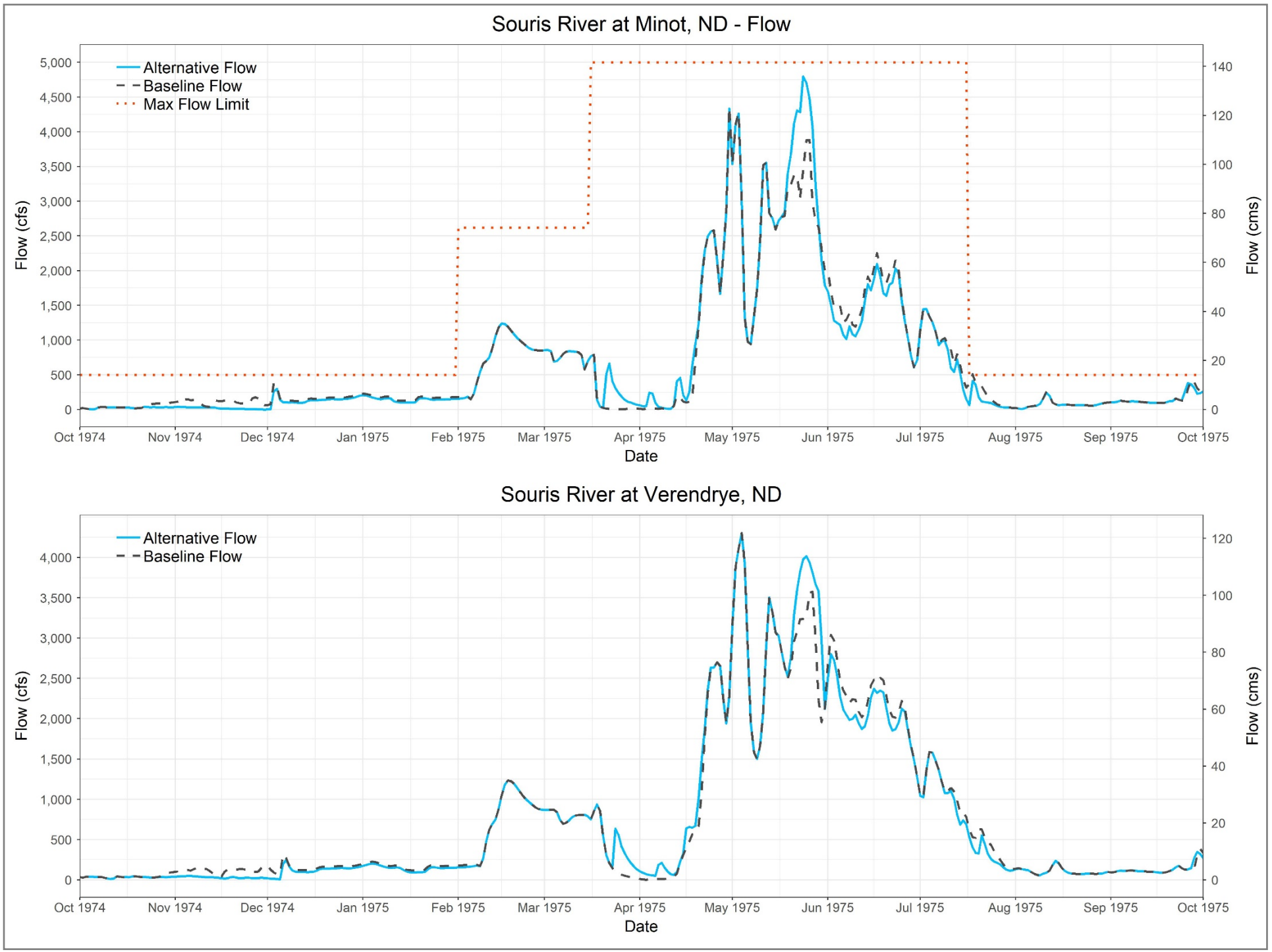
Critical Flow Locations – 1975

Alternative 11b (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 1974
Nov 1974
Dec 1974
Jan 1975
Feb 1975
Mar 1975
Apr 1975
May 1975
Jun 1975
Jul 1975
Aug 1975
Sep 1975
Oct 1975
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 1974
Nov 1974
Dec 1974
Jan 1975
Feb 1975
Mar 1975
Apr 1975
May 1975
Jun 1975
Jul 1975
Aug 1975
Sep 1975
Oct 1975
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date

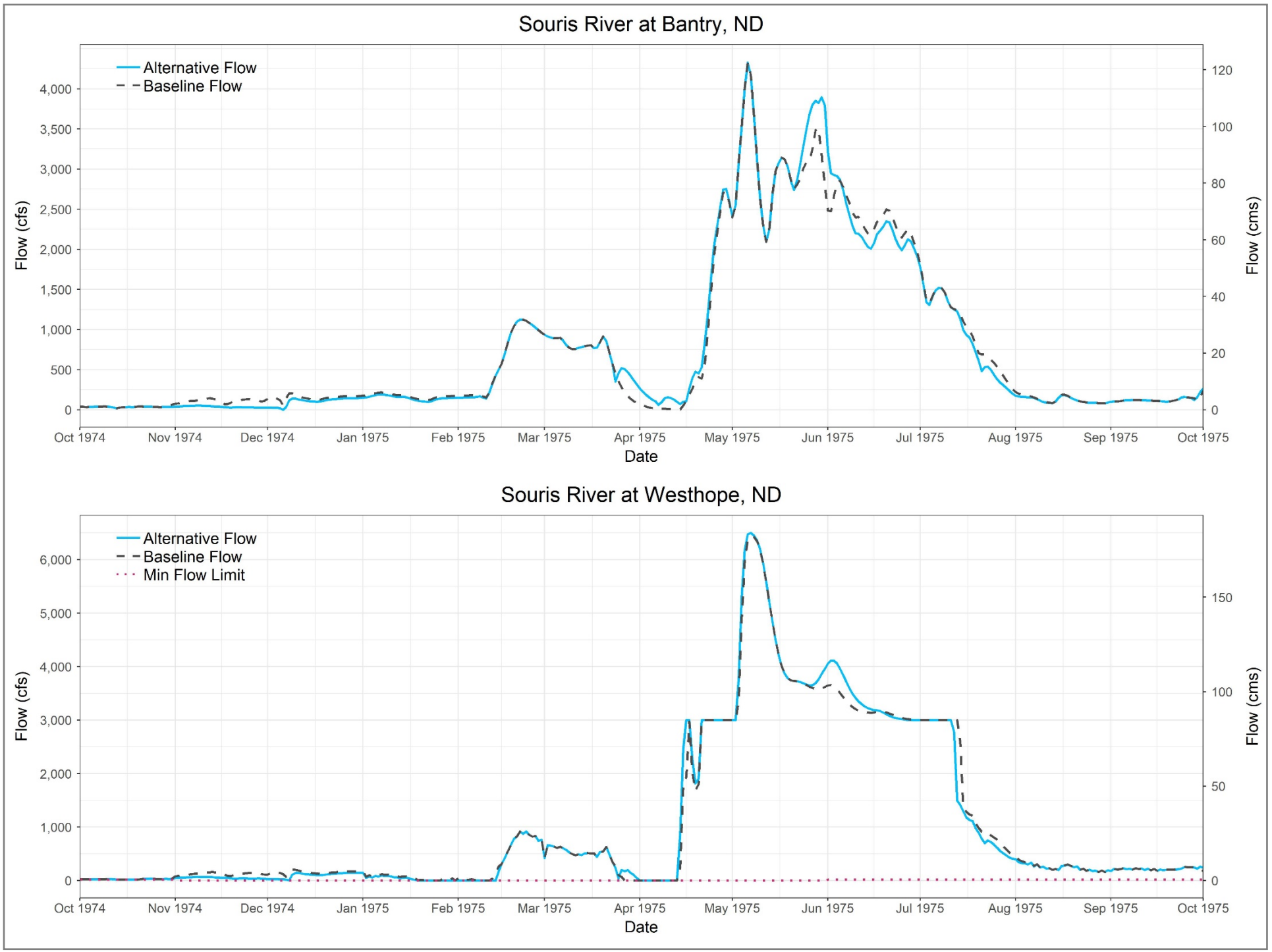
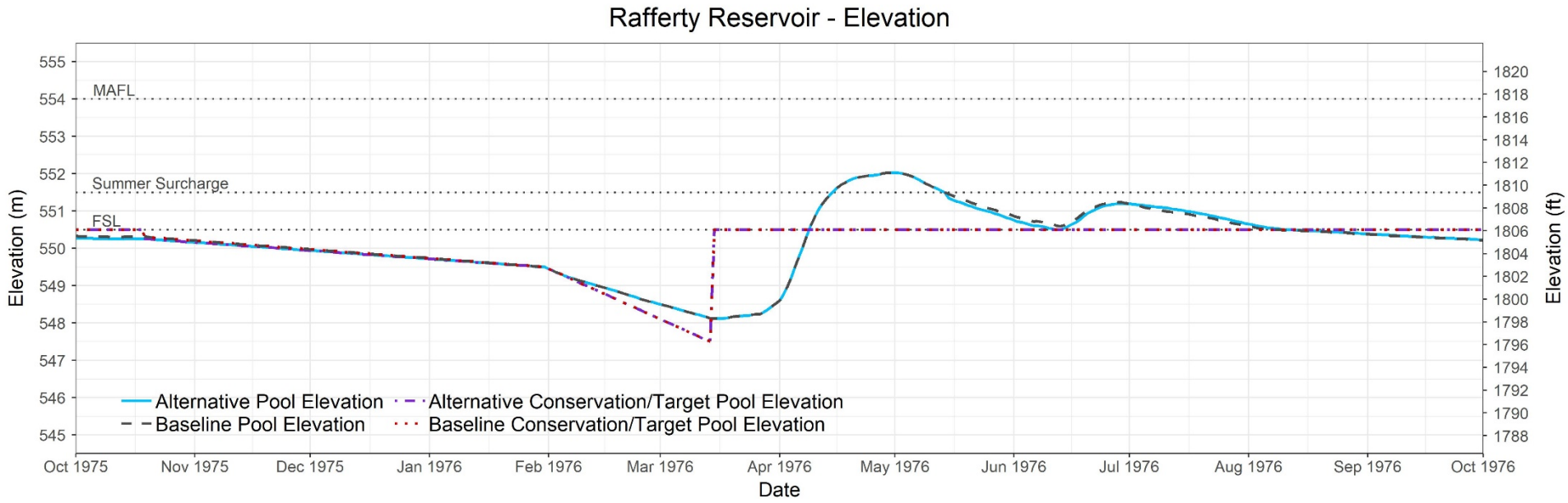
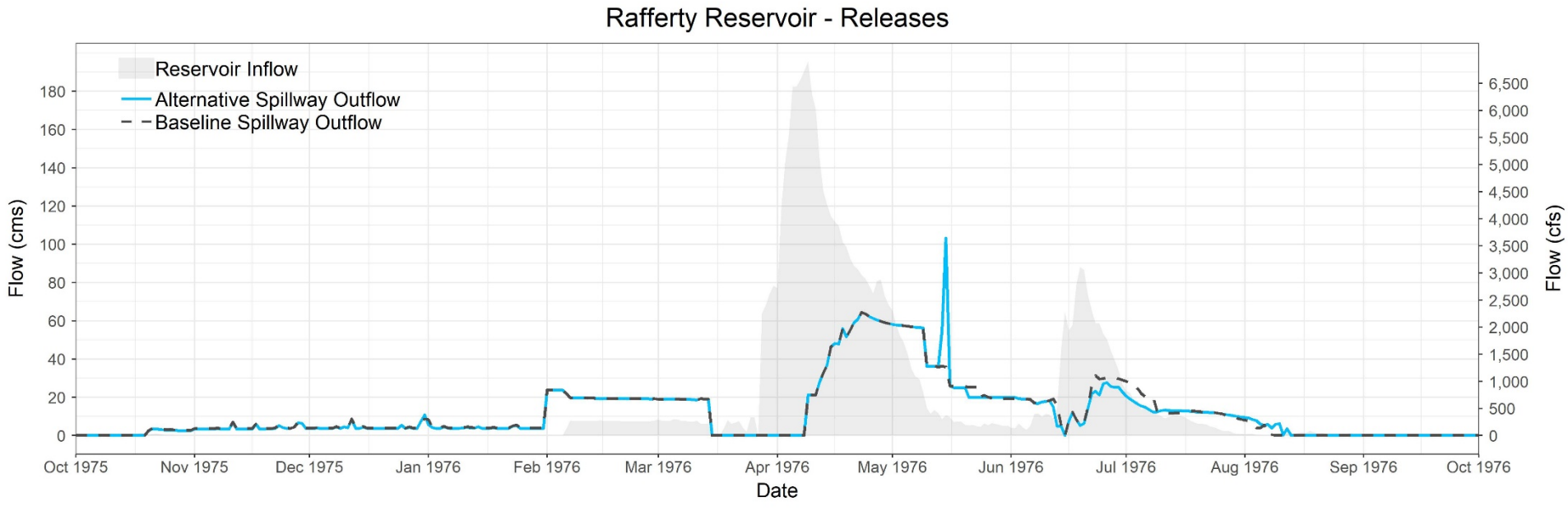
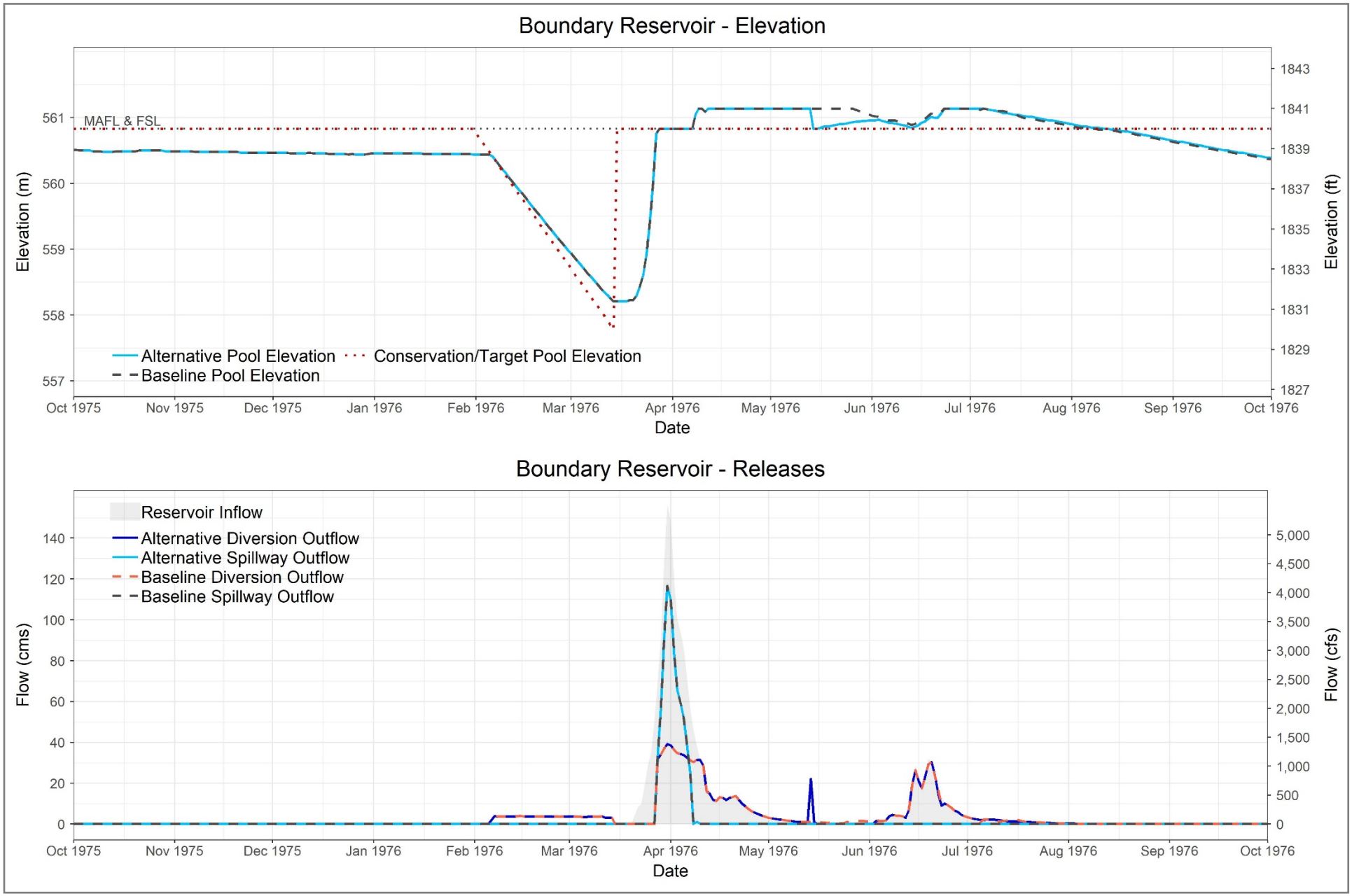

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date
Oct 1974
Nov 1974
Dec 1974
Jan 1975
Feb 1975
Mar 1975
Apr 1975
May 1975
Jun 1975
Jul 1975
Aug 1975
Sep 1975
Oct 1975
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
Date

Plate 14	Reservoirs – 1976	Alternative 11b (Phase 2) Souris River Plan of Study

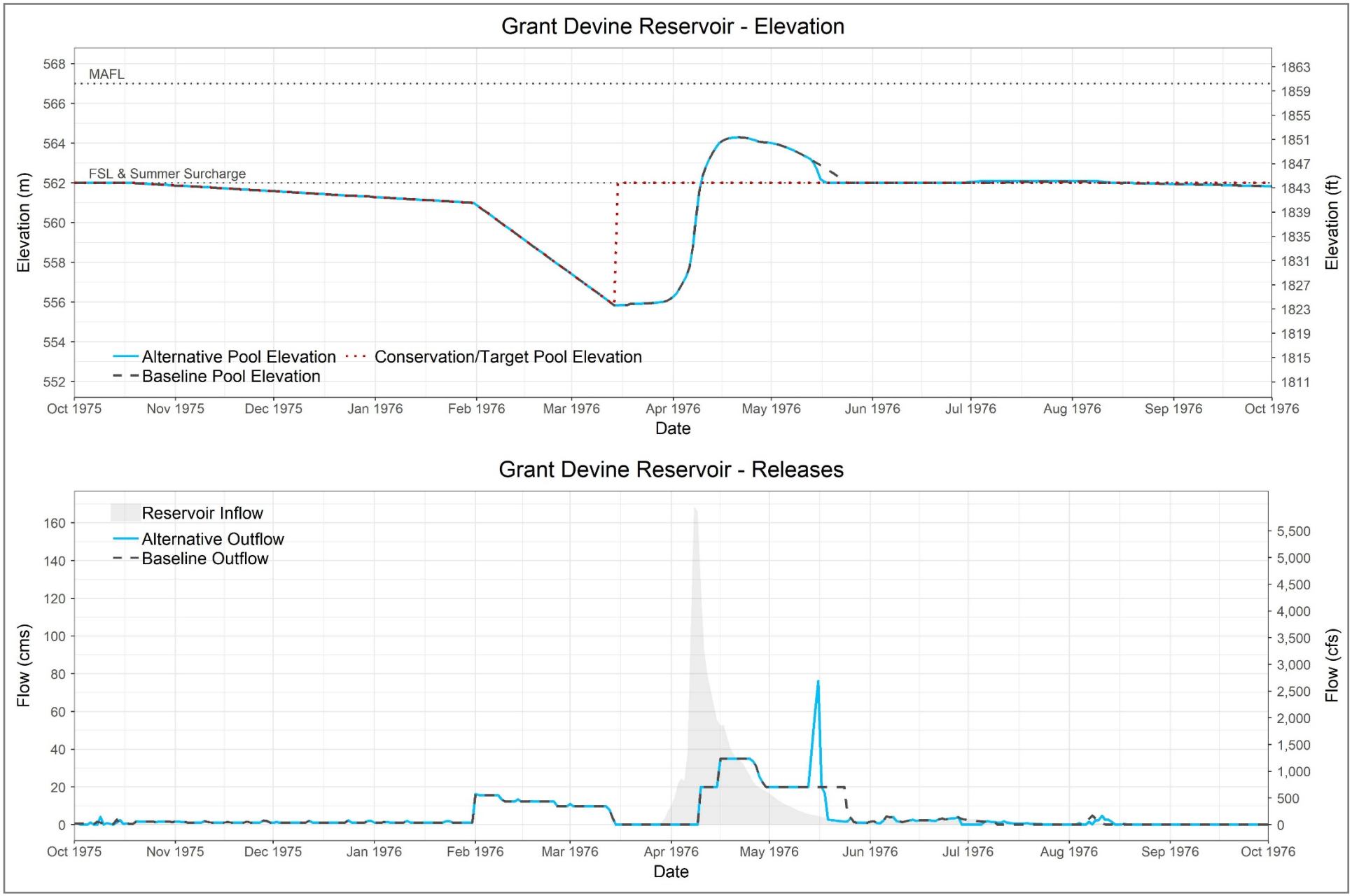




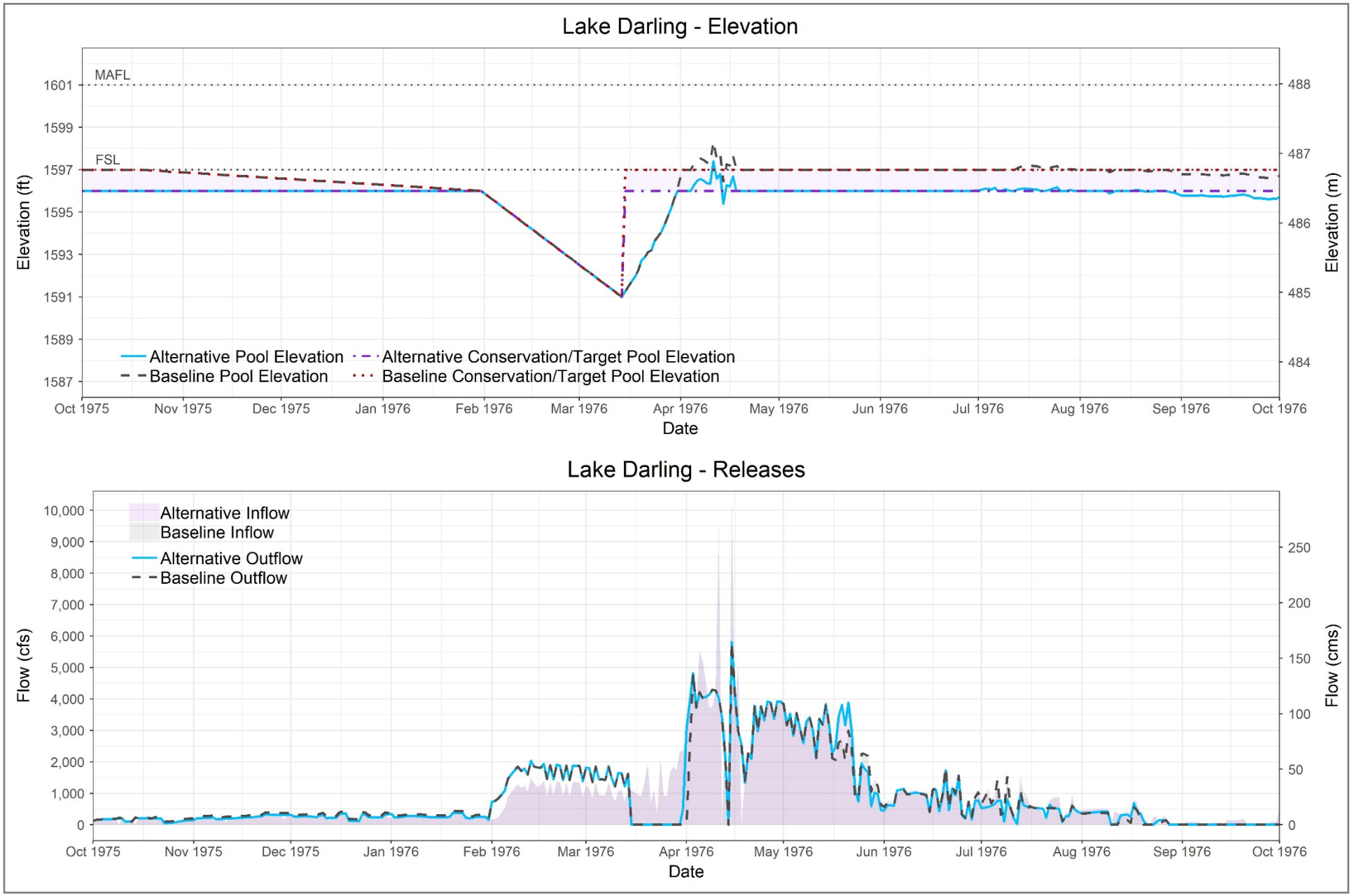
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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



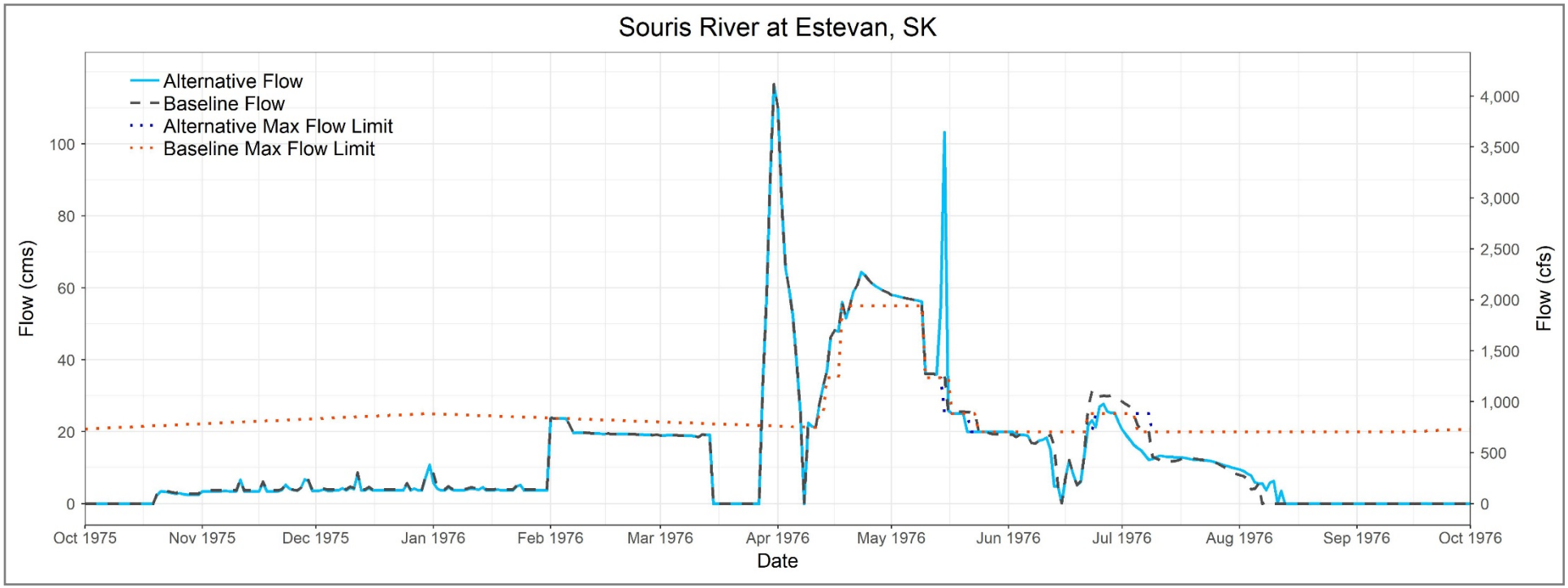
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*

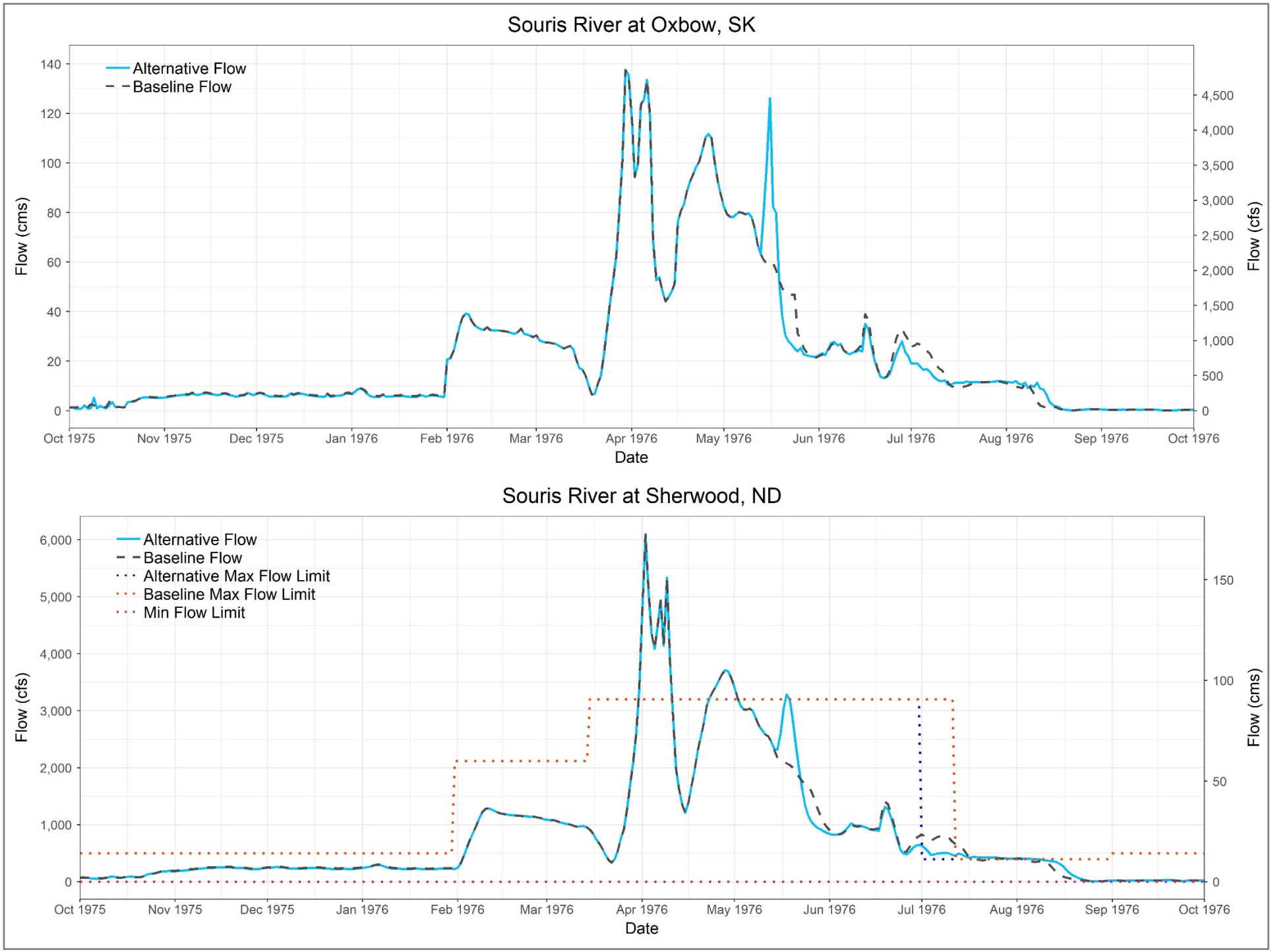
Plate 15

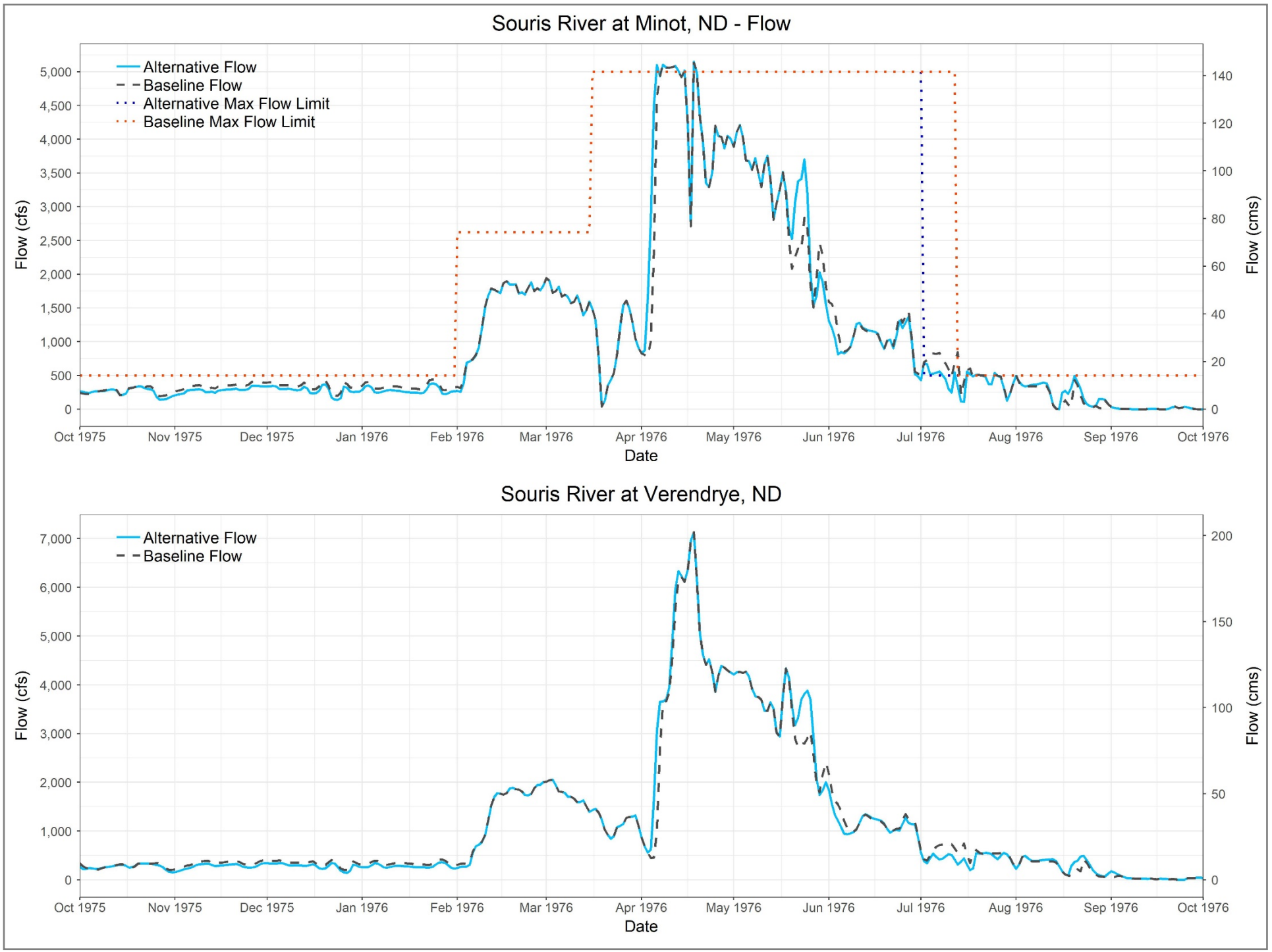
Critical Flow Locations – 1976

Alternative 11b (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 1975
Nov 1975
Dec 1975
Jan 1976
Feb 1976
Mar 1976
Apr 1976
May 1976
Jun 1976
Jul 1976
Aug 1976
Sep 1976
Oct 1976
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 1975
Nov 1975
Dec 1975
Jan 1976
Feb 1976
Mar 1976
Apr 1976
May 1976
Jun 1976
Jul 1976
Aug 1976
Sep 1976
Oct 1976
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date

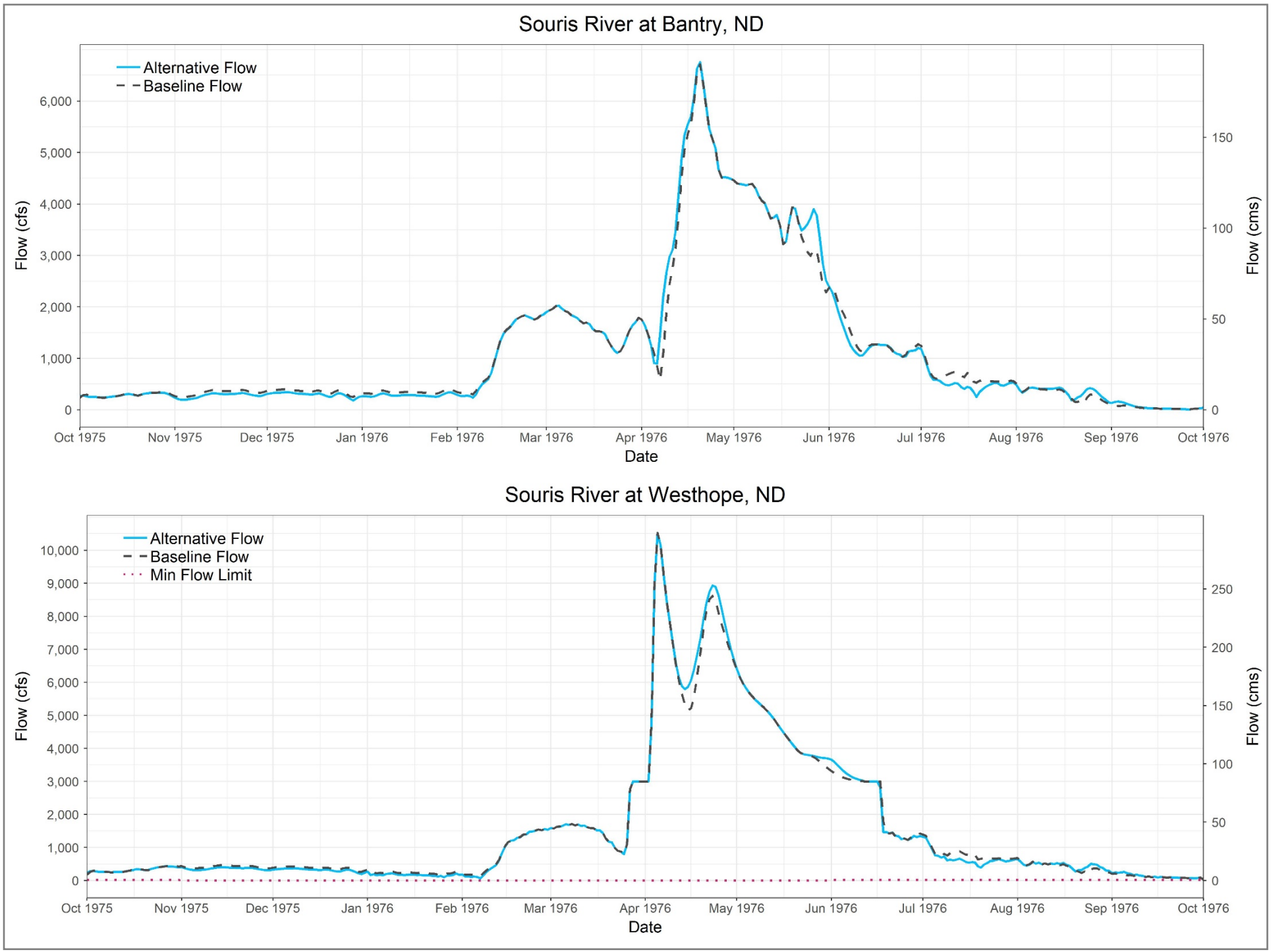
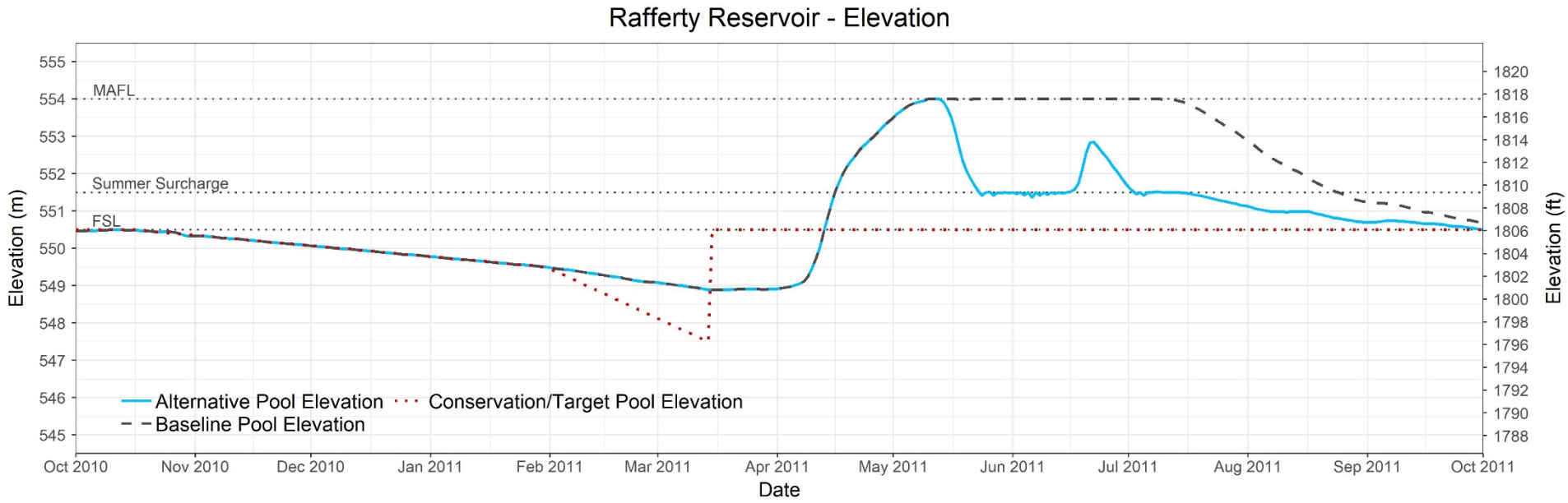
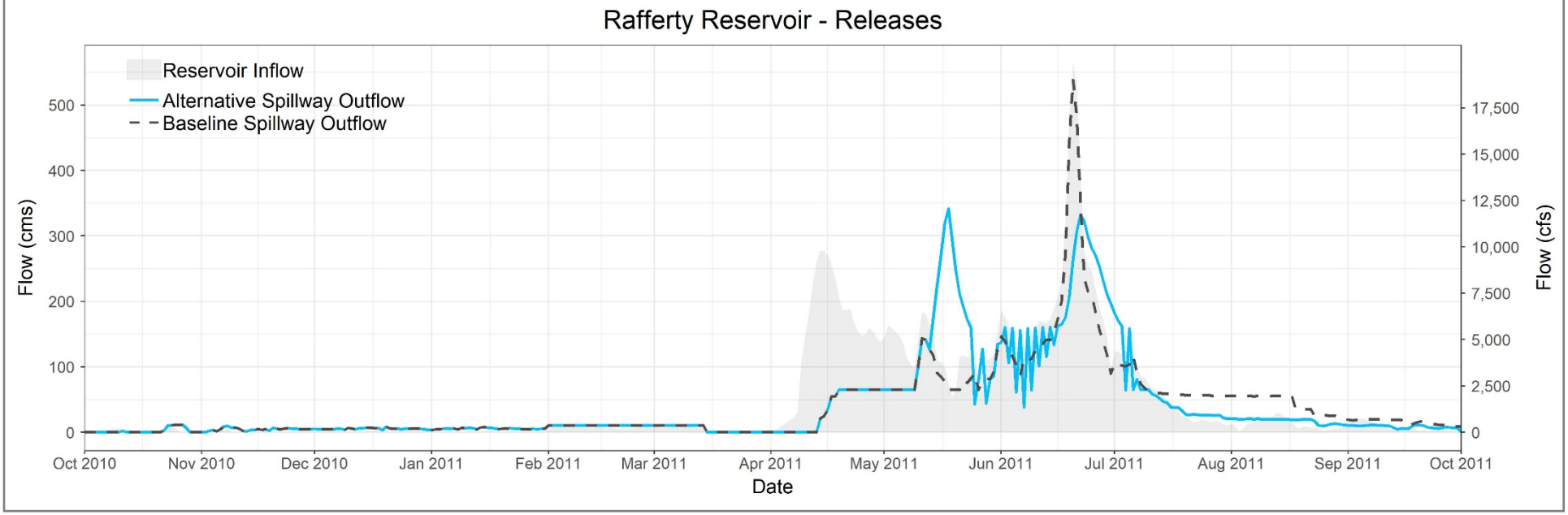
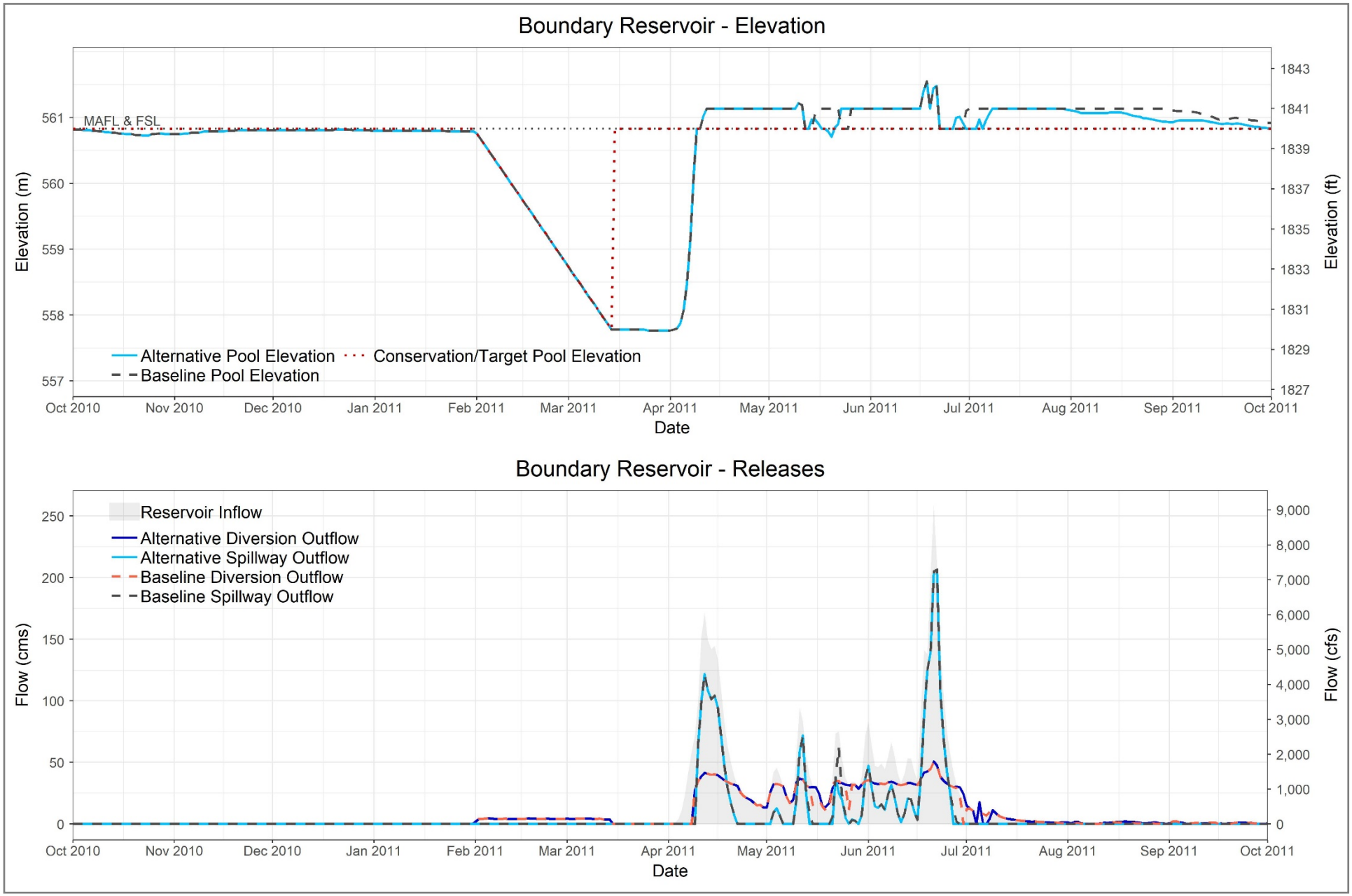

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date
Oct 1975
Nov 1975
Dec 1975
Jan 1976
Feb 1976
Mar 1976
Apr 1976
May 1976
Jun 1976
Jul 1976
Aug 1976
Sep 1976
Oct 1976
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
Date

Plate 16	Reservoirs – 2011	Alternative 11b (Phase 2) Souris River Plan of Study

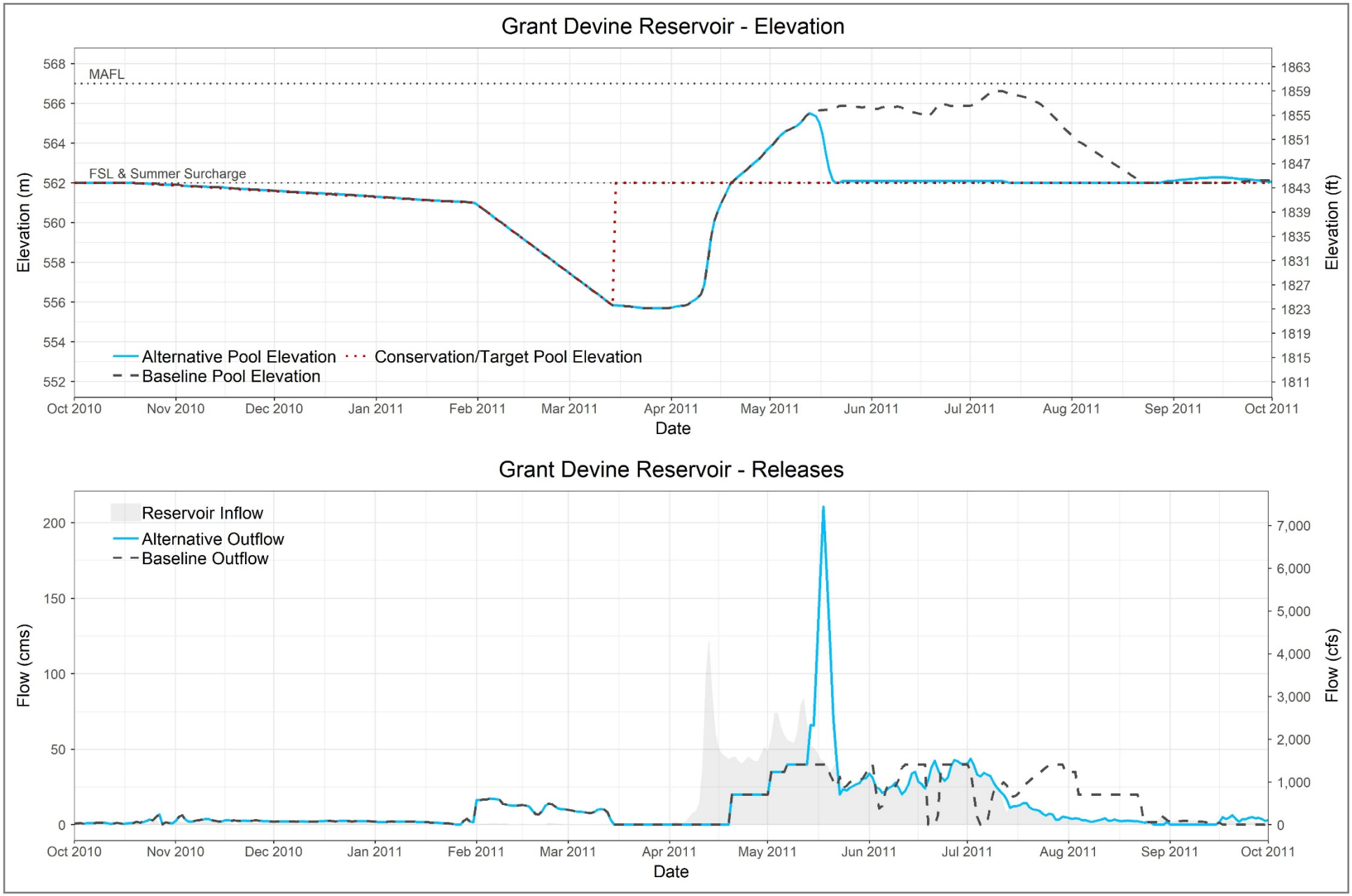




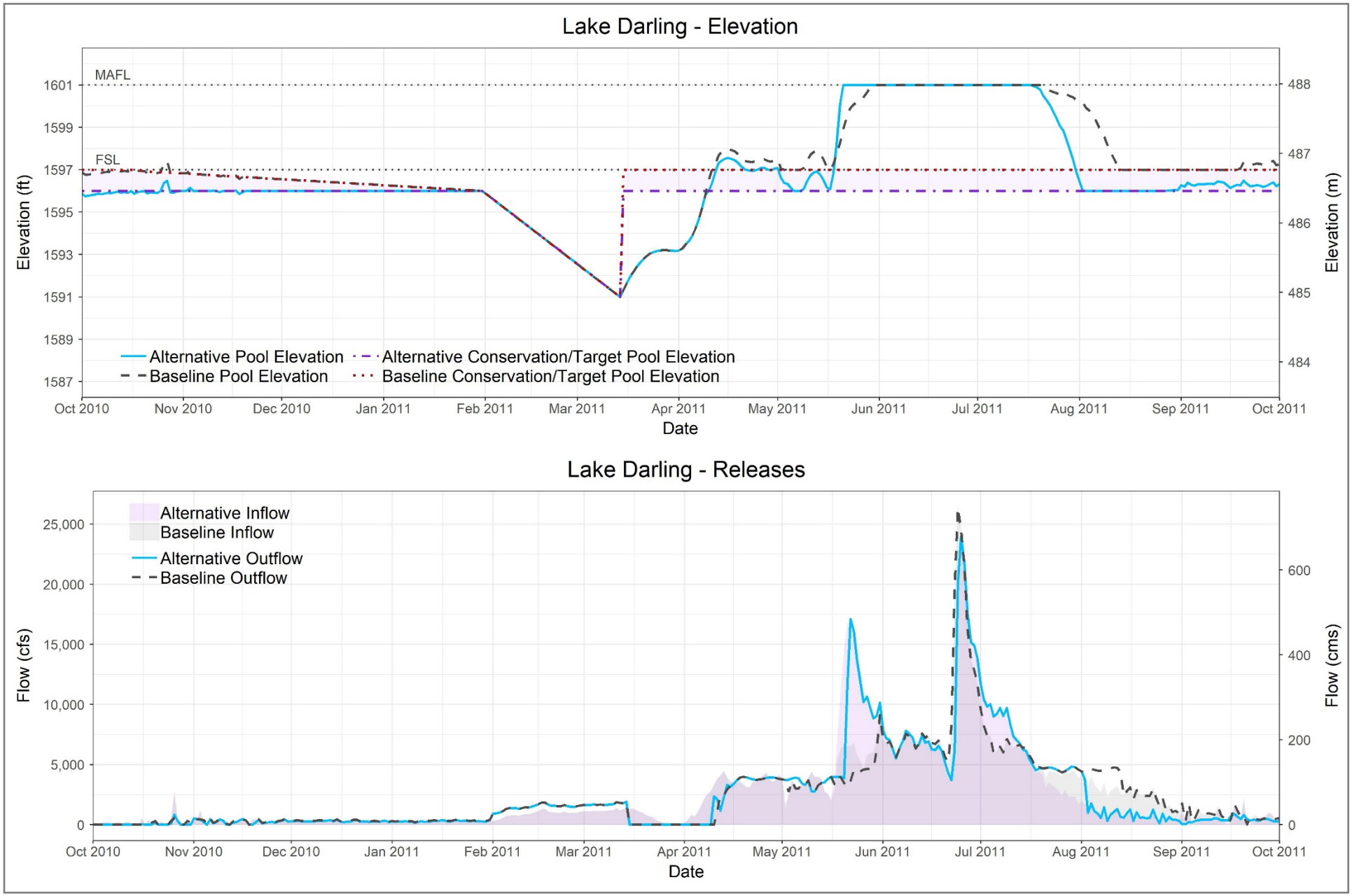
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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



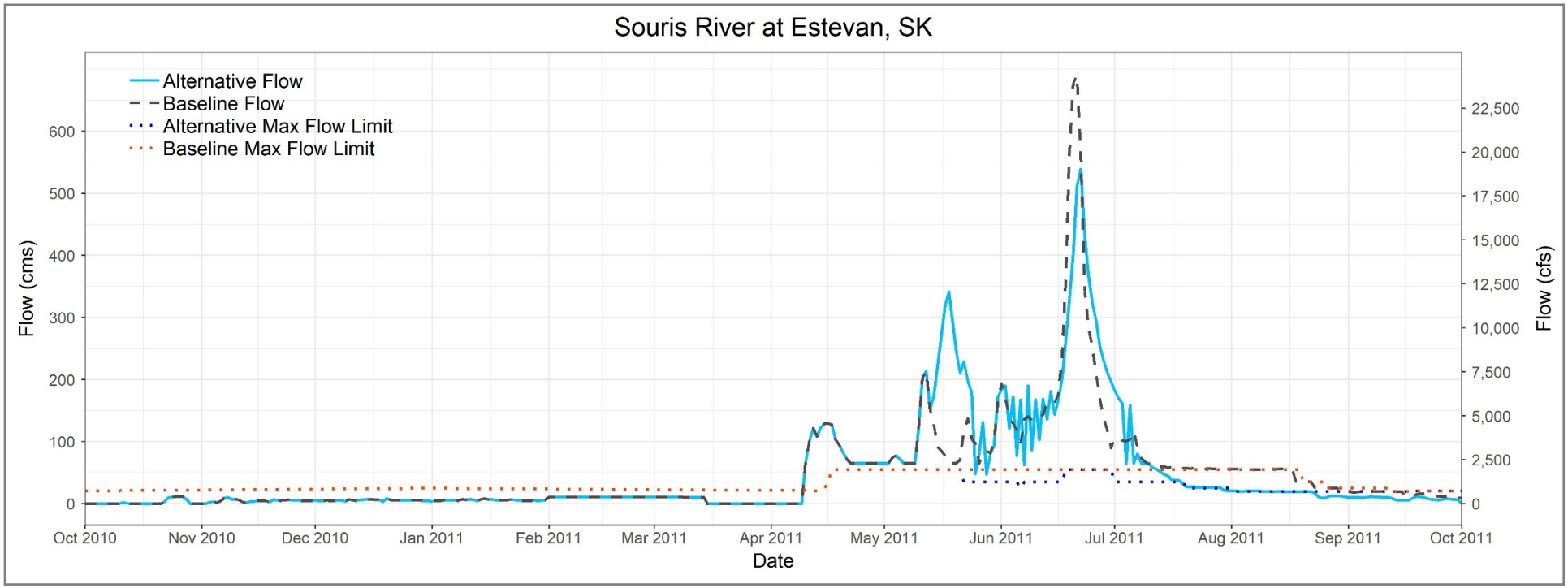
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*

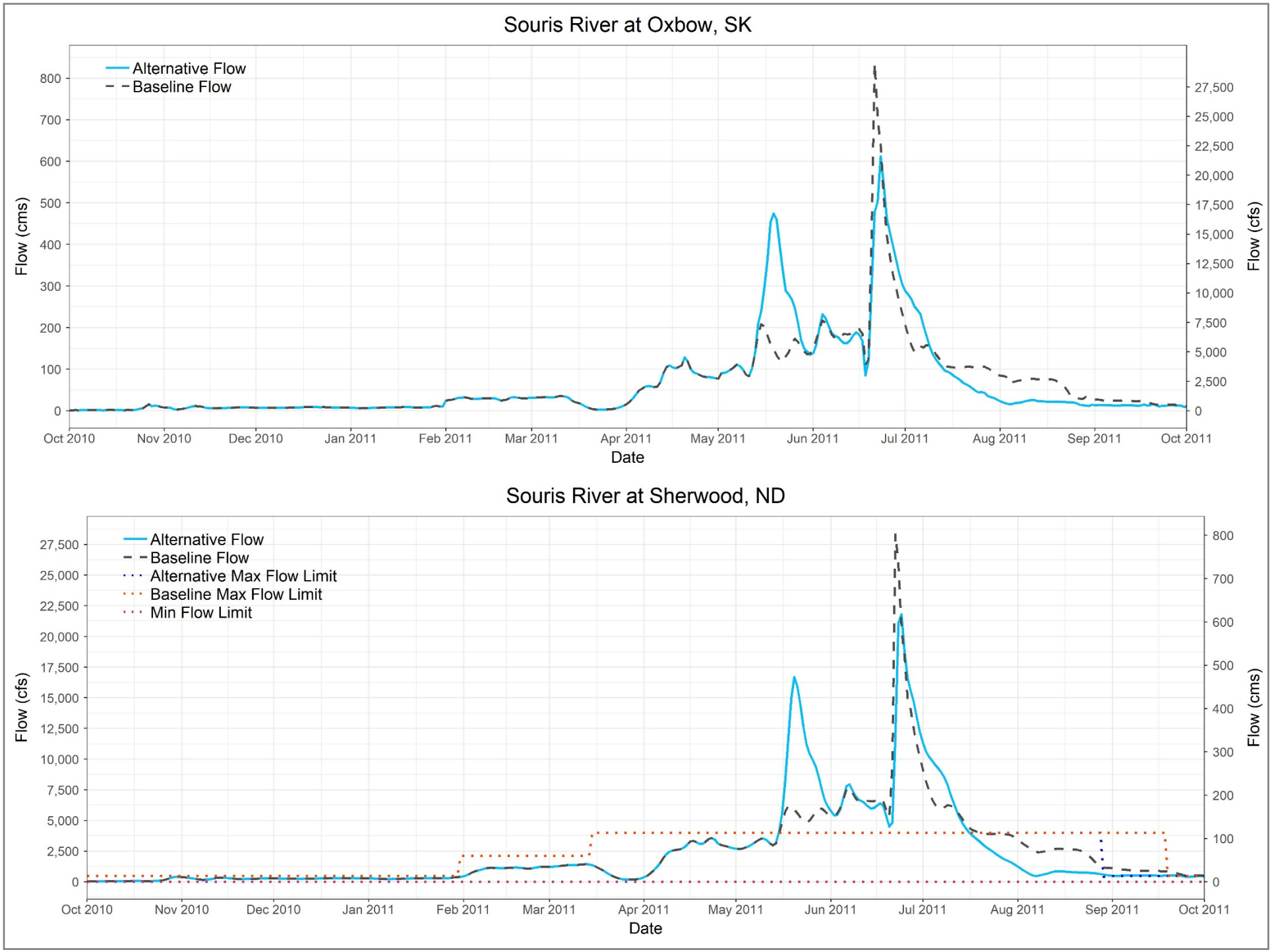
Plate 17

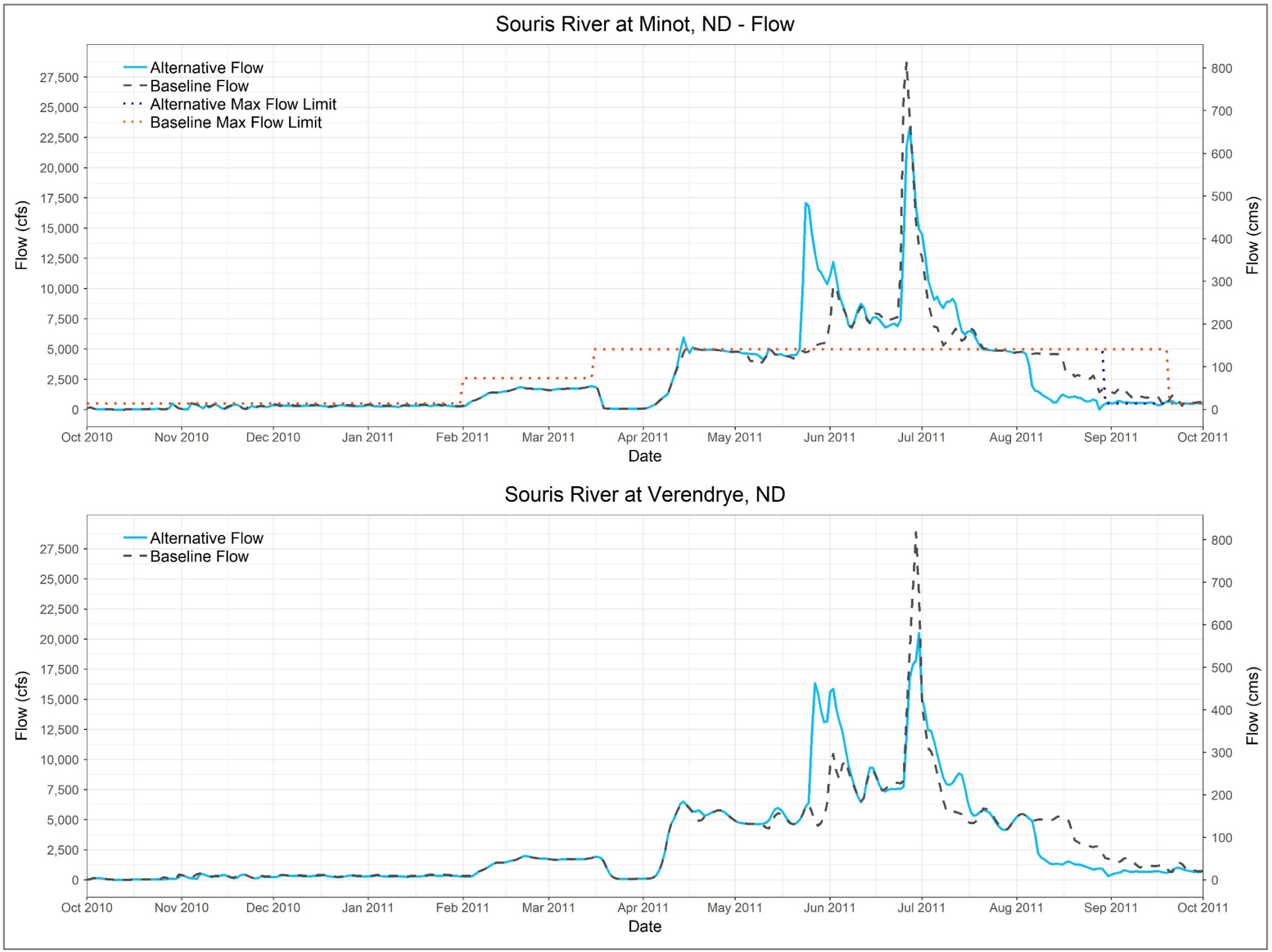
Critical Flow Locations – 2011

Alternative 11b (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Oct 2011
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Oct 2011
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date

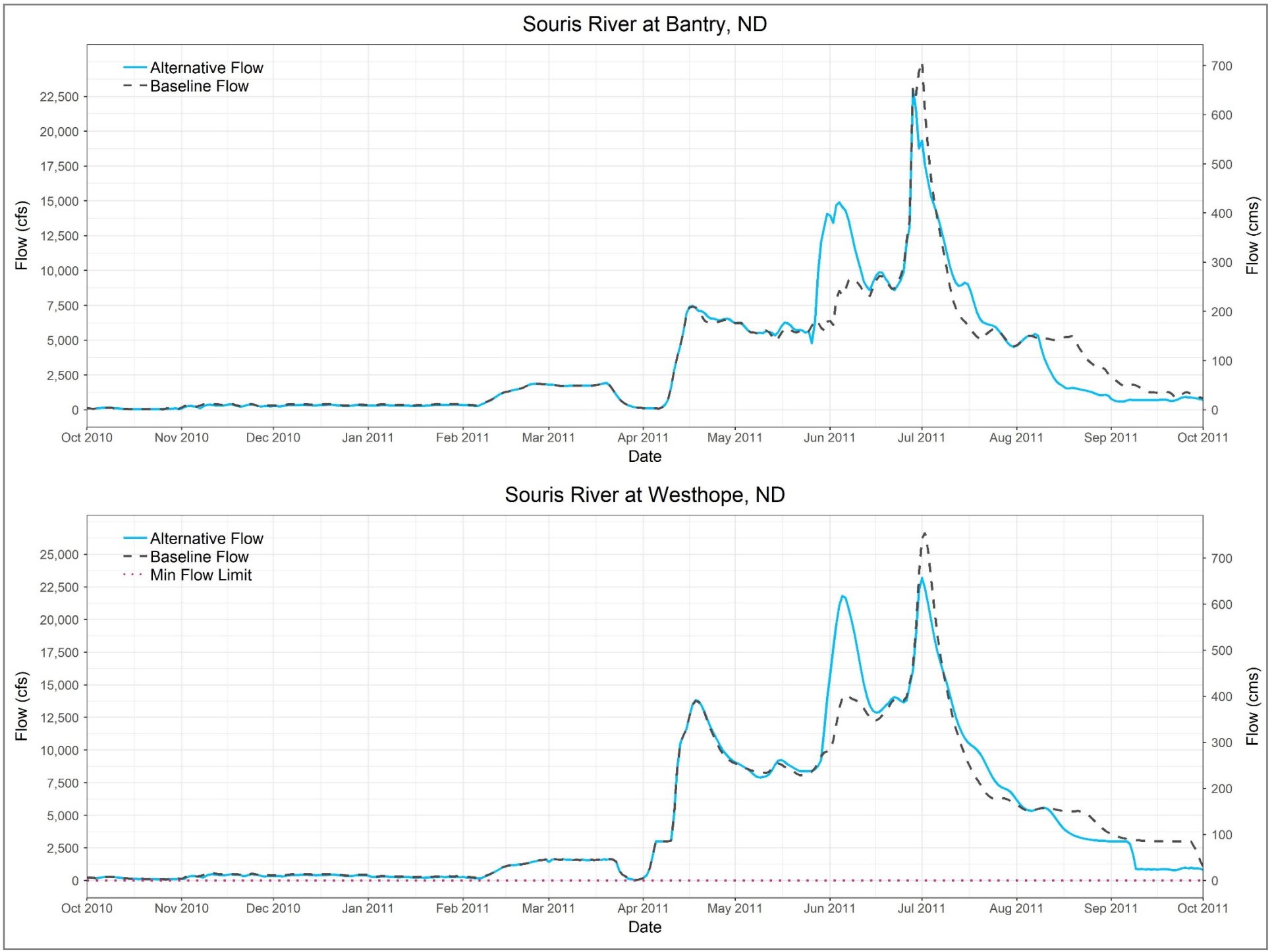
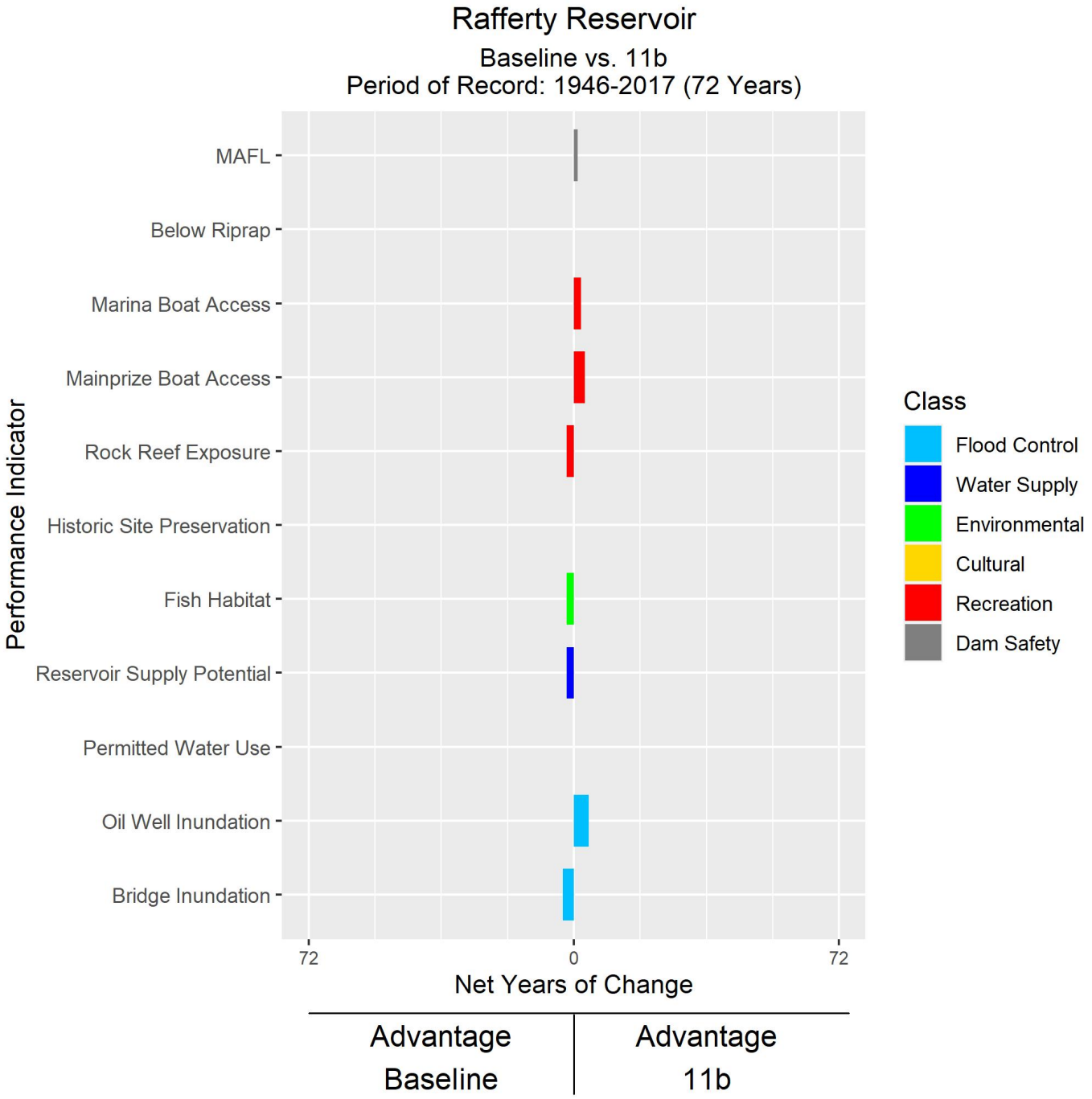
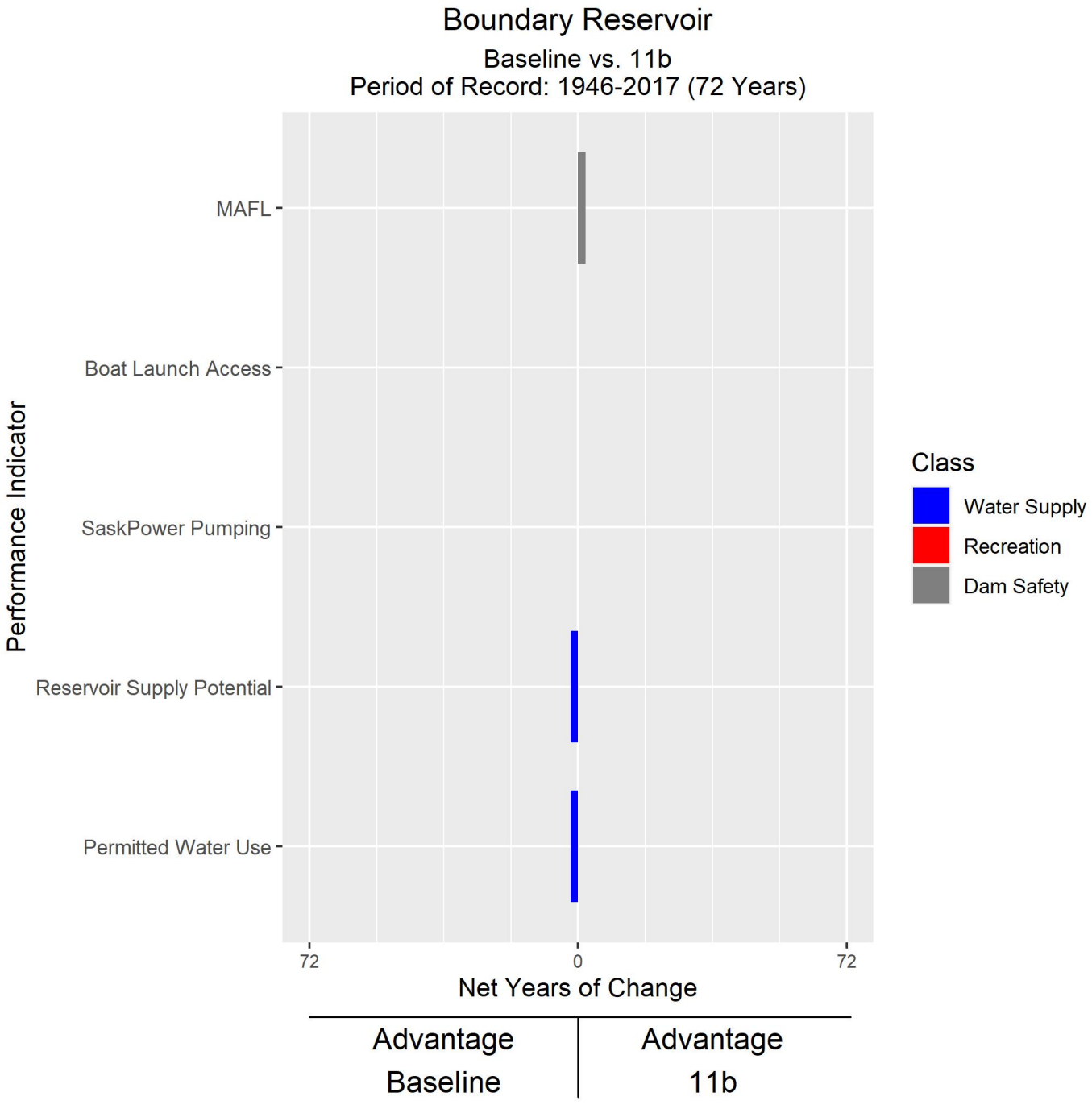
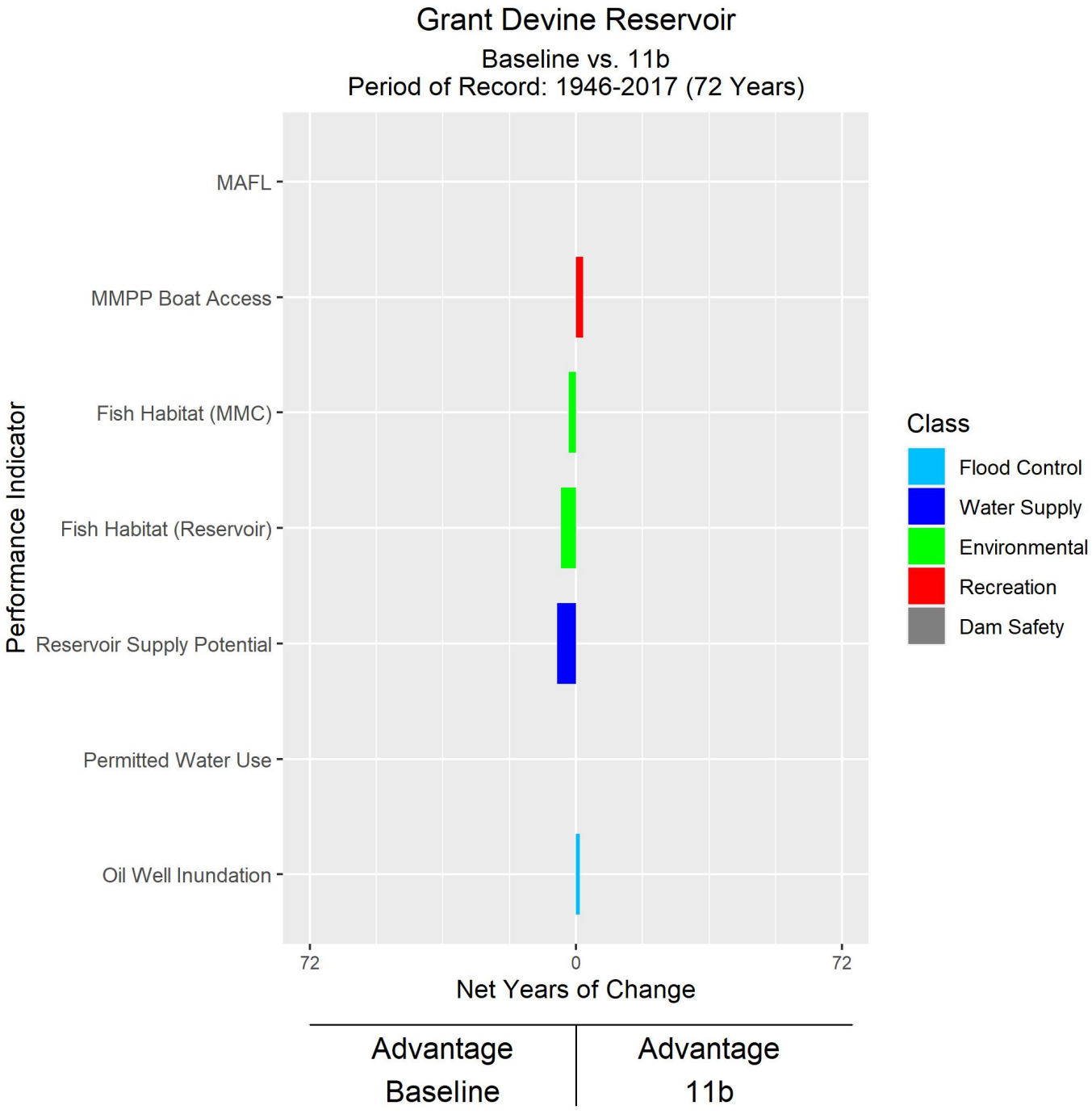
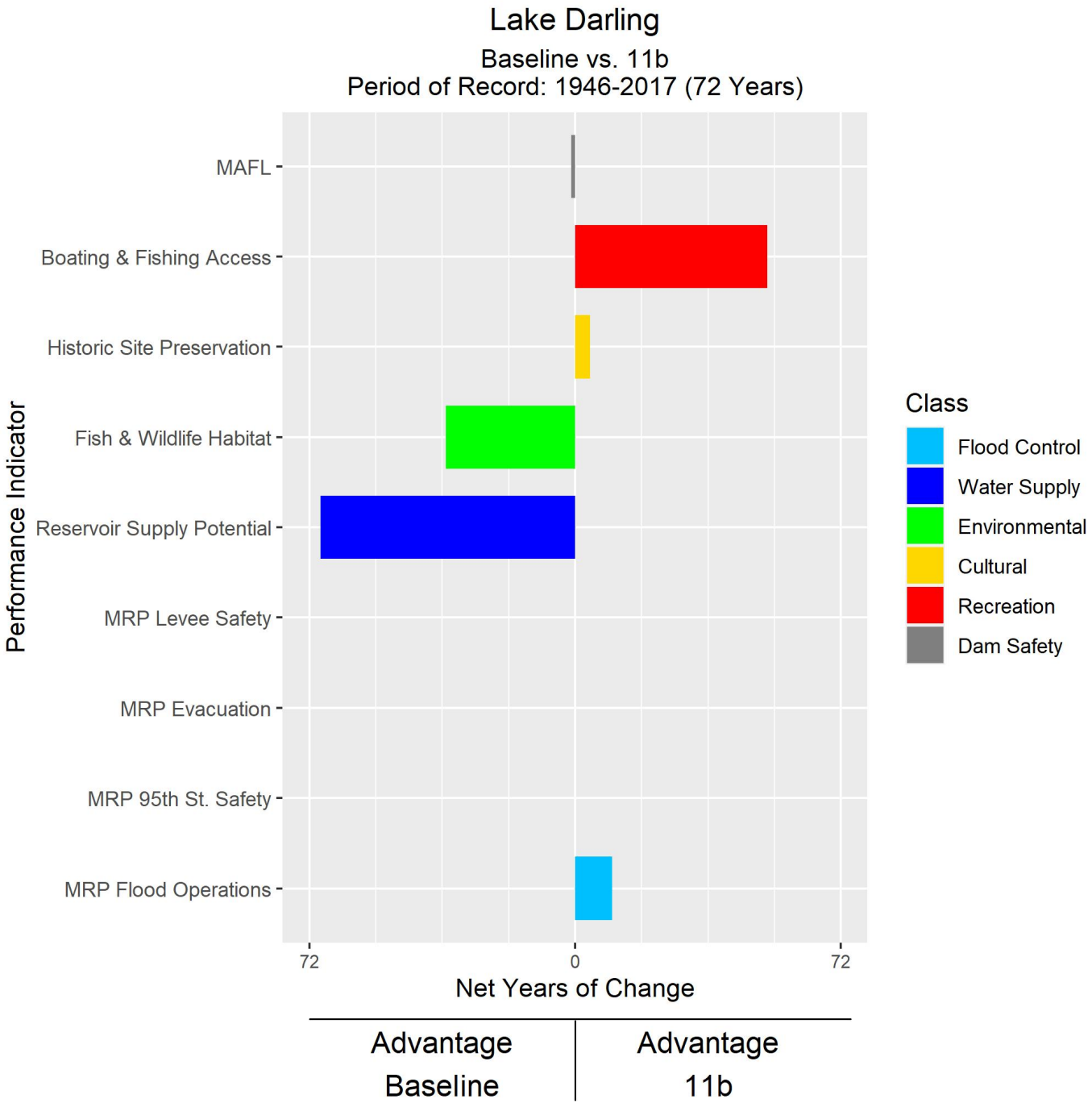

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Oct 2011
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
Date

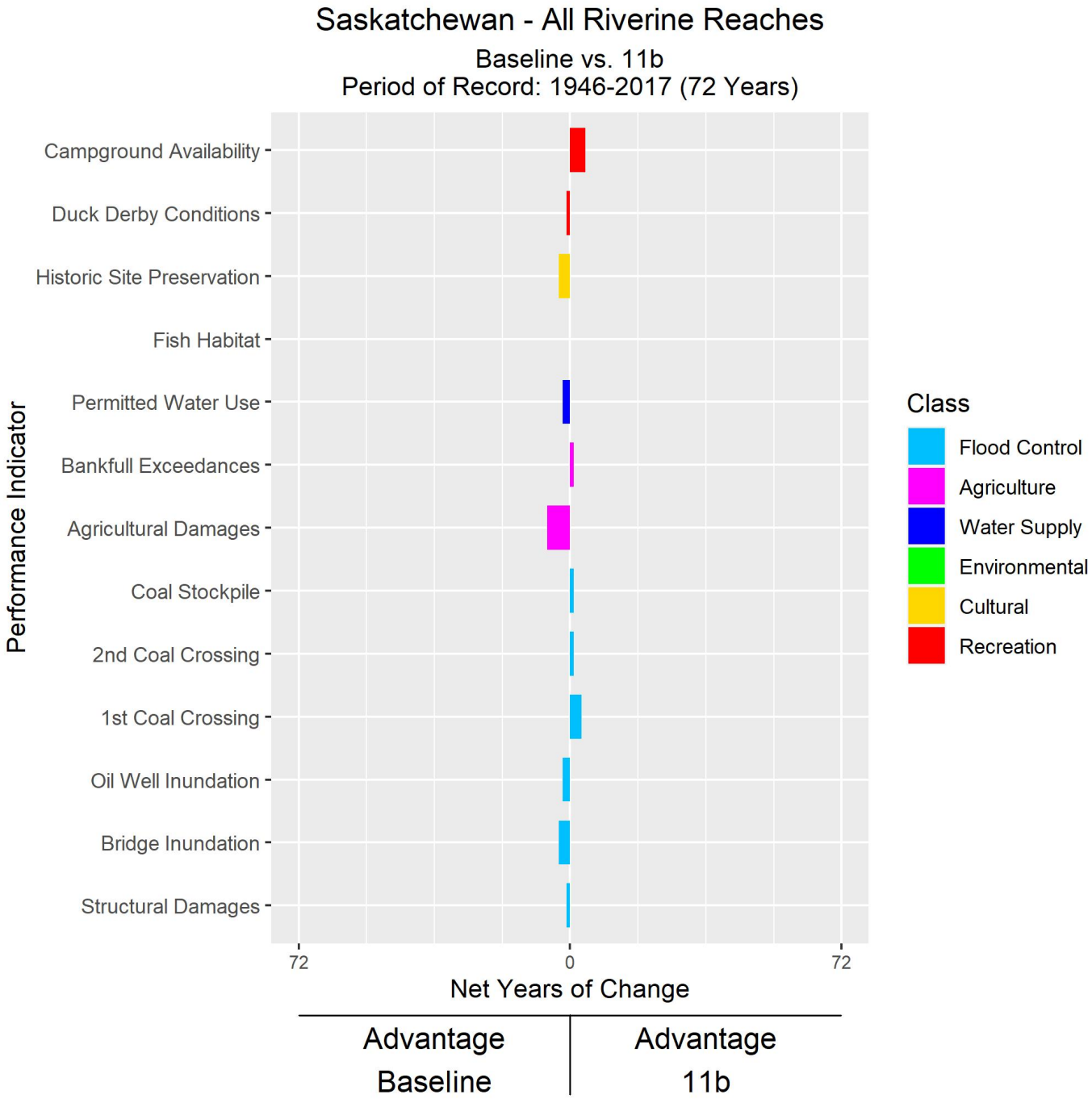
Plate 18	Performance Indicators 1946-2017 (72 years)	Alternative 11b vs. Baseline (Phase 2)

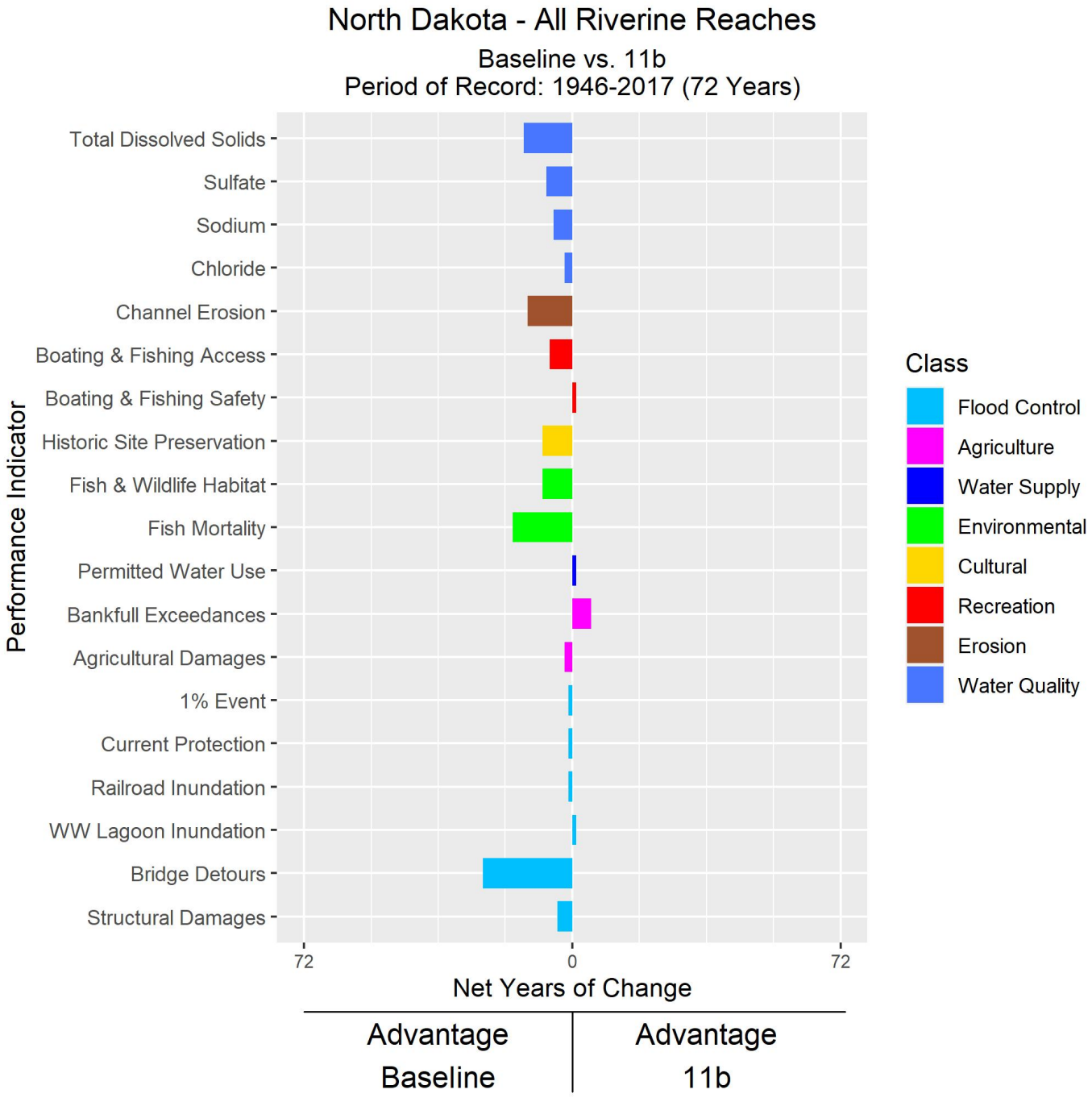


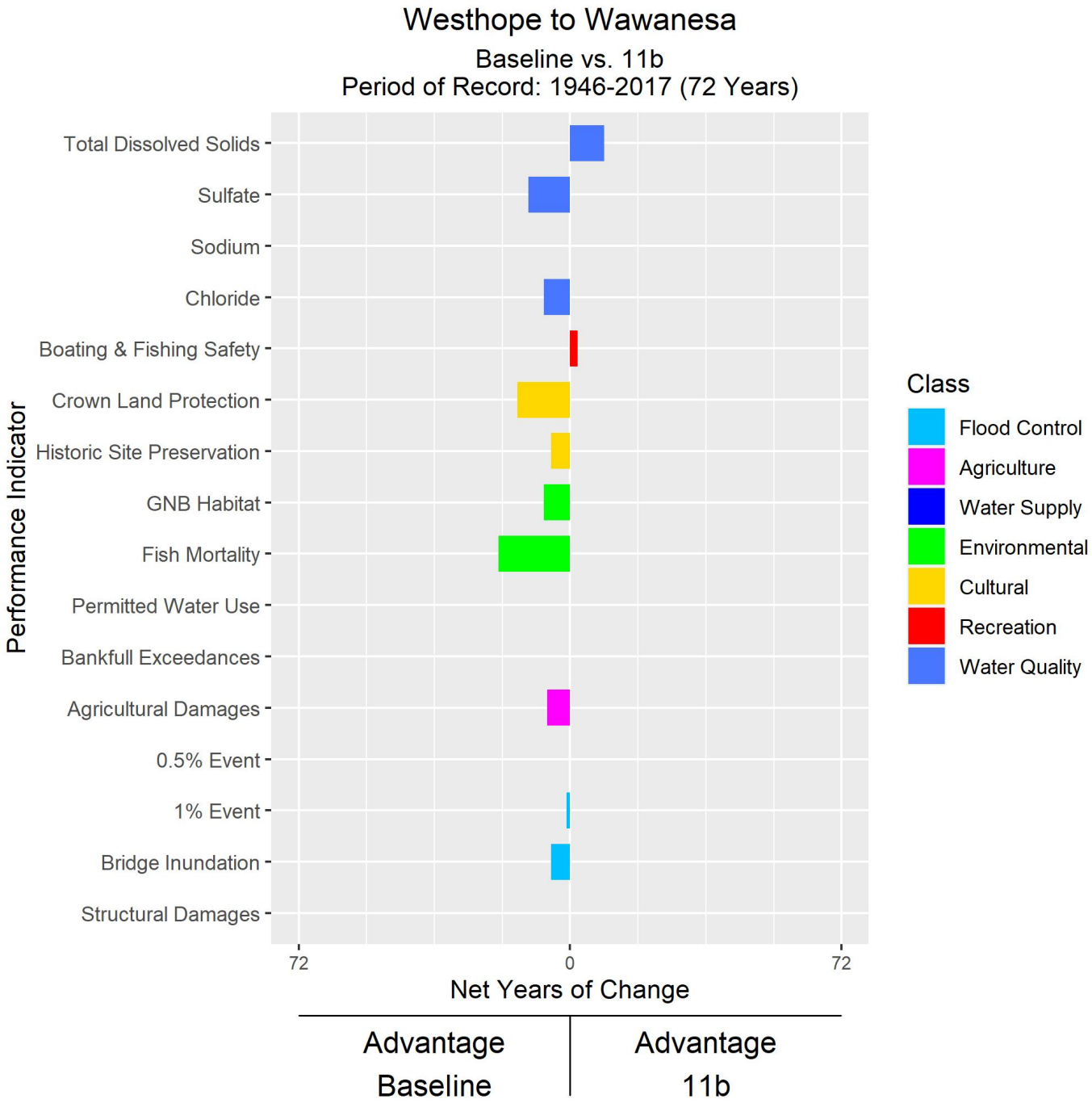

Boundary Reservoir
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
MAFL
Boat Launch Access
SaskPower Pumping
Reservoir Supply Potential
Permitted Water Use
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11b
Class
Water Supply
Recreation
Dam Safety

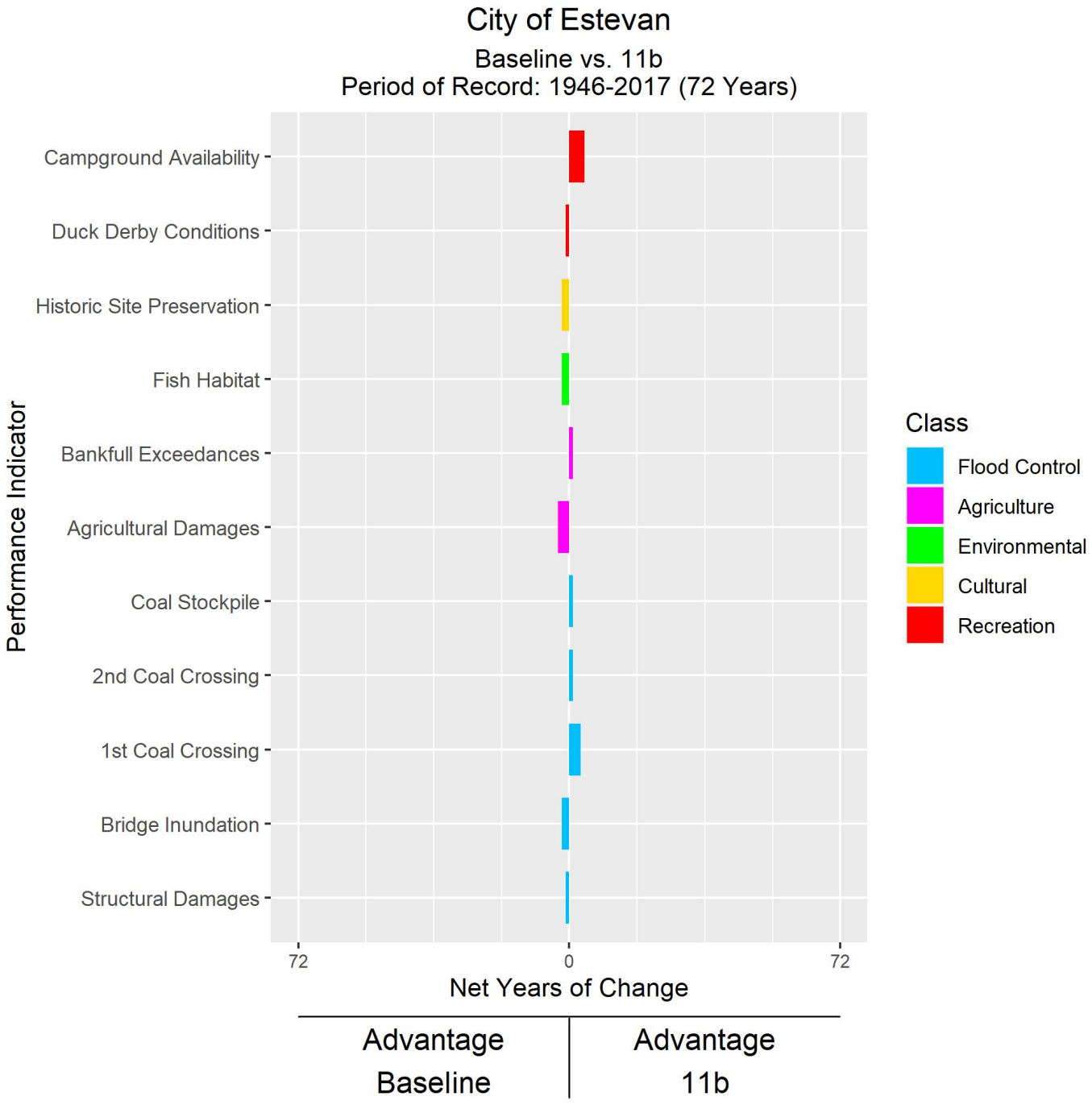

Grant Devine Reservoir
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
MAFL
MMPP Boat Access
Fish Habitat (MMC)
Fish Habitat (Reservoir)
Reservoir Supply Potential
Permitted Water Use
Oil Well Inundation
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11b
Class
Flood Control
Water Supply
Environmental
Recreation
Dam Safety

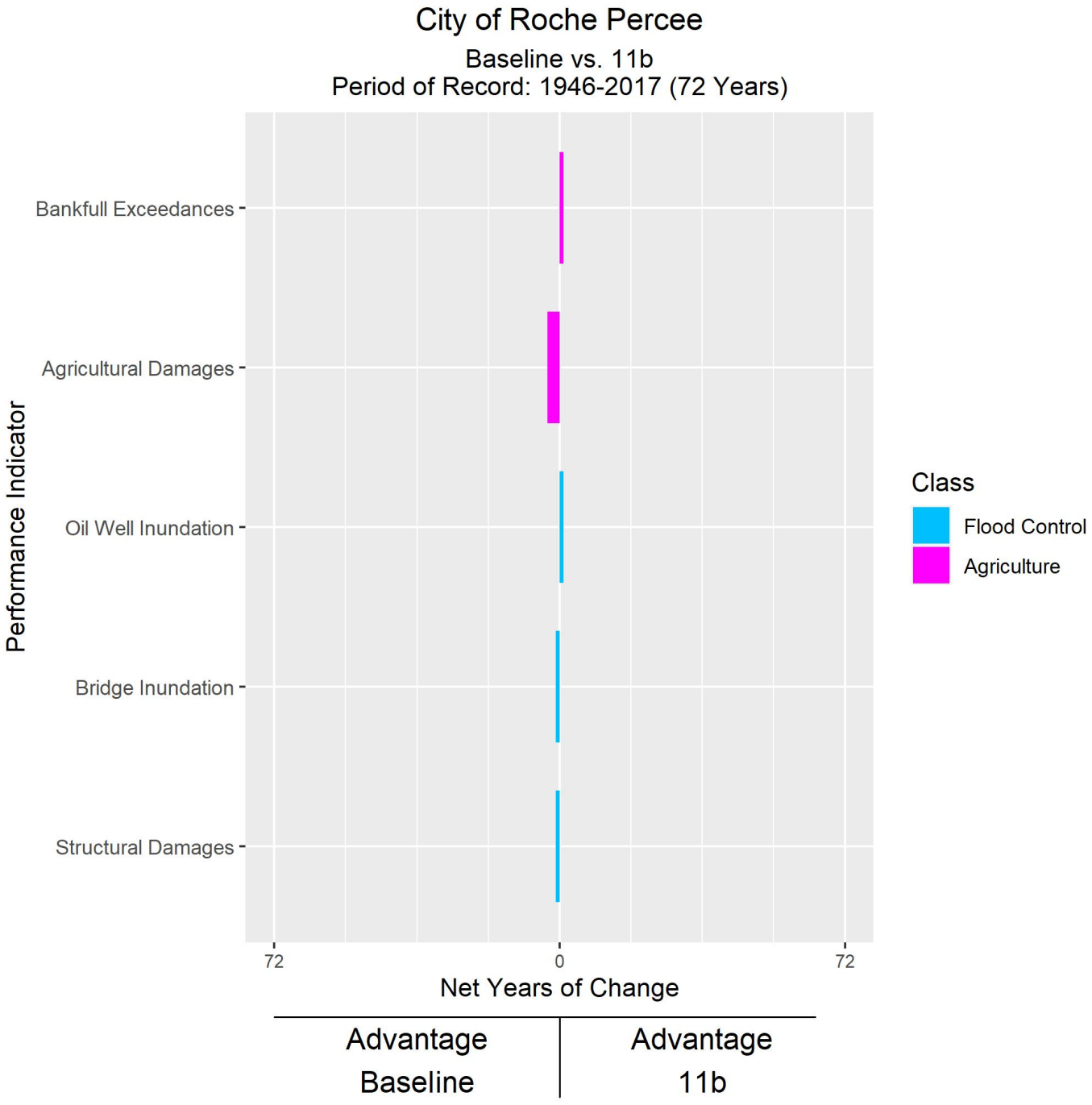

Lake Darling
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
MAFL
Boating & Fishing Access
Historic Site Preservation
Fish & Wildlife Habitat
Reservoir Supply Potential
MRP Levee Safety
MRP Evacuation
MRP 95th St. Safety
MRP Flood Operations
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11b
Class
Flood Control
Water Supply
Environmental
Cultural
Recreation
Dam Safety

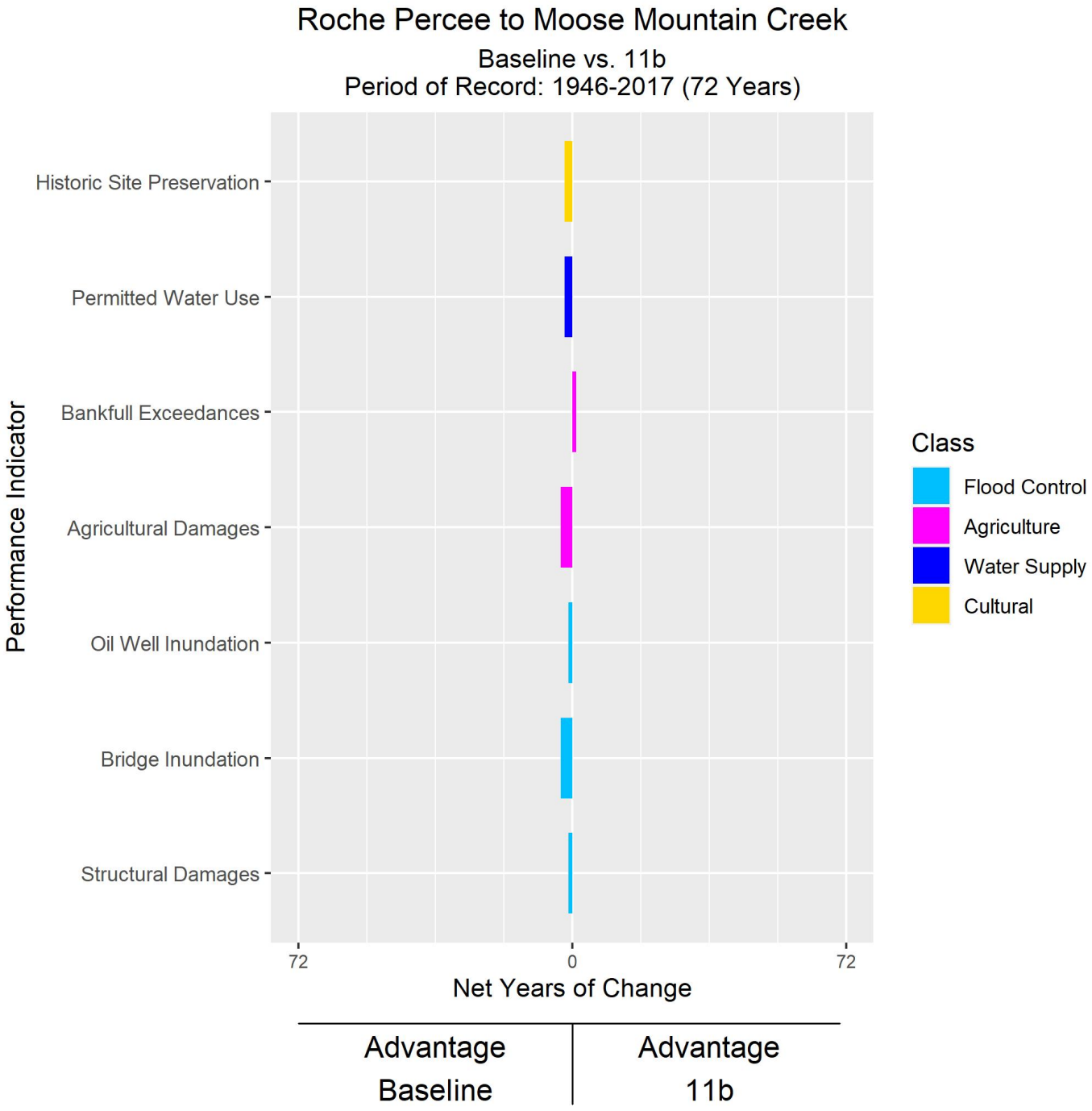

Saskatchewan - All Riverine Reaches
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Campground Availability
Duck Derby Conditions
Historic Site Preservation
Fish Habitat
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Coal Stockpile
2nd Coal Crossing
1st Coal Crossing
Oil Well Inundation
Bridge Inundation
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation

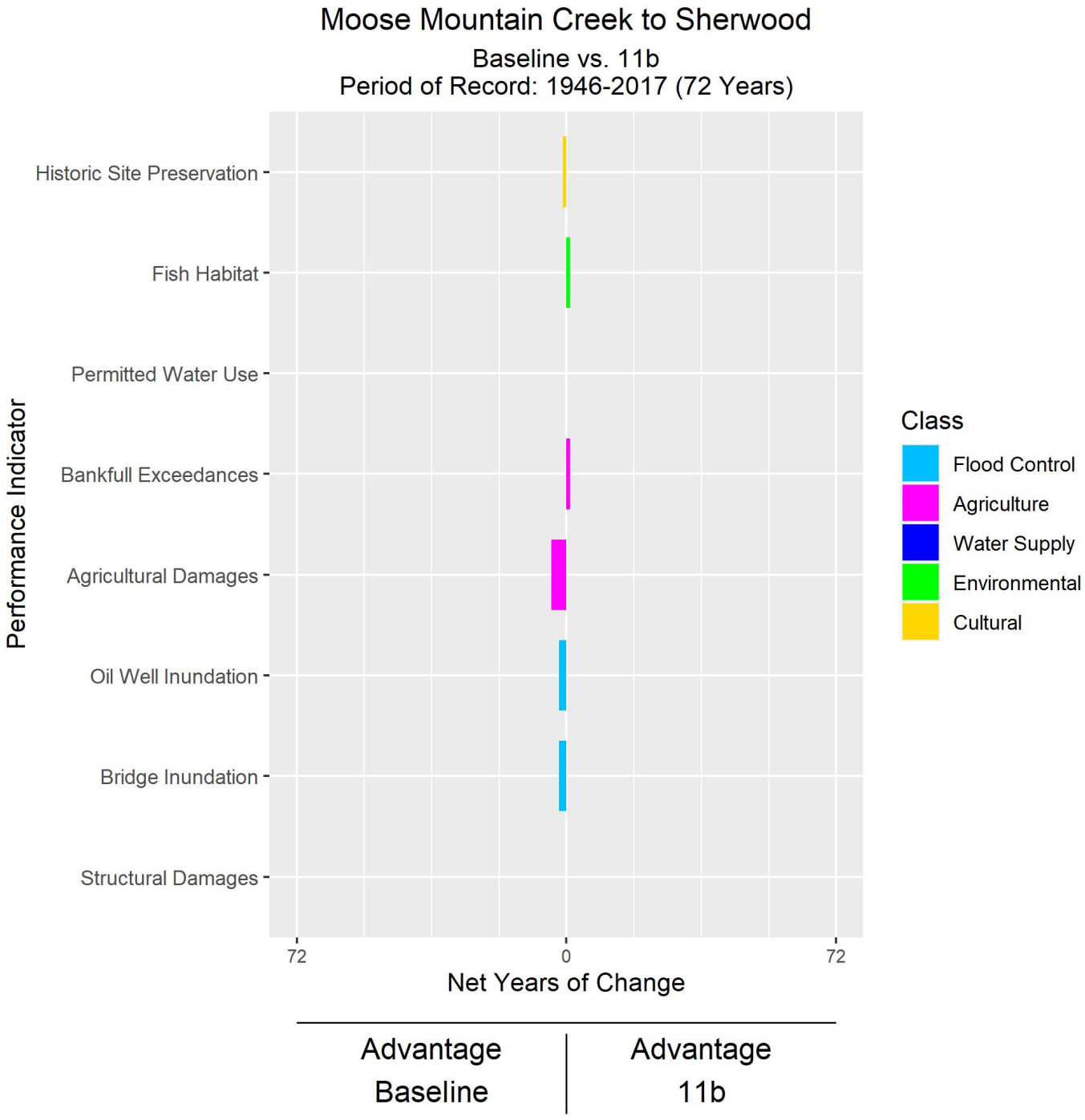

North Dakota - All Riverine Reaches
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Total Dissolved Solids
Sulfate
Sodium
Chloride
Channel Erosion
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
1% Event
Current Protection
Railroad Inundation
WW Lagoon Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion
Water Quality

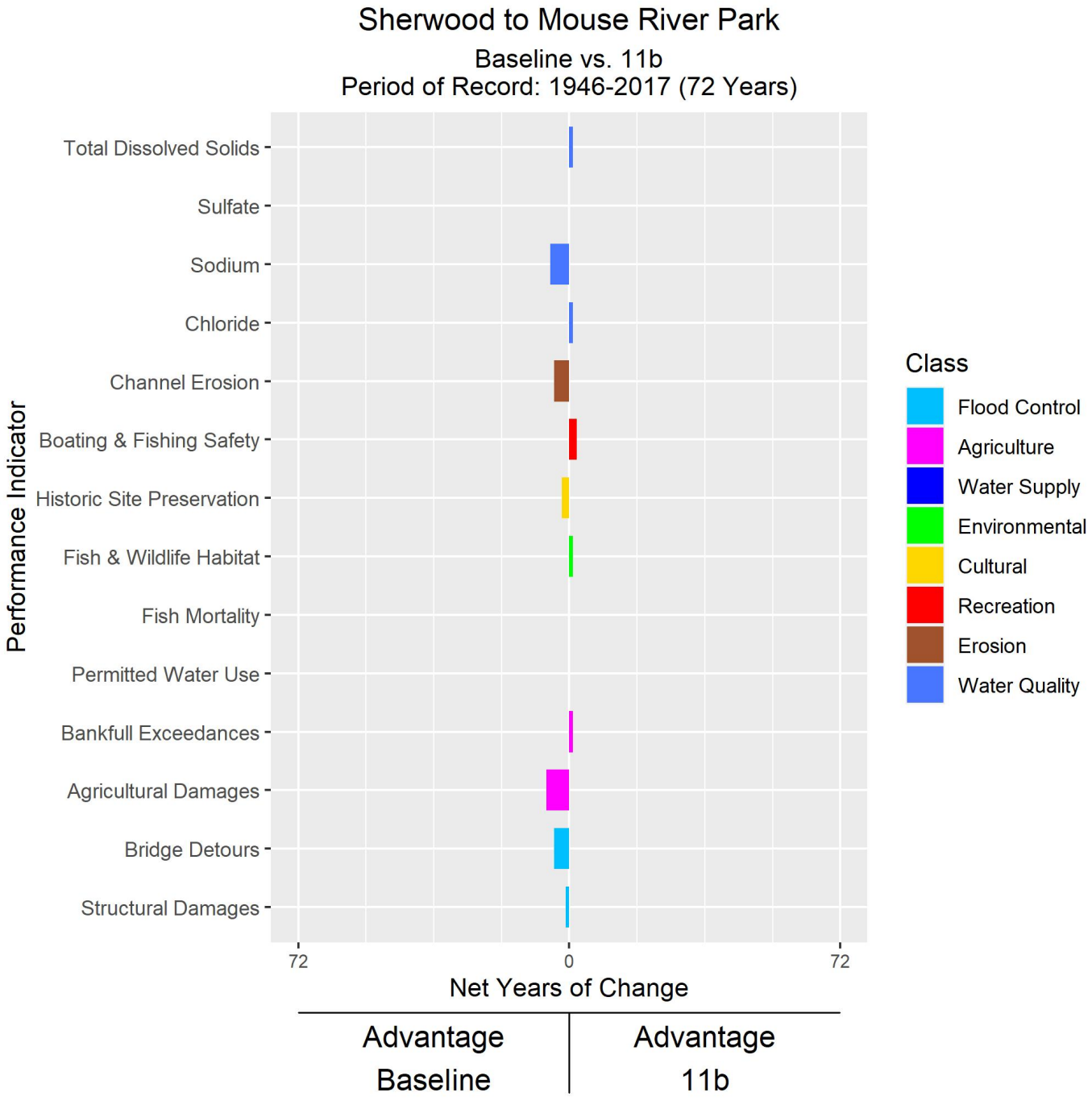

Westhope to Wawanesa
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Total Dissolved Solids
Sulfate
Sodium
Chloride
Boating & Fishing Safety
Crown Land Protection
Historic Site Preservation
GNB Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
0.5% Event
1% Event
Bridge Inundation
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Water Quality

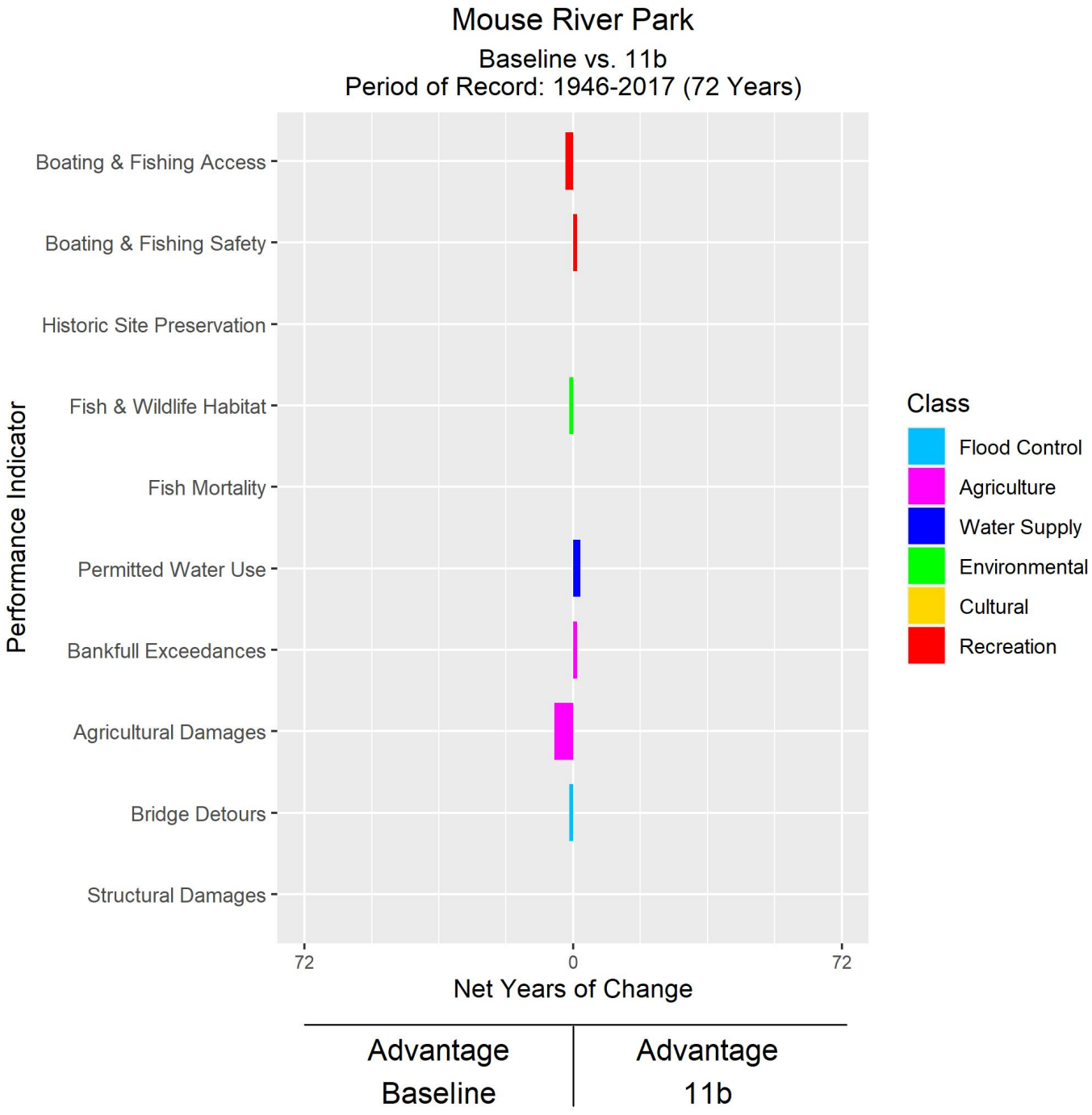

City of Estevan
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Campground Availability
Duck Derby Conditions
Historic Site Preservation
Fish Habitat
Bankfull Exceedances
Agricultural Damages
Coal Stockpile
2nd Coal Crossing
1st Coal Crossing
Bridge Inundation
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Environmental
Cultural
Recreation

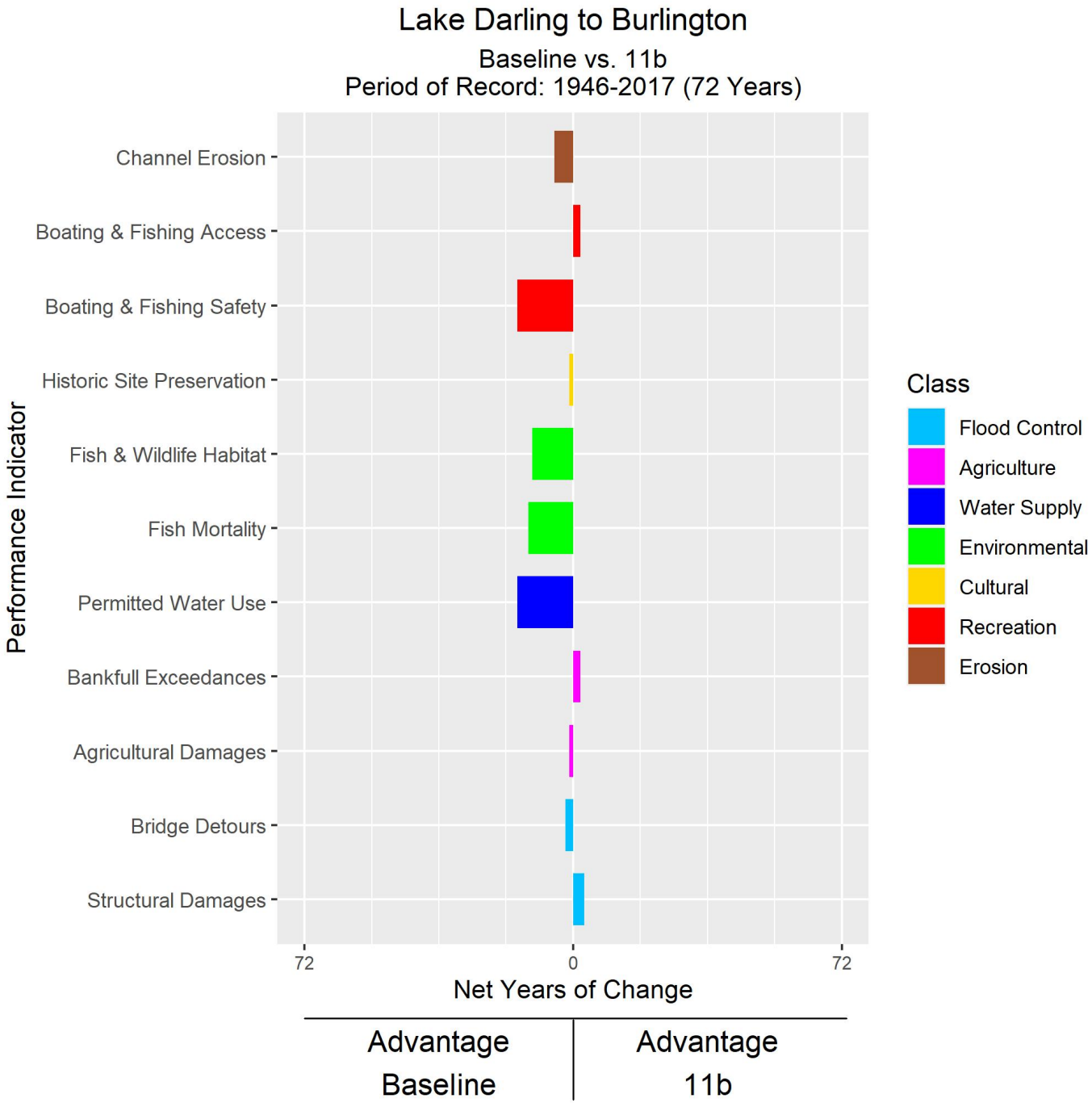

City of Roche Percee
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Bankfull Exceedances
Agricultural Damages
Oil Well Inundation
Bridge Inundation
Structural Damages
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11b
Class
Flood Control
Agriculture

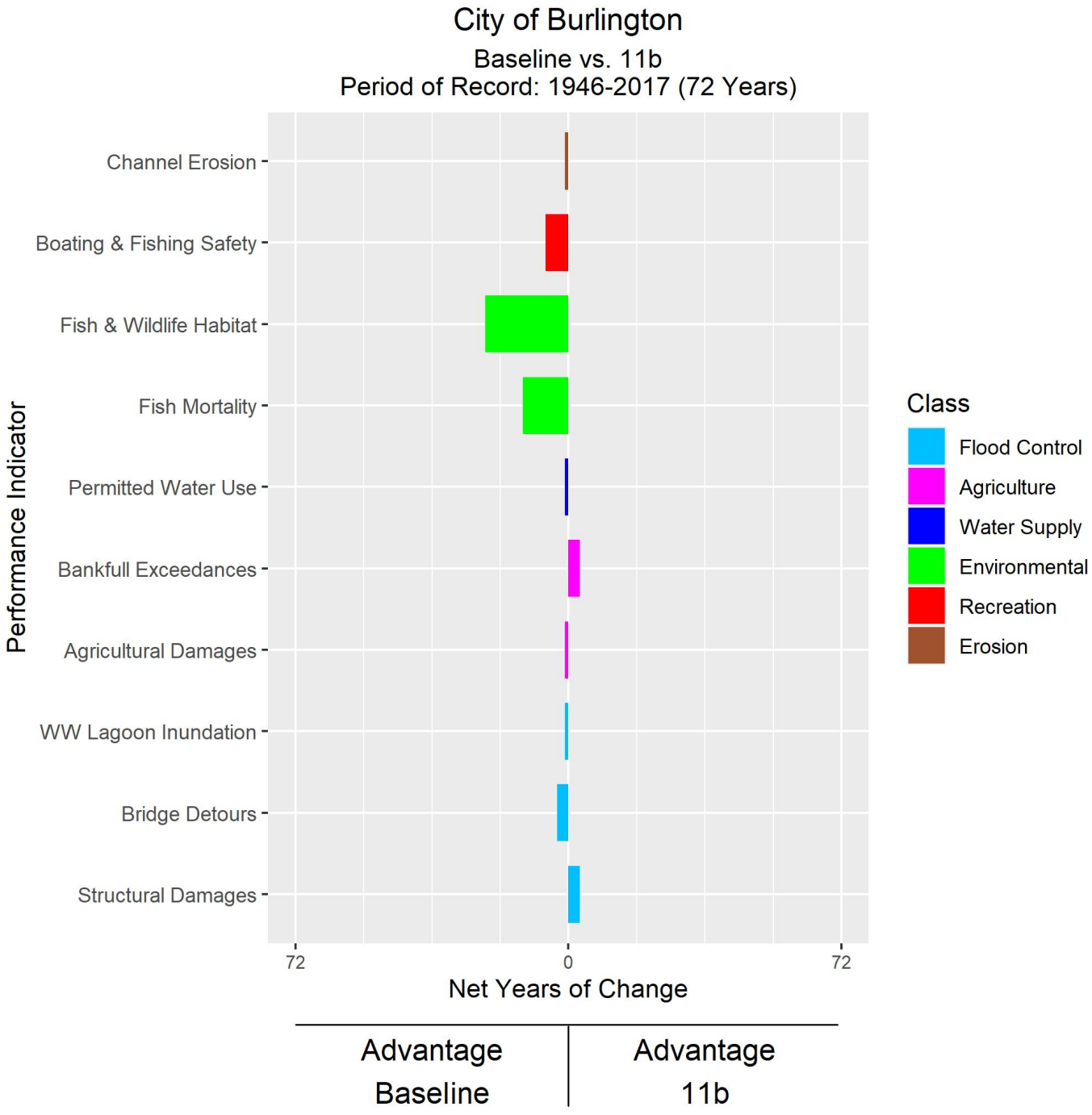

Roche Percee to Moose Mountain Creek
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Historic Site Preservation
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Oil Well Inundation
Bridge Inundation
Structural Damages
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11b
Class
Flood Control
Agriculture
Water Supply
Cultural

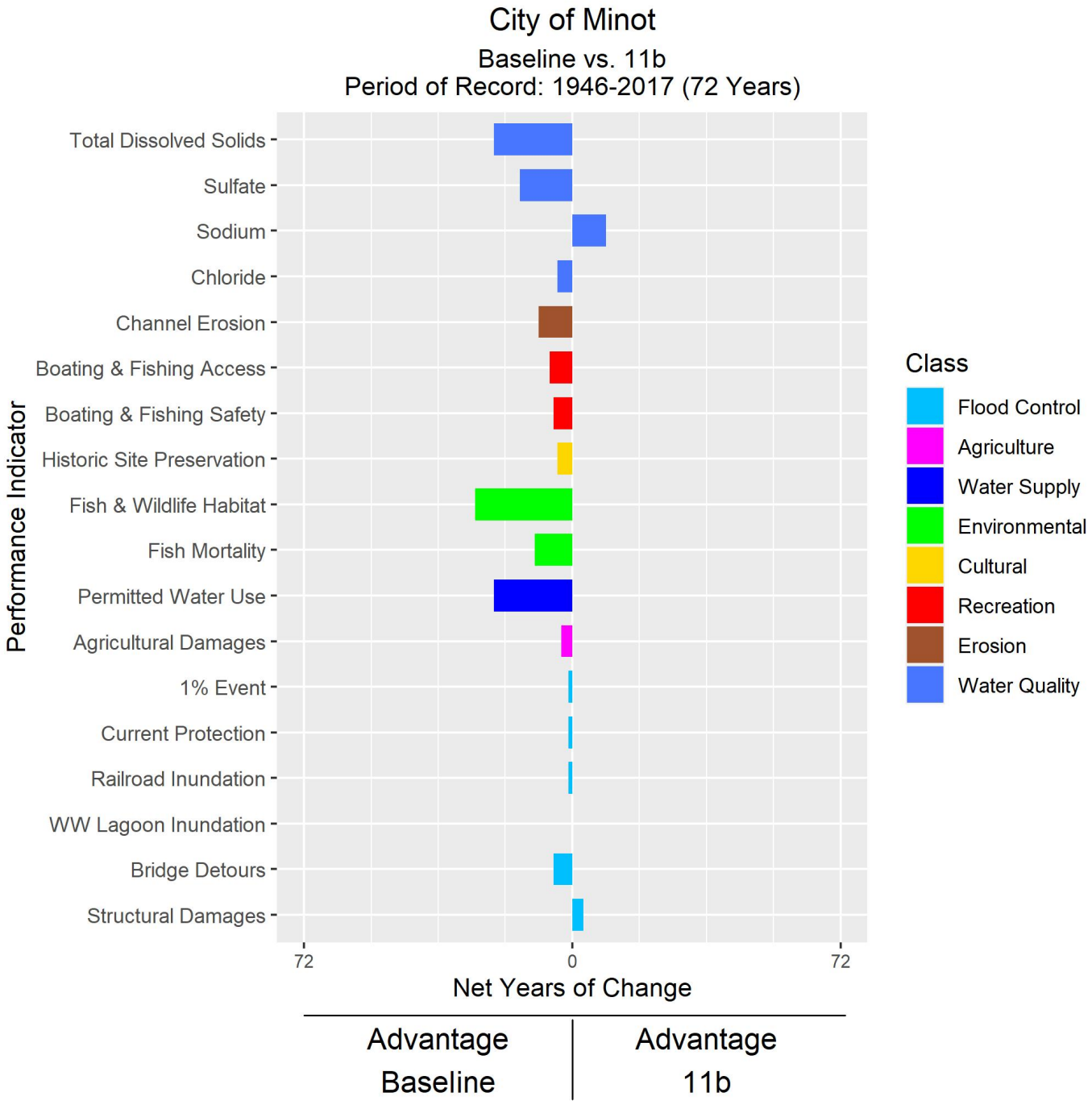

Moose Mountain Creek to Sherwood
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Historic Site Preservation
Fish Habitat
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Oil Well Inundation
Bridge Inundation
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural

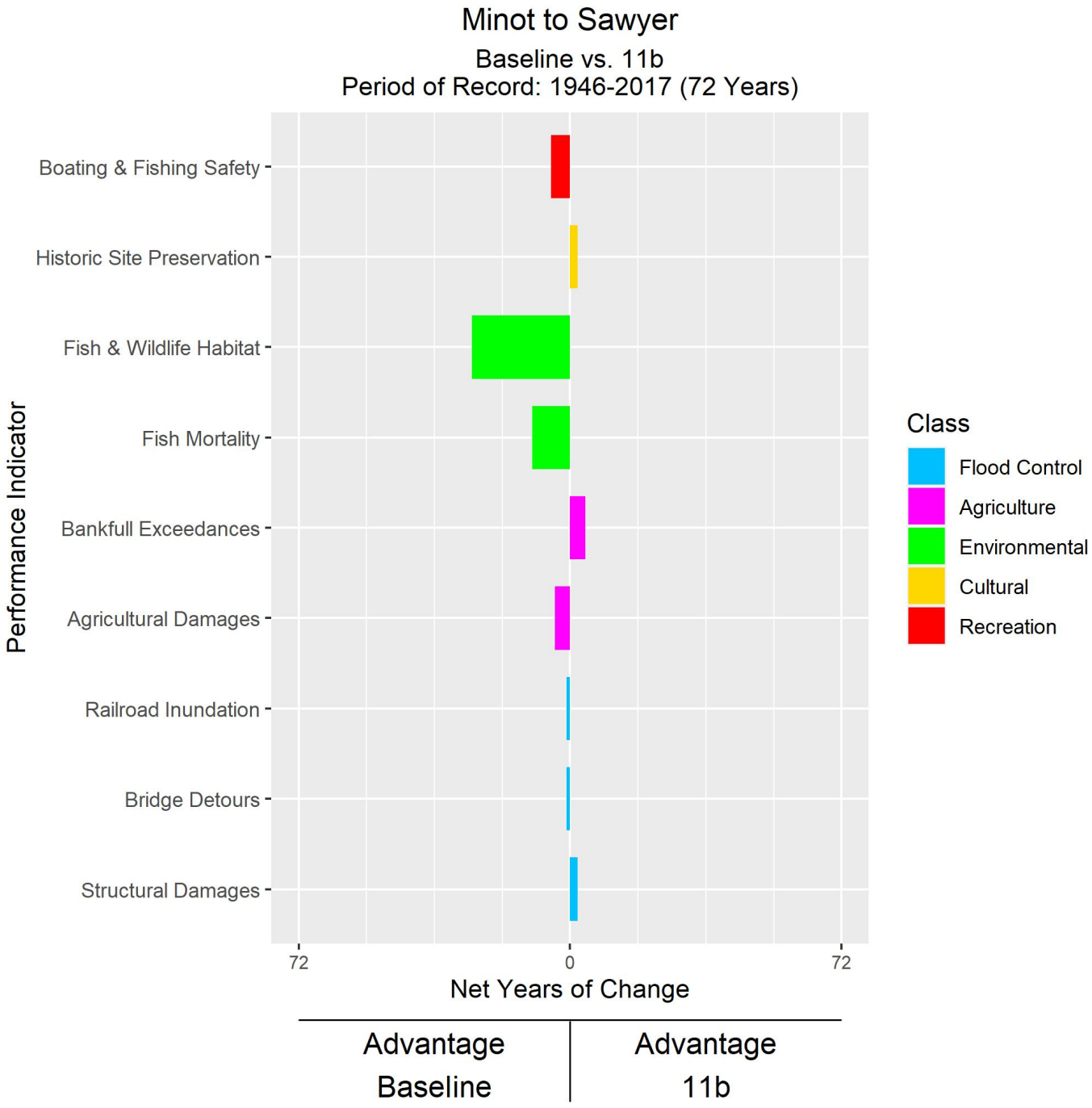

Sherwood to Mouse River Park
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Total Dissolved Solids
Sulfate
Sodium
Chloride
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion
Water Quality

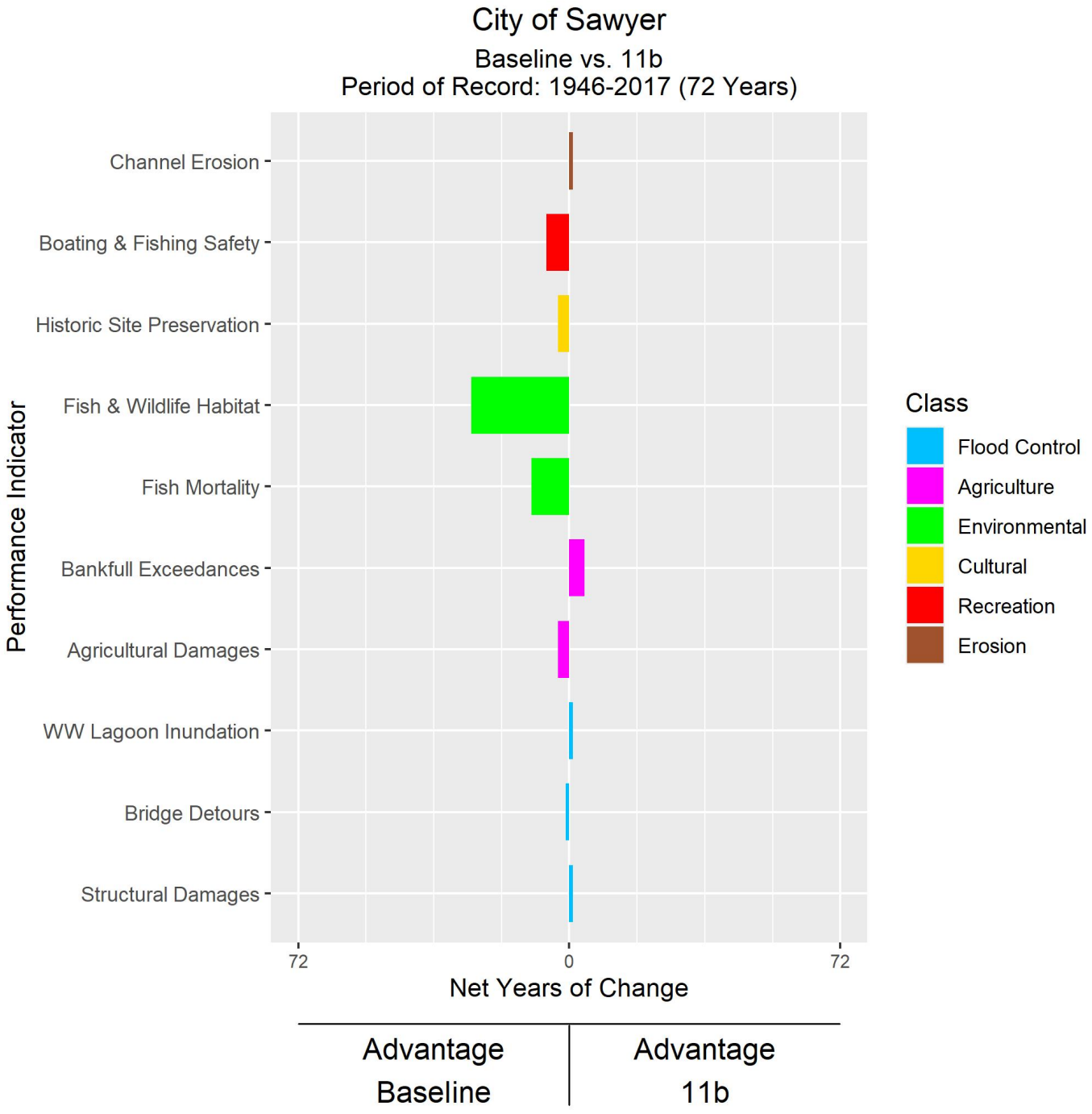

Mouse River Park
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation

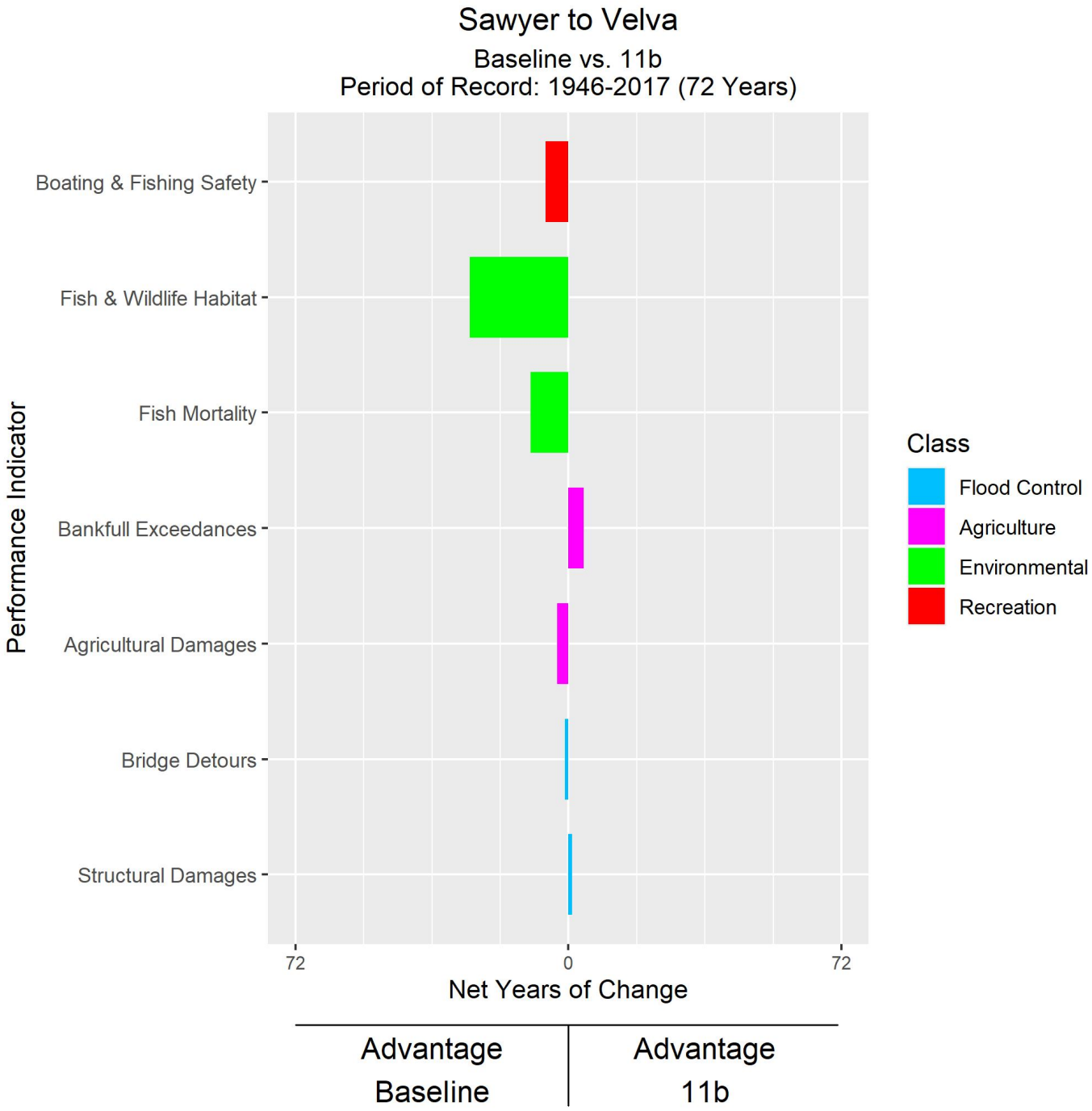

Lake Darling to Burlington
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion

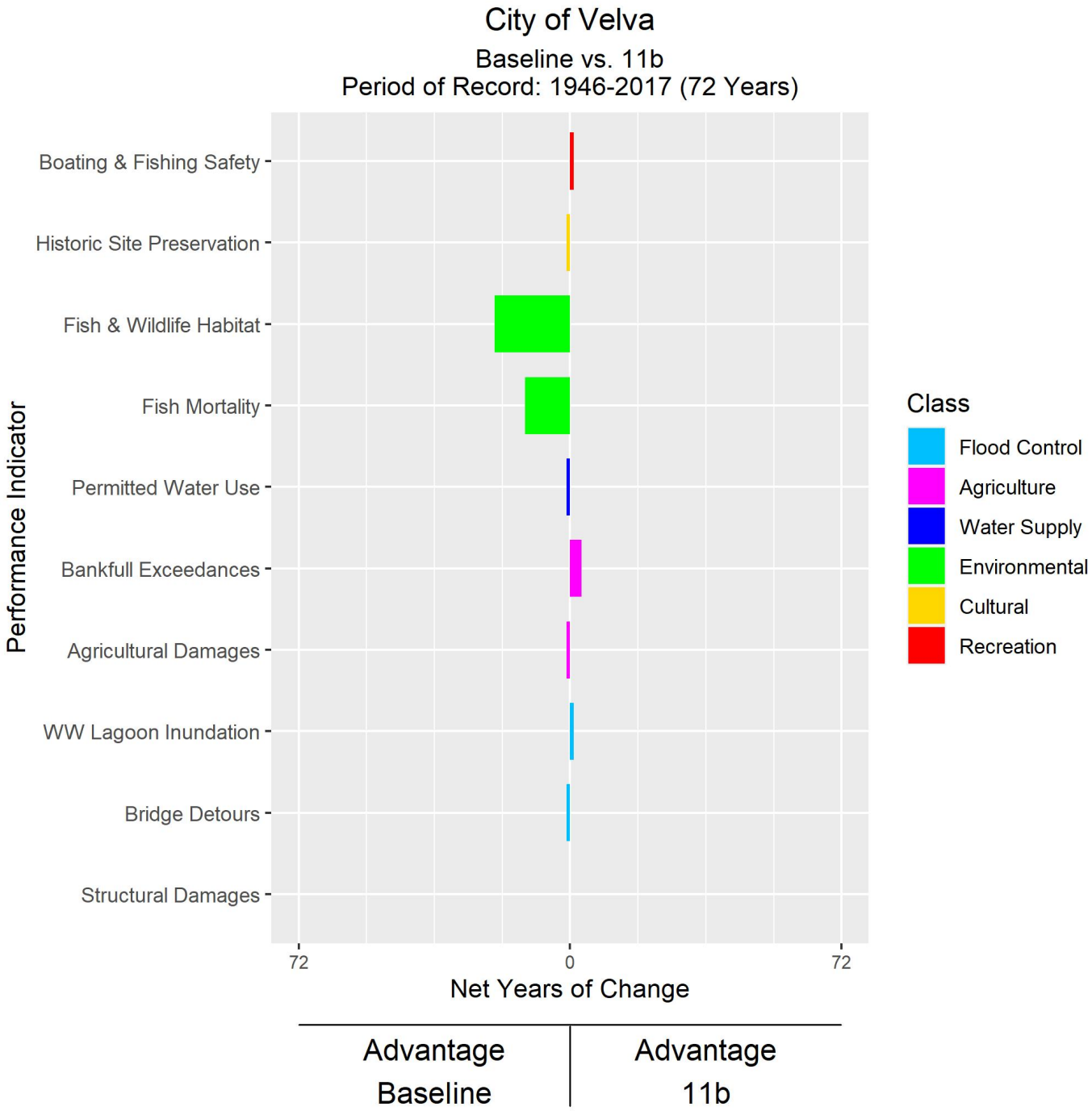

City of Burlington
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
WW Lagoon Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Recreation
Erosion

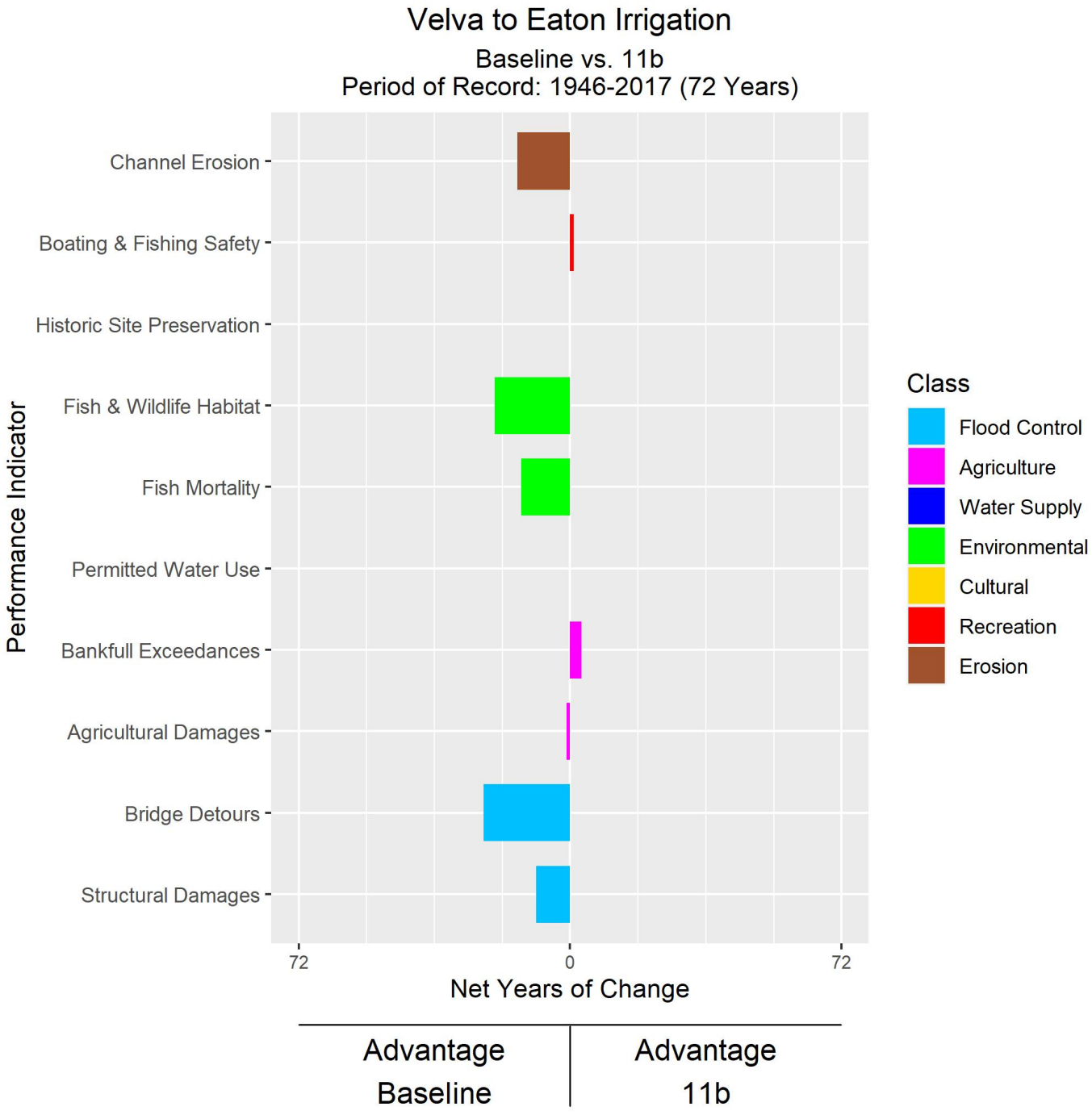

City of Minot
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Total Dissolved Solids
Sulfate
Sodium
Chloride
Channel Erosion
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Agricultural Damages
1% Event
Current Protection
Railroad Inundation
WW Lagoon Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion
Water Quality

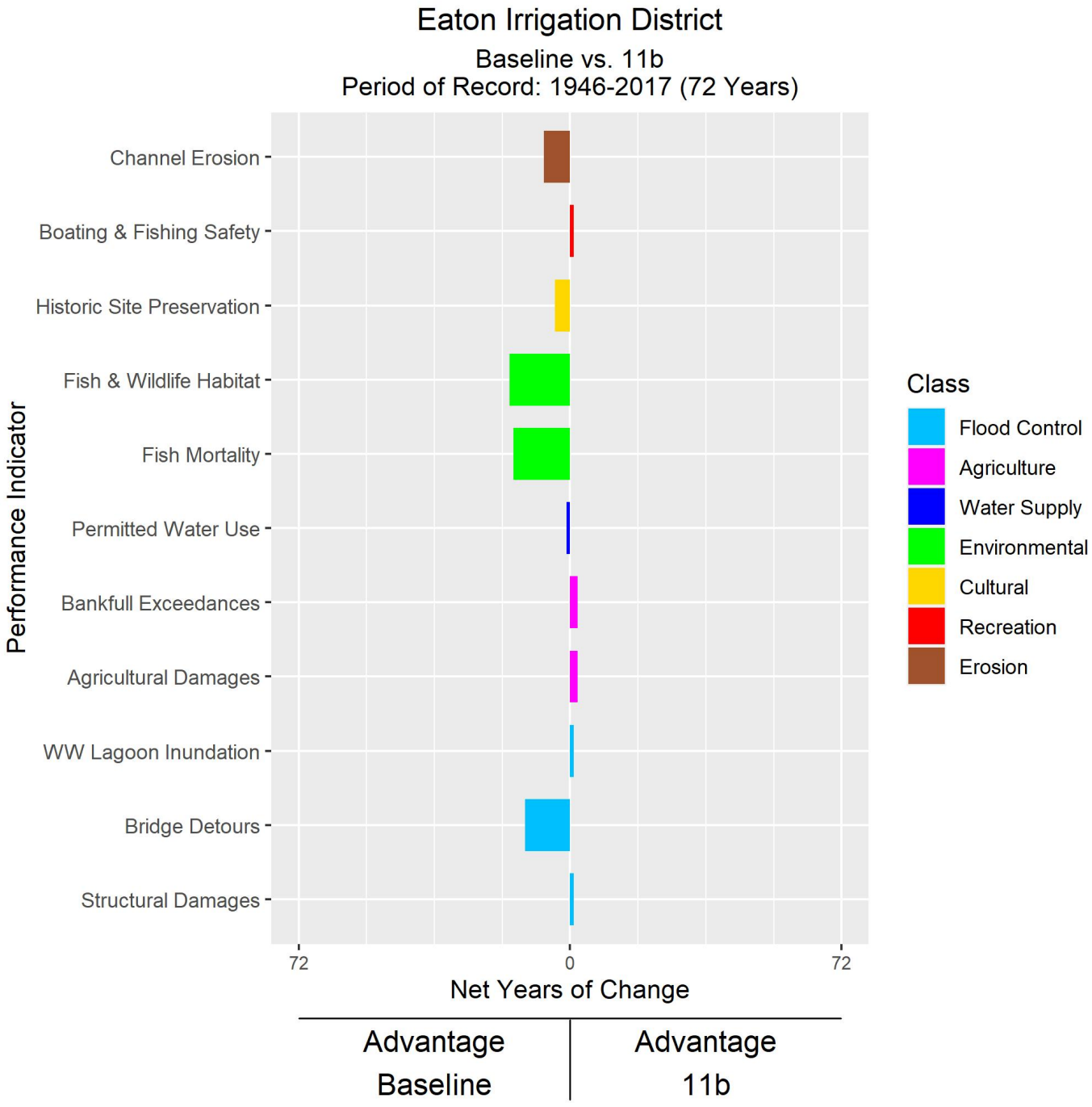

Minot to Sawyer
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Bankfull Exceedances
Agricultural Damages
Railroad Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Environmental
Cultural
Recreation

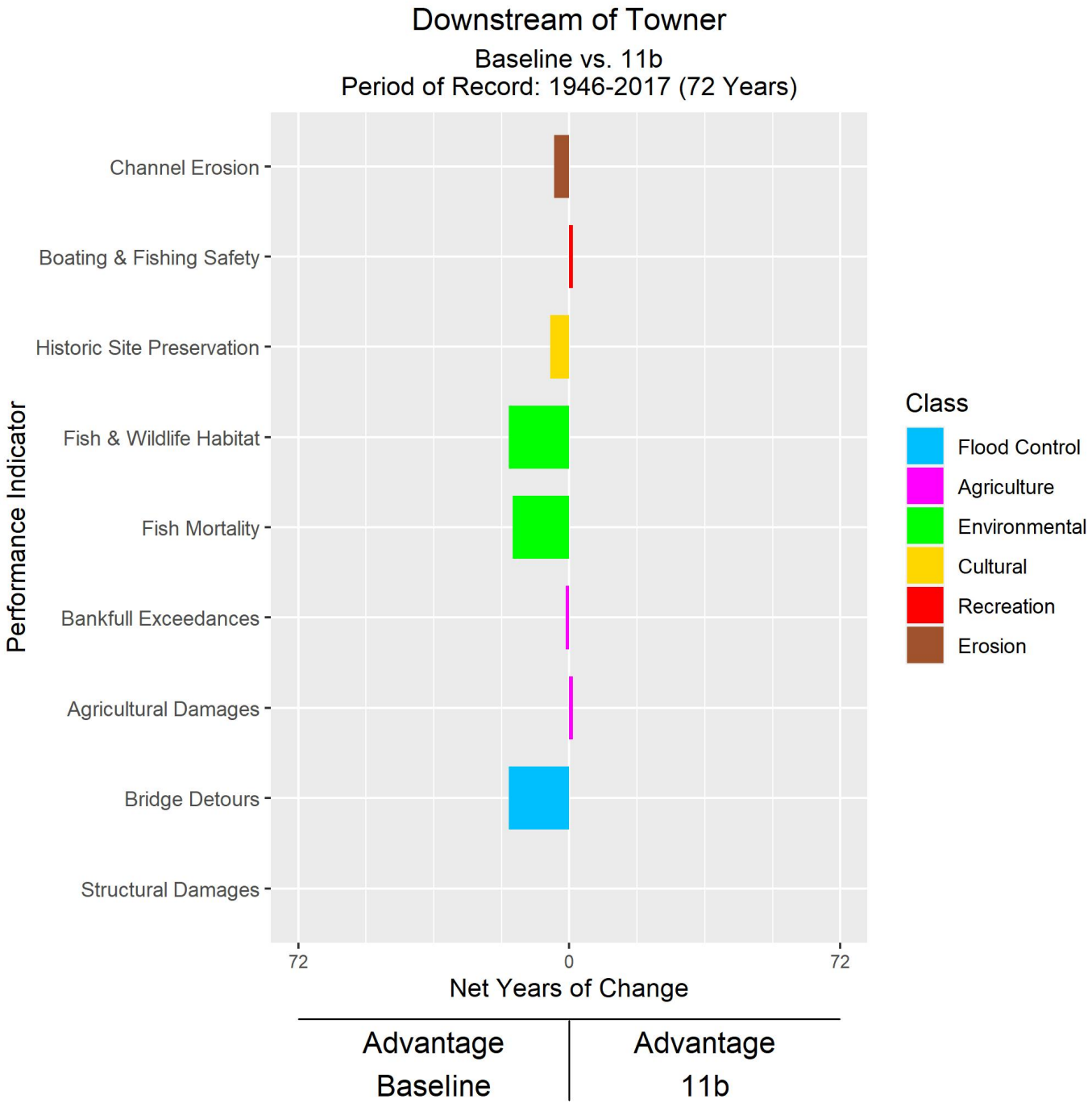

City of Sawyer
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Bankfull Exceedances
Agricultural Damages
WW Lagoon Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Environmental
Cultural
Recreation
Erosion

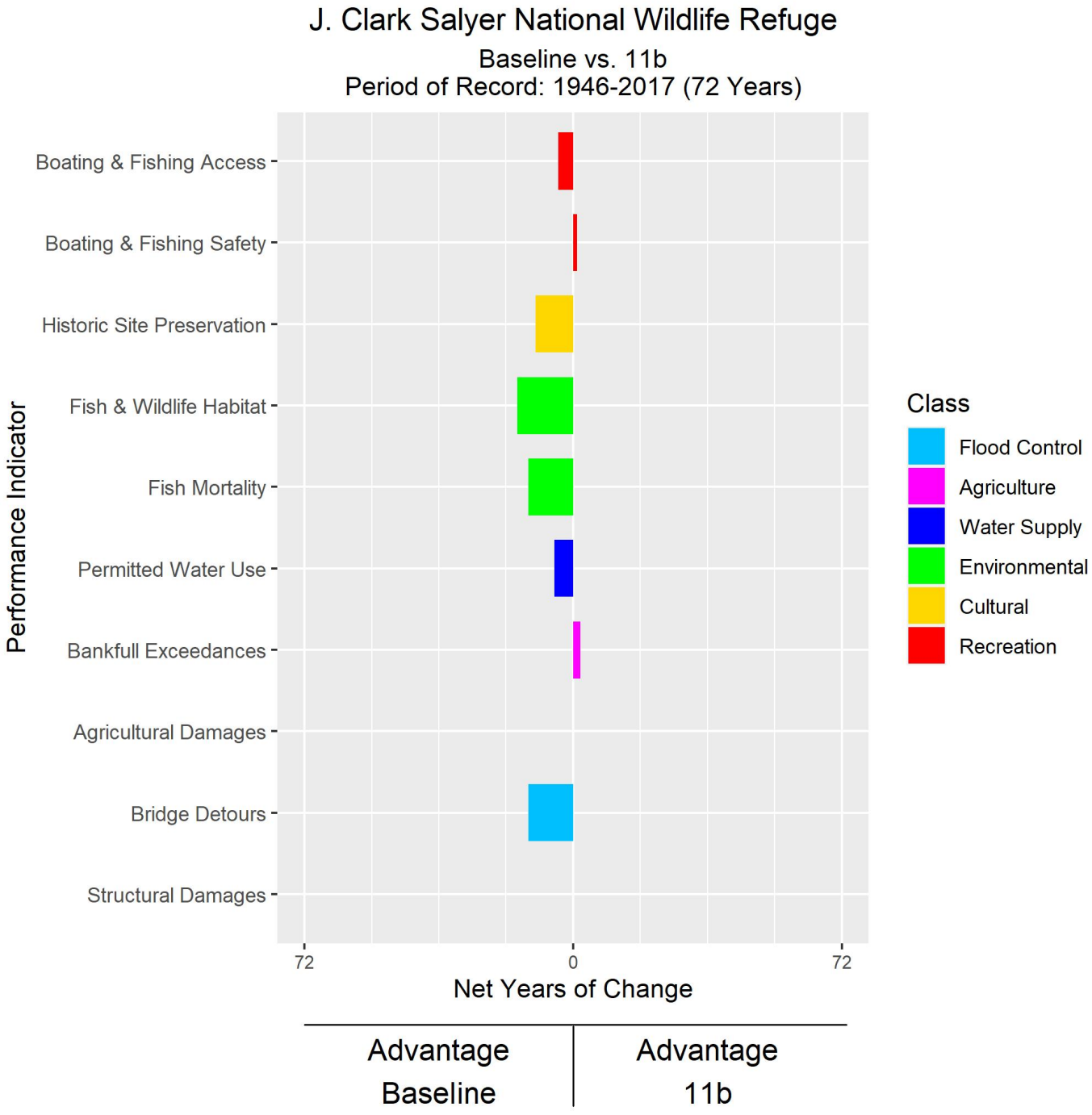

Sawyer to Velva
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Boating & Fishing Safety
Fish & Wildlife Habitat
Fish Mortality
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Environmental
Recreation


City of Velva
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
WW Lagoon Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation


Velva to Eaton Irrigation
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion


Eaton Irrigation District
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
WW Lagoon Inundation
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion


Downstream of Towner
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage Baseline
Advantage 11b
Class
Flood Control
Agriculture
Environmental
Cultural
Recreation
Erosion


J. Clark Salyer National Wildlife Refuge
Baseline vs. 11b
Period of Record: 1946-2017 (72 Years)
Performance Indicator
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
72
0
72
Net Years of Change
Advantage
Baseline
Advantage
11b
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation