US Army Corps of Engineers®
Portland District

WILLAMETTE VALLEY SYSTEM OPERATIONS AND MAINTENANCE

APPENDIX D: WATER QUALITY ANALYSIS

TABLE OF CONTENTS

CHAPTER 1 - WATER TEMPERATURE ANALYSIS..... 1
1.1 Limitations, Assumptions, and Uncertainty..... 1
1.2 Model Development..... 2
1.2.1 Calendar Year Selection..... 3
1.2.2 Model Configurations..... 6
1.3 Measure Assumptions..... 10
1.3.1 North Santiam..... 12
1.3.2 South Santiam..... 13
1.3.3 South Fork McKenzie..... 14
1.3.4 Middle Fork Willamette..... 16
1.4 Temperature Targets..... 17
1.4.1 North Santiam..... 17
1.4.2 South Santiam..... 20
1.4.3 South Fork McKenzie..... 20
1.4.4 Middle Fork Willamette..... 21
1.5 Simulated Results..... 23
1.5.1 No Action Alternative (NAA)..... 24
1.5.2 Alternative 1– Project Storage Alternative..... 57
1.5.3 Alternative 2a – Hybrid Alternative..... 101
1.5.4 Alternative 2b – Hybrid Alternative..... 146
1.5.5 Alternative 3a – Operations-Focused Fish Passage..... 192
1.5.6 Alternative 3b – Operations-Focused Fish Passage Alternative (using diversion tunnel at COU)..... 236
1.5.7 Alternative 4 – Structures-Based Fish Passage Alternative..... 281
1.5.8 Alternative 5 – Preferred Alternative..... 326
1.5.9 Alternative 6 – Cease Hydropower Operations..... 370
1.5.10 Interim Operations (Near Term Operations Measure (NTOM))..... 390
1.5.11 Interim Operations (i.e., Near Term Operations Measure (NTOM))..... 436
1.6 Supporting Data for Water Quality Effects analysis..... 454
1.6.1 No Action Alternative..... 458
1.6.2 Alternative 1 – Project Storage Alternative..... 462
1.6.3 Alternative 2a – Hybrid Alternative..... 469
1.6.4 Alternative 2b – Hybrid Alternative..... 475
1.6.5 Alternative 3a – Operations-Focused Fish Passage..... 482
1.6.6 Alternative 3b – Operations-Focused Fish Passage Alternative (using diversion tunnel at Cougar)..... 490
1.6.7 Alternative 4 – Structures-Based Fish Passage Alternative..... 497
1.6.8 Alternative 5 – Preferred Alternative Qualitative Assessments..... 504
1.6.9 Interim Operations (Near Term Operations Measure (NTOM))..... 510
1.6.10 Supplemental EIS..... 518
1.7 Supplemental Material..... 523
1.7.1 Comparison of NAA with Measurements..... 523

1.8 References 531

CHAPTER 2 - TOTAL DISSOLVED GAS (TDG) 536
2.1 Background 536
2.1.1 TDG Model Development 536
2.1.2 Structural TDG Abatement Modeling Assumptions 560
2.2 TDG results and effects analysis 563
2.2.1 No Action Alternative 566
2.2.2 Alternative 1 – Project Storage Alternative 567
2.2.3 Alternative 2a – Hybrid Alternative 569
2.2.4 Alternative 2b – Hybrid Alternative 571
2.2.5 Alternative 3a – Operations-Focused Fish Passage 573
2.2.6 Alternative 3b – Operations-Focused Fish Passage Alternative (using diversion tunnel at COU) 575
2.2.7 Alternative 4 – Structures-Based Fish Passage Alternative 577
2.2.8 Alternative 5 – Preferred Alternative 579
2.2.9 Near Term Operations Measure (NTOM) (i.e., Interim Operations) 582
2.2.10 Supplemental EIS 585
2.3 references 593

CHAPTER 3 - CLIMATE CHANGE ASSESSMENT FOR WATER TEMPERATURE AND TDG 596
3.1 Water Temperature 597
3.1.1 Methodology 598
3.2 Total Dissolved Gas (TDG) 599
3.2.1 Methodology 599
3.3 Assessments By Alternative 600
3.3.1 No Action Alternative 600
3.3.2 Alternative 1 – Project Storage Alternative 600
3.3.3 Alternative 2a – Hybrid Alternative 601
3.3.4 Alternative 2b – Hybrid Alternative 601
3.3.5 Alternative 3a – Operations-Focused Fish Passage 601
3.3.6 Alternative 3b – Operations-Focused Fish Passage 602
3.3.7 Alternative 4 – Structures-Based Fish Passage Alternative 602
3.3.8 Alternative 5 – Preferred Alternative 602
3.4 REFERENCES 602

CHAPTER 4 - OTHER IN-RESERVOIR WATER QUALITY BACKGROUND INFORMATION 604
4.1 Physical –Chemical Constituents 605
4.2 Nitrogen and phosphorus 606
4.3 Phytoplankton 608
4.4 REFERENCES 609

LIST OF FIGURES

Figure 1-1. Streamflow (top) and water temperature (bottom) at Salem/Keizer, Oregon in 2011, 2015, and 2016 (Reproduced from Stratton Garvin, 2022a)..... 4
Figure 1-2. Percent exceedance graphs of annual mean unregulated flow at Detroit, Oregon (left), air temperature at Salem, Oregon (middle), and unregulated streamflow at Salem, Oregon (right) over the period of record (1936-2019)..... 6
Figure 1-3 Blue River Lake water temperature as measured at monthly intervals in 2014 and 2019. Gray line represents the average of the two years. 15
Figure 1-4. Temperature targets used at each CE-QUAL-W2 reservoir temperature model within the WVS EIS for all alternatives except No Action ("AA") compared to maximum temperature targets used operationally by USACE from 2017 to 2022 ("NAA") and the Oregon Department of Environmental Quality (ODEQ) Total Maximum Daily Load Monthly Median Target Temperatures (“TDML”)..... 18
Figure 1-5. Resource Agencies (RA) Targets for South Fork McKenzie River below Cougar Dam. The maximum RA target was used for the Cougar Reservoir CE-QUAL-W2 temperature model in each of the WV EIS alternatives. 21
Figure 1-6. Hills Creek Dam operation temperature control target with comparison to relevant temperature ranges, the 2015 Detroit (DET) temperature target and anticipated Chinook salmon life stages. 22
Figure 1-7. Lookout Point Dam operation temperature control target with comparison to relevant temperature ranges, the Detroit (DET) temperature target and anticipated Chinook salmon life stages 23
Figure 1-8. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and outflow temperatures (bottom) at Detroit under NAA in 2011. 25
Figure 1-9. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under NAA in 2015. 26
Figure 1-10. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under NAA in 2016. 27
Figure 1-11. Comparison of DET Daily Lake Surface Elevations in NAA vs Measured..... 28
Figure 1-12. Comparison of DET Outflow Temperatures in NAA vs Measured..... 28
Figure 1-13. Comparison of DET 3-year Average, Min, Max Daily Outflow Temperatures in NAA vs Measured..... 29
Figure 1-14. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR in 2011. 30
Figure 1-15. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR in 2015. 31
Figure 1-16. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR in 2016. 32
Figure 1-17. Comparison of GPR Daily Lake Surface Elevations in NAA vs Measured. 33
Figure 1-18. Comparison of GPR Outflow Temperatures in NAA vs Measured. 33

Figure 1-19. Comparison of GPR 3-year average, min, max outflow temperatures in NAA vs Measured. 34
Figure 1-20. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and outflow temperatures (bottom) at FOS in 2011. 35
Figure 1-21. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and outflow temperatures (bottom) at FOS in 2015. 36
Figure 1-22. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and outflow temperatures (bottom) at FOS in 2016. 37
Figure 1-23. Comparison of FOS Daily Lake Surface Elevations in NAA vs Measured. 38
Figure 1-24. Comparison of FOS Outflow Temperatures in NAA vs Measured. 38
Figure 1-25. Comparison of FOS 3-year average, min, max outflow temperatures in NAA vs Measured. 39
Figure 1-26. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR in 2011. 40
Figure 1-27. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR in 2015. 41
Figure 1-28. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR in 2016. 42
Figure 1-29. Comparison of CGR Daily Lake Surface Elevations in NAA vs Measured. 43
Figure 1-30. Comparison of CGR Outflow Temperatures in NAA vs Measured. 43
Figure 1-31. Comparison of CGR 3-year average, min, max outflow temperatures in NAA vs Measured. 44
Figure 1-32. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR in 2011. 45
Figure 1-33. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR in 2015. 46
Figure 1-34. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR in 2016. 47
Figure 1-35. Comparison of HCR Daily Lake Surface Elevations in NAA vs Measured. 48
Figure 1-36. Comparison of HCR Outflow Temperatures in NAA vs Measured. 49
Figure 1-37. Comparison of HCR 3-year daily average, min, max outflow temperatures in NAA vs Measured. 49
Figure 1-38. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP in 2011. 51
Figure 1-39. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP in 2015. 52
Figure 1-40. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP in 2016. 53
Figure 1-41. Comparison of LOP Daily Lake Surface Elevations in NAA vs Measured. 54
Figure 1-42. Comparison of DEX Outflow Temperatures in NAA and Measured. 54

Figure 1-43. Comparison of DEX 3-year daily average, min, max outflow temperatures in NAA and Measured. 55
Figure 1-44. Comparison of Willamette River at SLMO Water Temperatures in NAA and Measured. 56
Figure 1-45. Comparison of Willamette River at SLMO 3-year daily average, min, max outflow temperatures in NAA and Measured. 56
Figure 1-46 WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA. 58
Figure 1-47. WV EIS HEC-ResSim gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA. 58
Figure 1-48. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA. 59
Figure 1-49. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under Alternative 1 in 2011. 60
Figure 1-50. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under Alternative 1 in 2015. 61
Figure 1-51. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under Alternative 1 in 2016. 62
Figure 1-52. Comparison of DET Outflow Temperatures in NAA and Alternative 1. 63
Figure 1-53. Comparison of DET 3-year average, min, max outflow temperatures in NAA and Alternative 1. Black line indicates temperature target. 63
Figure 1-54. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 1 and NAA. 64
Figure 1-55. WV EIS HEC-ResSim Green Peter Dam gate-specific Outflows in 2011, 2015, and 2016 Under Alternative 1 and NAA. 65
Figure 1-56. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 1 and NAA. 65
Figure 1-57. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 1 in 2011. 67
Figure 1-58. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 1 in 2015. 68
Figure 1-59. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 1 in 2016. 69
Figure 1-60. Comparison of GPR outflow temperatures in NAA and Alternative 1. 70
Figure 1-61. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black Line Indicates Temperature Target. 70
Figure 1-62. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA. 71
Figure 1-63. WV EIS HEC-ResSim Foster Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA. 72

Figure 1-64. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA. 72
Figure 1-65. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS Under Alternative 1 in 2011. 74
Figure 1-66. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS Under Alternative 1 in 2015. 75
Figure 1-67. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS Under Alternative 1 in 2016. 76
Figure 1-68. Comparison of FOS Outflow Temperatures in NAA and Alternative 1. 77
Figure 1-69. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black line indicates temperature target. 77
Figure 1-70. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA. 78
Figure 1-71. WV EIS HEC-ResSim Cougar Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA. 79
Figure 1-72. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA. 79
Figure 1-73. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 1 in 2011. 81
Figure 1-74. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 1 in 2015. 82
Figure 1-75. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 1 in 2016. 83
Figure 1-76. Comparison of CGR Outflow Temperatures in NAA and Alternative 1. 84
Figure 1-77 Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black line indicates temperature target. 84
Figure 1-78. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA. 85
Figure 1-79. WV EIS HEC-ResSim Hills Creek Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA. 86
Figure 1-80. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA. 86
Figure 1-81. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 1 in 2011. 88
Figure 1-82. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 1 in 2015. 89
Figure 1-83. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 1 in 2016. 90
Figure 1-84. Comparison of HCR Outflow Temperatures in NAA and Alternative 1. 91
Figure 1-85. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black line indicates temperature target. 91

Figure 1-86. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA. 92
Figure 1-87. WV EIS HEC-ResSim Lookout Point Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA. 93
Figure 1-88. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA. 93
Figure 1-89. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 1 in 2011. 95
Figure 1-90. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 1 in 2015. 96
Figure 1-91. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 1 in 2016. 97
Figure 1-92. Comparison of DEX Outflow Temperatures in NAA and Alternative 1. 98
Figure 1-93. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black line indicates temperature target. 98
Figure 1-94. Streamflow comparison of Daily Average, Min, Max at Willamette River at SLMO under NAA and Alternative 1 conditions. 99
Figure 1-95. Streamflow Comparison Between Alternative 1 and NAA at Willamette River at SLMO. 100
Figure 1-96. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 1. 100
Figure 1-97. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1 101
Figure 1-98. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA. 102
Figure 1-99. WV EIS HEC-ResSim gate-specific outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA. 103
Figure 1-100. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA. 103
Figure 1-101. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2a in 2011. 105
Figure 1-102. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2a in 2015. 106
Figure 1-103. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2a in 2016. 107
Figure 1-104. Comparison of DET Outflow Temperatures in NAA and Alternative 2a. 108
Figure 1-105. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target. 108
Figure 1-106. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA. 109

Figure 1-107. WV EIS HEC-ResSim Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA. 110
Figure 1-108. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA. 110
Figure 1-109. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2a in 2011. 112
Figure 1-110. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2a in 2015. 113
Figure 1-111. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2a in 2016. 114
Figure 1-112. Comparison of GPR outflow temperatures in NAA and Alternative 2a. 115
Figure 1-113. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target. 115
Figure 1-114. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA. 116
Figure 1-115. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alernative 2a and NAA. 117
Figure 1-116. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA. 117
Figure 1-117. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2a in 2011. 119
Figure 1-118. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2a in 2015. 120
Figure 1-119. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2a in 2016. 121
Figure 1-120. Comparison of FOS Outflow Temperatures in NAA and Alternative 2a. 122
Figure 1-121. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target. 122
Figure 1-122. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 under Alternative 2a and NAA. 123
Figure 1-123. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA. 124
Figure 1-124. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA. 124
Figure 1-125. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2a in 2011. 126
Figure 1-126. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2a in 2015. 127
Figure 1-127. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2a in 2016. 128
Figure 1-128. Comparison of CGR outflow temperatures in NAA and Alternative 2a. 129

Figure 1-129. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target. 129
Figure 1-130. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA. 130
Figure 1-131. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 2a and NAA. 131
Figure 1-132. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 under Alternative 2a and NAA. 131
Figure 1-133. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2a in 2011. 133
Figure 1-134. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2a in 2015. 134
Figure 1-135. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2a in 2016. 135
Figure 1-136. Comparison of HCR Outflow Temperatures in NAA and Alternative 2a. 136
Figure 1-137. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target. 136
Figure 1-138 WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA. 137
Figure 1-139. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA. 138
Figure 1-140. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA. 138
Figure 1-141. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2a in 2011. 140
Figure 1-142. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2a in 2015. 141
Figure 1-143. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2a in 2016. 142
Figure 1-144. Comparison of DEX Outflow Temperatures in NAA and Alternative 2a. 143
Figure 1-145 Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target. 143
Figure 1-146. Streamflow Comparison of Average, Min, and Max Willamette River at SLMO under NAA and Alternative 2a Conditions. 144
Figure 1-147. Streamflow Comparison Between Alternative 2a and NAA at Willamette River at SLMO. 145
Figure 1-148. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 2a 145
Figure 1-149. Comparison of Willamette River at SLMO 3-year Average, Min, Max Outflow Temperatures in NAA and Alternative 2a 146

Figure 1-150. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 Under Alternative 2b and NAA. 147
Figure 1-151. WV EIS HEC-ResSim Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2b and NAA. 148
Figure 1-152. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 Under Alternative 2b and NAA. 148
Figure 1-153. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2b in 2011. 150
Figure 1-154. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2b in 2015. 151
Figure 1-155. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2b in 2016. 152
Figure 1-156. Comparison of DET outflow temperatures in NAA and Alternative 2b. 153
Figure 1-157. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target. 153
Figure 1-158. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 2b and NAA. 154
Figure 1-159. WV EIS HEC-ResSim Green Peter Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 2b and NAA. 155
Figure 1-160. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2b and NAA. 155
Figure 1-161. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2b in 2011. 157
Figure 1-162. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2b in 2015. 158
Figure 1-163. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2b in 2016. 159
Figure 1-164. Comparison of GPR Outflow Temperatures in NAA and Alternative 2b. 160
Figure 1-165. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target. 160
Figure 1-166. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 under Alternative 2b and NAA. 161
Figure 1-167. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2b and NAA. 162
Figure 1-168. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2b and NAA. 162
Figure 1-169. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2b in 2011. 164
Figure 1-170. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2b in 2015. 165

Figure 1-171. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2b in 2016. 166
Figure 1-172. Comparison of FOS outflow temperatures in NAA and Alternative 2b. 167
Figure 1-173. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black line indicates temperature target. 167
Figure 1-174. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 2b and NAA. 168
Figure 1-175. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2b and NAA. 169
Figure 1-176. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2b and NAA. 169
Figure 1-177. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2b in 2011..... 171
Figure 1-178. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2b in 2015..... 172
Figure 1-179. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2b in 2016..... 173
Figure 1-180. Comparison of CGR Outflow Temperatures in NAA and Alternative 2b..... 174
Figure 1-181. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target. 174
Figure 1-182. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 under Alternative 2b and NAA. 175
Figure 1-183. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 2b and NAA..... 176
Figure 1-184. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 under Alternative 2b and NAA. 176
Figure 1-185. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2b in 2011..... 178
Figure 1-186. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2b in 2015..... 179
Figure 1-187. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2b in 2016..... 180
Figure 1-188. Comparison of HCR outflow temperatures in NAA and Alternative 2b. 181
Figure 1-189. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target. 181
Figure 1-190. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 2b and NAA. 182
Figure 1-191. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 2b and NAA..... 183
Figure 1-192. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 2b and NAA..... 183

Figure 1-193. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2b in 2011. 185
Figure 1-194. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2b in 2015. 186
Figure 1-195. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2b in 2016. 187
Figure 1-196. Comparison of DEX Outflow Temperatures in NAA and Alternative 2b. 188
Figure 1-197. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target. 188
Figure 1-198. Streamflow Comparison of Daily Average, Min, and Max Willamette River at SLMO under NAA and Alternative 2b Conditions. 190
Figure 1-199. Streamflow Comparison Between Alternative 2b and NAA at Willamette River at SLMO. 190
Figure 1-200. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 2b. 191
Figure 1-201. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. 191
Figure 1-202. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA. 193
Figure 1-203. WV EIS HEC-ResSim Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 3a and NAA. 193
Figure 1-204. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 3a and NAA. 194
Figure 1-205. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3a in 2011. 195
Figure 1-206. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3a in 2015. 196
Figure 1-207. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3a in 2016. 197
Figure 1-208. Comparison of DET Outflow Temperatures in NAA and Alternative 3a. 198
Figure 1-209. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target. 198
Figure 1-210. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA. 199
Figure 1-211. WV EIS HEC-ResSim Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 3a and NAA. 200
Figure 1-212. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3a and NAA. 200
Figure 1-213. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3a in 2011. 202

Figure 1-214. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3a in 2015. 203
Figure 1-215. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3a in 2016. 204
Figure 1-216. Comparison of GPR Outflow Temperatures in NAA and Alternative 3a. 205
Figure 1-217. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target. 205
Figure 1-218. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA. 206
Figure 1-219. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3a and NAA. 207
Figure 1-220. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 3a and NAA. 207
Figure 1-221. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3a in 2011. 209
Figure 1-222. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3a in 2015. 210
Figure 1-223. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3a in 2016. 211
Figure 1-224. Comparison of FOS outflow temperatures in NAA and Alternative 3a. 212
Figure 1-225. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target. 212
Figure 1-226. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA. 213
Figure 1-227. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3a and NAA. 214
Figure 1-228. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3a and NAA. 214
Figure 1-229. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3a in 2011. 216
Figure 1-230. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3a in 2015. 217
Figure 1-231. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3a in 2016. 218
Figure 1-232. Comparison of CGR Outflow Temperatures in NAA and Alternative 3a. 219
Figure 1-233. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target. 219
Figure 1-234. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA. 220
Figure 1-235. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3a and NAA. 221

Figure 1-236. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3a and NAA. 221
Figure 1-237. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3a in 2011. 223
Figure 1-238. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3a in 2015. 224
Figure 1-239. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3a in 2016. 225
Figure 1-240. Comparison of HCR Outflow Temperatures in NAA and Alternative 3a. 226
Figure 1-241. Comparison of HCR 3-year Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target. 226
Figure 1-242. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA. 227
Figure 1-243. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3a and NAA. 228
Figure 1-244. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3a and NAA. 228
Figure 1-245. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3a in 2011. 230
Figure 1-246. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3a in 2015. 231
Figure 1-247. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3a in 2016. 232
Figure 1-248. Comparison of DEX Outflow Temperatures in NAA and Alternative 3a. 233
Figure 1-249. Comparison of DEX 3-year Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target. 233
Figure 1-250. Streamflow Comparison of Average, Min, Max Willamette River at SLMO under NAA and Alternative 3a Conditions. 234
Figure 1-251. Streamflow Comparison Between Alternative 3a and NAA at Willamette River at SLMO. 235
Figure 1-252. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 3a 235
Figure 1-253. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a 236
Figure 1-254. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA. 237
Figure 1-255. WV EIS HEC-ResSim Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 3b and NAA. 238
Figure 1-256. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 Under Alternative 3b and NAA. 238

Figure 1-257. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3b in 2011. 240
Figure 1-258. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3b in 2015. 241
Figure 1-259. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3b in 2016. 242
Figure 1-260. Comparison of DET outflow temperatures in NAA and Alternative 3b. 243
Figure 1-261. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target. 243
Figure 1-262. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA. 244
Figure 1-263. WV EIS HEC-ResSim Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA. 245
Figure 1-264. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Alternative 3b and NAA. 245
Figure 1-265. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3b in 2011. 247
Figure 1-266. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3b in 2015. 248
Figure 1-267. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3b in 2016. 249
Figure 1-268. Comparison of GPR Outflow Temperatures in NAA and Alternative 3b. 250
Figure 1-269. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target. 250
Figure 1-270. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA. 251
Figure 1-271. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA. 252
Figure 1-272. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3b and NAA. 252
Figure 1-273. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3b in 2011. 254
Figure 1-274. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3b in 2015. 255
Figure 1-275. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3b in 2016. 256
Figure 1-276. Comparison of FOS outflow temperatures in NAA and Alternative 3b. 257
Figure 1-277. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target. 257
Figure 1-278. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA. 258

Figure 1-279. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA. 259
Figure 1-280. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 3b and NAA. 259
Figure 1-281. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3b in 2011. 261
Figure 1-282. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3b in 2015. 262
Figure 1-283. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3b in 2016. 263
Figure 1-284. Comparison of CGR Outflow Temperatures in NAA and Alternative 1. 264
Figure 1-285. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target. 264
Figure 1-286. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA. 265
Figure 1-287. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA. 266
Figure 1-288. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 under Alternative 3b and NAA. 266
Figure 1-289. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3b in 2011. 268
Figure 1-290. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3b in 2015. 269
Figure 1-291. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3b in 2016. 270
Figure 1-292. Comparison of HCR Outflow Temperatures in NAA and Alternative 3b. 271
Figure 1-293. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target. 271
Figure 1-294. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA. 272
Figure 1-295. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA. 273
Figure 1-296. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3b and NAA. 273
Figure 1-297. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3b in 2011. 275
Figure 1-298. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3b in 2015. 276
Figure 1-299. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3b in 2016. 277
Figure 1-300. Comparison of DEX Outflow Temperatures in NAA and Alternative 3b. 278

Figure 1-301. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target. 278
Figure 1-302. Streamflow Comparison of Average, Min, and Max Willamette River at SLMO under NAA and Alternative 3b Conditions. 279
Figure 1-303. Streamflow Comparison Between Alternative 3b and NAA at Willamette River at SLMO. 280
Figure 1-304. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 3b. 280
Figure 1-305. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. 281
Figure 1-306. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 4 and NAA. 282
Figure 1-307. WV EIS HEC-ResSim Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA. 283
Figure 1-308. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA. 283
Figure 1-309. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 4 in 2011. 285
Figure 1-310. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 4 in 2015. 286
Figure 1-311. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 4 in 2016. 287
Figure 1-312. Comparison of DET outflow temperatures in NAA and Alternative 4. 288
Figure 1-313 Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target. 288
Figure 1-314. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 under Alternative 4 and NAA. 289
Figure 1-315. WV EIS HEC-ResSim Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA. 290
Figure 1-316. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA. 290
Figure 1-317. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 4 in 2011. 292
Figure 1-318. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 4 in 2015. 293
Figure 1-319. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 4 in 2016. 294
Figure 1-320. Comparison of GPR Outflow Temperatures in NAA and Alternative 4. 295
Figure 1-321. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target. 295

Figure 1-322. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 4 and NAA. 296
Figure 1-323. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA. 297
Figure 1-324. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA. 297
Figure 1-325. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 4 in 2011. 299
Figure 1-326. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 4 in 2015. 300
Figure 1-327. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 4 in 2016. 301
Figure 1-328. Comparison of FOS outflow temperatures in NAA and Alternative 4. 302
Figure 1-329 Comparison of FOS 3-year daily Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target. 302
Figure 1-330. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 4 and NAA. 303
Figure 1-331. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA. 304
Figure 1-332. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA. 304
Figure 1-333. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 4 in 2011. 306
Figure 1-334. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 4 in 2015. 307
Figure 1-335. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 4 in 2016. 308
Figure 1-336. Comparison of CGR Outflow Temperatures in NAA and Alternative 4. 309
Figure 1-337. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target. 309
Figure 1-338. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 4 and NAA. 310
Figure 1-339. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA. 311
Figure 1-340. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 4 and NAA. 311
Figure 1-341. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 4 in 2011. 313
Figure 1-342. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 4 in 2015. 314

Figure 1-343. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 4 in 2016. 315
Figure 1-344. Comparison of HCR outflow temperatures in NAA and Alternative 4. 316
Figure 1-345. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target. 316
Figure 1-346. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 4 and NAA. 317
Figure 1-347. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA. 318
Figure 1-348. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA. 318
Figure 1-349. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 4 in 2011. 320
Figure 1-350. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 4 in 2015. 321
Figure 1-351. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 4 in 2016. 322
Figure 1-352. Comparison of DEX Outflow Temperatures in NAA and Alternative 4. 323
Figure 1-353. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target. 323
Figure 1-354. Streamflow Comparison of Daily Average, Min, Max Willamette River at SLMO under NAA and Alternative 4 Conditions. 324
Figure 1-355. Streamflow Comparison Between Alternative 4 and NAA at Willamette River at SLMO. 325
Figure 1-356. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 4. 325
Figure 1-357. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. 326
Figure 1-358. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 5 and NAA. 327
Figure 1-359. WV EIS HEC-ResSim Detroit Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5 and NAA. 328
Figure 1-360. WV EIS HEC-ResSim Detroit Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5 and NAA. 328
Figure 1-361. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 5 in 2011. 330
Figure 1-362. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 5 in 2015. 331
Figure 1-363. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 5 in 2016. 332
Figure 1-364. Comparison of DET outflow temperatures in NAA and Alternative 5. 333

Figure 1-365. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 5. Black Line Indicates Temperature Target. 333
Figure 1-366. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 5 and NAA. 334
Figure 1-367. WV EIS HEC-ResSim Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5 and NAA. 334
Figure 1-368. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 5 and NAA. 335
Figure 1-369. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 under Alternative 5 and NAA. 336
Figure 1-370. WV EIS HEC-ResSim Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5 and NAA. 336
Figure 1-371. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5 and NAA. 337
Figure 1-372. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 5 in 2011. 338
Figure 1-373. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 5 in 2015. 339
Figure 1-374. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 5 in 2016. 340
Figure 1-375. Comparison of GPR Outflow Temperatures in NAA and Alternative 5. 341
Figure 1-376. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 5. Black Line Indicates Temperature Target. 341
Figure 1-377. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 5 and NAA. 342
Figure 1-378. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5 and NAA. 343
Figure 1-379. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5 and NAA. 343
Figure 1-380. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 5 in 2011. 345
Figure 1-381. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 5 in 2015. 346
Figure 1-382. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 5 in 2016. 347
Figure 1-383. Comparison of FOS Outflow Temperatures in NAA and Alternative 5. 348
Figure 1-384. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 5. Black Line Indicates Temperature Target. 348
Figure 1-385. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 5 and NAA. 349

Figure 1-386. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5 and NAA. 350
Figure 1-387. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5 and NAA. 350
Figure 1-388. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 5 in 2011. 352
Figure 1-389. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 5 in 2015. 353
Figure 1-390. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 5 in 2016. 354
Figure 1-391. Comparison of CGR Outflow Temperatures in NAA and Alternative 5. 355
Figure 1-392. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 5. Black Line Indicates Temperature Target. 355
Figure 1-393. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 5 and NAA. 356
Figure 1-394. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5 and NAA. 357
Figure 1-395. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 5 and NAA. 357
Figure 1-396. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 5 in 2011. 359
Figure 1-397. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 5 in 2015. 360
Figure 1-398. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 5 in 2016. 361
Figure 1-399. Comparison of HCR outflow temperatures in NAA and Alternative 5. 362
Figure 1-400. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 5. Black Line Indicates Temperature Target. 362
Figure 1-401. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 5 and NAA. 363
Figure 1-402. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 Alternative 5 and NAA. 364
Figure 1-403. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5 and NAA. 364
Figure 1-404. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 5 in 2011. 366
Figure 1-405. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 5 in 2015. 367
Figure 1-406. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 5 in 2016. 368
Figure 1-407. Comparison of DEX Outflow Temperatures in NAA and Alternative 5. 369

Figure 1-408. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 5. Black Line Indicates Temperature Target. 369
Figure 1-1-409. Streamflow Comparison Between Alternative 5 and NAA at Willamette River at SLMO. 370
Figure 1-410 WV EIS RES-SIM Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA. 372
Figure 1-411. WV EIS RES-SIM Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA..... 372
Figure 1-412. WV EIS RES-SIM Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA..... 373
Figure 1-413. WV EIS Percent Spill Allocated in CE-QUAL-W2 Detroit Lake model for 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA. Note: For Alt6 and Alt5, the lines represent percent outflow from the SWS near-surface outlet. 374
Figure 1-414. Comparison of Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023). 374
Figure 1-415 WV EIS RES-SIM Green Peter Lake Levels in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA..... 375
Figure 1-416. WV EIS RES-SIM Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA..... 376
Figure 1-417. WV EIS RES-SIM Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA..... 376
Figure 1-418. WV EIS Percent Spill Allocated in CE-QUAL-W2 Green Peter model for 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA. 377
Figure 1-419. Comparison of Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Green Peter dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively..... 378
Figure 1-420 WV EIS RES-SIM Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA. 379
Figure 1-421. WV EIS RES-SIM Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA. 379
Figure 1-422. WV EIS RES-SIM Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA..... 380
Figure 1-423. WV EIS Percent Spill Allocated in CE-QUAL-W2 Foster model for 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA. 381
Figure 1-424. Comparison of Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam. Black line and grey dotted lines represent

the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively..... 381
Figure 1-425 WV EIS RES-SIM Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA. 382
Figure 1-426. WV EIS RES-SIM Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA. 383
Figure 1-427. WV EIS RES-SIM Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA..... 383
Figure 1-428 WV EIS RES-SIM Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA..... 384
Figure 1-429. WV EIS RES-SIM Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA. 385
Figure 1-430. WV EIS RES-SIM Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA..... 385
Figure 1-431. Comparison of Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively..... 386
Figure 1-432 WV EIS RES-SIM Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA..... 387
Figure 1-433. WV EIS RES-SIM Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA..... 387
Figure 1-434. WV EIS RES-SIM Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA..... 388
Figure 1-435. WV EIS Percent Spill Allocated in CE-QUAL-W2 Lookout Point model for 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA. 389
Figure 1-436. Comparison of Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively..... 389
Figure 1-437. Streamflow Comparison Between Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA at Willamette River at SLMO. 390
Figure 1-438. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 under NTOM (DEIS), NTOM_FEIS (FEIS), and NAA. 392
Figure 1-439. WV EIS HEC-ResSim Gate-Specific Outflows in 2011, 2015, and 2016 under NTOM (DEIS), NTOM_FEIS (FEIS), and NAA..... 393
Figure 1-440. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 under NTOM (DEIS), NTOM_FEIS (FEIS), and NAA. 393

Figure 1-441. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under NTOM in 2011. 395
Figure 1-442. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under NTOM in 2015. 396
Figure 1-443. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under NTOM in 2016. 397
Figure 1-444. Comparison of DET outflow temperatures in NAA and NTOM. 398
Figure 1-445. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. Black Line Indicates Temperature Target. 398
Figure 1-446. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 under NTOM (DEIS), NTOM_FEIS (FEIS), and NAA. 399
Figure 1-447. WV EIS HEC-ResSim Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under NTOM (DEIS), NTOM_FEIS (FEIS), and NAA. 400
Figure 1-448. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 under NTOM (DEIS), NTOM_FEIS (FEIS), and NAA. 400
Figure 1-449. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under NTOM in 2011. 402
Figure 1-450. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under NTOM in 2015. 403
Figure 1-451. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under NTOM in 2016. 404
Figure 1-452. Comparison of GPR Outflow Temperatures in NAA and NTOM. 405
Figure 1-453. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. Black Line Indicates Temperature Target. 405
Figure 1-454. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 Under NTOM and NAA. 406
Figure 1-455. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under NTOM and NAA. 407
Figure 1-456. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 under NTOM and NAA. 407
Figure 1-457. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under NTOM in 2011. 409
Figure 1-458. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under NTOM in 2015. 410
Figure 1-459. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under NTOM in 2016. 411
Figure 1-460. Comparison of FOS outflow temperatures in NAA and NTOM. 412
Figure 1-461. Comparison of FOS 3-year daily Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. Black Line Indicates Temperature Target. 412
Figure 1-462. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 Under NTOM and NAA. 413

Figure 1-463. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under NTOM and NAA. 414
Figure 1-464. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 under NTOM and NAA..... 414
Figure 1-465. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under NTOM in 2011. 416
Figure 1-466. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under NTOM in 2015. 417
Figure 1-467. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under NTOM in 2016. 418
Figure 1-468. Comparison of CGR Outflow Temperatures in NAA and NTOM. 419
Figure 1-469 Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. Black Line Indicates Temperature Target..... 419
Figure 1-470. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 Under NTOM and NAA. 420
Figure 1-471. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under NTOM and NAA. 421
Figure 1-472. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under NTOM and NAA..... 421
Figure 1-473. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under NTOM in 2011. 423
Figure 1-474. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under NTOM in 2015. 424
Figure 1-475. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under NTOM in 2016. 425
Figure 1-476. Comparison of HCR outflow temperatures in NAA and NTOM. 426
Figure 1-477. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. Black Line Indicates Temperature Target..... 426
Figure 1-478. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under NTOM and NAA..... 427
Figure 1-479. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 in NTOM and NAA..... 428
Figure 1-480. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under NTOM and NAA. 428
Figure 1-481. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under NTOM in 2011. 430
Figure 1-482. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under NTOM in 2015. 431
Figure 1-483. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under NTOM in 2016. 432
Figure 1-484. Comparison of DEX Outflow Temperatures in NAA and NTOM..... 433

Figure 1-485. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. Black Line Indicates Temperature Target..... 433
Figure 1-486. Streamflow Comparison Between NTOM and NAA at Willamette River at SLMO. 434
Figure 1-487. Comparison of Willamette River at SLMO Water Temperatures in NAA and NTOM. 435
Figure 1-488. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. 435
Figure 1-489 WV EIS RES-SIM Detroit Lake Levels in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 436
Figure 1-490. WV EIS RES-SIM Gate-Specific Outflows in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 437
Figure 1-491. WV EIS RES-SIM Detroit Total Outflow in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 437
Figure 1-492. WV EIS Percent Spill Allocated in CE-QUAL-W2 Detroit Lake model for 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 438
Figure 1-493. Comparison of Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028)..... 439
Figure 1-494 WV EIS RES-SIM Green Peter Lake Levels in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 440
Figure 1-495. WV EIS RES-SIM Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA..... 440
Figure 1-496. WV EIS RES-SIM Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 441
Figure 1-497. WV EIS Percent Spill Allocated in CE-QUAL-W2 Green Peter Lake model for 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 442
Figure 1-498. Comparison of Interim Operations (RevIntOps) for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Green Peter dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028). 442
Figure 1-499 WV EIS RES-SIM Foster Lake Levels in 2011, 2015, and 2016 Under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 443
Figure 1-500. WV EIS RES-SIM Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA..... 444
Figure 1-501. WV EIS RES-SIM Foster Dam Total Outflow in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 444

Figure 1-502. Comparison of Interim Operations (RevIntOps) for 2011, 2015, 2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028). 445
Figure 1-503 WV EIS RES-SIM Cougar Lake Levels in 2011, 2015, and 2016 Under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 446
Figure 1-504. WV EIS RES-SIM Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 447
Figure 1-505. WV EIS RES-SIM Cougar Dam Total Outflow in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 447
Figure 1-506. Comparison of Interim Operations (RevIntOps) for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028). 448
Figure 1-507 WV EIS RES-SIM Hills Creek Lake Levels in 2011, 2015, and 2016 Under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 449
Figure 1-508. WV EIS RES-SIM Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 449
Figure 1-509. WV EIS RES-SIM Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 450
Figure 1-510. Comparison of Interim Operations (RevIntOps) for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black Line indicates simulated temperature target. 450
Figure 1-511 WV EIS RES-SIM Lookout Point Lake Levels in 2011, 2015, and 2016 Under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 451
Figure 1-512. WV EIS RES-SIM Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 in Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 452
Figure 1-513. WV EIS RES-SIM Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 452
Figure 1-514. WV EIS Percent Spill Allocated in CE-QUAL-W2 Lookout Point Lake model for 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 453
Figure 1-515. Comparison of Interim Operations (RevIntOps) for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028). 453
Figure 1-516. Streamflow Comparison Between Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA at Willamette River at SLMO. 454
Figure 1-517. Annual number of days within 2^{o}F of Temperature target April-August (top row of tables), September-March (middle row of tables), and all year (bottom row of tables). Explanation: “3YrAvg” = three-year average 455

Figure 1-518. Difference, compared to NAA, in annual number of days within 2°F of Temperature target April-August (top row of tables), September-March (middle row of tables), and all year (bottom row of tables). Explanation: “3YrAvg” = three-year average 456
Figure 1-519. Days Below 18 Degrees C (64.4 Degrees F) in Each Year. Explanation: “3YrAvg” = three-year average. 456
Figure 1-520. Difference, compared to NAA, in Days Below 18 Degrees C (64.4 Degrees F) in Each Year. Explanation: “3YrAvg” = three-year average. 457
Figure 1-521. Difference in estimated chinook egg emergence timing relative to NAA (Alternative - NAA), in days. 458
Figure 1-522. Simulated No Action Alternative Monthly Mean Water Temperature (deg F) in 2011, 2015, 2016, and average of these 3 years (3YrAvg). 459
Figure 1-523. Comparison of NAA 7dADM temperature (Degrees F) for 2011,2015,2016 downstream of Big Cliff dam. Black line indicates temperature target. 459
Figure 1-524. Comparison of NAA 7dADM temperature (Degrees F) for 2011,2015,2016 downstream of Foster dam. Black line indicates temperature target. 460
Figure 1-525. Comparison of NAA 7dADM temperature (Degrees F) for 2011,2015,2016 downstream of Cougar dam. Black line indicates temperature target. 461
Figure 1-526. Comparison of NAA 7dADM temperature (Degrees F) for 2011,2015,2016 downstream of Hills Creek dam. Black line indicates temperature target. 461
Figure 1-527. Comparison of NAA 7dADM temperature (Degrees F) for 2011,2015,2016 downstream of Dexter dam. Black line indicates temperature target. 462
Figure 1-528. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 1. 462
Figure 1-529. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 1. 463
Figure 1-530. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. Black line indicates temperature target. 464
Figure 1-531. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam. Black line indicates temperature target..... 465
Figure 1-532. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black line indicates temperature target. 466
Figure 1-533. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black line indicates temperature target. 467
Figure 1-534. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target at Dexter Dam. Black line indicates temperature target. 468

Figure 1-535. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) for Alternative 2a. 469
Figure 1-536. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 2a. 470
Figure 1-537. Comparison of Alternative 2a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target at Big Cliff dam. 471
Figure 1-538. Comparison of Alternative 2a and NAA for 2011,2015,2016 with 7dADM temperatures (degrees F) and difference from the NAA downstream of Foster dam. Black line indicates temperature target..... 472
Figure 1-539. Comparison of Alternative 2a and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black line indicates temperature target..... 473
Figure 1-540. Comparison of Alternative 2a and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black line indicates temperature target. 474
Figure 1-541. Comparison of Alternative 2a and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black line indicates temperature target. 475
Figure 1-542. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 2b. 476
Figure 1-543. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 2b. 477
Figure 1-544. Comparison of Alternative 2b and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. 478
Figure 1-545. Comparison of Alternative 2b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam.... 479
Figure 1-546. Comparison of Alternative 2b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black Line indicates temperature target. 480
Figure 1-547. Comparison of Alternative 2b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black Line indicates temperature target. 481
Figure 1-548. Comparison of Alternative 2b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black Line indicates temperature target. 482
Figure 1-549. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 3a 483
Figure 1-550. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 3a. 484
Figure 1-551. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. Black line indicates temperature target. 485

Figure 1-552. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam. Black line indicates temperature target..... 486
Figure 1-553. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black line indicates temperature target. 487
Figure 1-554. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black line indicates temperature target..... 488
Figure 1-555. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek Dam. Black line indicates temperature target. 489
Figure 1-556. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 3b. 490
Figure 1-557. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 3b. 491
Figure 1-558. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff Dam. Black line indicates temperature target. 492
Figure 1-559. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster Dam. Black line indicates temperature target..... 493
Figure 1-560. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster Dam. Black line indicates temperature target..... 494
Figure 1-561. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter Dam. Black line indicates temperature target. 495
Figure 1-562. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek Dam. Black line indicates temperature target. 496
Figure 1-563. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 4. 497
Figure 1-564. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 4. 498
Figure 1-565. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff Dam. Black line indicates temperature target. 499
Figure 1-566. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster Dam. Black line indicates temperature target..... 500
Figure 1-567. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar Dam. Black line indicates temperature target. 501

Figure 1-568. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter Dam. Black line indicates temperature target. 502
Figure 1-569. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek Dam. Black line indicates temperature target. 503
Figure 1-570. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 5. 504
Figure 1-571. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 5. 505
Figure 1-572. Comparison of Alternative 5 and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023). 506
Figure 1-573. Comparison of Alternative 5 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Green Peter dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively. 507
Figure 1-574. Comparison of Alternative 5 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively. 507
Figure 1-575. Comparison of Alternative 5 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively. 508
Figure 1-576. Comparison of Alternative 5 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively. 509
Figure 1-577. Comparison of Alternative 5 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively. 510
Figure 1-578. Monthly Mean of Water Temperatures (Fahrenheit) for NTOM. 511
Figure 1-579. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to NTOM. 512
Figure 1-580. Comparison of NTOM and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028). 513
Figure 1-581. Comparison of NTOM for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Green Peter dam. Black Line

indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028). 514
Figure 1-582. Comparison of NTOM for 2011, 2015, 2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028). 515
Figure 1-583. Comparison of NTOM for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028). 516
Figure 1-584. Comparison of NTOM for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black Line indicates simulated temperature target. 517
Figure 1-585. Comparison of NTOM for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028). 517
Figure 1-586. Annual number of days within 2^{o}F of Temperature target April-August (top row of tables), September-March (middle row of tables), and all year (bottom row of tables). Explanation: “3YrAvg” = three-year average 519
Figure 1-587. Difference, compared to NAA, in annual number of days within 2^{o}F of Temperature target April-August (top row of tables), September-March (middle row of tables), and all year (bottom row of tables). Explanation: “3YrAvg” = three-year average 519
Figure 1-588. Days Below 18 Degrees C (64.4 Degrees F) in Each Year. Explanation: “3YrAvg” = three-year average. 519
Figure 1-589. Difference, compared to NAA, in Days Below 18 Degrees C (64.4 Degrees F) in Each Year. Explanation: “3YrAvg” = three-year average. 520
Figure 1-590. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 6. 521
Figure 1-591. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 6. 521
Figure 1-592. Monthly Mean of Water Temperatures (Fahrenheit) for Interim Operations (RevIntOps). 522
Figure 1-593. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Interim Operations (RevIntOps). 523
Figure 1-594. Monthly Mean of Measured Water Temperatures (Fahrenheit). 524
Figure 1-595. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from Measurements to NAA. 524
Figure 1-596. Detroit Lake Level Comparison of Measurements and NAA in 2011, 2015, and 2016. Grey Line Represents the Rule Curve. 525

Figure 1-597. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference From NAA Downstream of Big Cliff Dam. Black Line Indicates Temperature Target..... 526
Figure 1-598. Green Peter Lake Level Comparison of Measurements and NAA in 2011, 2015, and 2016. Grey Line Represents the Rule Curve. 527
Figure 1-599. Foster Lake Level Comparison of Measurements and NAA in 2011, 2015, and 2016. Grey Line Represents the Rule Curve. 527
Figure 1-600. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference from NAA Downstream of Foster Dam. Black Line Indicates Temperature Target..... 528
Figure 1-601. Cougar Lake Level Comparison of Measurements, NAA in 2011, 2015, and 2016. 529
Figure 1-602. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference from NAA Downstream of Cougar Dam. Black Line Indicates Temperature Target..... 529
Figure 1-603. Lookout Point Lake Level Comparison of Measurements and NAA in 2011, 2015, and 2016. 530
Figure 1-604. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference from NAA Downstream of Dexter Dam. Black Line Indicates Temperature Target..... 530
Figure 1-605. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference from NAA Downstream of Hills Creek Dam. Black Line Indicates Temperature Target..... 531
Figure 2-1. Example Time series of North Santiam model results at BCLO..... 539
Figure 2-2. Model estimation of TDG compared to measurements at BCLO..... 540
Figure 2-3. Model estimation and measurements of TDG compared to spill at Detroit spillway. 540
Figure 2-4. Model estimation and measurements of TDG compared to spill at Detroit regulating outlet..... 541
Figure 2-5. Model estimation and measurements of TDG compared to spill at Big Cliff spillway. 541
Figure 2-6. Model predictions of TDG downstream of Big Cliff Dam. Assumes that there is only one spill source and there is no mixing with generation flow. 542
Figure 2-7. Example time series of South Santiam model results at SSFO..... 543
Figure 2-8. Model estimation of TDG compared to measurements at SSFO. 544
Figure 2-9. Model estimation and measurements of TDG compared to spill at Green Peter regulating outlet. 544
Figure 2-10. Model estimation and measurements of TDG compared to spill at Green Peter spillway. 545
Figure 2-11. Model estimation and measurements of TDG compared to spill at Foster spillway. 545

Figure 2-12. Model predictions of TDG at Green Peter and Foster Dams. Only one spill source and no mixing with generation flow assumed at Green Peter Dam due to absence of spillway data. 546
Figure 2-13 Example time series of Middle Fork Willamette model results at HCRO. 546
Figure 2-14 Model estimation of TDG compared to measurements at HCRO. 547
Figure 2-15. Model estimation and measurements of TDG compared to spill at Hills Creek regulating outlet. 548
Figure 2-16. Example time series of Middle Fork Willamette model results at DEXO. 549
Figure 2-17. Model estimation of TDG compared to measurements at DEXO. 550
Figure 2-18. Model estimation and measurements of TDG compared to spill at Lookout Point regulating outlet. 550
Figure 2-19. Model estimation and measurements of TDG compared to spill at Lookout Point spillway. 551
Figure 2-20. Model estimation and measurements of TDG compared to spill at Dexter spillway. 551
Figure 2-21. Model predictions of TDG below Lookout Point-Dexter Dams. Only one spill source and no mixing with generation flow assumed at Lookout Point Dam due to absence of spillway data. 552
Figure 2-22. Example time series of South Fork McKenzie model results at CGRO. 553
Figure 2-23. Model estimation of TDG compared to measurements at CGRO. 554
Figure 2-24. Model estimation and measurements of TDG compared to spill at Cougar regulating outlet. 554
Figure 2-25. Model predictions of TDG below Cougar Dam. Only one spill source and no mixing with generation flow assumed below Cougar Dam. 555
Figure 2-26. Percentage of Days Below a Given Threshold TDG (non-exceedance cumulative distribution function) as Estimated below Big Cliff (BCL), Foster (FOS), Cougar (CGR), and Dexter (DEX) Dams. 556
Figure 2-27. 50th and 95th percentile non-exceedance of estimated TDG under NAA (Estimated) compared to observed historical data (Observed) below Big Cliff (BCL), Foster (FOS), Cougar (CGR), and Dexter (DEX) Dams. 557
Figure 2-28. Number of days above 110% TDG in each bi-monthly period as estimated under NAA (Estimated) compared to observed historical data (Observed) below Big Cliff (BCL), Foster (FOS), Cougar (CGR), and Dexter (DEX) Dams. 557
Figure 2-29. Simulated operations and TDG at Detroit (DET) and Big Cliff (BCL) During three relatively large spring-time flow events comparing NAA (Estimated) to observed historical data (Observed). Abbreviations: spillRO; Regulating Outlet spill flow, spillSW; Spillway outlet flow, spilltotal; Total outflow. 558
Figure 2-30. Simulated operations and TDG at Green Peter (GPR) and Foster (FOS) During Two relatively large spring-time flow events comparing NAA (Estimated) to observed historical data (Observed). Abbreviations: spillRO; Regulating Outlet spill flow, spillSW; Spillway outlet flow, spilltotal; Total outflow. 558

Figure 2-31. Simulated operations and TDG at Cougar (CGR) During Two relatively large spring-time flow events comparing NAA (Estimated) to observed historical data (Observed). Abbreviations: spillRO; Regulating Outlet spill flow, spillSW; Spillway outlet flow, spilltotal; Total outflow..... 559
Figure 2-32. Simulated operations and TDG at Lookout Point (LOP) and Dexter (DEX) During two relatively large spring-time flow events comparing NAA (Estimated) to observed historical data (Observed). Abbreviations: spillRO; Regulating Outlet spill flow, spillSW; Spillway outlet flow, spilltotal; Total outflow. 559
Figure 2-33. Conceptual Diagram of Potential Structural TDG Gas Abatement Structures (Figure 3.06.1 in USACE, 1996). 560
Figure 2-34. Average Number of Days with Spill per Year Under Each Alternative 564
Figure 2-35. Average Number of Days above 110% TDG (numerical values shown) in Dam Tailraces Under Each Alternative. Note: Impacts at GPR, HCR, LOP are underestimates; extensive TDG data from spillgate operations at these projects did not exist at the time of the EIS development. 565
Figure 2-36. Annual Difference in Number of Days Above 110% TDG Compared to the No Action Alternative. Note: Impacts at GPR, HCR, LOP are underestimates; extensive TDG data from spillgate operations at these projects did not exist at the time of the EIS development. 566
Figure 2-37. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 1 and NAA. 568
Figure 2-38. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 1 and NAA. Boxes represent the first and third quantile (25^{th} and 75^{th} percentiles). 568
Figure 2-39. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 2a and NA 570
Figure 2-40. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 2a and NAA. Boxes represent the first and third quantile (25^{th} and 75^{th} percentiles). 570
Figure 2-41. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 2b and NAA. 572
Figure 2-42. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 2b and NAA. Boxes represent the first and third quantile (25^{th} and 75^{th} percentiles). 572
Figure 2-43. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 3a and NAA. 574
Figure 2-44. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 3a and NAA. Boxes represent the first and third quantile (25^{th} and 75^{th} percentiles). 574
Figure 2-45. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 3b and NAA. 576

Figure 2-46. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 3b and NAA. Boxes represent the first and third quantile (25th and 75th percentiles). 576
Figure 2-47. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 4 and NAA. 578
Figure 2-48. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 4 and NAA. Boxes represent the first and third quantile (25th and 75th percentiles). 578
Figure 2-49. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 5 and NAA. 581
Figure 2-50. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 5 and NAA. Boxes represent the first and third quantile (25th and 75th percentiles). 581
Figure 2-51. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for NTOM and NAA. 584
Figure 2-52. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for NTOM and NAA. Boxes represent the first and third quantile (25th and 75th percentiles). 584
Figure 2-53. Average Number of Days with Spill per Year Under Each Alternative 586
Figure 2-54. Average Number of Days above 110% TDG (numerical values shown) in Dam Tailraces Under Each Alternative. Note: Impacts at GPR, HCR, LOP are under-estimates; extensive TDG data from spillgate operations at these projects did not exist at the time of the EIS development. 586
Figure 2-55. Annual Difference in Number of Days Above 110% TDG Compared to the No Action Alternative. Note: Impacts at GPR, HCR, LOP are under-estimates; extensive TDG data from spillgate operations at these projects did not exist at the time of the EIS development. 587
Figure 2-56. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 6 (Alt6), Alternative 5 (Alt5), Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 588
Figure 2-57. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 6 (Alt6), Alternative 5 (Alt5), Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. Boxes represent the first and third quantile (25th and 75th percentiles). 589
Figure 2-58. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. 592
Figure 2-59. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. Boxes represent the first and third quantile (25th and 75th percentiles). 593

Figure 3-1. Summer Maximum air temperature boxplots at Salem, Oregon. (Source: Northwest Climate Toolbox: https://climatetoolbox.org/tool/Future-Boxplots). 598
Figure 4-1. Number of surveys per year and site. 605
Figure 4-2. Water temperature profiles collected during each synoptic survey (2007-2021) displayed by month. 605
Figure 4-3. Dissolved oxygen profiles collected during each synoptic survey (2007-2021) displayed by month. 606
Figure 4-4. Boxplots of total nitrogen and total phosphorus measurements at each WVP location. 606
Figure 4-5. Depth-averaged nitrogen to phosphorus ratio at each WVP reservoir forebay location. 607
Figure 4-6. Depth-averaged trophic state at each WVP reservoir forebay location using equations from State of Florida (1996). 607
Figure 4-7. Annual total biovolume for each species of cyanobacteria present in WVP forebays (2007-2021)..... 608
Figure 4-8. Month in which peak cyanobacteria biovolume occurred during years sampled at each WVP forebay. 608

LIST OF TABLES

Table 1-1. CE-QUAL-W2 Water Temperature Model Fit Statistics (on Subdaily, Daily Maximum, and Daily Minimum Basis) for Calendar Years 2011, 2015, and 2016 at Select Streamgage Locations Downstream of WVP Dams 3
Table 1-2. Exceedance percentiles for mean annual Salem air temperature (Slm_AirT(Degrees F)), Salem unregulated streamflow (SLM_FlowUnreg), Detroit unregulated streamflow (DET_FlowUnreg) in 1936-2019 (only 2000-2019 data are shown here for brevity)..... 5
Table 1-3. Minimum flow values applied to inflow (cms) of river water temperature models below each WVP dam (as floor to HEC-ResSim-provided outflow from project listed). 8
Table 1-4. Reservoir Model Gate Configurations and Centerline Elevations for CE-QUAL-W2 Reservoir Models. 9
Table 1-5. Comparison of Oregon Department of Environmental Quality (ODEQ) Total Maximum Daily Load Monthly Median Target Temperatures (“TDML”), maximum temperature targets used operationally ("NAA"), and temperature targets used in the WVS EIS temperature simulations for all alternatives except No Action ("AA"). 19
Table 1-6. Temperature targets used in WV EIS and sources. 20
Table 1-7 Percent of Rule Curve Fill Level in Alternative 2b..... 189
Table 1-8. Average Annual Days Within 2 Degrees F of Temperature Target..... 457
Table 1-9. Average Days Below 18 Degrees C (64.4 Degrees F) per Year..... 457
Table 1-10. Average Annual Days Within 2 Degrees F of Temperature Target..... 520
Table 1-11. Average Days Below 18 Degrees C (64.4 Degrees F) per Year..... 520

Table 2-1. Representation of project outlets and configuration 538
Table 2-2. Empirical coefficients for TDG production. If the a, b, c coefficient set results in TDG production less than 100%, then a floor was set. 538
Table 2-3. WILTDG Error statistics 539
Table 2-4. Projected Annual Turbine Outage (percentage of days per year) Applied to HEC-ResSim WVP Outflow Data in WV EIS Alternatives for Estimating TDG. 556
Table 2-5. Summary of literature regarding observed TDG reduction associated with TDG abatement strategies. 562
Table 2-6. Average Number of Days With TDG Above 110 %. 565
Table 2-7. Average Number of Days With TDG Above 110 %. 587
Table 3-1. Projected air temperature summary at Salem, Oregon based on RCP8.5 (climatetoolbox.org) 597

ACRONYMS AND ABBREVIATIONS

7-DADM	Seven-Day Moving Average of Daily Maximum
ALBO	Willamette River at Albany
ATU	Average Thermal Units
BCL	Big Cliff Dam
BCLO	Big Cliff Reservoir near Niagara gage
BLU	Blue River Dam
CFS	Cubic Feet per Second (flowrate)
CMS	Cubic Meters per Second (flowrate)
CE-QUAL-W2	A two-dimensional hydrodynamic, temperature and water quality model
CGR	Cougar Dam
CGRO	South Fork McKenzie River near Rainbow
DEXO	Middle Fork Willamette River near Dexter gage
DET	Detroit Dam
FOS	Foster Dam
FSC	Floating Surface Collector
FSS	Floating Screen Structure
FWWS	Foster Warm-Water Supply
GPR	Green Peter Dam
GPRO	Green Peter Reservoir gage
HCR	Hills Creek Dam
HCRO	Middle Fork Willamette River above Salt Creek gage
HEC-HEC-ResSim	Hydrologic Engineering Center Reservoir System Simulation Model
HIR	High Intake Gate
LIG	Low-intake Gate
LOP	Lookout Point Dam
LRO	Lower Regulating Outlet
ODFW	Oregon Department of Fish and Wildlife

NOAA	National Oceanic and Atmospheric Administration
NTOM	Near Term Operations Measure
RA	Resource Agencies (NOAA, USFWS, and ODFW)
ROs	Regulating Outlets
SLMO	Willamette River at Salem
SSFO	South Santiam near Foster gage
SWS	Selective Withdrawal Structure
TDG	Total Dissolved Gas
TMDL	Total Daily Maximum Load
TW	Tailwater
URO	Upper Regulating Outlet
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WATER	Willamette Action Team for Ecosystem Restoration
WTCT	Water Temperature Control Tower
WVP	Willamette Valley Project
WVEIS	Willamette Valley Environmental Impact Statement

CHAPTER 1 - WATER TEMPERATURE ANALYSIS

Resource Name: Water Quality

Preparer's Name: Norm Buccola

Date of Last Revision: 11/5/2025

Water temperature within the Willamette Valley System (WVS) was assessed through a series of 2-dimensional (longitudinal/vertical) hydrodynamic CE-QUAL-W2 reservoir and river models (Wells, 2020). This model has been widely used and applied to water bodies around the world (Berger, Annear, and Wells 2002; West Consultants, 2005; Sullivan and Rounds, 2007; Buccola, et al., 2012; Threadgill et al., 2012; Buccola, et al., 2013; Buccola and Stonewall 2016; Buccola, Turner, and Rounds 2016; Buccola, 2018; Sullivan and Rounds, 2021; USACE, 2020c). For a complete list of the model applications, see the W2 website: http://www.ce.pdx.edu/w2/. The water temperature models were driven primarily by outlet gate flows and lake elevations simulated in HEC-HEC-ResSim (https://www.hec.usace.army.mil/software/hec-ressim/) and are described further in Chapter 3.2 (Effects Analysis – Hydrology and Hydraulics) and Technical Appendix B (Hydrology and Hydraulics). Additional inputs to the temperature models consist of temperature targets and outlet configurations that allow for comparison of temperature management options and are discussed in this Appendix.

1.1 LIMITATIONS, ASSUMPTIONS, AND UNCERTAINTY

- The Willamette River reach downstream of Willamette Falls is not included in the water quality analysis for the Willamette Valley EIS.
- The impact of operations to temperature were quantified using mechanistic models (CE-QUAL-W2). All models are simplifications of the real world and represent the processes that are important to water temperature.
- Daily average flows were used in the HEC-ResSim, CE-QUAL-W2, and TDG modeling. Sub-daily temperature variation was simulated in the CE-QUAL-W2 modeling, but results were summarized as daily mean and maximum values.
- Water temperature was not simulated at Blue River, Fall Creek, Dorena, Cottage Grove, or Fern Ridge lakes due to one or more of the following reasons: negligible difference in operation from Affected Environment, negligible combined heating effect to downstream waters, or lack of a CE-QUAL-W2 model. The simulated water temperature effects of proposed structures (Selective Withdrawal Structure [SWS], Floating Screen Structure [FSS], Floating Surface Collector [FSC]) are based on the most current design (where applicable). The actual functionality and resulting temperatures could vary if plans, specifications, materials, and as-built construction vary from current design.
- Due to extreme low water and resulting CE-QUAL-W2 model instabilities during summer/fall of 2015, a minimum streamflow rule was applied at some locations downstream of the

dams so that model output can be passed downstream to the Willamette River (see Model Configurations).

1.2 MODEL DEVELOPMENT

Previous research has examined the extent to which operational or structural solutions can improve temperature management below WVP dams.

In the North Santiam subbasin, the extent to which a hypothetical temperature control structure at Detroit Dam can control water temperature has been examined in each season (Buccola et.al., 2012; USACE, 2019; Keefer, et.al., 2019). In any given year, the heat absorbed by the lake during summer from solar radiation will be released downstream at some point later in the autumn. As part of the design process for the Detroit SWS (Selective Withdrawal Structure) and FSS (Floating Screen Structure), USACE compared simulated water temperature derived from cooler and warmer spring-summer targets with and without the presence of a temperature control structure at Detroit. These model simulations were shared with University of Idaho to support a study of the trade-offs associated with each scenario and the effects on adult chinook salmon in the North Santiam (Keefer, et.al., 2019). One conclusion of this study was that cooler spring-summer targets lead to warmer autumn temperature, even with the presence of a water temperature control structure at Detroit Dam (see Section 7 and Figures 12-15 in Keefer, et. al., 2019).

Previous water temperature modeling in the South Santiam (Buccola, 2017; Sullivan and Rounds, 2021) and Middle Fork subbasins (Buccola et. al., 2016) has shown how a variety of hypothetical structures and operations can improve temperature control downstream of USACE dams. However, each subbasin is unique in the relative ability to provide cool water temperature downstream of the dams, even with the inclusion of a water temperature control structure in place. For example, Lookout Point and Dexter dams on the Middle Willamette River are relatively lower in their respective sub-basins than Detroit, Green Peter, Cougar, and Hills Creek Dams. This results in longer travel times and warmer temperatures at Lookout Point – Dexter Dams compared to higher dam locations. Previous studies investigating the potential for structural and operational changes to Middle Fork Willamette dams (Buccola, et.al., 2016) resulted in less ideal thermal habitat for ESA-listed Chinook and steelhead associated with those changes than seen in other subbasins.

To evaluate water temperature throughout the WVP with the proposed operations and structures included in the WVS EIS alternatives, CE-QUAL-W2 water temperature models were updated and refined (Stratton-Garvin, et. al., 2022a; Stratton-Garven, et.al., 2023). Summary fit statistic ranges for the models on a subdaily, daily maximum, and daily minimum basis over the calendar years 2011, 2015, and 2016 are shown in Table 1-1 and rarely exceed 1 degree Celsius mean absolute error, which is within the acceptable range for water temperature models.

Table 1-1. CE-QUAL-W2 Water Temperature Model Fit Statistics (on Subdaily, Daily Maximum, and Daily Minimum Basis) for Calendar Years 2011, 2015, and 2016 at Select Streamgage Locations Downstream of WVP Dams

Sub-Basin/Reach Name	Model	Model Outflow Fit Statistic Range (Mean Absolute Error in degrees C)	Source
North Santiam River	Detroit – Big Cliff (USGS 14181500)	0.46 to 0.78	Table 10 in Stratton-Garvin (2023)
Santiam River	Santiam River Near Jefferson (USGS 14189050)	0.44 to 0.86	Table 3 in Stratton-Garvin (2022a)
South Santiam River	Green Peter – Foster (USGS 14187200)	0.58 to 0.75	Table 10 in Stratton-Garvin (2023)
McKenzie River	Cougar Lake (USGS 14159500)	0.68 to 1.15	Table 8 in Stratton-Garvin (2023)
	McKenzie River (USGS 14164900)	0.48 to 1.13	Table 3 in Stratton-Garvin (2022a)
Middle Fork Willamette River	Hills Creek Lake (USGS 14145500)	0.29 to 1.09	Table 5 in Stratton-Garvin (2023)
	Lookout Point – Dexter Lakes (USGS 14150000)	0.51 to 1.00	Table 7 in Stratton-Garvin (2023)
	Middle Fork / Coast Fork Willamette (USGS 14152000)	0.25 to 0.66	Table 3 in Stratton-Garvin (2022a)
Upper Willamette River	Willamette at Albany (USGS 14174000)	0.47 to 0.75	Table 3 in Stratton-Garvin (2022a)
Middle Willamette River	Willamette at Keizer (USGS 14192015)	0.44 to 0.62	Table 3 in Stratton-Garvin (2022a)

1.2.1 Calendar Year Selection

Three representative calendar-years from recent decades were chosen to simulate water temperature in the network of Willamette Basin CE-QUAL-W2 models used in the WV EIS (Figure 1-1). The three years can be described qualitatively and relative to the past two decades as follows: 2011 (high flow, cool temperature), 2015 (extreme low flow, extreme warm temperature), and 2016 (low flow, warm temperature). Annual statistics and exceedance values of Salem Airport McNary Field air temperature (NOAA USW00024232 [NOAA, 2020]; *Slm_AirT(Degrees F)*), unregulated streamflow at Salem (derived from HEC-ResSim; *SLM_FlowUnreg(Kcfs)*), and unregulated streamflow at Detroit, Oregon (derived from HEC-ResSim; *DET_FlowUnreg(Kcfs)*) for these three years are shown in Figure 1-2 and Table 1-2. More background on the year selection process and environmental conditions can be found in Stratton Garven (2022a).

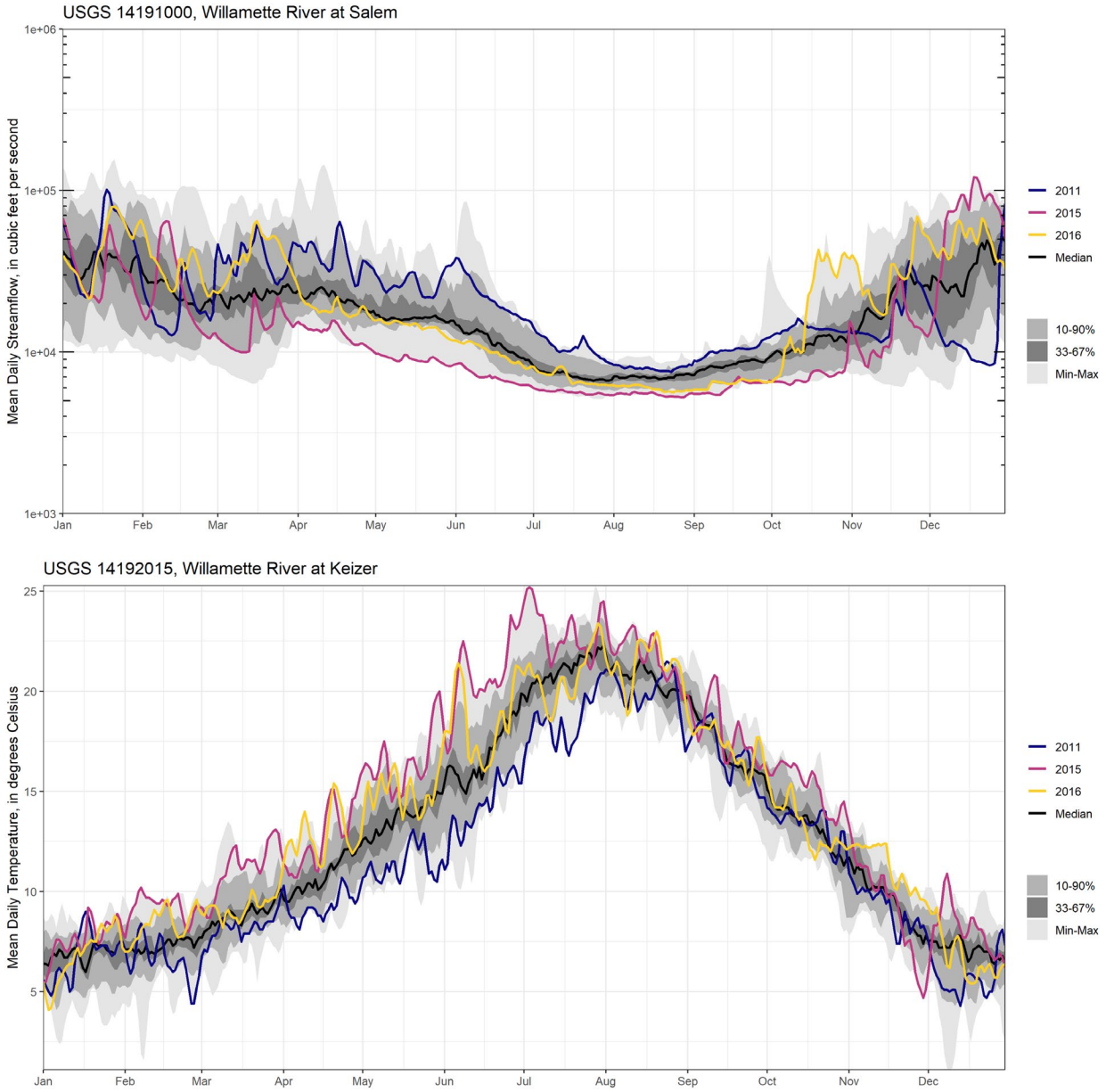


Figure 1-1. Streamflow (top) and water temperature (bottom) at Salem/Keizer, Oregon in 2011, 2015, and 2016 (Reproduced from Stratton Garvin, 2022a).

Table 1-2. Exceedance percentiles for mean annual Salem air temperature (Slm_AirT(Degrees F)), Salem unregulated streamflow (SLM_FlowUnreg), Detroit unregulated streamflow (DET_FlowUnreg) in 1936-2019 (only 2000-2019 data are shown here for brevity).

Year	Slm_AirT (Degrees F)	SLM_FlowUnreg (Kcfs)	DET_FlowUnreg (Kcfs)
2000	21	51	61
2001	39	15	12
2002	60	36	86
2003	86	37	26
2004	68	26	33
2005	43	48	32
2006	76	30	44
2007	20	11	13
2008	10	82	100
2009	55	54	69
2010	45	93	65
2011	11	94	81
2012	49	98	80
2013	46	32	40
2014	96	52	37
2015	100	1	1
2016	94	10	4
2017	83	79	62
2018	95	27	20
2019	40	85	50

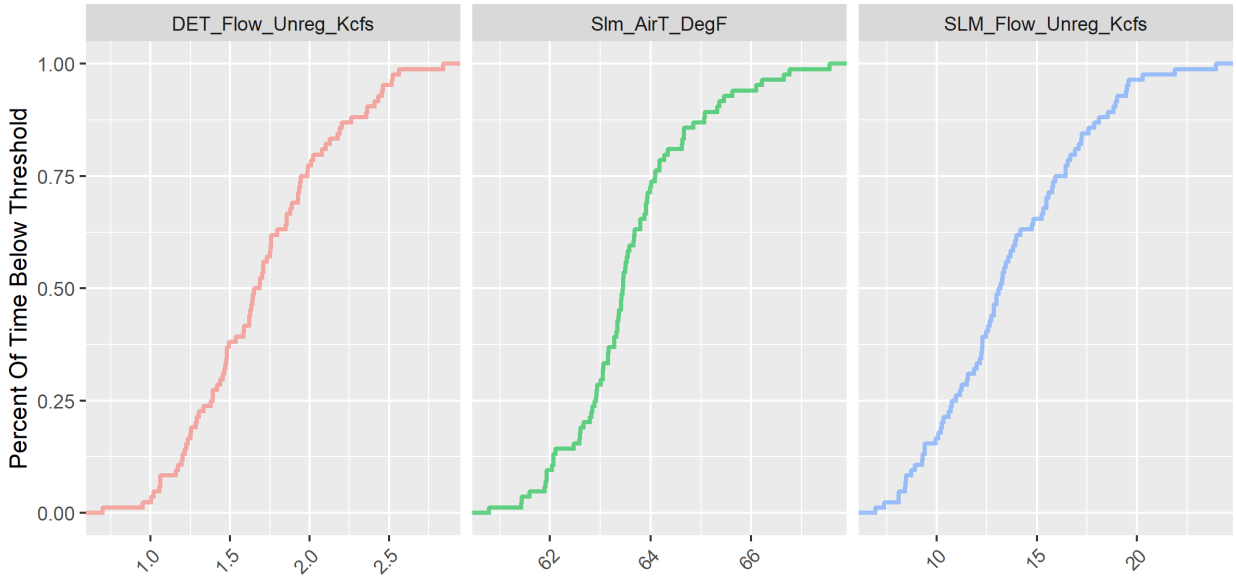


Figure 1-2. Percent exceedance graphs of annual mean unregulated flow at Detroit, Oregon (left), air temperature at Salem, Oregon (middle), and unregulated streamflow at Salem, Oregon (right) over the period of record (1936-2019).

1.2.2 Model Configurations

A network of 7 hydrodynamic CE-QUAL-W2 water temperature models have been developed for the major WVP reservoirs (Wells, 2020) and are utilized in the WV EIS to examine potential operational and structural measures on USACE-managed projects. Reservoir temperature models were developed for Detroit (Sullivan and Rounds, 2007), Big Cliff (Buccola, et al., 2012), Green Peter-Foster (West Consultants, 2005; Buccola, et al., 2013), Cougar (Threadgill et al., 2012), and the Middle Fork Willamette complex including Hills Creek, Lookout Point, and Dexter Dams (West Consultants Inc, 2004a; West Consultants Inc, 2004b; Buccola, et al., 2013). Since the development of these models, many studies have examined scenarios including hypothetical structures and operations at Detroit Dam (Buccola, et.al, 2016 and 2017; USACE, 2019b), Green Peter-Foster (Buccola, 2018; Sullivan and Rounds, 2021; USACE, 2020c), Cougar (USACE, 2019a), and the Middle Fork Willamette complex of dams (Buccola, et al., 2016). There was no additional model calibration for the WV EIS simulations. However, CE-QUAL-W2 model code was modified to increase model stability and decrease model run-times, especially during deep reservoir drawdowns (Stratton et al., 2023).

Below the CE-QUAL-W2 reservoir models were a network of CE-QUAL-W2 river models, previously calibrated for the North Santiam (Sullivan and Round, 2004), South Santiam (Bloom, 2016), and other tributaries to the Willamette River (Annear et al., 2004; Berger and others, 2004; Sullivan and Rounds, 2004; Oregon Department of Environmental Quality, 2006). This network of river models has been used to examine Willamette temperature in the absence of dams (Rounds, 2010) and the effect of flow on temperature in the Willamette (Stratton Garvin

and Rounds, 2022b). Further updates to these models and assemblage of boundary conditions for 2011, 2015, and 2016 are documented in Stratton Garvin and others (2021).

While HEC-ResSim modeling incorporates an 84-year simulation (spanning 1935 – 2019), CE-QUAL-W2 modeling included three calendar years under each alternative (2011: "wet", 2015: "dry", 2016: "normal") due to the level of effort involved in compiling boundary conditions for temperature modeling (Stratton Garvin and others, 2021). Reservoir models were simulated for the January through December period, while river models were simulated April through October. Distributed tributary flows added or withdrawn from the system to ensure lake levels matched intended operations were estimated using a Water Balance Utility available with the CE-QUAL-W2 download.

A simplifying assumption was made in HEC-ResSim and CE-QUAL-W2 that Big Cliff Dam (a re-regulating reservoir) outflow was equal to Detroit outflow on a daily average basis through each WV EIS alternative (i.e., no tributary inputs to Big Cliff Reservoir were included). Similarly, the re-regulating reservoir of Dexter Lake is relatively shallow and fluctuating generally between 690 and 695 ft lake surface elevation. Residence times in Dexter Lake are on the order of 1 week, which leads to a general warming of the outflow from LOP. For this reason, the combined effect from LOP-DEX was analyzed at the downstream outlet below DEX.

In some instances, total outflow from individual dams as output from HEC-ResSim was too low for the downstream river models to simulate. In these cases, an iteratively determined minimum discharge value was applied to the upstream boundary condition for the river model in question. For example, in Alternative 3b outflow from Foster Dam was modeled by HEC-ResSim to be less than 8 cms (283 cfs) on 63 days of 2016. In these cases, HEC-ResSim-derived outflow was used to specify outflow from Foster Dam but increased to a minimum of 8 cms (283 cfs) when input to the South Santiam River model. This artificial increase in flow may bias the modeled temperature in the South Santiam (or other rivers where this correction was applied) slightly cooler than the actual alternative specifies, but the effect is likely small and diminishes downstream. These flow changes in CE-QUAL-W2 models below some dams occurred primarily during summer/fall of 2015 and 2016, where minimum streamflow rules were applied as shown in Table 1-3.

Table 1-3. Minimum flow values applied to inflow (cms) of river water temperature models below each WVP dam (as floor to HEC-ResSim-provided outflow from project listed).

Model inflow (source)	2011	2015	2016
NAA			
Cottage Grove	NA	1.42	NA
Foster	NA	8	NA
Big Cliff	NA	11	NA
Alt1			
Cottage Grove	NA	1.42	NA
Foster	NA	8	NA
Big Cliff	NA	11	NA
Alt4			
Cottage Grove	NA	1.42	NA
Foster	NA	8	
Big Cliff	NA	11	NA
Alt3a			
Foster	8	8	8
Big Cliff	11	11	15
Alt3b			
Cottage Grove	1.42	1.42	NA
Dexter	NA	NA	NA
Foster	NA	8	8
Big Cliff	NA	11	NA

Existing and proposed outlet properties for CE-QUAL-W2 reservoir temperature models are shown in Table 1-4. These properties are inputs to the model (w2_selective.npt file) for blending between multiple outlets in the attempt to meet a downstream temperature target (Rounds and Buccola, 2015). All elevations are centerline elevations except for spillways and weirs, which are the crest elevation. MAXFLOW values are given to limit the amount flow released from a particular outlet. General configurations for each project are listed below.

- Detroit (DET) has 9 gates. Gates Q1 to Q4 currently exist at the dam, while Q5 to Q9 are proposed gates as part of the SWS and FSS in Measure 105. Note: Further investigation into actual centerline elevations of Upper RO and Lower ROs were found to be 1340’ and 1265’, respectively. While these changes were not incorporated into WV EIS temperature models, they will be included in further studies as updates to the Detroit Lake CE-QUAL-W2 model.
- Cougar (CGR) has 7 gates. All gates currently exist at the dam, but not all are used as described in the WV EIS: Q2 (RO) includes an internal bifurcation that leads to Q6 (Penstock), which does not currently have a direct connection to the reservoir. Q1, Q3, Q4,

and Q5 represent approximate gaps within the existing Water Temperature Control Tower (WTCT). Model calibration has led to an approximation of the weir leakage as 10% of total outflow through each of Q3, Q4, and Q5. The diversion tunnel (Q7: Dtnnl) does not currently exist as a regularly operable outlet but is considered in Measure 479 (see Measure Assumptions) with structural/mechanical modifications for regular operation.

- Foster Dam (FOS) has 7 gates. The primary gates currently in use at the dam are Q2 through Q7. There are three Power intakes: Q3 (*PowerUp*); providing attraction water to the fish ladder side entrance, Q6 (*PowerLow*); supplying the fish facility and fish ladder, and Q5 (*PowerMain*) providing the bulk of the river flow for most of the year. 7.5 % of total outflow was assumed to flow through both Q3 and Q6, with a maximum of 58.6 cfs through either gate at any time, as a simplification of typical current operations. All gates except Q1: *FWWS* (see Measure Assumptions) currently exist at the dam. Q7 is not used in the WV EIS analysis as it typically discharges negligible flow levels to the fish hatchery during the spring and summer.
- Green Peter (GPR), Lookout Point (LOP), and Hills Creek (HCR) have 3 gates at each project.
- Big Cliff (BCL) and Dexter (DEX) have 2 gates at each project (Power and Spillway)

Table 1-4. Reservoir Model Gate Configurations and Centerline Elevations for CE-QUAL-W2 Reservoir Models.

Site	Outlet Number	Outlet Name	Elevation (m)	Elevation (ft)
DET	Q1	URO	410.0	1345.0
DET	Q2	Spillway	469.7	1541.0
DET	Q3	Power	427.6	1403.0
DET	Q4	LRO	387.1	1270.0
DET	Q5	SWS_HIW*	429.8	1410.1
DET	Q6	FSS1*	429.8	1410.1
DET	Q7	FSS2*	429.8	1410.1
DET	Q8	FSS3*	429.8	1410.1
DET	Q9	SWS_LIG*	406.0	1332.0
BCL	Q1	Spillway	354.0	1161.5
BCL	Q2	Power	347.5	1140.0
GPR	Q1	Spillway	295.3	968.7
GPR	Q2	Power	246.9	810.0
GPR	Q3	RO	228.6	750.0
FOS	Q1	FWWS*	192.0	630.0
FOS	Q2	Weir	193.1	633.5
FOS	Q3	PowerUp	182.7	599.3
FOS	Q4	Spillway	181.9	596.8

Site	Outlet Number	Outlet Name	Elevation (m)	Elevation (ft)
FOS	Q5	PowerMain	179.8	590.0
FOS	Q6	PowerLow	178.1	584.3
FOS	Q7	HatchLow**	175.6	576.0
CGR	Q1	WTC4	512.1	1680.0
CGR	Q2	RO	452.6	1485.0
CGR	Q3	WTC3	500.0	1640.3
CGR	Q4	WTC2	487.9	1600.6
CGR	Q5	WTC1	475.8	1561.0
CGR	Q6	Penstock**	434.3	1424.8
CGR	Q7	DTnnl	396.2	1300.0
HCR	Q1	RO	431.3	1415.0
HCR	Q2	Power	423.7	1390.0
HCR	Q3	Spillway	455.8	1495.5
LOP	Q1	Spillway	270.5	887.5
LOP	Q2	Power	237.7	780.0
LOP	Q3	RO	222.3	729.3
DEX	Q1	Spillway	201.2	660.0
DEX	Q2	Power	198.2	650.4

URO = Upper Regulating Outlets, LRO = Lower Regulating Outlets, SWS = Selective Withdrawal Structure, CL = Centerline, FSS= Floating Screen Structure, HIW=High Invert Weirs, LIG = Low Intake Gates
* Proposed Outlet, ** Outlet Not Used in WV EIS analysis
Vertical Datums are Specific to As-Built Drawings for Each Site.

1.3 MEASURE ASSUMPTIONS

Measures associated with water temperature are designed to provide more seasonally appropriate temperatures downstream of Willamette Project dams and improve habitat for Spring chinook and winter steelhead fish. Measures are designed to align with fish passage measures and balance other authorized purposes as best as possible. Many structural modifications are assumed and would require detailed design work to be implemented. Full measure descriptions are provided in Appendix A, and assumptions used for ResSim modeling are provided in Appendix B. General measure descriptions pertaining to water temperature modeling are as follows:

- **Measure 105** *Construction of selective withdrawal structures (SWS):* The SWS would be constructed on the face of high-head WVP hydropower dams to allow the release and blending of water at various temperatures (depths) in the reservoir to improve water temperature downstream of the dam. The new structure would send this water through the powerhouse and continue to generate power while meeting downstream water quality targets. These structures could also be attached to or combined with new fish passage

facilities (notably Measure 392: construct downstream passage) to meet the requirements of fish passage RPAs (NMFS 2008).

- **Measure 479** *Modify existing outlets to allow releases at varying depths for temperature control:* Outlets exist at some WVP dams would permit enhanced temperature control if such outlets were modified to allow for regular operation at relatively low flows during April-November. This measure would call for modifying existing outlets to allow for routine usage specific to each project to help restore normative temperatures to extent possible using existing outlets.
- **Measure 166** *Operational Temperature Control for Cooler Water:* Use existing outlets to discharge colder water during drawdown operations in fall and winter to reduce water temperatures below dams. Due to the strong stratification that most the valley lakes experience during the spring, summer, and fall (before lake turnover), there is an opportunity at some projects to release relatively cool water from the regulating outlets (below the power intakes). This cooler water (compared to releases through the turbines) can provide a benefit for chinook egg incubation downstream. Projects that include various usable outlet inverts include Detroit, Green Peter, and Lookout Point dams. This measure specifies up to 60% of total release through ROs in the fall. Water temperature simulations assume outlet details and temperature targets align with those used in previous studies (Buccola, et.al, 2016; Buccola, et.al, 2017, USACE, 2019a; USACE 2019b). Simulated mixing between outlets depends on temperature targets imposed in temperature models and may differ from outlet flow ratios simulated in HEC-ResSim model. Note: Minimum gate openings are not accounted for in HEC-ResSim or CE-QUAL-W2.
- **Measure 721** *Operational Temperature Control for Warmer Water:* Use of the spillway to improve downstream water temperature management from spring through autumn. By extending the use of the spillway, a larger volume of warm surface water from the reservoir can be released and cold deep water can be reserved for later in the fall/early winter when necessary for fish incubation. In the fall, the deeper ROs can release a limited amount of cooler water at Detroit, Green Peter, Hills Creek, and Lookout Point Dams. Water temperature simulations assume outlet details and temperature targets align with those used in previous studies (Buccola, et.al, 2016; Buccola, et.al, 2017, USACE, 2019a; USACE 2019b). Simulated mix between outlets depends on temperature targets imposed in temperature models and may differ from mix simulated in HEC-ResSim model. Note: Minimum gate openings are not accounted for in HEC-ResSim or CE-QUAL-W2.
- **Near-Term Operations Measure (NTOM):** Based upon the U.S. District Court for the District of Oregon interim injunction directing the Corps to implement interim injunction measures intended to improve conditions for fish passage and water quality in the WVS to avoid irreparable harm to ESA-listed salmonids during the interim period until the completion of the reinitiated ESA consultation, issued on September 1, 2021. The NTOM includes sixteen measures that require changes to how the WVS dams are operated and three measures that modify existing structures (Described in further in Chapter 2 (overall descriptions) and Appendix A (detailed descriptions), and Appendix B (Hydraulic modeling assumptions).

Details of the NTOM as they may affect water temperature simulations are provided for each sub-basin in Section 1.3 below.

1.3.1 North Santiam

The following are site-specific measure details applied to the Detroit CE-QUAL-W2 model:

Measures 105, 392 at Detroit Dam contain outlet details and temperature targets similar to those used in previous studies (Buccola, et.al, 2016; Buccola, et.al, 2017, USACE 2019b) with some simplifying assumptions applied to be consistent with WV EIS Measure 392 description. Those modifications are as follows: Rather than multiple floating intakes (simulating a distributed inflow to the FSS), a single floating outlet at 25 feet deep (*Q3 DEPTH* = 7.62 [m] in *w2_selective.npt* file) was used. Maximum outflow from the FSS was assumed to be 4600 cfs (*Q3 MAXFLOW* = 130.26 [cms]).

Measures 166, 721 at Detroit Dam were implemented in HEC-ResSim as 60% of the total outflow assigned to the spillway from April 15 to Aug 30 and up to 60% of total outflow through the ROs from Sep 1 to Nov 15. However, these flow values were adjusted by the temperature blending routine within the CE-QUAL-W2 model (*Q3 MINFLOW* = 0.4) to meet the downstream temperature target optimally. A 200 ft maximum head restriction was placed on the ROs in NAA to simulate the operational limits of these gates due to structural/mechanical safety concerns. This *MAXHEAD* restriction was removed for Alternative 3a/3b to match the Measure 479 description below. When Measures 721 and 166 were combined with Measure 714 (Alternative 3b), *MINFLOW* values for all outlets were set to 0 which allowed the model optimization to meet downstream temperature target with no restraint. The lower RO (*Q4 PRIORITY = 1*) was allowed to be blended in Alternative 3b during autumn. When Measures 721 and 166 were combined with 720 (operational downstream passage: Alternatives 3a), temperature blending was not used, so that fish passage could be given higher priority.

Measure 479 at Detroit Dam describes the reinforcement and strengthening of regulating outlet (RO) gates and tunnels, which exist at elevations 1340 ft (upper ROs) and 1265 ft (lower ROs). The ROs were not designed to be operated regularly with extreme head pressure. Under this measure, head pressure limits are not to exceed the spillway crest for the upper and lower ROs *(Q1 MINFRAC = 59.7, Q4 MINFRAC = 82.6)*. This measure describes additional structural reinforcement, lining of the RO tunnels, and strengthening of the gates to provide additional reliability, and limit cavitation/scouring of the dam when head pressure exceeds thresholds described above. This would allow for additional capability to release cooler flows in the late fall (typically November).

NTOM at Detroit Dam includes a spring spillway operation for downstream fish passage and operational downstream temperature management from mid-March until the lake is below the spillway crest (typically until July-August). In the autumn and winter, use of the upper and lower ROs during night-time hours when lake elevation is below 1500 feet at Detroit Dam is intended to improve fish passage and access relatively cooler water temperature downstream (similar to Measure 166 and Alternative 3a/3b). Under this measure, head pressure limits are not to

exceed 200 feet for the upper and lower ROs *(Q1 MINFRAC = 61.3, Q4 MINFRAC = 61.3)*. While the precise description of this measure specifies night-time RO usage, the ResSim boundary conditions to the water temperature models are daily averages and will not contain this hourly specificity. ResSim rules specified a 75% / 25% spill-to-power ratio (spillway when lake is above spillway crest, ROs when below spillway crest) from 01 March to 15 November as an approximation of ideal temperature management. However, temperature blending in CE-QUAL-W2 was assumed to occur year-round to attempt at meeting the downstream temperature target and resulted in refined time-varying spill-to-power splits.

1.3.2 South Santiam

The following are site-specific measure details applied to the Green Peter -Foster CE-QUAL-W2 model:

Measures 105, 392 at Green Peter Dam consists of assumptions similar to those used at Detroit Dam with a floating outlet at 25 feet deep (*Q2 DEPTH* = 7.62 [m] in *w2_selective.npt* file). Maximum outflow from the FSS was assumed to be 4000 cfs (*Q2 MAXFLOW* = 113.27 [cms]).

Measure 392 at Foster Dam generalizes a downstream fish passage structure with 500-800 cfs surface spill through a safe and effective route (spillway or screened intake). This structure was simulated in HEC-ResSim with the assumption of a year-round fish passage of 600 cfs as "Spillway" flow. In CE-QUAL-W2, this surface spill was designated in the Q2 (Weir) outlet with a floating DEPTH value of 1 m (3.3 ft), minimum flow (MINFRAC) value of -16.99 (600 cfs), and the same blending (PRIORITY) group of 1 with the Q5 (*PowerMain*) outlet (designating that both outlets were blended to meet a mutual temperature target). Further, Q5 was designated a minimum flow (MINFRAC) value of -4.2475 (150 cfs).

Measures 166, 721 at Green Peter Dam was implemented in HEC-ResSim as 60% of the total outflow assigned to the spillway as soon as it is available in May to Aug 30 and up to 60% of total outflow through the ROs from Sep 1 to Nov 15. However, these flow values were adjusted by the temperature blending routine within the CE-QUAL-W2 model (*Q2 MINFLOW* = 0.4) to meet the downstream temperature target optimally. When Measures 721 and 166 were combined with Measure 714 (Alternative 3a), *MINFLOW* values for all outlets were set to 0 which allowed the model to optimize to meet downstream temperature target with no restraint. When Measures 721 and 166 were combined with 720 (operational downstream passage: Alternatives 3a), temperature blending was not used, so that fish passage could be given higher priority.

Measure 479 at Foster Dam is described as the Foster Warm-Water Supply pipe (FWWS) to the existing adult fish ladder at the Foster Fish Facility (USACE, 2020). Currently, the Foster fish ladder is fed by deeper water in Foster Lake via the turbine intakes. This measure would add flexibility to provide more normative temperatures in the fish ladder and attract upstream migrant fish in a timelier manner during the spring. Assumptions for HEC-ResSim modeling include 144 cfs in May and 72 cfs during June through the FWWS (by-passing the turbines). CE-QUAL-W2 modeling allocates these exact flows through the FWWS outlet (Q1) with a centerline

elevation of 630 ft. Post-processing can refine this flowrate and calculate an optimal flow that will meet a separate temperature target for the fish ladder, similar to methods in Foster Fish Ladder Improvements Project Design Documentation Report (USACE, 2020).

NTOM details for the South Santiam sub-basin are as follows:

- Green Peter includes a spring spillway operation for improved downstream fish passage when lake elevation is above spillway crest (971 ft) from 01 March until 01 May or for 30 days, whichever is longer (similar to Measure 714 in Alternatives 3a and 2b). From early September to mid-December, a deep drawdown at Green Peter (targeting 780 ft elevation 15 November to 15 December) and RO prioritization (when lake is below 887 ft) is prescribed for improved downstream fish passage (similar to Measure 40 in Alternatives 2a, 2b, 3a, and 3b).
- Foster Dam includes a delayed refill until 15 May (targeting 637 ft between 16 May and 5 September). Spring spillway is used to improve downstream fish passage from 1-February to 15 June (lake elevation 613 ft. from February to May; lake elevation 637 ft. May to July). Summer fish weir use (300 cfs [8.5 cms] through QOT2) from 16 June to 31 July to improve downstream temperature management and upstream fish migration/passage. Utilize the spillway for 60% of the day with 40% through the penstocks for improved downstream fish passage in the fall from 01-October to 15-December when the lake is at minimum conservation pool (613 feet).
- These outlet-specific release rules for Green Peter and Foster were simulated in HEC-ResSim and passed onto CE-QUAL-W2 as QOT boundary condition files using the assumptions consistent with those described in Section 1.2.2, without utilizing the blending routine (SELECTC = OFF).

1.3.3 South Fork McKenzie

The following are site-specific measure details applied to the Cougar CE-QUAL-W2 model:

Measure 479:

- Cougar Dam: The Cougar Diversion Tunnel is the deepest outlet at Cougar Dam (invert elevation 1290 ft; centerline elevation 1300 ft) and has the potential to release deep, cold water under scenarios in which lake level is below the RO intake (invert elevation 1479 ft; centerline elevation 1485 ft). This measure assumes new structural and mechanical gate improvements have been made to allow for safe remote routine operation of the diversion tunnel. Measure 479 coincides with Measure 720 (spring drawdown) in Alternative 3b, the lake level is below the WTCT, so blending between the RO bypass intake and the diversion tunnel is specified (Q2 and Q7 PRIORITY = 1 in w2_selective.npt file).
- Blue River Dam: Blue River Dam was built with two spillway gates (spillway crest elevation 1321 ft) and a spillway channel, designed for extreme flow events. This measure assumes the current spillway gates and spillway channel could be re-designed to enable low-flow

releases when the lake is above spillway crest. This would provide more normative temperatures during the summer through the release of warmer water, saving cooler deeper water for the fall. Water temperatures downstream of Blue River Dam were estimated based on the simulated HEC-ResSim pool elevation and the average monthly thermocline as measured monthly in 2014 and 2019 (Figure 1-3).

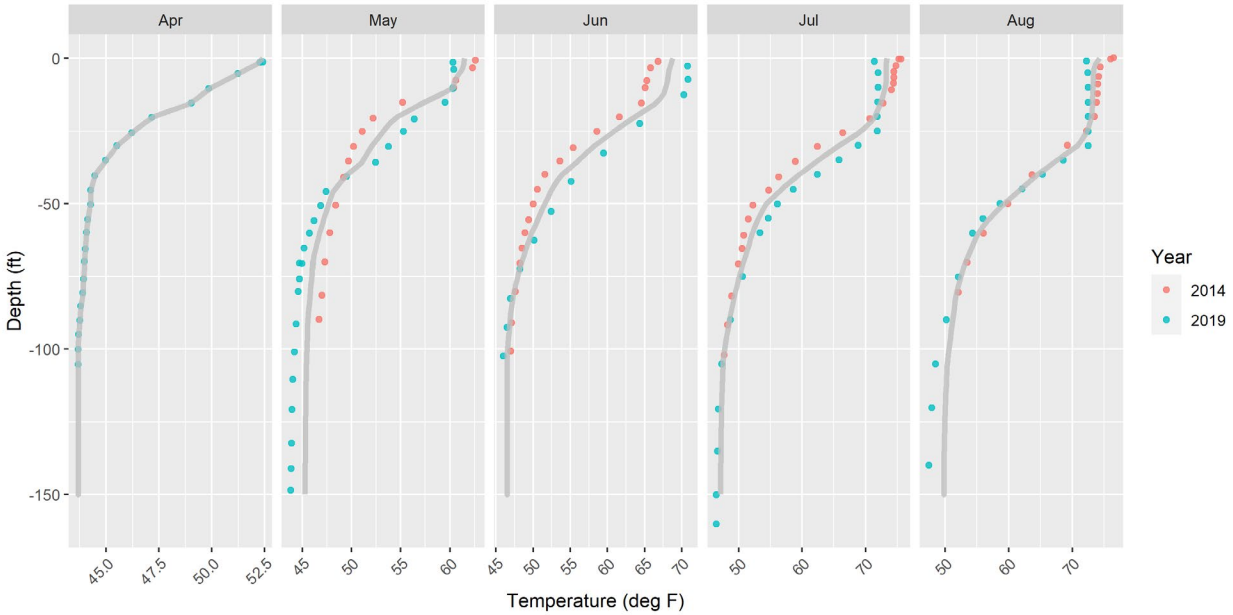


Figure 1-3 Blue River Lake water temperature as measured at monthly intervals in 2014 and 2019. Gray line represents the average of the two years.

Measures 105, 392 outlet details and temperature targets at Cougar Dam are similar to those used in previous studies (USACE, 2019a) with some simplifying assumptions applied to be consistent with WV EIS Measure 392. A single floating outlet at 25 feet deep (*Q3 DEPTH* = 7.62 [m] in *w2_selective.npt* file) was used with maximum outflow from the FSS assumed to be 1000 cfs (*Q1 MAXFLOW* = 28.32 [cms]).

NTOM at Cougar Dam includes a delayed refill targeting 1520' between 01 February and 15 May, followed by targeting of the rule curve until 01 July. At this point, a deep drawdown begins 01 July, targeting the usual rule curve 01 October elevation one month early on 01 September and targeting 1505 ft elevation from 15 November to 15 December with RO operation for fish passage (similar to Measure 40 in Alternative 3a). On 16 December, the rule curve is targeted until the following spring and refill begins again as described above. From 01 February to 15 May or when the lake is below 1580 ft, all flow is released through the ROs for 60% of the day while penstock is allowed a maximum 40% of the day. A maximum draft and refill rate of 880 cfs is allowed. Both operations prioritize the RO to improve downstream fish passage. These outlet-specific release rules for Cougar were simulated in HEC-ResSim and passed onto CE-QUAL-W2 as QOT boundary condition files using the assumptions consistent with those described in Section 1.2.2, and only utilizing the blending routine between the floating outlet and the RO (PRIORITY for Q1 and Q2 = 1) and when the lake was above elevation

1565 ft. This led to custom start and stop times for the blending routine in each year as follows -- 2011: TSTR = 136, TEND = 315; 2015: SELECTC = OFF (lake did not exceed 1565 ft); 2016: TSTR = 136, TEND = 324.

1.3.4 Middle Fork Willamette

The following are site-specific measure details applied to the Hills Creek and Lookout Point-Dexter CE-QUAL-W2 models:

Measures 105, 392:

- Lookout Point Dam consists of assumptions similar to those used at Detroit Dam with a floating outlet at 25 feet deep (*Q2 DEPTH* = 7.62 [m] in *w2_selective.npt* file). Maximum outflow from the FSS was assumed to be 6000 cfs (*Q2 MAXFLOW* = 169.90 [cms]) to be consistent with Measure 392 description for Lookout Point Dam.
- Hills Creek Dam FSS assumptions include a single floating outlet at 25 feet deep (*Q3 DEPTH* = 7.62 [m] in *w2_selective.npt* file) with maximum outflow from the FSS assumed to be 1000 cfs (*Q1 MAXFLOW* = 28.32 [cms]).

Measures 166, 721 at Lookout Point Dam were implemented in HEC-ResSim as 60% of the total outflow assigned to the spillway from April 15 to Aug 30 and up to 60% of total outflow through the ROs from Sep 1 to Nov 15. However, these flow values were adjusted by the temperature blending routine within the CE-QUAL-W2 model (*Q2 MINFLOW* = 0.4) to meet the downstream temperature target optimally. When Measures 721 and 166 were combined with Measure 714 (Alternative 3b), *MINFLOW* values for all outlets were set to 0 which allowed the model to optimize to meet downstream temperature target with no restraint. When Measures 721 and 166 were combined with 720 (operational downstream passage: Alternatives 3a), temperature blending was not used, so that fish passage could be given higher priority.

Measure 479: Hills Creek Dam was built with 3 spillway gates (spillway crest elevation 1495.5 ft) and a spillway channel, designed for extreme flow events. This measure assumes the current spillway gates and spillway channel could be re-designed to enable low-flow releases when the lake is above spillway crest. This would provide more normative temperatures during the summer through the release of warmer water, saving cooler, deeper water for the fall. When Measures 721 and 166 were combined with Measure 714 (Alternative 3a), *MINFLOW* values for all outlets were set to 0 which allowed the model to optimize to meet downstream temperature target with no restraint. When Measures 721 and 166 were combined with 720 (operational downstream passage: Alternatives 3b), temperature blending was not used, so that fish passage could be given higher priority.

NTOM details for Hills Creek, Lookout Point, and Dexter Dams in the Middle Fork Willamette sub-basin are as follows:

- RO prioritization at Hills Creek Dam during evening from 1800 to 2200 hours (approximated by 17% of daily flow) for improved downstream fish passage October to March when lake

elevation is below 1459 feet. A minimum release of 1000 cfs was used when Lookout Point was less than 95% between minimum conservation elevation and the spillway crest until 01 May to supplement for downstream passage operations at Lookout Point during spring.

- Utilize Lookout Point Dam spillway for improved downstream fish passage in the spring (mid-March to May/June when lake elevation is 890-893 ft release all flow all day over the spillway from 15 March to 01 May, then release all flow over the spillway for 60% of the day and all flow through the penstock up to the penstock max for 40% of the day from 02 May to 31 May) and RO use in autumn (15 July to 15 October when lake elevation is less than 887.5 ft release all flow through the RO for 60% of the day and all flow through the penstock up to the penstock max for 40% of the day) for downstream temperature management (similar to Measures 166 and 721 in Alternative 3a). CE-QUAL-W2 models will be allowed to blend between turbines and RO during autumn (TSTR = 196, TEND = 288).
- Deep drawdown and nighttime RO prioritization at Lookout Point Dam for improved downstream fish passage 15 November to 15 December to lake elevation of 750 feet (similar to Measure 40 in Alternative 3a, 3b).
- These rules were simulated in HEC-ResSim and passed onto CE-QUAL-W2 as QOT boundary condition files, without utilizing the blending routine (SELECTC = OFF).

A complete listing of the measure descriptions included in each alternative can be found in Chapter 3 and Appendix A, while the Hydrologic and ResSim modeling assumptions can be found in Appendix B.

1.4 TEMPERATURE TARGETS

Natural temperature patterns and magnitude immediately downstream of each project are estimated using an 'upstream mix' calculation based on Rounds 2010. The 'upstream mix' is a flow-weighted averaging of upstream temperature and a maximum warming rate of 0.11 degrees C per river mile which is decreased for cooler upstream temperatures. The upstream mix calculations were determined for the period of available data. It is assumed that upstream flow and temperatures are reasonable surrogates for natural conditions given most of the watershed is forested and managed by the USFS.

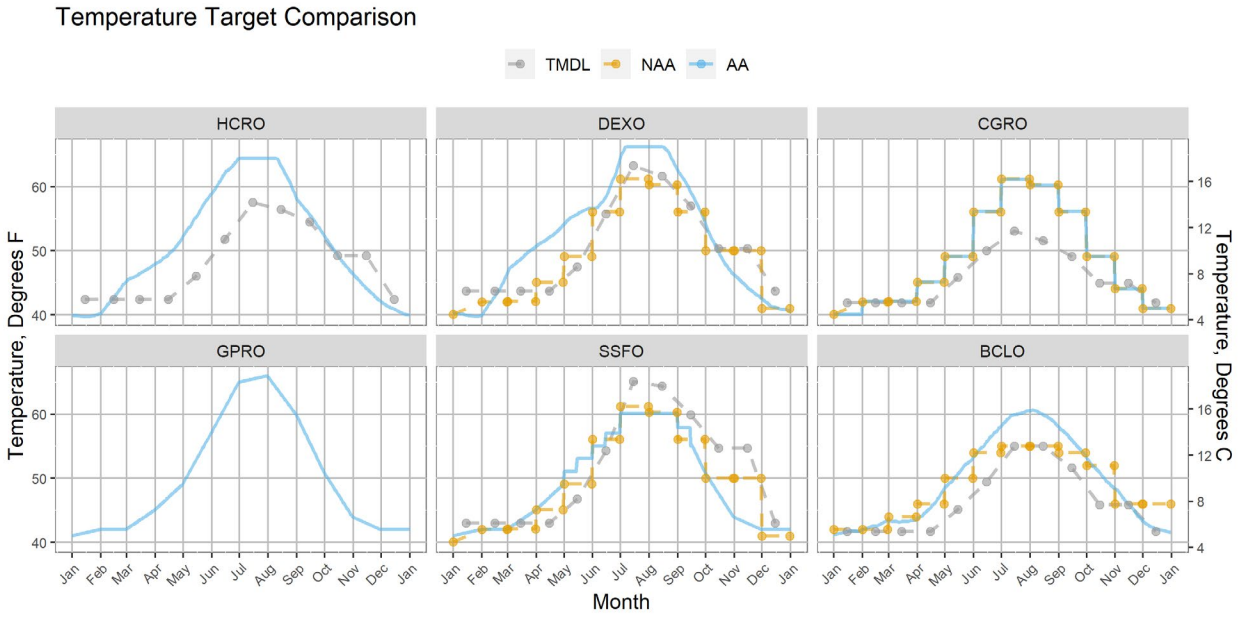
1.4.1 North Santiam

Two separate temperature targets for Detroit Dam were used in the WV EIS:

- The current operational temperature target was applied to NAA (BCLO – NAA in Figure 1-4): Minimum and maximum temperature targets were developed and agreed upon for Detroit Dam by the resource agencies (NOAA, USFWS, and ODFW) in 1984 to benefit the downstream ESA listed anadromous fish (NOAA, 2008). These targets were later modified through the WATER process to be lower in the spring-summer (USACE, 2017). This maximum target is used by the CE-QUAL-W2 model in NAA for the WV EIS to release up to

60% of the maximum volume of warm surface water during the summer, saving cooler deeper water for the fall.

- A target based on the long-term water temperature data record above Detroit dam was applied to all action alternatives (*BCLO – AA*) in Figure 1-4 and Table 1-6. This temperature target was based on long-term average daily of the 7dADM without-dam water temperatures estimates at the location of Detroit Dam using methods developed by Rounds (2010) and further in (Buccola, et al., 2012). This target was applied further in the design of the Selective Withdrawal Structure at Detroit (USACE, 2019b) and ranges from about 5.1°C (41.2°F) in winter to a high of near 15.8°C (60.5°F) in August (Table 1-5).



Sites are defined as below the following dams: Detroit-Big Cliff: BCLO, Green Peter: GPRO, Foster: SSFO, Cougar: CGRO, Hills Creek: HCRO, Lookout Point-Dexter: DEXO. Note: HCRO and GPRO sites did not have NAA operational temperature targets defined.

Figure 1-4. Temperature targets used at each CE-QUAL-W2 reservoir temperature model within the WVS EIS for all alternatives except No Action ("AA") compared to maximum temperature targets used operationally by USACE from 2017 to 2022 ("NAA") and the Oregon Department of Environmental Quality (ODEQ) Total Maximum Daily Load Monthly Median Target Temperatures ("TDML").

Table 1-5. Comparison of Oregon Department of Environmental Quality (ODEQ) Total Maximum Daily Load Monthly Median Target Temperatures ("TDML"), maximum temperature targets used operationally ("NAA"), and temperature targets used in the WVS EIS temperature simulations for all alternatives except No Action ("AA").

Mon	HCRO TMDL	HCRO AA	DEXO TMDL	DEXO NAA	DEXO AA	CGRO TMDL	CGRO NAA	CGRO AA	GPRO AA	SSFO TMDL	SSFO NAA	SSFO AA	BCLO TMDL	BCLO NAA	BCLO AA
Jan	42.4	40.0	43.7	40.1	40.4	41.9	40.1	40.1	41.0	43.0	40.1	41.0	41.7	42.0	41.2
Feb	42.4	40.2	43.7	42.0	39.9	41.9	42.0	42.1	42.0	43.0	42.0	42.0	41.7	42.0	42.0
Mar	42.4	45.2	43.7	42.1	46.6	41.9	42.1	42.1	42.1	43.0	42.1	42.1	41.7	44.0	43.4
Apr	42.4	48.0	43.7	45.1	50.7	41.9	45.1	45.1	45.1	43.0	45.1	45.1	41.7	46.0	43.7
May	46.0	52.3	47.5	49.1	54.2	45.9	49.1	49.1	49.3	46.8	49.1	51.1	45.1	50.0	48.5
Jun	51.8	59.0	55.8	56.1	56.6	50.0	56.1	56.1	57.3	54.3	56.1	55.0	49.5	54.0	53.4
Jul	57.6	64.4	63.3	61.2	64.6	53.1	61.2	61.2	65.0	65.1	61.2	60.1	55.0	55.0	58.2
Aug	56.5	64.4	61.7	60.3	66.2	51.6	60.3	60.3	65.8	64.4	60.3	60.1	55.0	55.0	60.5
Sep	54.5	58.1	57.0	56.1	62.5	49.1	56.1	56.1	59.7	59.9	56.1	57.9	51.6	54.0	58.0
Oct	49.3	52.3	50.4	50.0	54.2	45.0	49.1	49.1	50.8	54.7	50.0	50.8	45.9	52.0	53.2
Nov	49.3	46.4	50.4	50.0	46.3	45.0	44.1	44.1	43.9	54.7	50.0	43.9	45.9	46.0	48.4
Dec	42.4	42.1	43.7	41.0	42.6	41.9	41.0	41.0	42.0	43.0	41.0	42.0	41.7	46.0	43.3

Monthly values for AA targets are provided based on the target for the 1st day of each month even though targets vary daily. Sites are defined as below the following dams: Detroit-Big Cliff: BCLO, Green Peter: GPRO, Foster: SSFO, Cougar: CGRO, Hills Creek: HCRO, Lookout Point-Dexter: DEXO. Note: HCRO and GPRO sites did not have NAA operational temperature targets defined.

Table 1-6. Temperature targets used in WV EIS and sources.

Site	Alternatives Applied	Citations
Detroit-Big Cliff (BCLO)	NAA	NOAA, 2008; USACE, 2017
	1, 2a, 2b, 3b, 4, 5, NTOM	Buccola, et al., 2012; USACE, 2019b
Green Peter (GPRO)	1, 2a, 2b, 3a, 4, 5, NTOM	Moore, 1964; Buccola, 2017
Foster (SSFO)	1, 2a, 2b, 3a, 4, 5, NTOM	Moore, 1964; Buccola, 2017; USACE, 2020c
Cougar (CGRO)	NAA, 1, 2a, 4, NTOM	NOAA, 2008
Hills Creek (HCRO)	3a, 4	Moore, 1964; Buccola, et al., 2016; USACE, 2016
Lookout Point-Dexter (DEXO)	1, 3b, 4, NTOM	Moore, 1964; Buccola, et al., 2016; USACE, 2016

1.4.2 South Santiam

A temperature target based on measured monthly mean temperature 0.7 mi upstream from the mouth of the Middle Santiam River, prior to construction of Green Peter and Foster Dams from 1954 to 1962 (site 14-1865 in Moore, 1964), was developed for both the GPR and FOS models in all WV EIS alternatives (*GPR_Moore1964* in Buccola, 2017; *GPRO - AA* in Figure 1-4). This temperature target based on pre-dam temperature measurements from the Middle Santiam River ranges from about 5.0 °C (41.0 °F) in winter to a high of near 19.0 °C (66.2 °F) in July (Table 1-5).

A temperature target for Foster was developed in Buccola (2017) using similar methods as described above for Green Peter (Figure 1-4). However, the operational rules at Foster balancing flood risk management, re-regulating Green Peter, fish passage, etc. resulted in limited ability for the temperature model to blend flow between release outlets to meet a target. Further, the elevation of the spillway crest and turbine intakes at Foster Dam (both relatively deep), limits the ability to affect water temperature immediately downstream of Foster and is typically dominated by Green Peter release temperature and the unregulated South Santiam River temperature upstream of Foster.

1.4.3 South Fork McKenzie

Minimum and maximum temperature targets were developed and agreed upon for Cougar Dam by the resource agencies (NOAA, USFWS, and ODFW) in 1984 to benefit the downstream ESA listed anadromous fish (NOAA, 2008). The maximum target is used by the CE-QUAL-W2

model in all WV EIS alternatives to release the maximum volume of warm surface water during the summer, saving cooler deeper water for the fall.

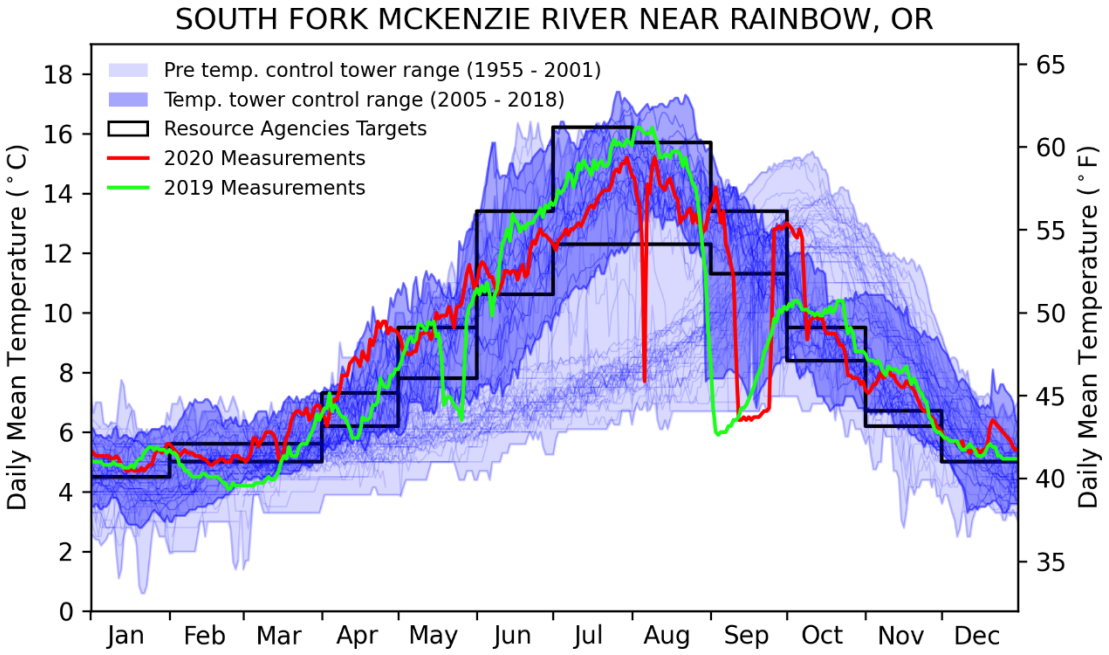


Figure 1-5. Resource Agencies (RA) Targets for South Fork McKenzie River below Cougar Dam. The maximum RA target was used for the Cougar Reservoir CE-QUAL-W2 temperature model in each of the WV EIS alternatives.

1.4.4 Middle Fork Willamette

Temperature targets were developed for Hills Creek and Lookout Point Dams (Buccola, et al., 2016; USACE, 2016) based on upstream temperature and flow data from USGS gages. The Hills Creek temperature target (HCR Upstream Mix in Figure 1-4) was based on Middle Fork Willamette River near Oakridge, OR, USGS 14144800 (located 8.0 river miles upstream of the dam) and Hills Creek above Hills Creek Reservoir, USGS 14144900 (located 4.1 river miles upstream of the dam). A flow-weighted average temperature of these two tributaries was calculated using a watershed area estimation method as a surrogate for missing flow data (264 and 52.7 square miles respectively).

The calculations for developing a temperature target downstream of Lookout Point and Dexter Dams (LOP Upstream Mix in Figure 1-4) were more complex. Upstream temperature and flow were from North Fork of Middle Fork Willamette River near Oakridge, OR (USGS 14147500, 5.0 river miles upstream of the Lookout Point Reservoir) and the upstream mix temperature and inflow at Hills Creek Reservoir (calculated as described above; 11.5 miles upstream of Lookout Point Reservoir). Little data is available for Salt and Salmon Creeks, tributaries to the Middle Fork downstream of Hills Creek Dam and upstream of Lookout Point Reservoir. Therefore, it was assumed that water temperature at the mouth of these tributaries is similar to the North

Fork measurements and Middle Fork upstream mix calculations. It is 18.7 river miles from the head of the Lookout Point Reservoir to the gage downstream of Dexter Dam.

The warmest daily mean outflow temperature from Hills Creek Dam between 1978 and 2014 typically occurs around October 8th and has ranged 13.9 to 17.6 degrees C with a mean of 14.9 degrees C (Figure 1-6). The peak upstream mix temperature between 1956 and 2014 typically occurs on July 27th and has ranged from 13.8 to 20.6 with a mean of 16.6 degrees C. The magnitude and pattern of the upstream mix temperatures is similar to the measurements of the North Fork of the Middle Fork Willamette near its mouth, an unregulated system. The headwaters of both watersheds are in the high Cascades and the Middle Fork watershed area is 392 square miles while the North Fork is 246 square miles. The temperature similarity increases confidence in using the upstream mix calculation as a surrogate for natural temperatures.

The warmest daily mean outflow temperature from Dexter Dam between 1978 and 2014 typically occurs around September 14th and has ranged 14.6 to 19.5 degrees C with a mean of 16.3 degrees C (Figure 1-7). The peak upstream mix daily mean temperature between 2001 and 2013 typically occurs around August 4th and has ranged from 18.0 to 21.1 with a mean of 19.4 degrees C. The magnitude and pattern of the upstream mix calculation is similar to monthly average temperature collected prior to construction of the dams from 1950 – 1953 (Moore 1964). The temperature similarity increases confidence in using the upstream mix calculation as a surrogate for natural temperatures.

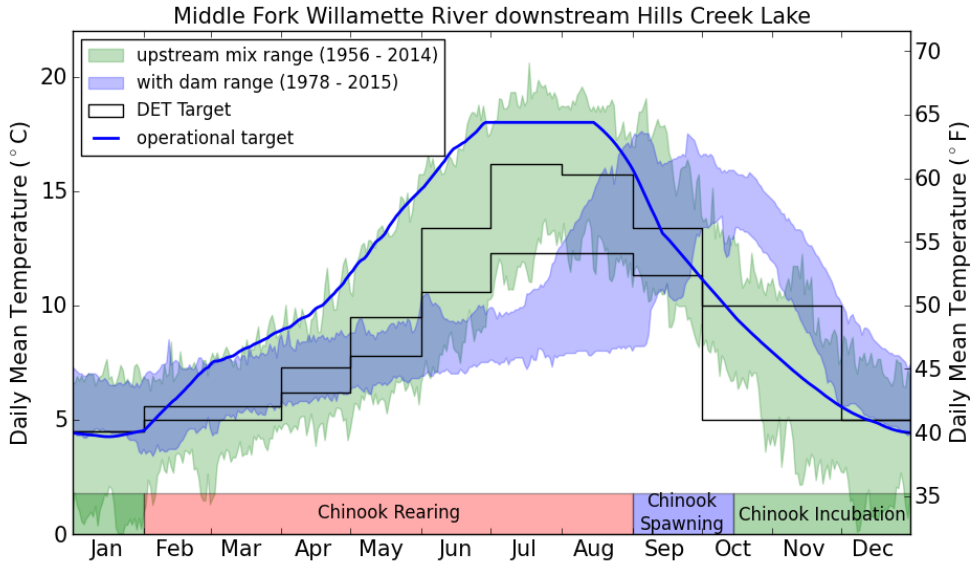


Figure 1-6. Hills Creek Dam operation temperature control target with comparison to relevant temperature ranges, the 2015 Detroit (DET) temperature target and anticipated Chinook salmon life stages.

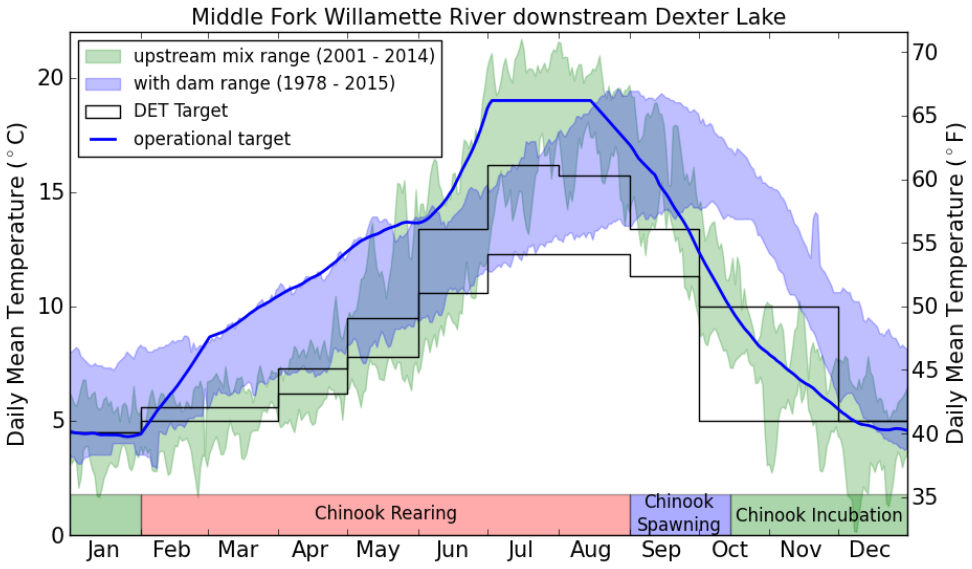


Figure 1-7. Lookout Point Dam operation temperature control target with comparison to relevant temperature ranges, the Detroit (DET) temperature target and anticipated Chinook salmon life stages

1.5 SIMULATED RESULTS

The model CE-QUAL W2 was utilized to simulate water temperatures at all sub-basins and downstream to Salem, except for the Coast Fork and Long Tom sub-basins, for the years 2011, 2015, and 2016. Each year represented a different climatological condition: wet year (2011), dry year (2015), and average year (2016). CE-QUAL-W2 reservoir water temperature model output was analyzed for each of the three calendar years and alternative, aside from Alternative 5 (qualitatively assessed due to time constraints and close resemblance to Alternative 2b). CE-QUAL-W2 water temperature simulations in the reservoirs and downstream were based on inflow discharge, inflow water temperature, air temperature, dew point temperature, wind speed, wind direction, solar radiation, cloud cover, and gate-specific outflow as data inputs for each simulation. Daily average gate-specific outflows and lake elevations were derived from HEC-ResSim simulations under each alternative. Lake surface elevations in CE-QUAL-W2 reservoirs were forced to match lake levels from HEC-ResSim through a *water balance* process in which a time-series of distributed tributary inflow values (*QDT*) was added to (or subtracted from) specific to each reservoir, year, and alternative model run. Inflows generated by HEC-ResSim were occasionally near zero, due to evaporation loss assumptions at each reservoir.

This section will focus on discussion of the water management and water temperature implications generally between April and December each year simulated through CE-QUAL-W2, as this is the time of year that is most impacted by the heat-exchange process occurring in the reservoirs during summer and conveyance of heated water downstream of the dams through autumn. A full description of hydrology and water management operations throughout the

entire calendar year can be found in the Hydrology and Hydraulics Appendix B and Chapter 3.2. Please refer to section 3.5 Water Quality Affected Environment for additional discussion of water temperature under the NAA.

1.5.1 No Action Alternative (NAA)

The NAA simulations are based on HEC-ResSim inflow hydrology (including constant reservoir-specific evaporation rates in each year), gate-specific outflows, and lake surface elevations that are different from those that took place historically. Simulated outflow temperatures depend on lake surface elevations and gate-specific outflow data from HEC-ResSim rulesets established for the NAA to allow for equivalent assumptions in each year and could differ from measurements in 2011, 2015, and 2016. Differences in lake surface elevation and gate-specific outflows can affect lake surface area, volume, heat content stored in the lake, and the amount of heat released in downstream water in a given year. See the section Comparison of NAA with Measurements for more details comparing simulated HEC-ResSim operations and simulated NAA temperatures with measurements.

1.5.1.1 North Santiam Dams

The North Santiam sub-basin is represented at BCLO and includes Detroit reservoir interim temperature operations. NAA included up to 60% of total outflow released through the Detroit Dam spillway from June 1 to August 30 (if/when the lake is above the spillway crest) and up to 60% of total outflow released through the Regulating Outlets from October 1st to November 15. The low water year of 2015 (Figure 1-9) resulted in Detroit Lake not filling to the spillway crest (Figure 1-11), which resulted in relatively warmer temperatures compared to 2011 (Figure 1-8) and 2016 (Figure 1-10), especially in July-October. Water temperature under the NAA would be similar to observed values since the issuance of the BiOp and implementation of operational water temperature management (Figure 1-12; Figure 1-13).

1.5.1.1.1. Detroit

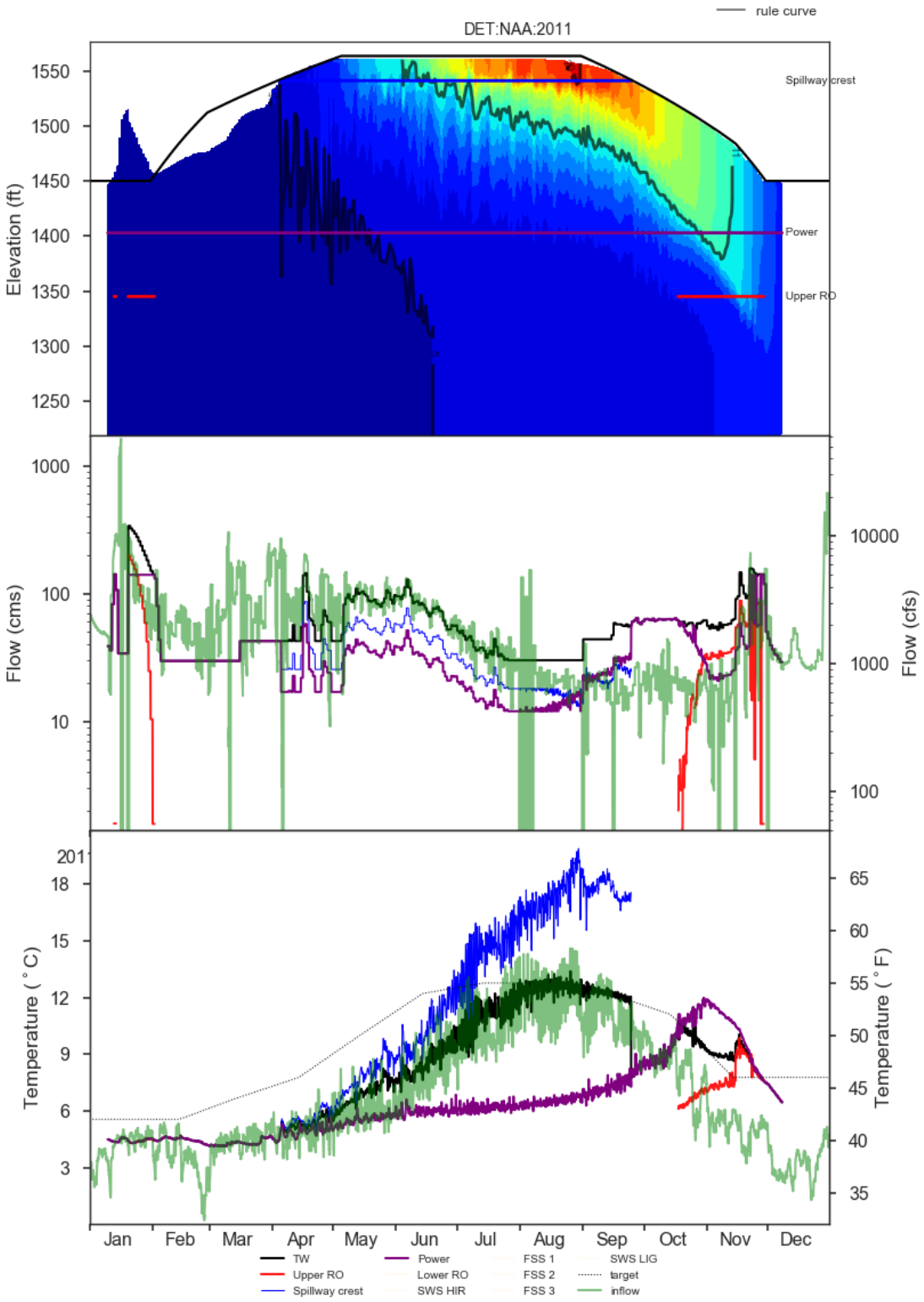


Figure 1-8. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and outflow temperatures (bottom) at Detroit under NAA in 2011.

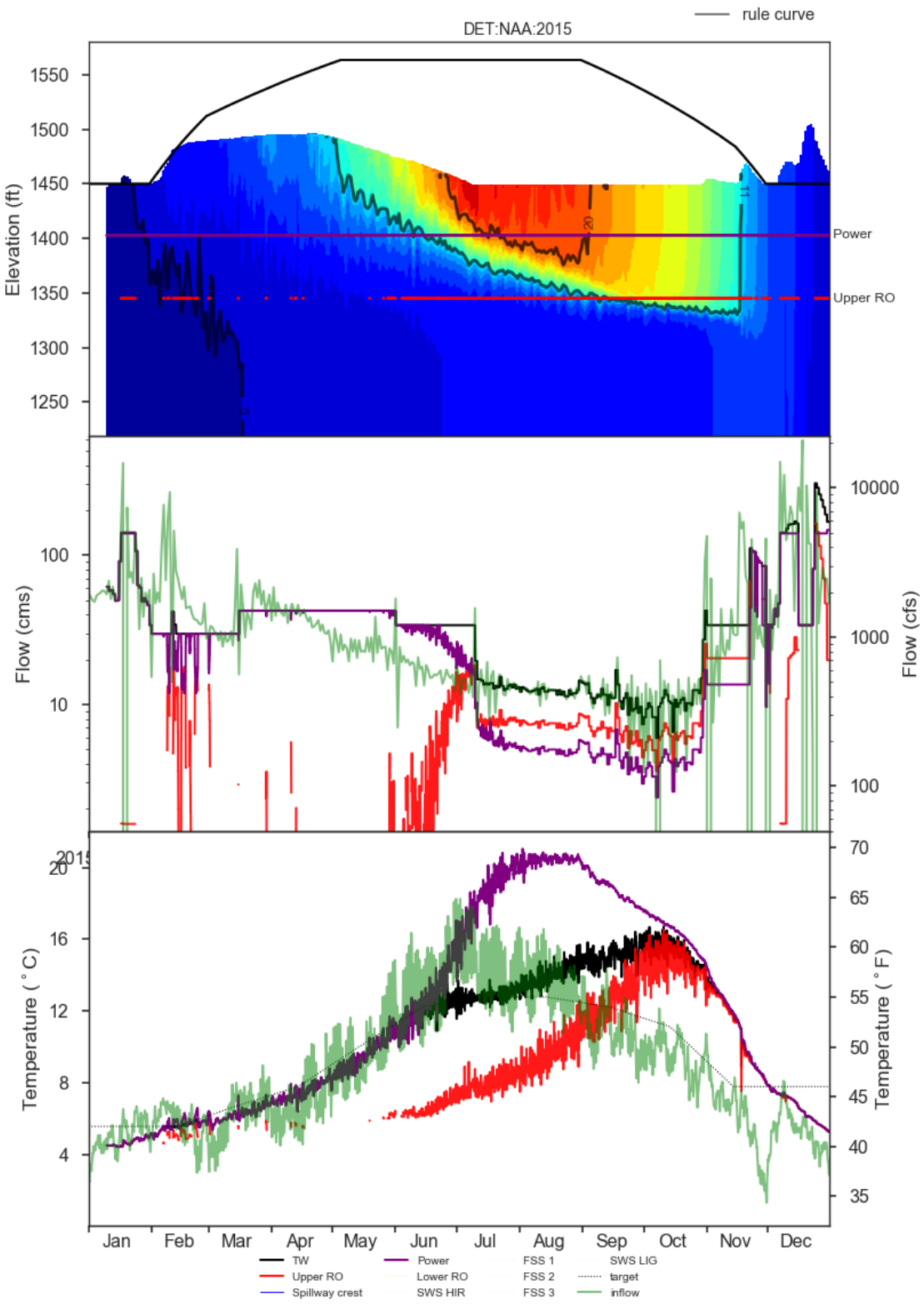


Figure 1-9. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under NAA in 2015.

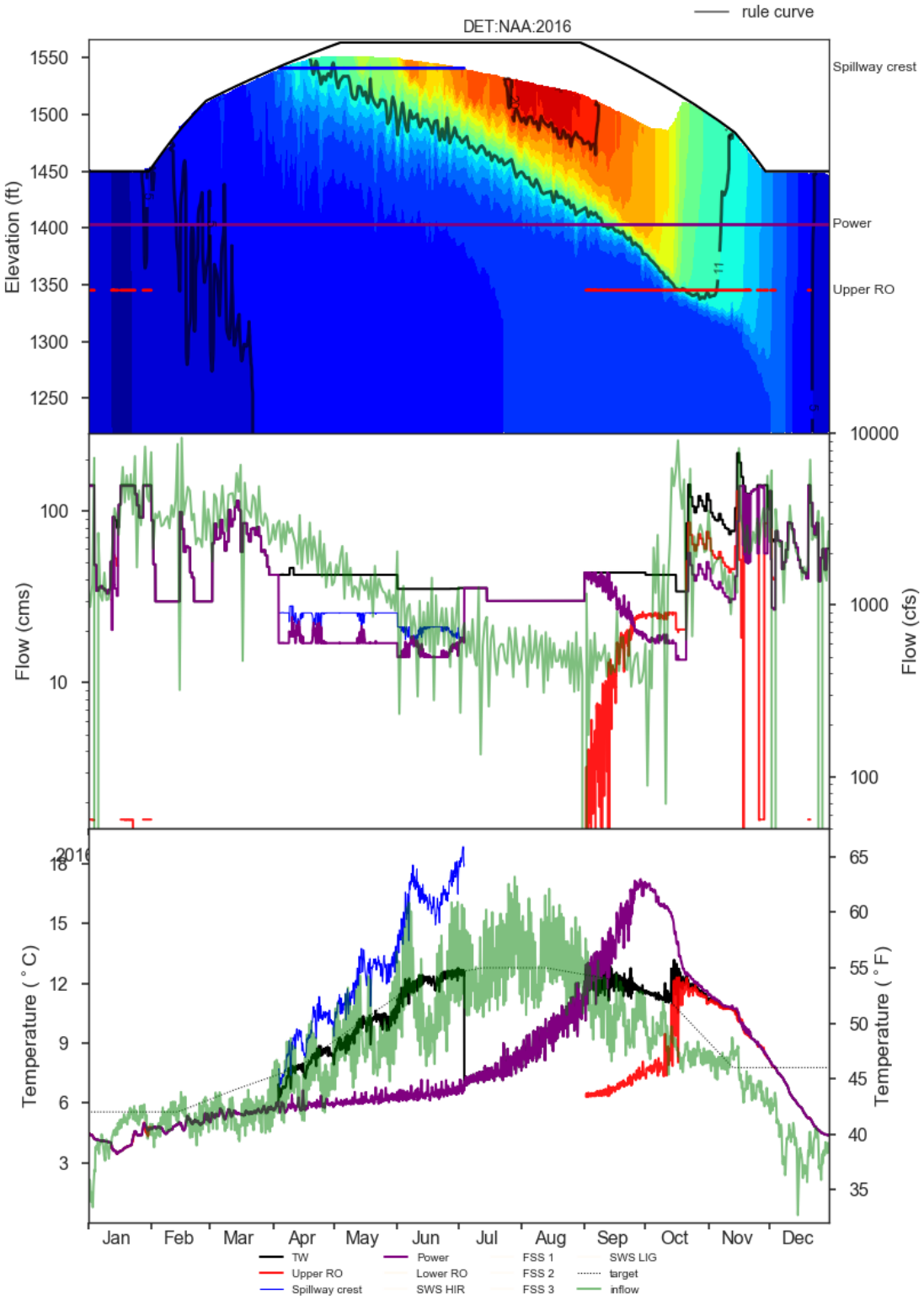


Figure 1-10. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under NAA in 2016.

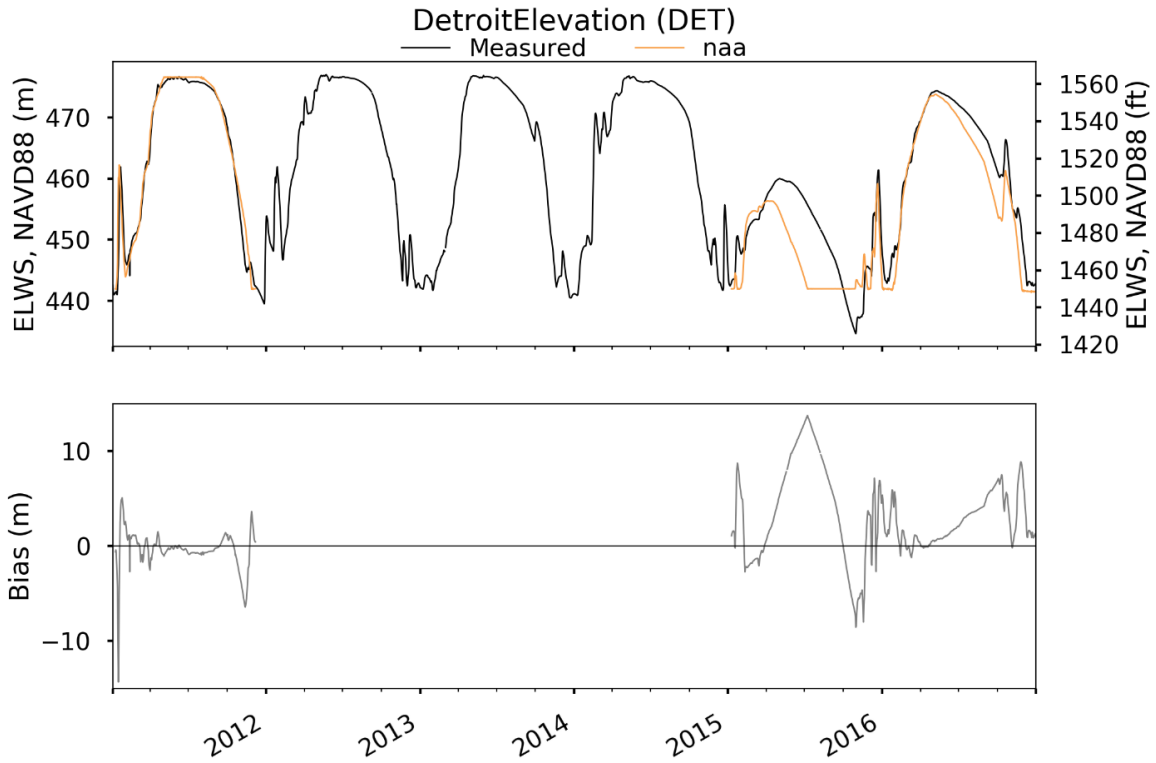


Figure 1-11. Comparison of DET Daily Lake Surface Elevations in NAA vs Measured.

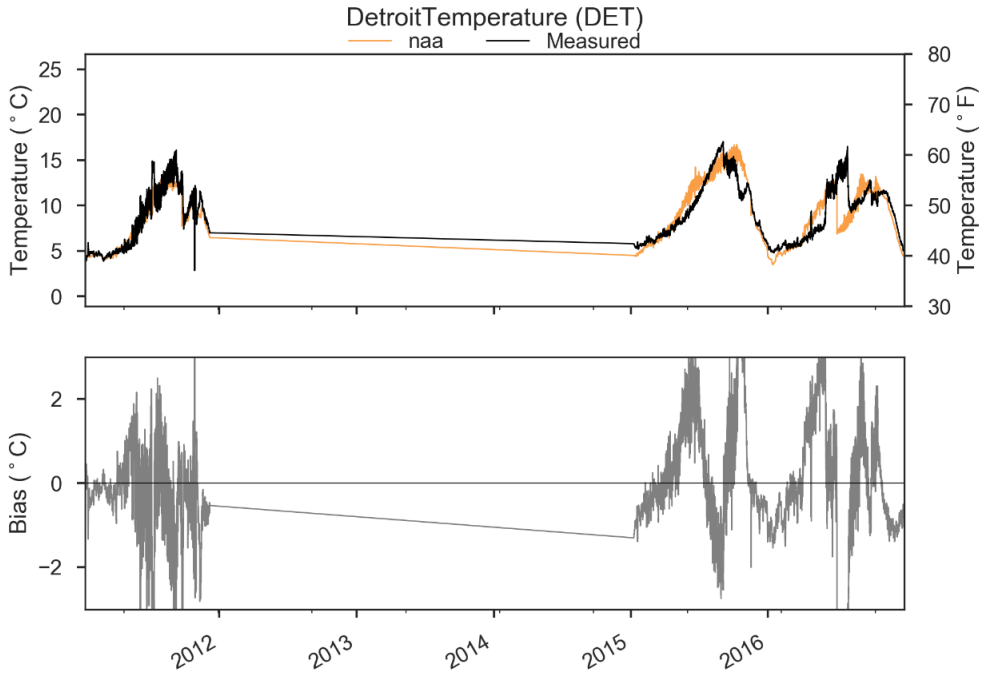


Figure 1-12. Comparison of DET Outflow Temperatures in NAA vs Measured.

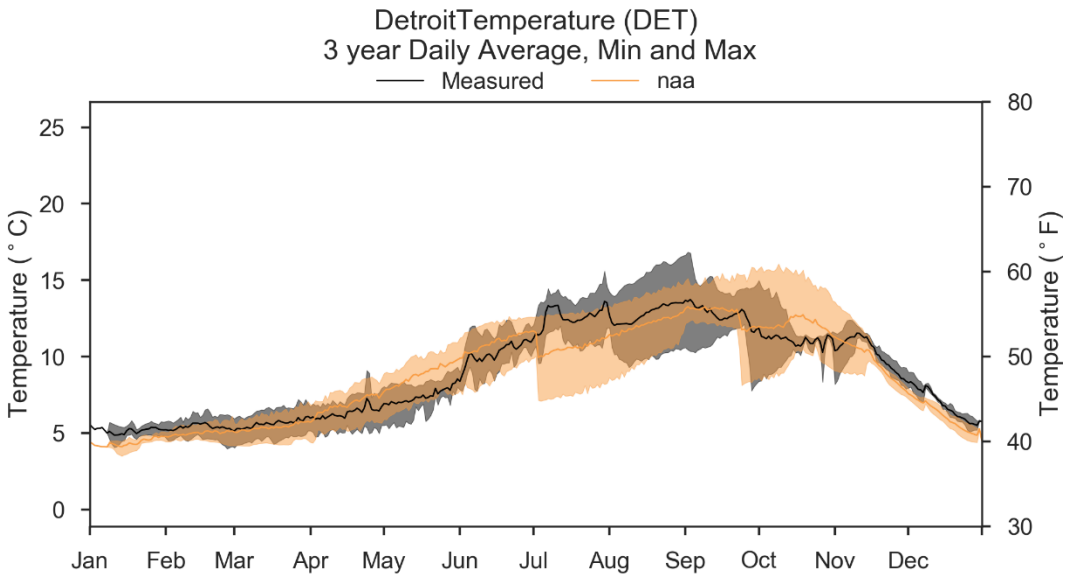


Figure 1-13. Comparison of DET 3-year Average, Min, Max Daily Outflow Temperatures in NAA vs Measured.

1.5.1.2 South Santiam Dams

1.5.1.2.1 Green Peter

Green Peter operations in NAA are identical to those under the Affected Environment, consisting of relatively deep releases from the Power penstock and ROs year-round (Figure 1-14; Figure 1-15; Figure 1-16). Differences between NAA and measurements in lake levels in the three calendar-year scenarios were relatively minor, aside from 2015 (Figure 1-17), and generally led to differences in outflow tailwater temperatures less than 2 degrees Celsius. Short-term differences between NAA and Measurements in fall of 2016 can be attributed to model sensitivity during fall storms as the lake is drafted and the thermocline depth is affected by upstream inflow temperatures (Figure 1-18; Figure 1-19).

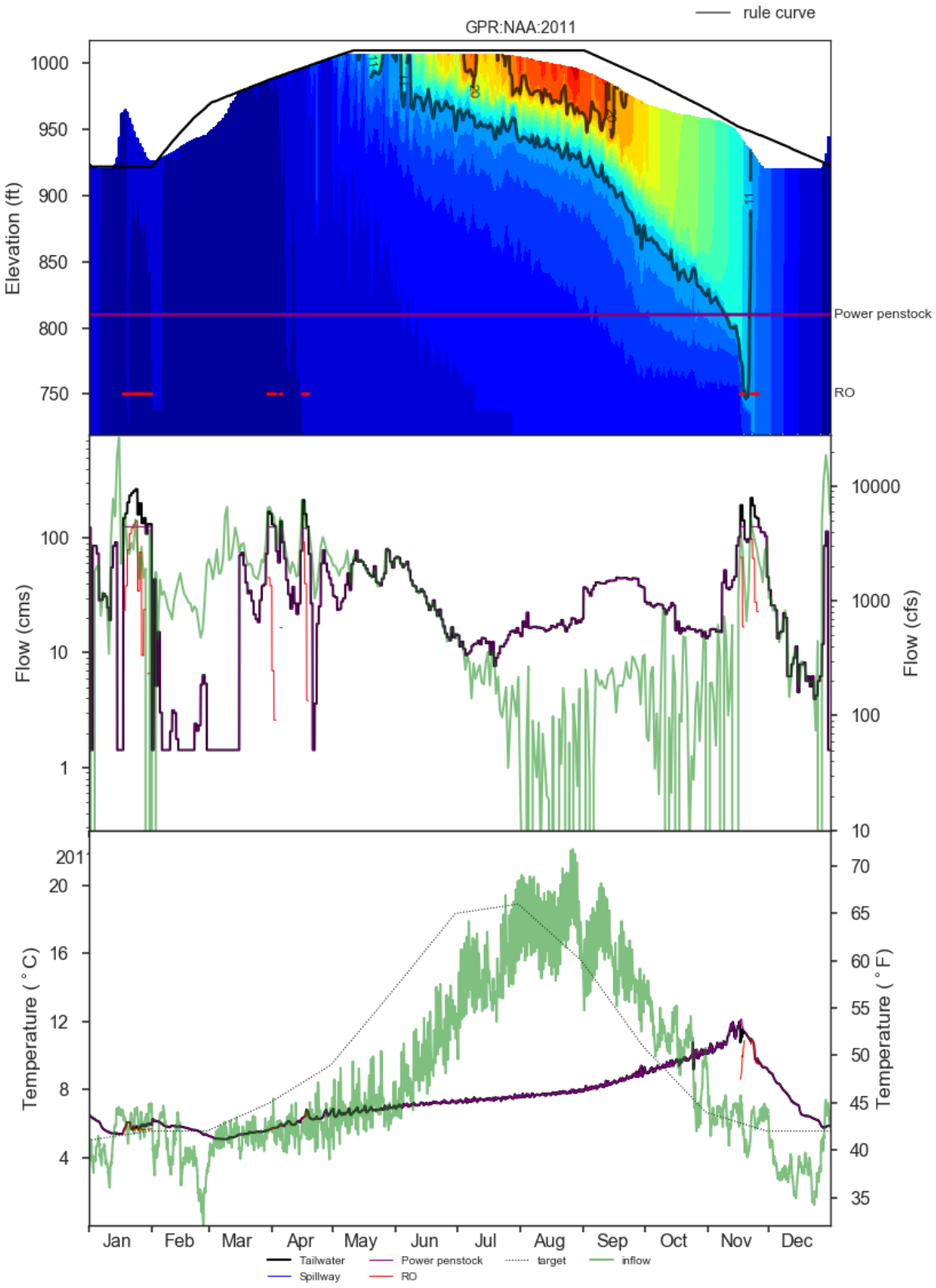


Figure 1-14. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR in 2011.

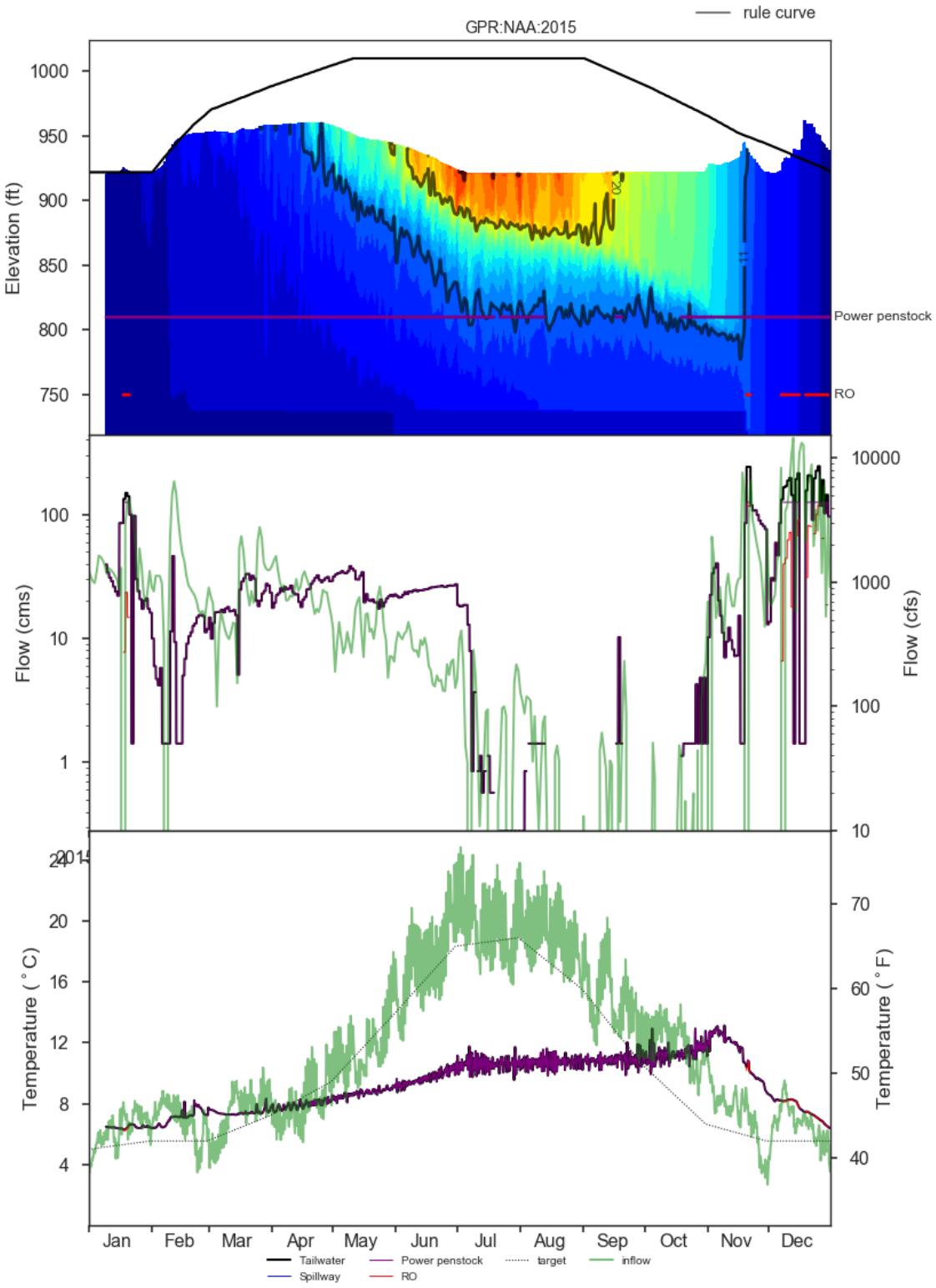


Figure 1-15. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR in 2015.

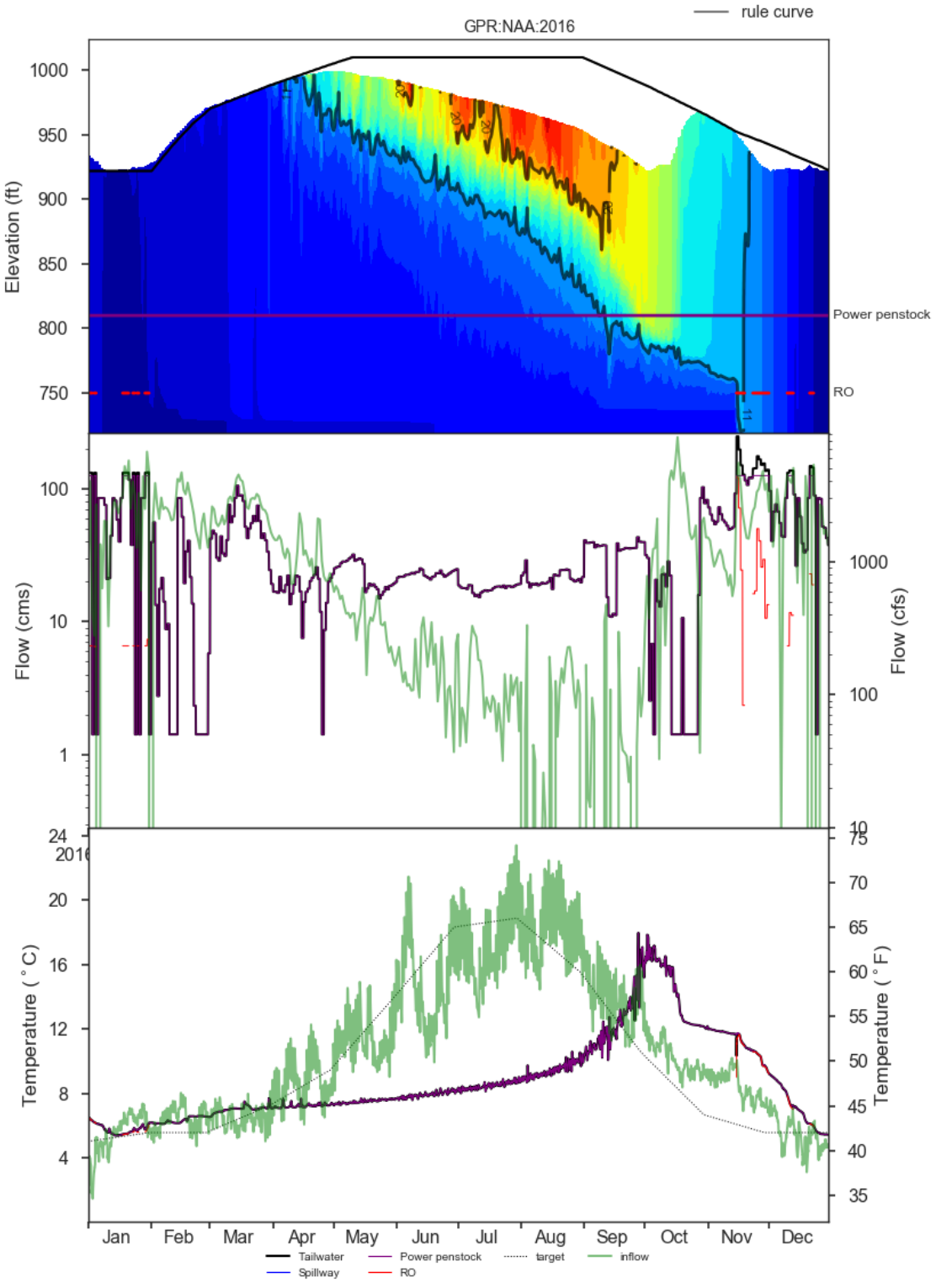


Figure 1-16. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR in 2016.

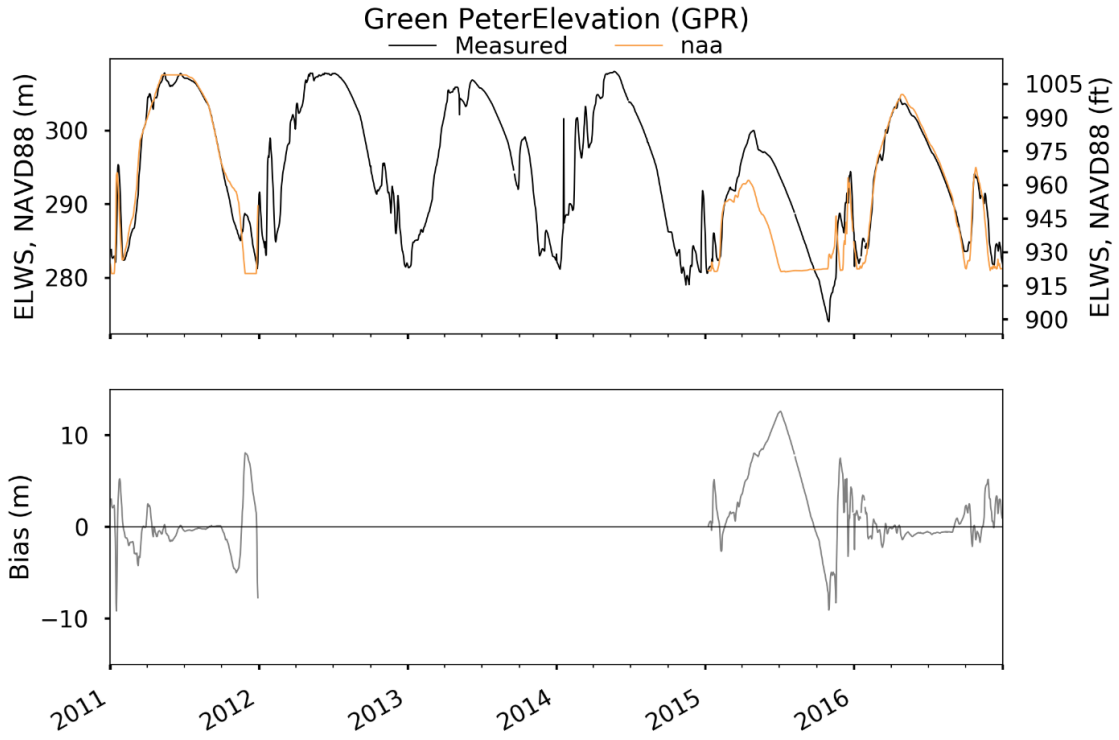


Figure 1-17. Comparison of GPR Daily Lake Surface Elevations in NAA vs Measured.

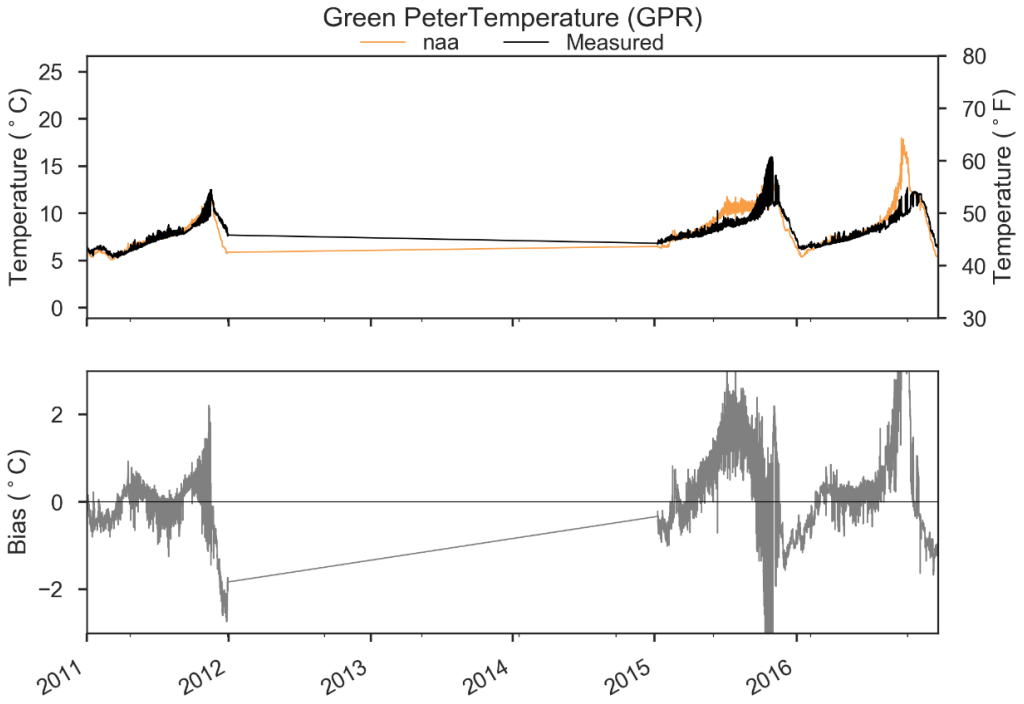


Figure 1-18. Comparison of GPR Outflow Temperatures in NAA vs Measured.

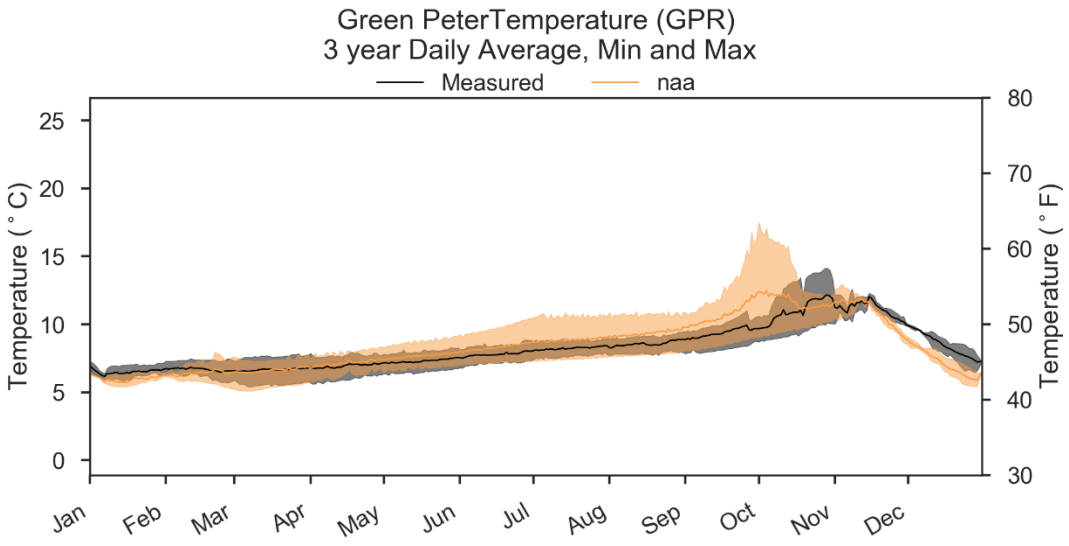


Figure 1-19. Comparison of GPR 3-year average, min, max outflow temperatures in NAA vs Measured.

1.5.1.2.2 Foster

At Foster, temperature operations under the NAA would remain similar to the Affected Environment whereby the Foster fish weir and night-time spill operations of 300 cfs would remain in effect from June 16 until August 15 (Figure 1-20; Figure 1-21; Figure 1-22). As Foster is a reregulating dam for Green Peter, Foster Lake temperature was affected by Green Peter Dam operations release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the temperature pattern (Sullivan and Rounds, 2021). Major differences between NAA and measurements can be linked to operational lake levels (Figure 1-23), especially in 2015 (Figure 1-24), where the time during which the fish weir could be used was reduced. Generally, NAA was warmer in July-October and cooler in December compared to measurements (Figure 1-25).

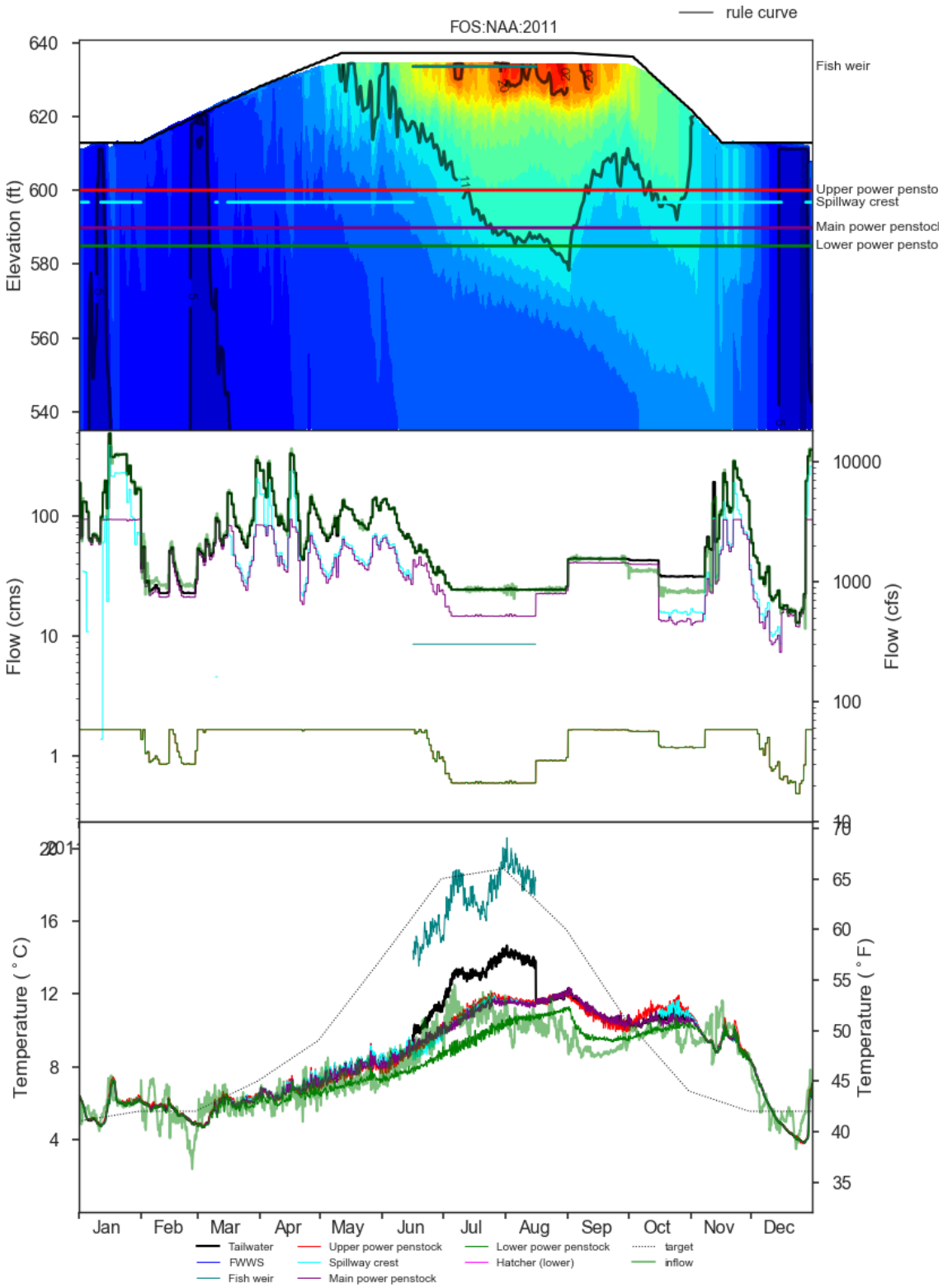


Figure 1-20. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and outflow temperatures (bottom) at FOS in 2011.

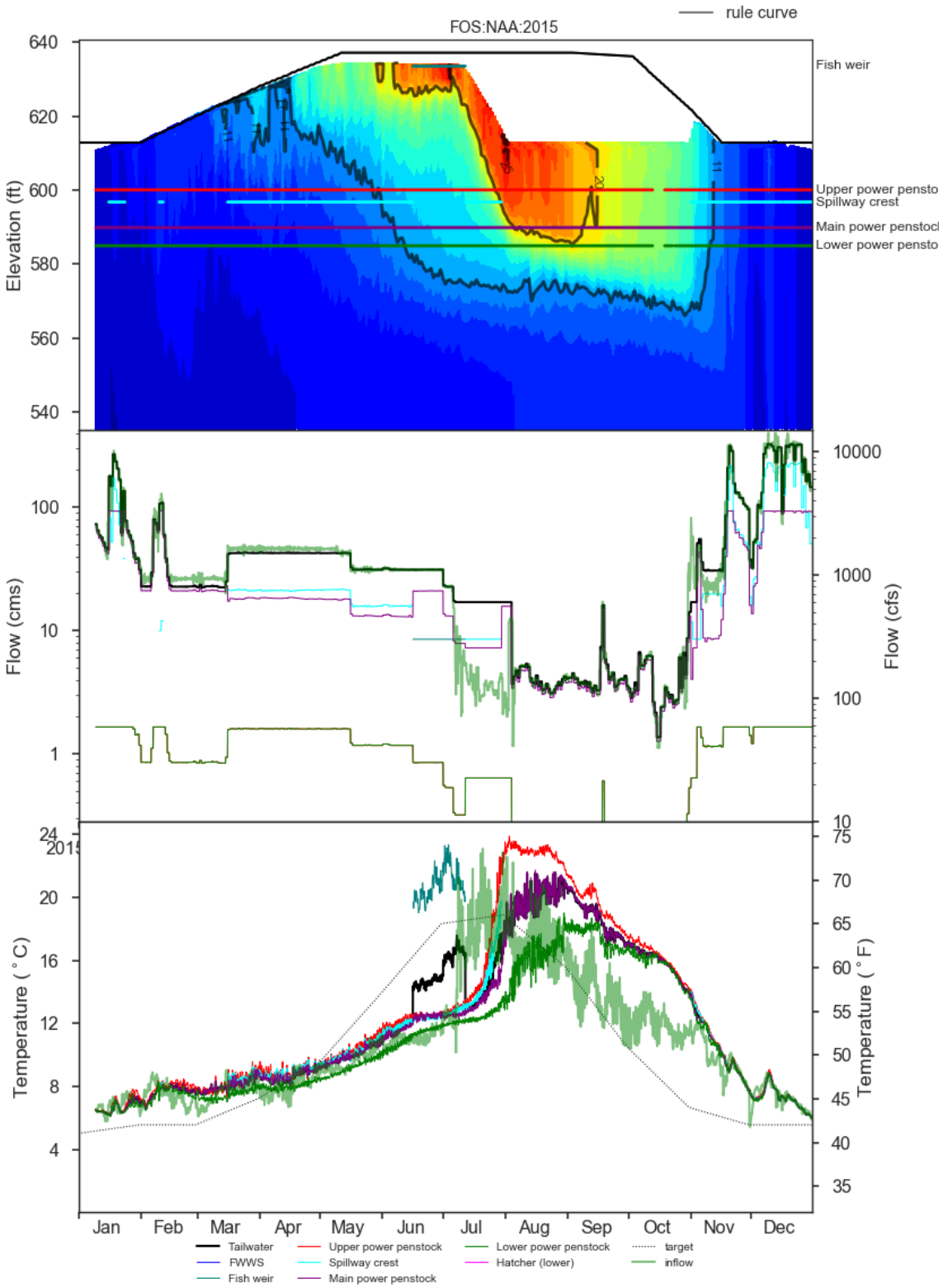


Figure 1-21. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and outflow temperatures (bottom) at FOS in 2015.

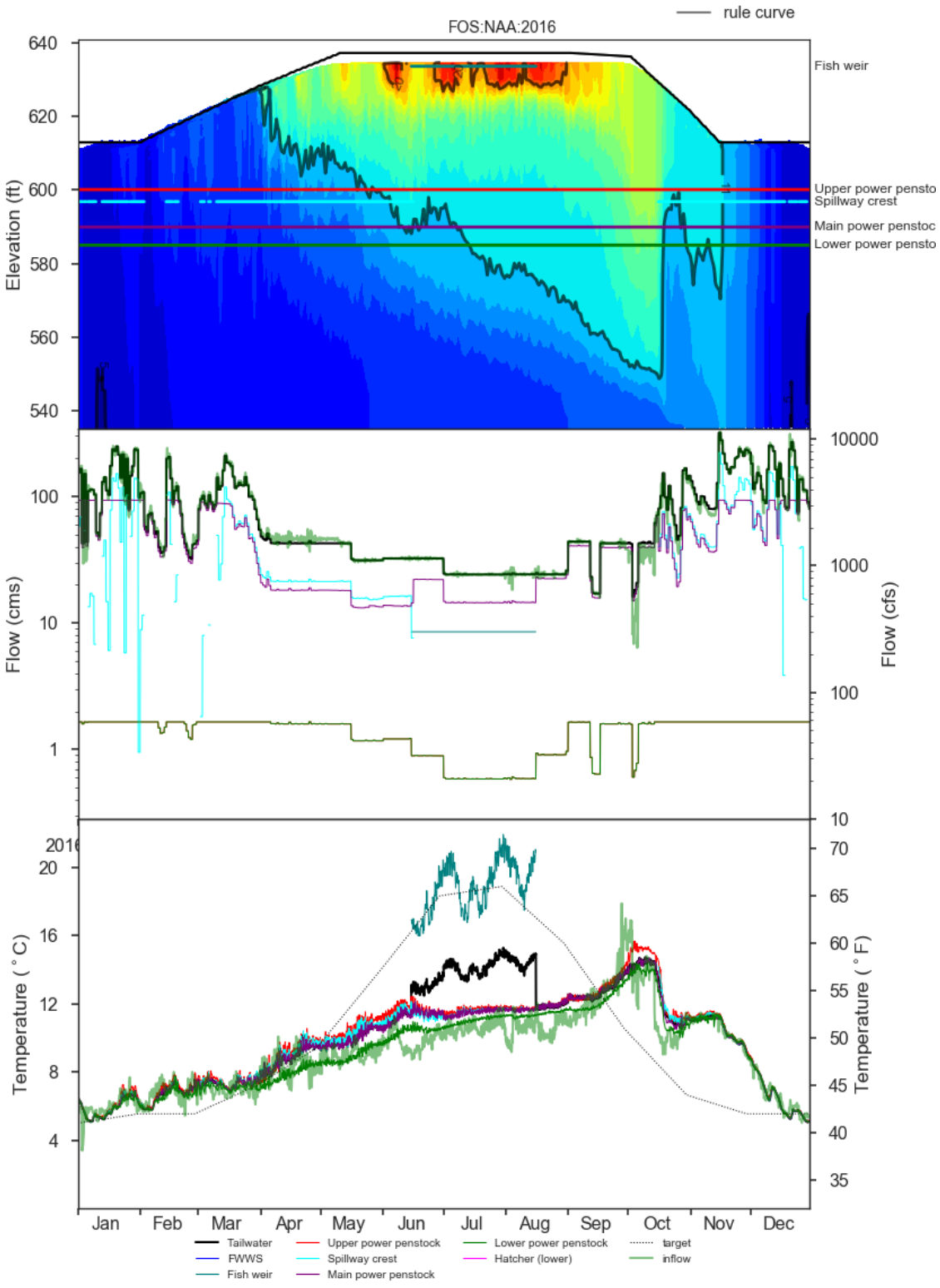


Figure 1-22. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and outflow temperatures (bottom) at FOS in 2016.

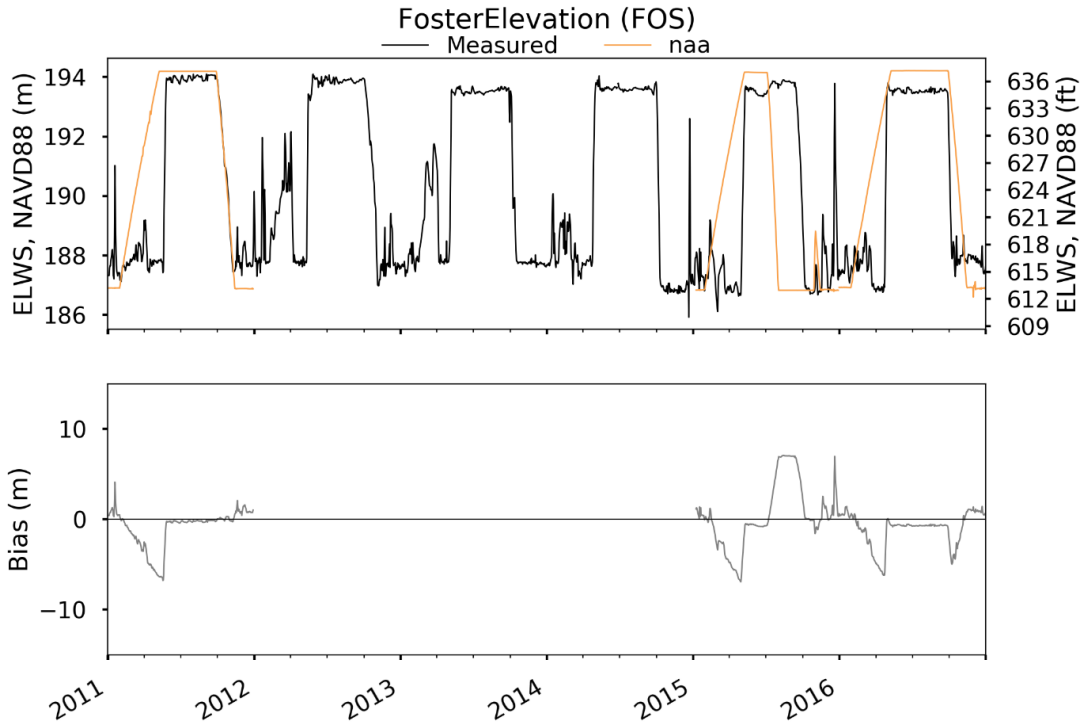


Figure 1-23. Comparison of FOS Daily Lake Surface Elevations in NAA vs Measured.

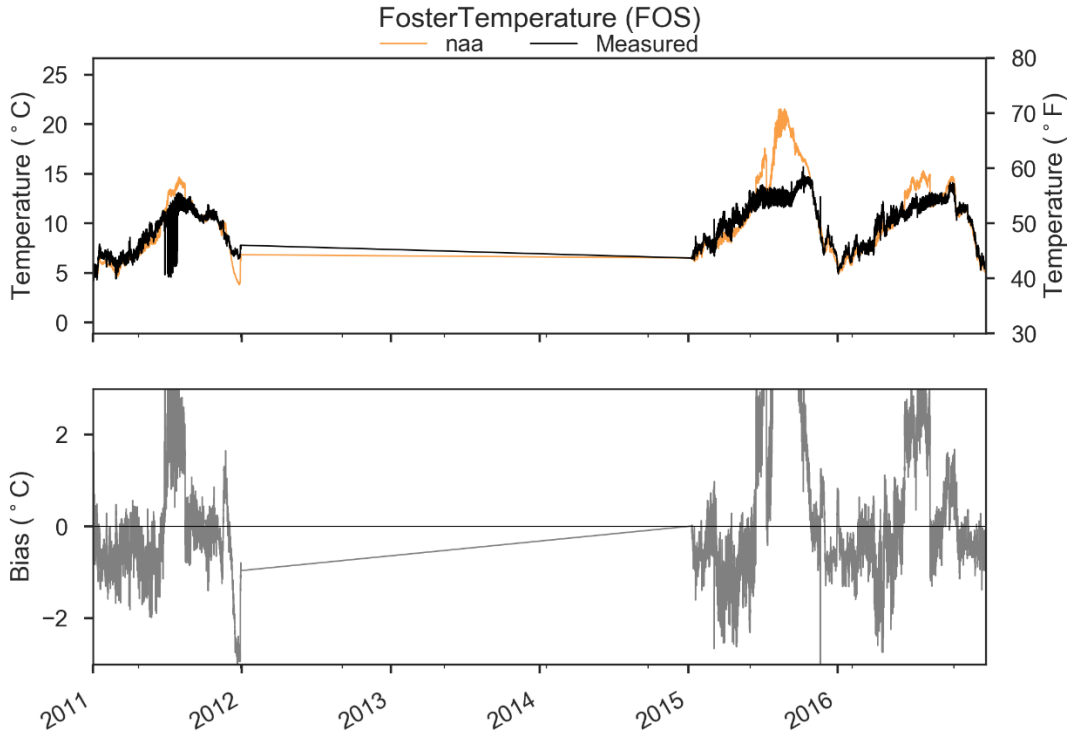


Figure 1-24. Comparison of FOS Outflow Temperatures in NAA vs Measured.

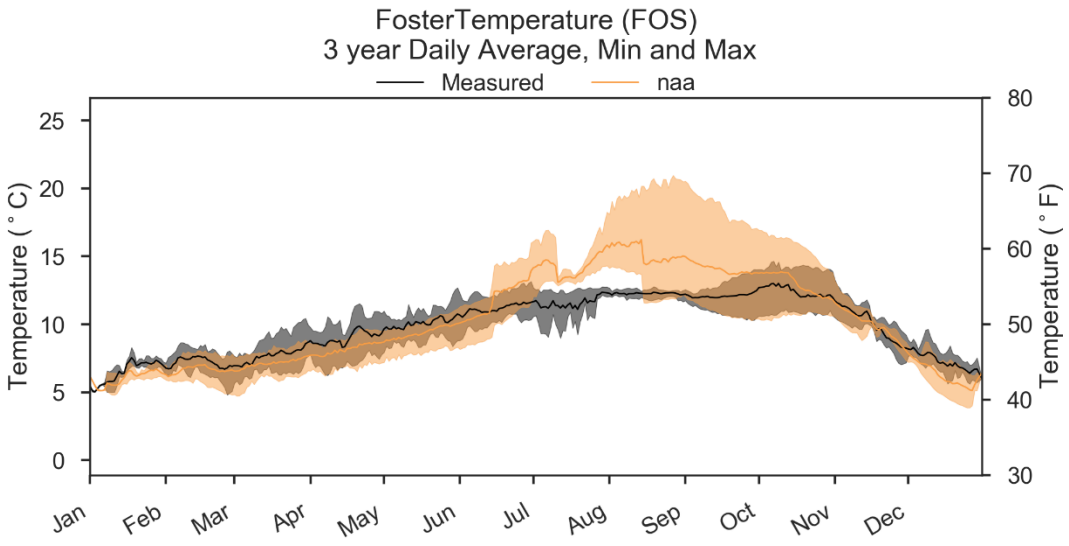


Figure 1-25. Comparison of FOS 3-year average, min, max outflow temperatures in NAA vs Measured.

1.5.1.3 McKenzie Dams

1.5.1.3.1 Cougar

The Cougar water temperature control tower would continue to be operated annually to draft water to 1541 ft elevation by November 15 under NAA. Once water elevation is below 1541 ft there are no temperature control operations (Figure 1-26; Figure 1-27; Figure 1-28). The largest temperature differences between NAA and measurements can be linked to operational lake levels (Figure 1-29), especially in 2016 (Figure 1-30), when a drawdown occurred in the measurement record that resulted in no ability to use the temperature control tower. Generally, NAA was warmer in July and cooler in November-December compared to measurements (Figure 1-31).

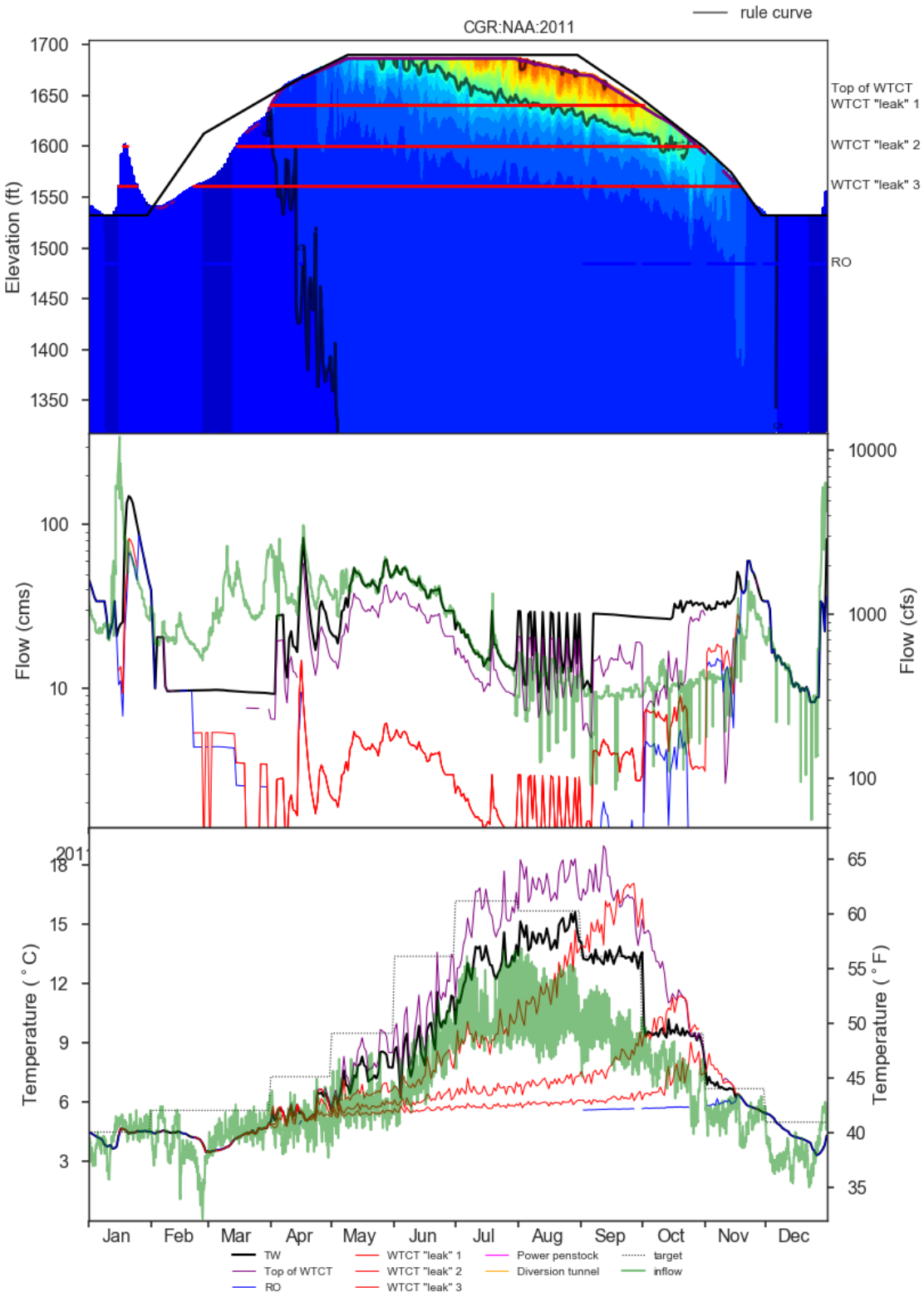


Figure 1-26. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR in 2011.

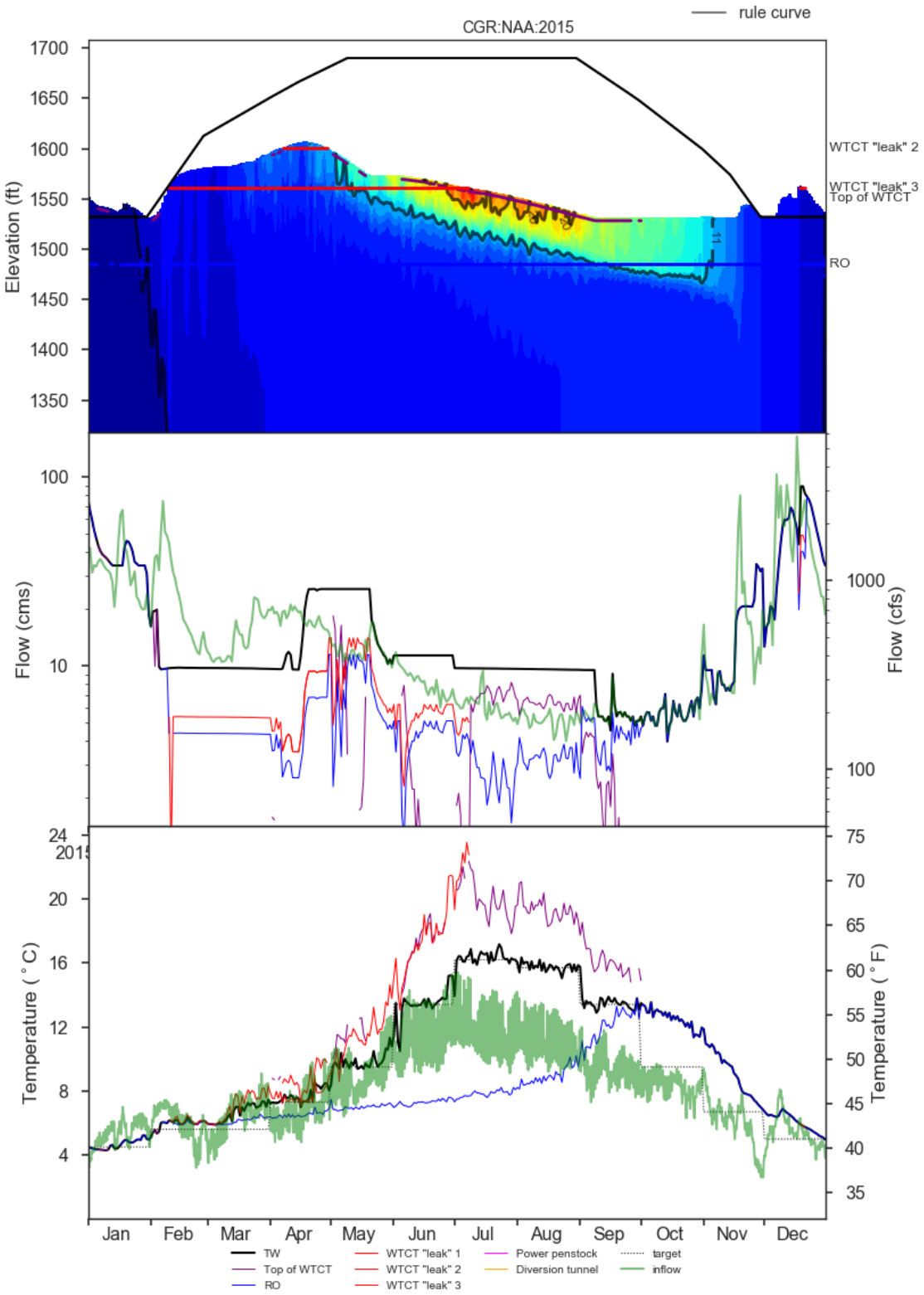


Figure 1-27. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR in 2015.

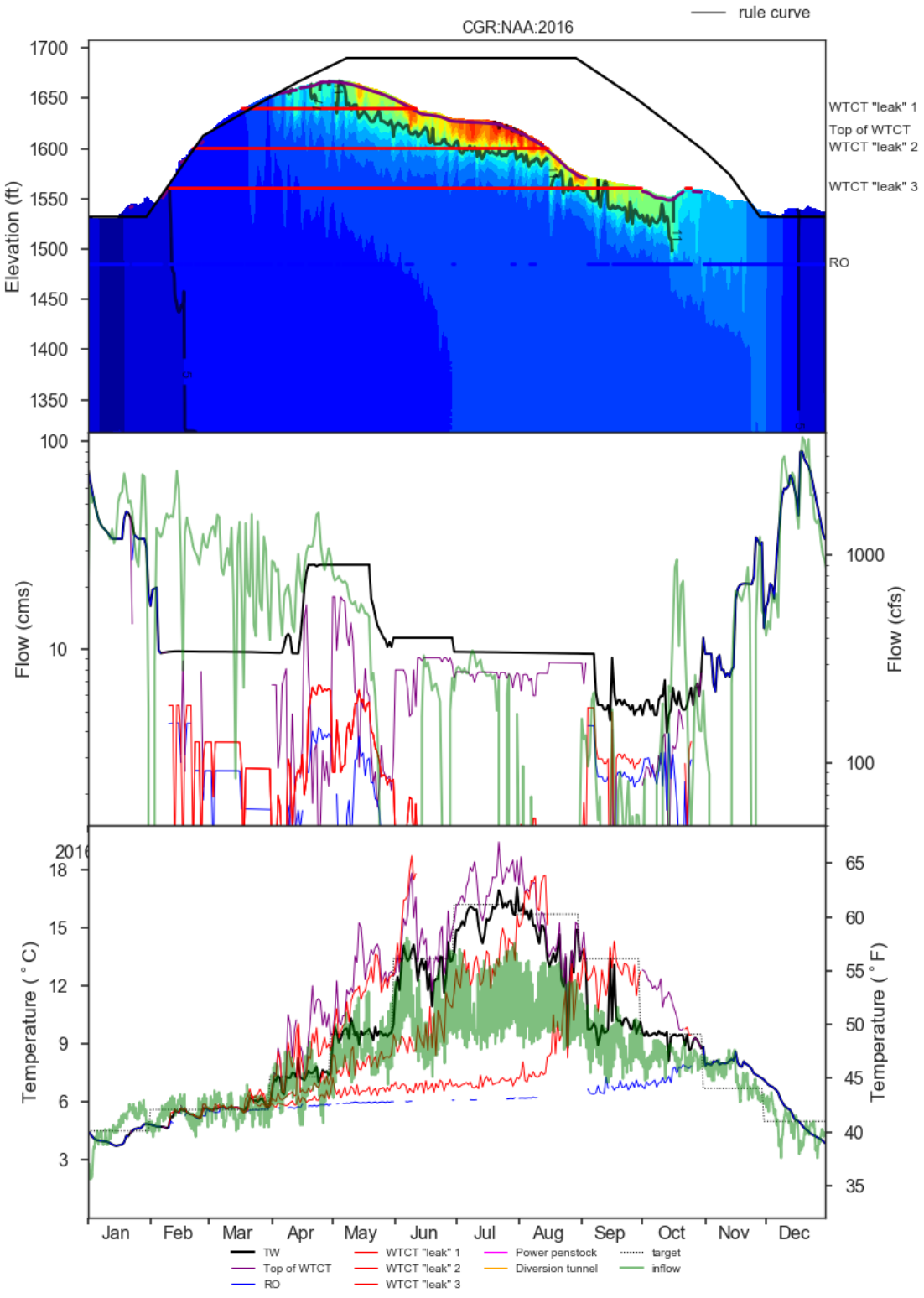


Figure 1-28. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR in 2016.

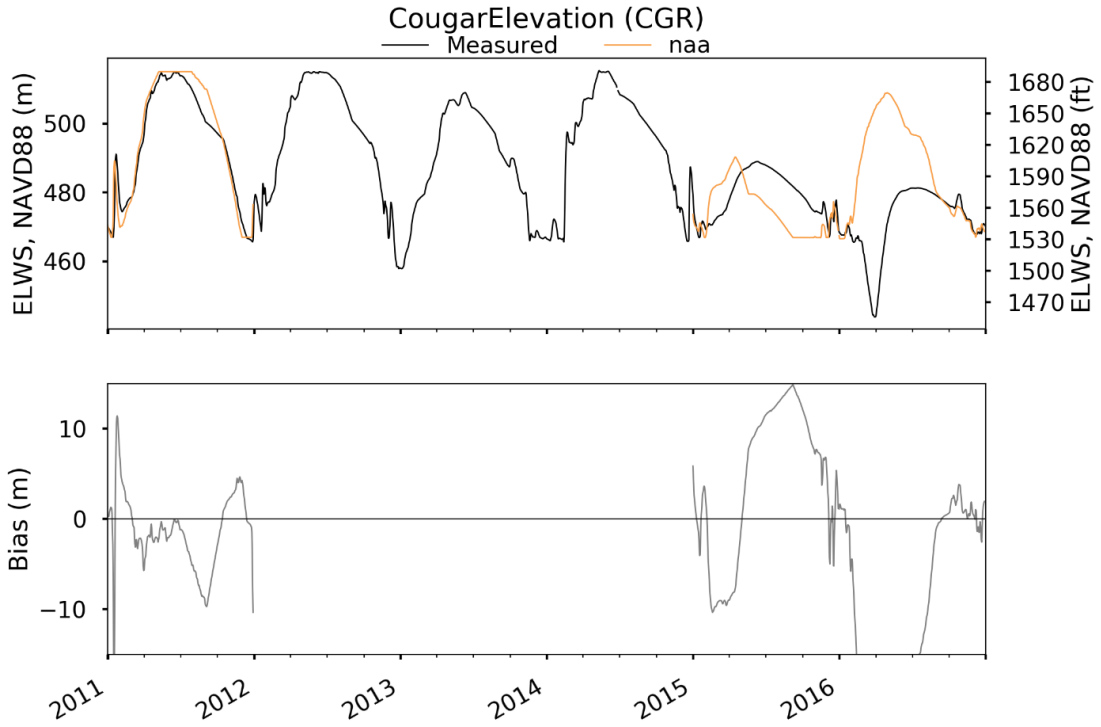


Figure 1-29. Comparison of CGR Daily Lake Surface Elevations in NAA vs Measured.

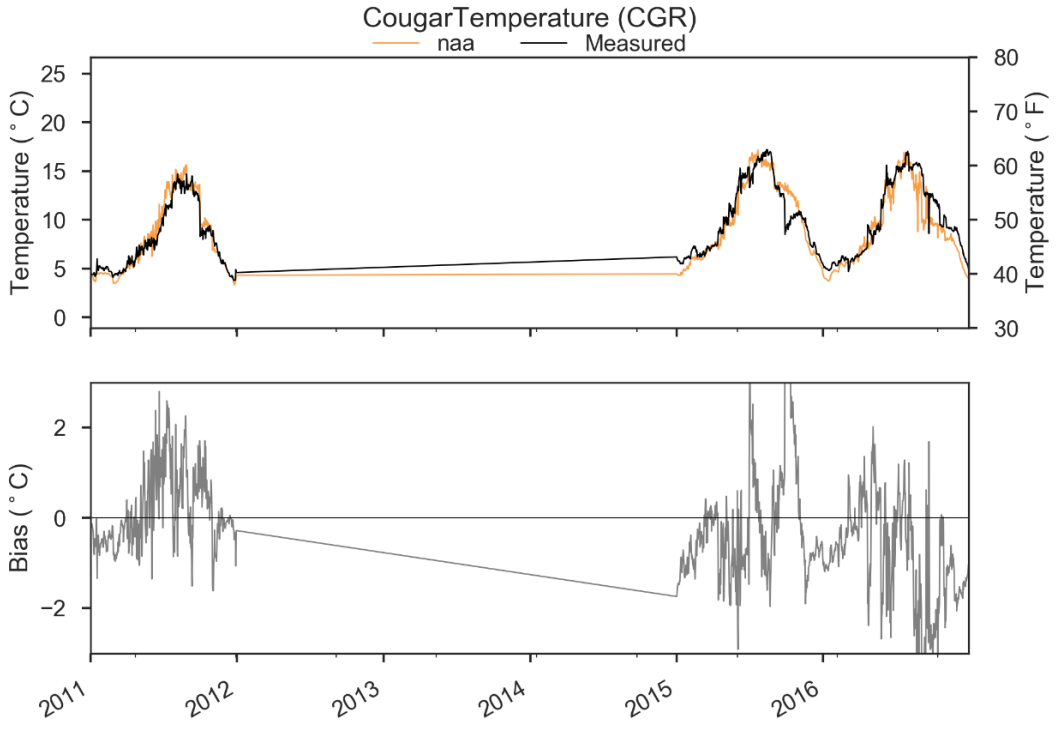


Figure 1-30. Comparison of CGR Outflow Temperatures in NAA vs Measured.

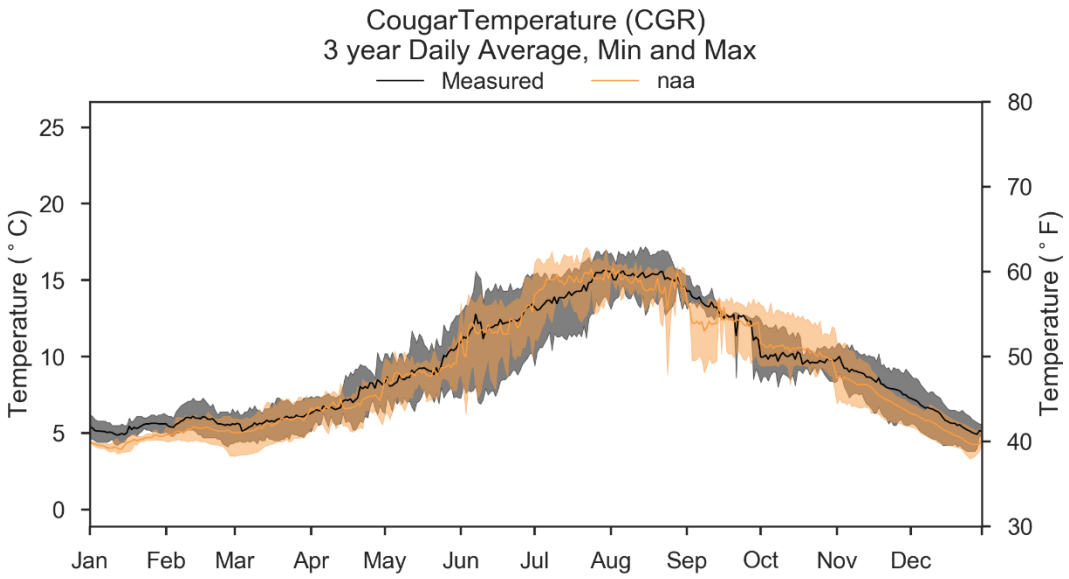


Figure 1-31. Comparison of CGR 3-year average, min, max outflow temperatures in NAA vs Measured.

1.5.1.4 Middle Fork Willamette Dams

1.5.1.4.1 Hills Creek

Hills Creek operations in NAA are identical to those under the Affected Environment, consisting of relatively deep releases from the Power penstock and ROs year-round (Figure 1-32; Figure 1-33; Figure 1-34). Differences between NAA and measurements in lake levels in the three calendar-years were relatively minor, aside from 2015 (Figure 1-35), and generally led to differences in outflow tailwater temperatures less than 2 degrees Celsius. Short-term differences between NAA and Measurements in 2015 can be attributed to lower lake levels in NAA (Figure 1-36; Figure 1-37).

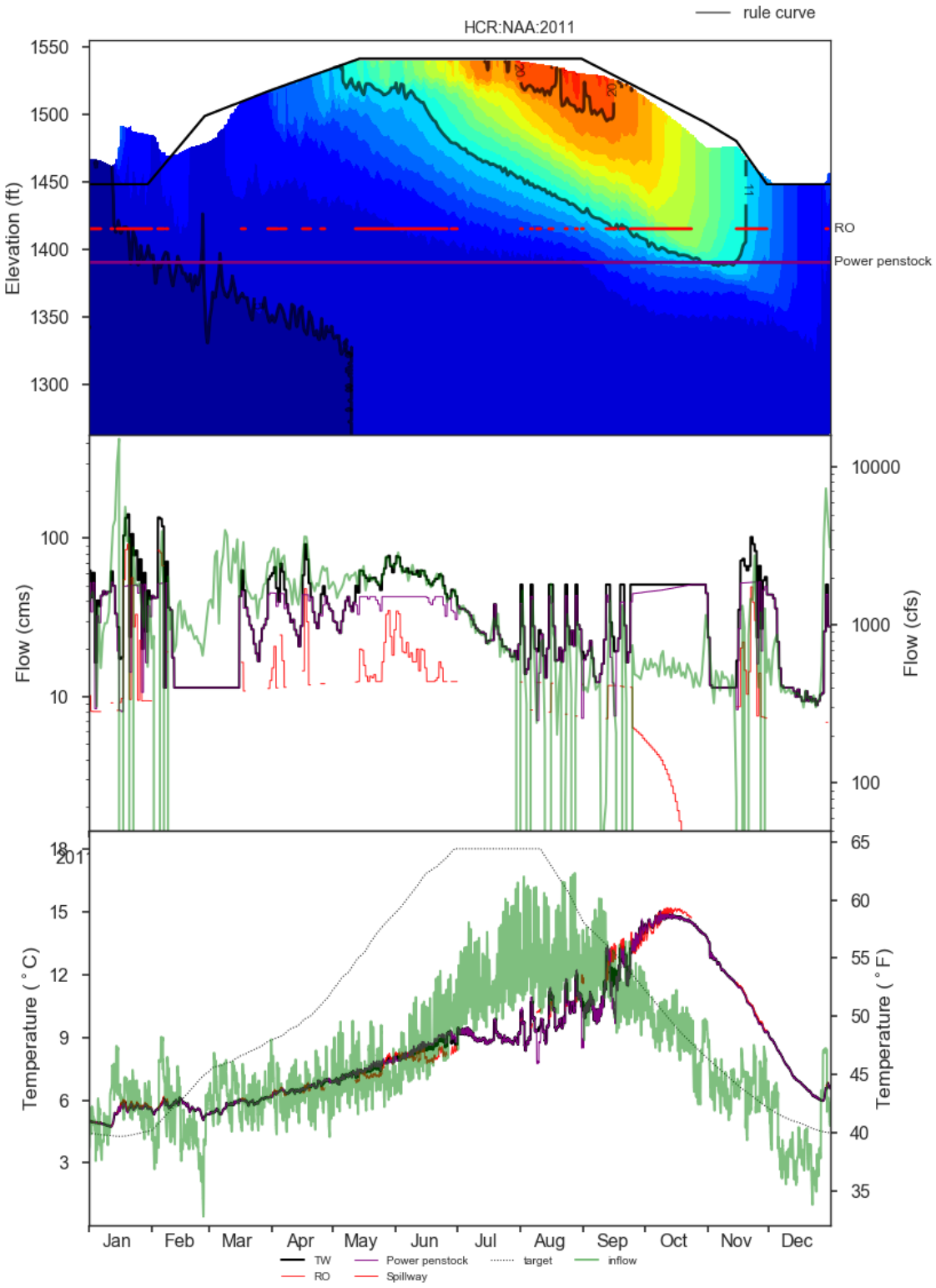


Figure 1-32. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR in 2011.

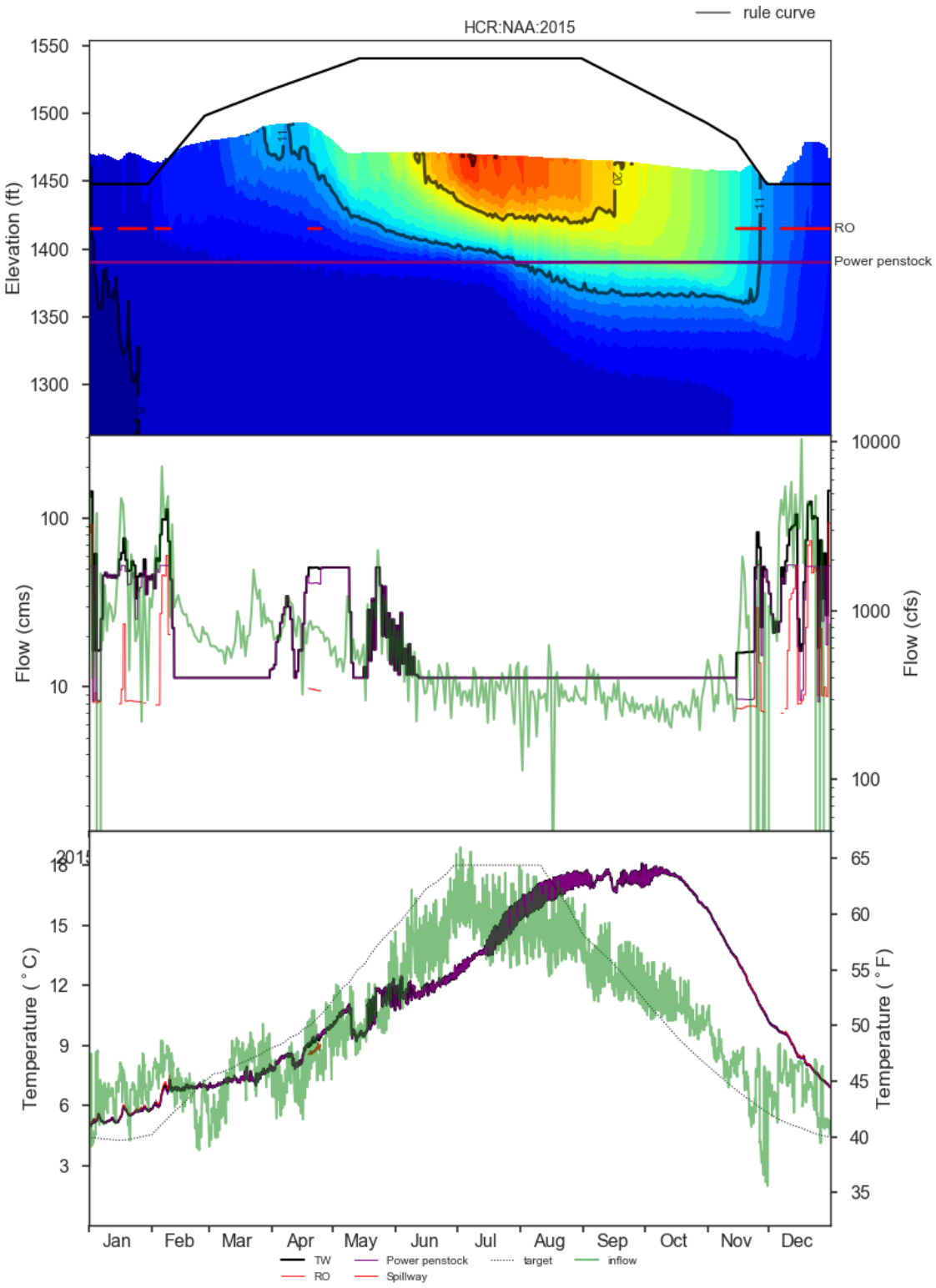


Figure 1-33. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR in 2015.

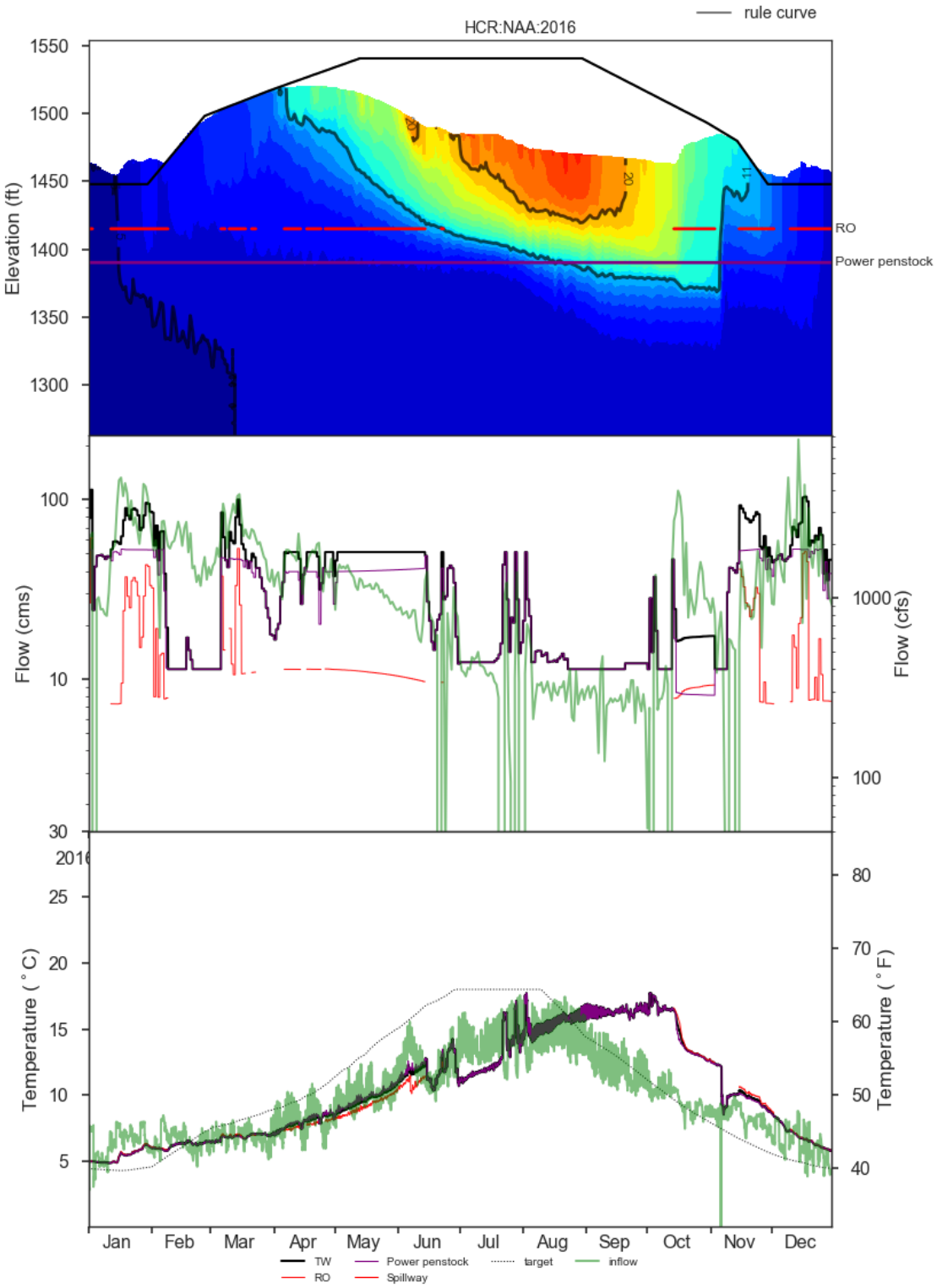


Figure 1-34. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR in 2016.

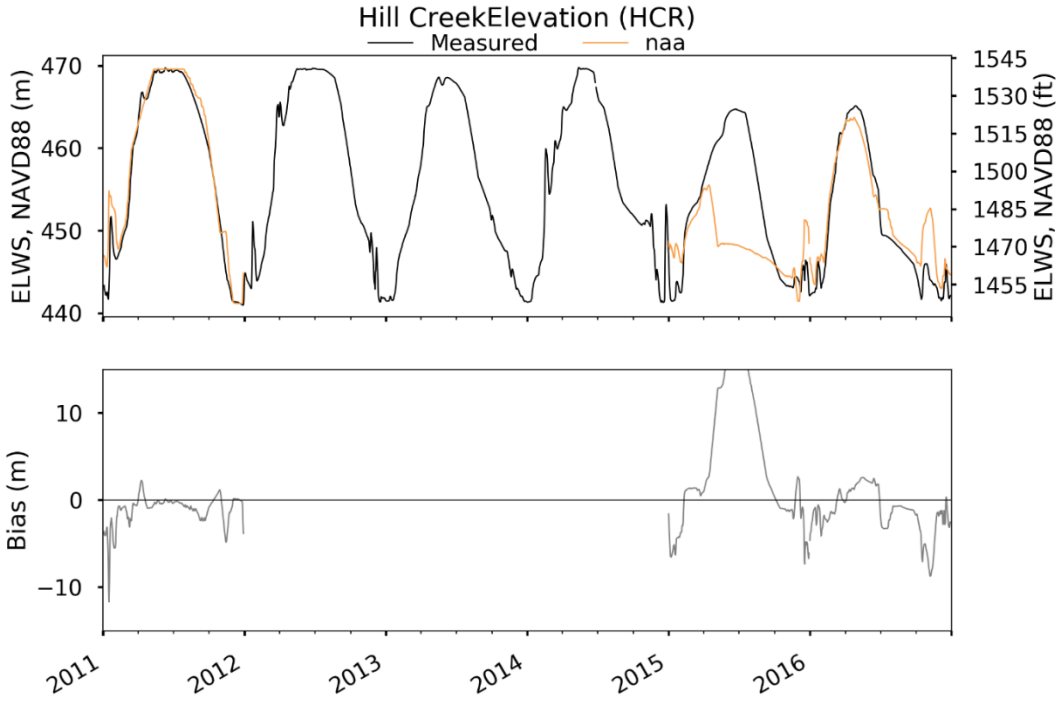


Figure 1-35. Comparison of HCR Daily Lake Surface Elevations in NAA vs Measured.

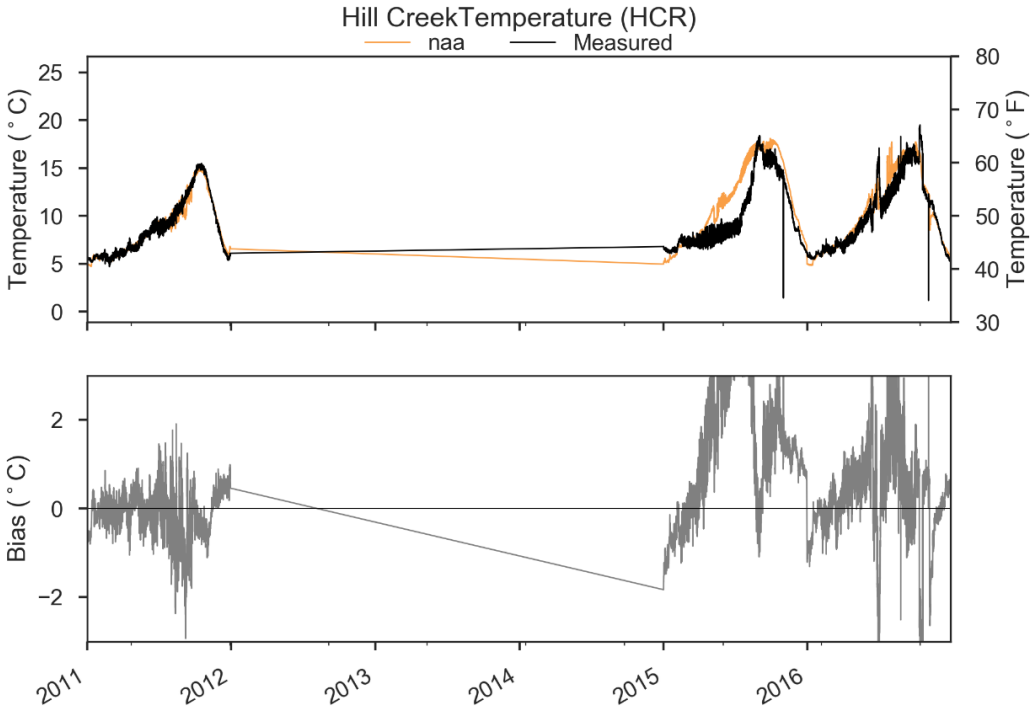


Figure 1-36. Comparison of HCR Outflow Temperatures in NAA vs Measured.

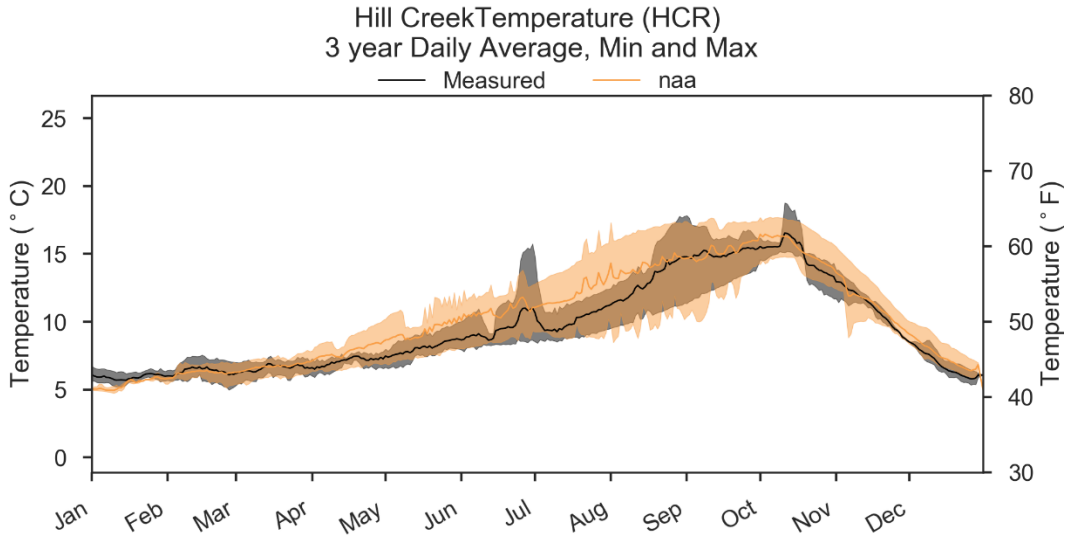


Figure 1-37. Comparison of HCR 3-year daily average, min, max outflow temperatures in NAA vs Measured.

1.5.1.4.2 Lookout Point - Dexter

Lookout Point operations in NAA are identical to those under the Affected Environment, consisting of relatively deep releases from the Power penstock and ROs year-round (Figure 1-38; Figure 1-39; Figure 1-40). Differences between NAA and measurements in lake levels in the three calendar-year scenarios were relatively minor in 2011, aside from 2015 and 2016 (Figure 1-41). Short-term temperature differences between NAA and measurements in 2015 can be attributed to lower lake levels in NAA (Figure 1-42; Figure 1-43) while other differences in outflow tailwater temperatures were less than 2 degrees Celsius.

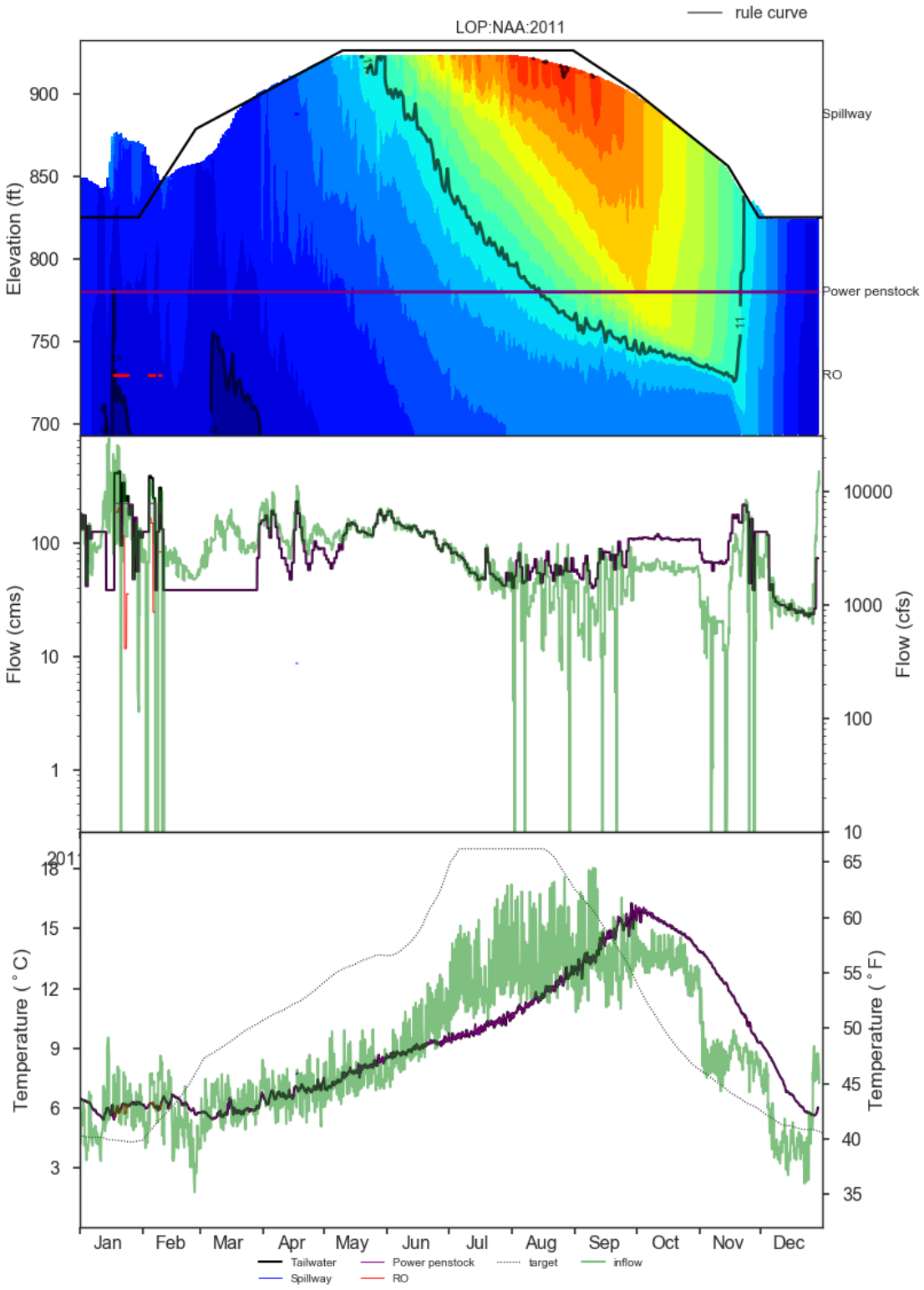


Figure 1-38. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP in 2011.

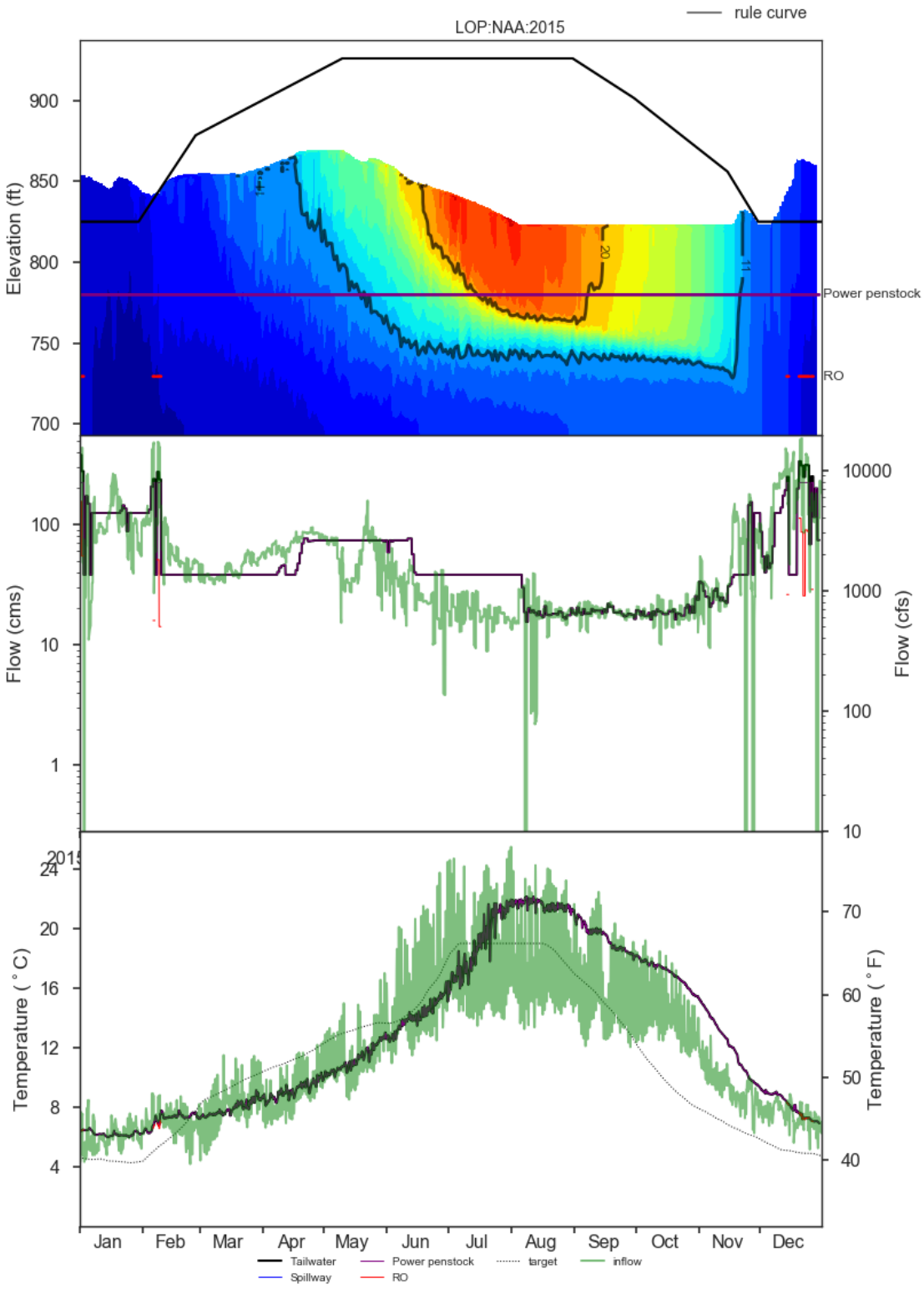


Figure 1-39. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP in 2015.

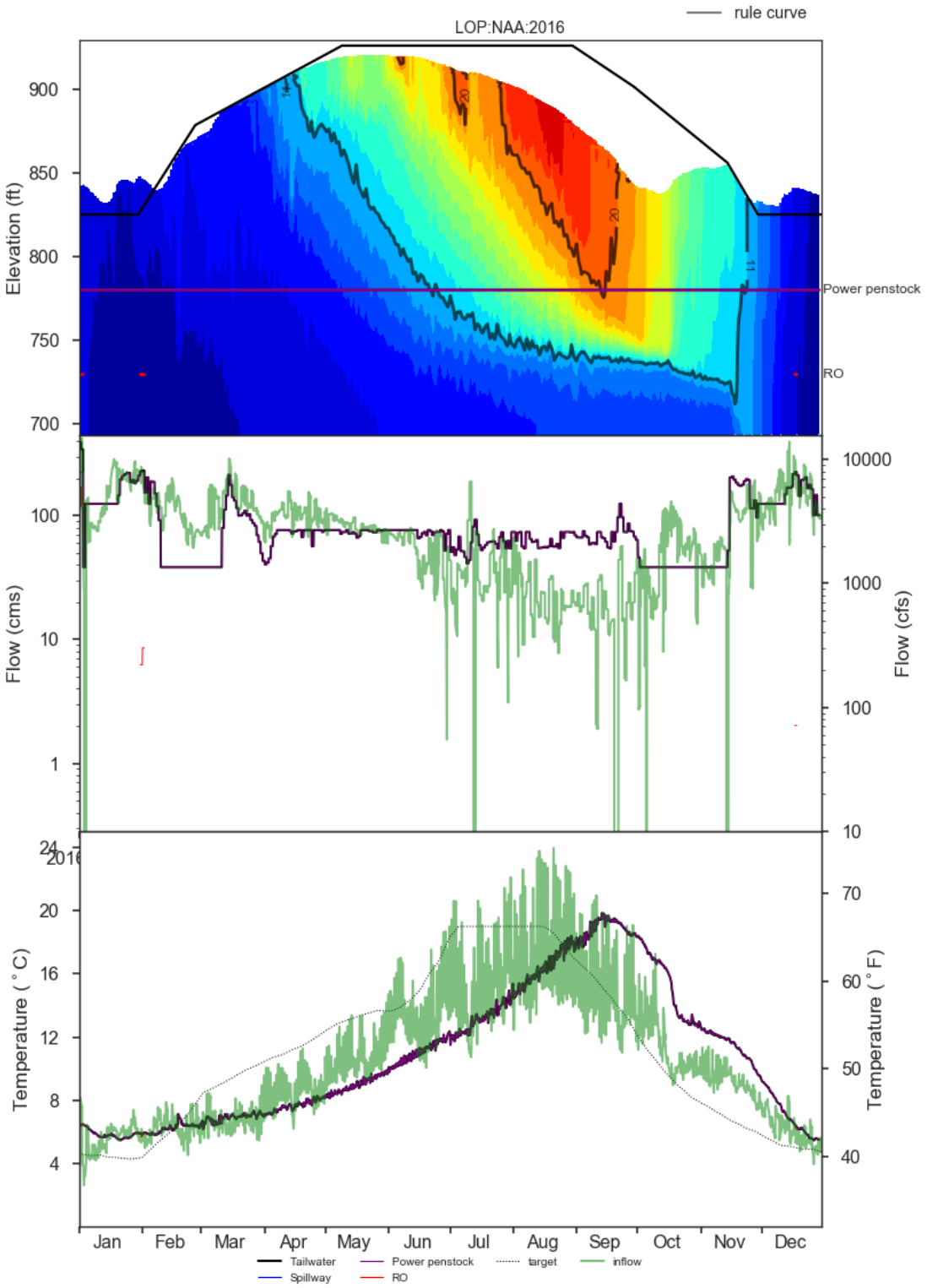


Figure 1-40. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP in 2016.

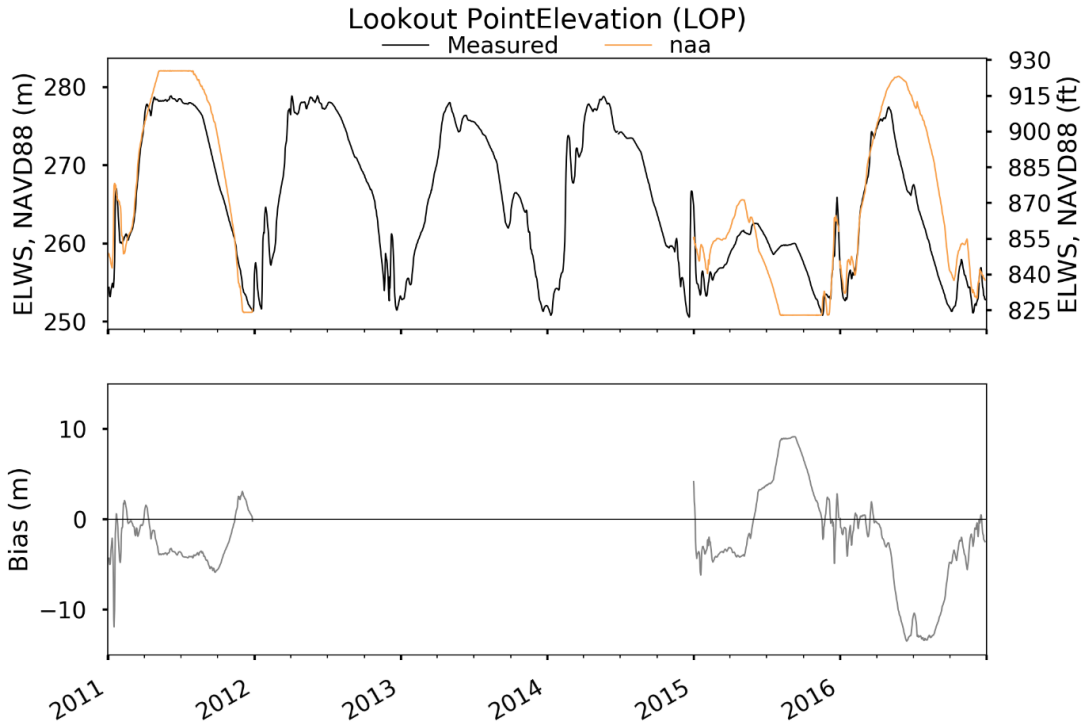


Figure 1-41. Comparison of LOP Daily Lake Surface Elevations in NAA vs Measured.

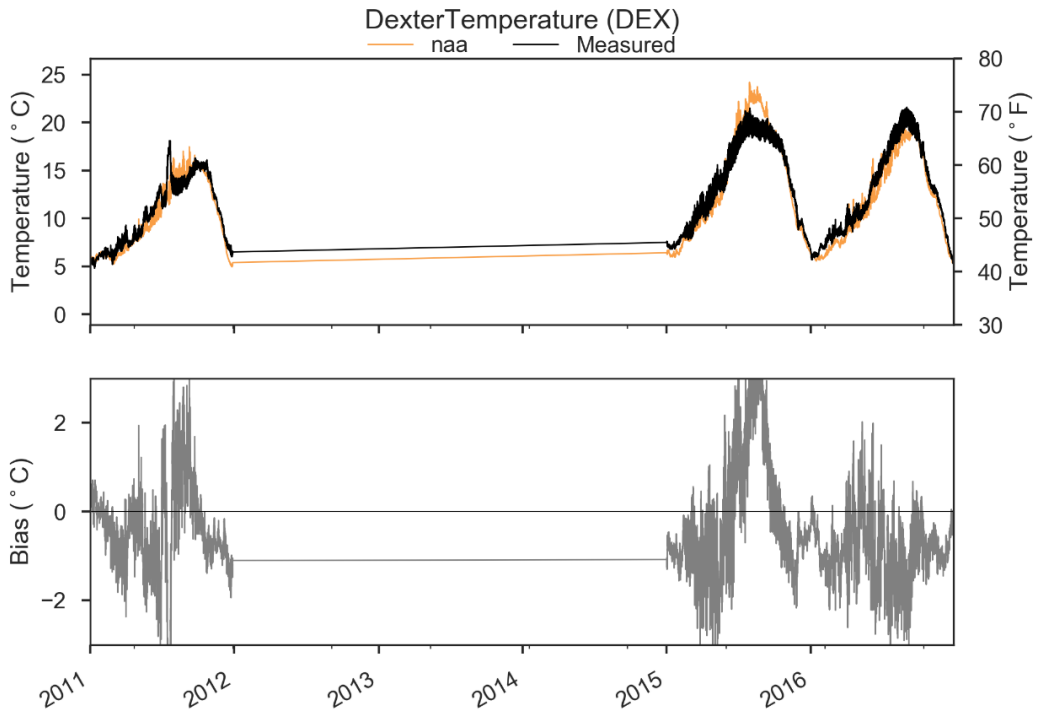


Figure 1-42. Comparison of DEX Outflow Temperatures in NAA and Measured.

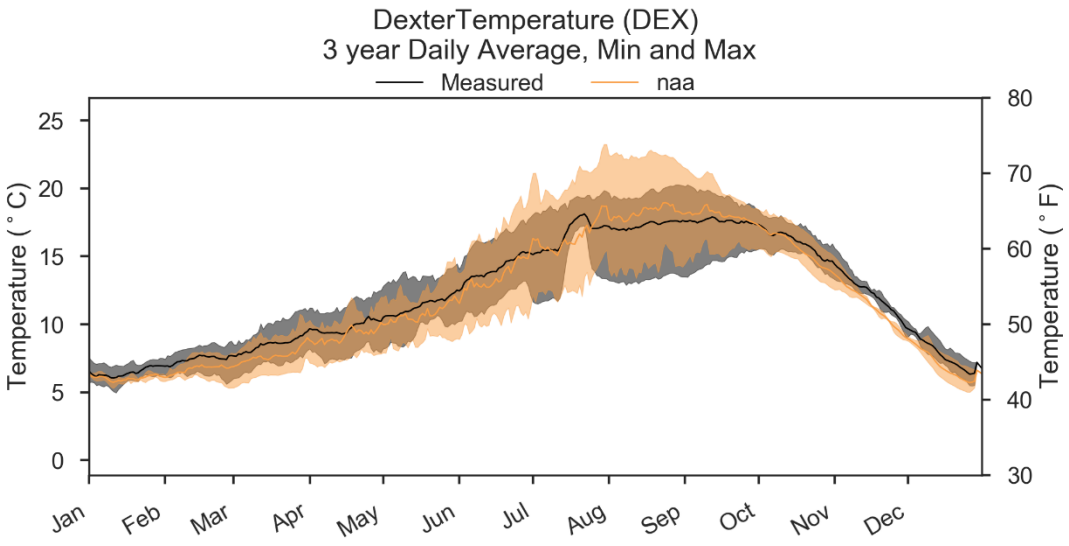


Figure 1-43. Comparison of DEX 3-year daily average, min, max outflow temperatures in NAA and Measured.

1.5.1.5 Mainstem Willamette River

There are no WVS projects located on the Mainstem Willamette River, however water temperatures downstream of the WVS projects can influence temperature regulation on the Willamette River. Heat source tracking in the Willamette has shown the heat content in the Willamette at Salem/Keizer during May-August in 2011, 2015, and 2016 was typically less than 20 percent sourced from upstream dam releases, despite the fact that roughly 50 percent of total streamflow during those months is attributed to upstream dam releases (Stratton-Garvin and Rounds, 2022a). Water temperature in NAA is compared with measurements in each of the three calendar-years for the Willamette River at Salem (SLMO) are shown in Figure 1-44 and Figure 1-45. Overall water temperature differences between NAA and measurements were generally less than 2 degrees Celsius, with the greatest differences occurring in 2015.

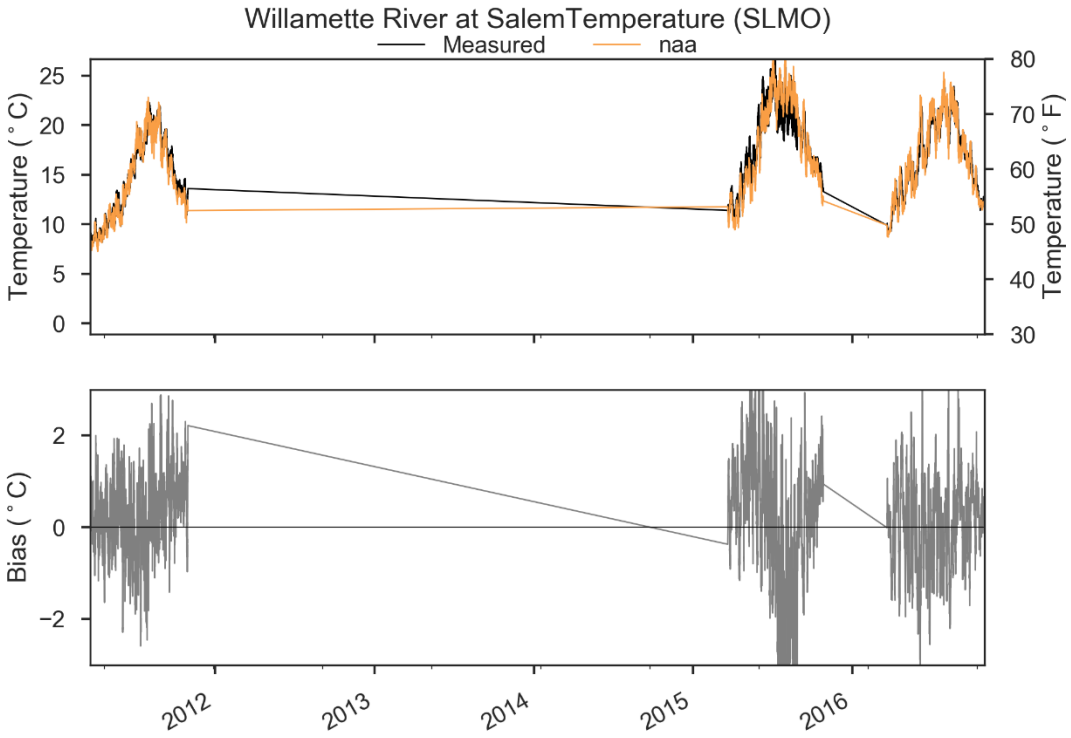


Figure 1-44. Comparison of Willamette River at SLMO Water Temperatures in NAA and Measured.

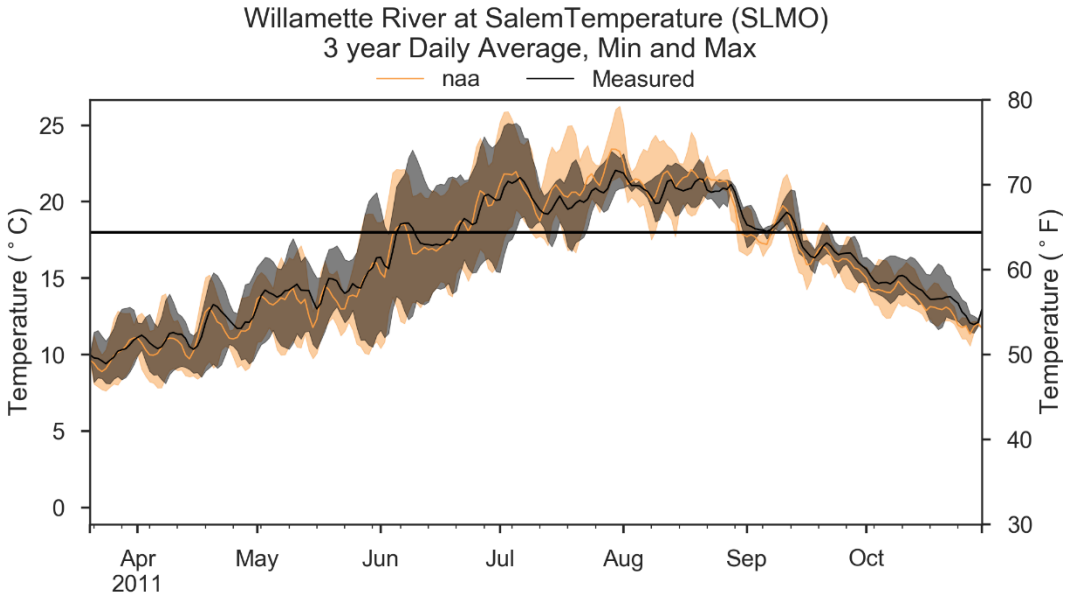


Figure 1-45. Comparison of Willamette River at SLMO 3-year daily average, min, max outflow temperatures in NAA and Measured.

1.5.2 Alternative 1– Project Storage Alternative

Alternative 1 measures that affected operations, lake storage, and water temperature included:

- Structural improvements for water temperature (water temperature control towers or selective water withdrawal structures) at Detroit, Green Peter, and Lookout Point dams.
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.
- Reduced minimum flow rules (compared to NAA) to congressionally authorized minimum flow rules.
- Flow augmentation by using the power pool or inactive storage.

1.5.2.1 North Santiam Dams

1.5.2.1.1 Detroit

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Detroit Lake generally increased in Alternative 1 compared to NAA in 2015 and 2016 aside from September-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-46; Figure 1-48). The increased storage coincided with reduced outflows during spring and increased outflows in summer during 2015 and 2016. The proposed SWS and FSS in Alternative 1 allowed all outflow within powerhouse capacity (assumed at 4600 cfs) to be routed from a floating outlet through the Power outlets for temperature management, rather than the Spillway or URO flow for temperature management that was used in NAA (Figure 1-47). 2011 operations were generally similar in Alternative 1 and NAA at Detroit Lake.

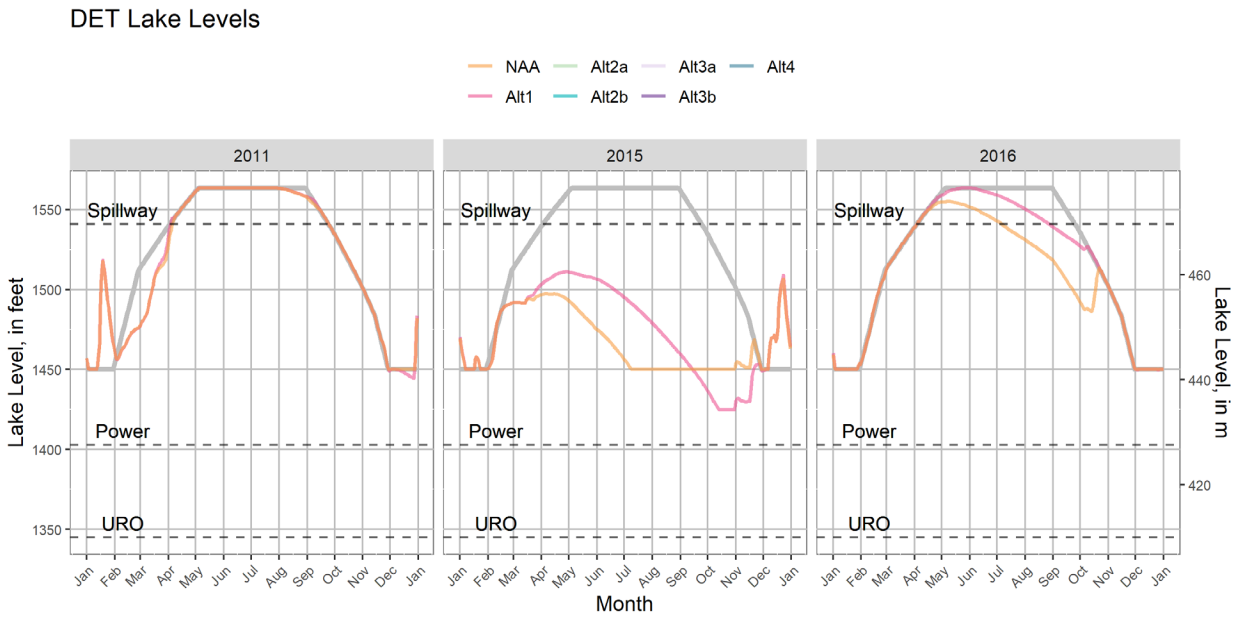


Figure 1-46 WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA.

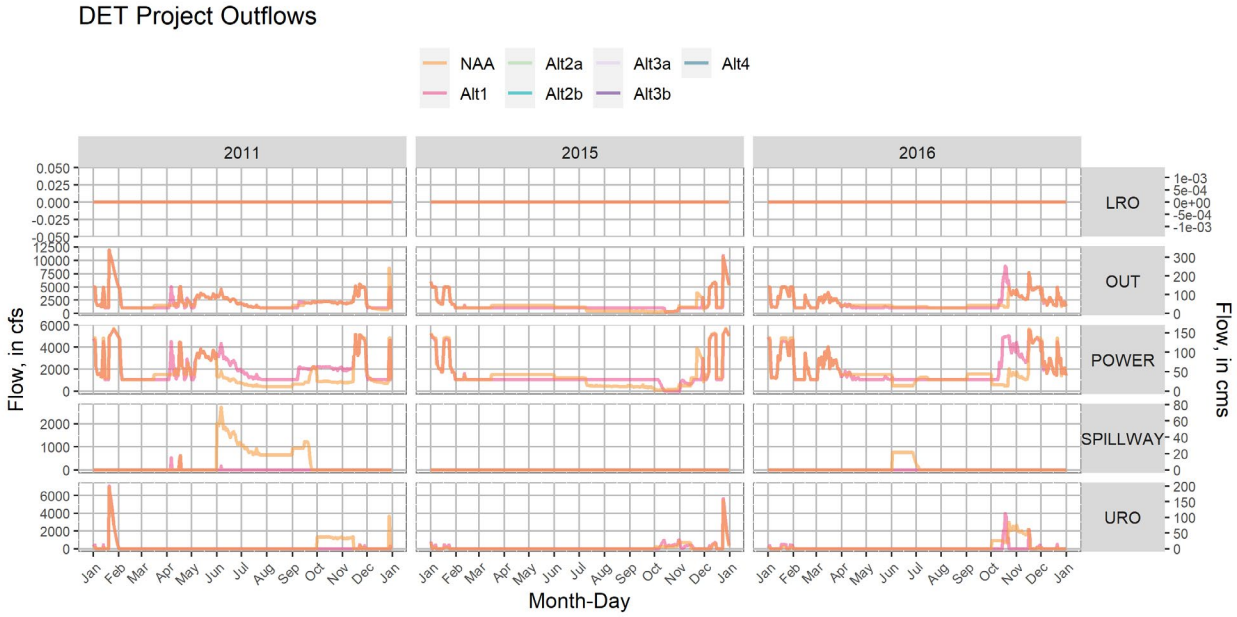


Figure 1-47. WV EIS HEC-ResSim gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA.

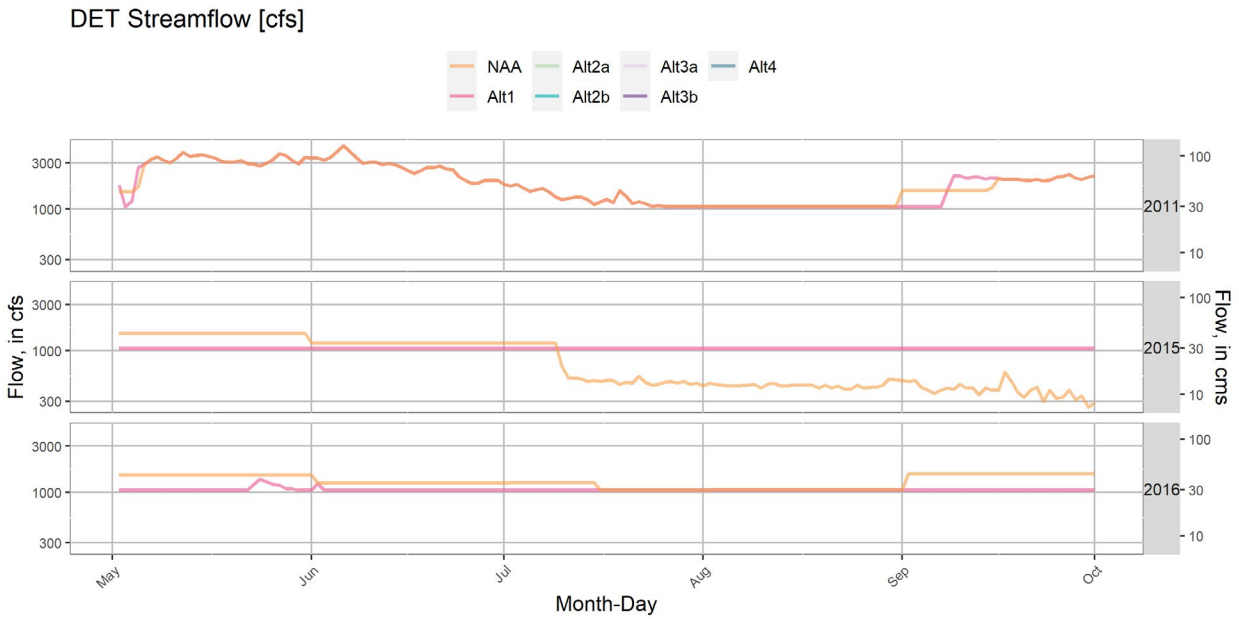


Figure 1-48. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-49, Figure 1-50, and Figure 1-51. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the Upper RO. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, this structure allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn (Figure 1-52, Figure 1-53).

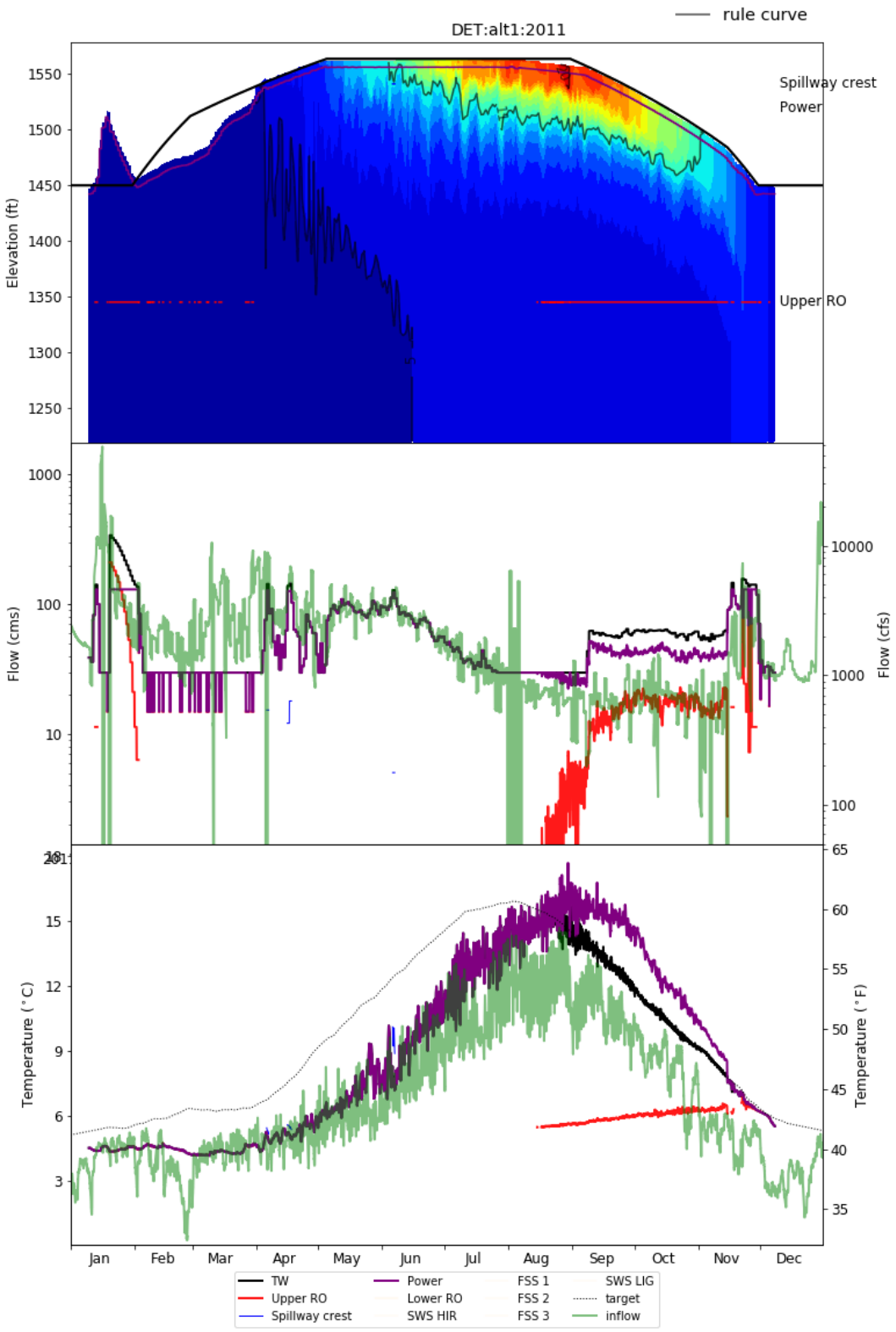


Figure 1-49. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under Alternative 1 in 2011.

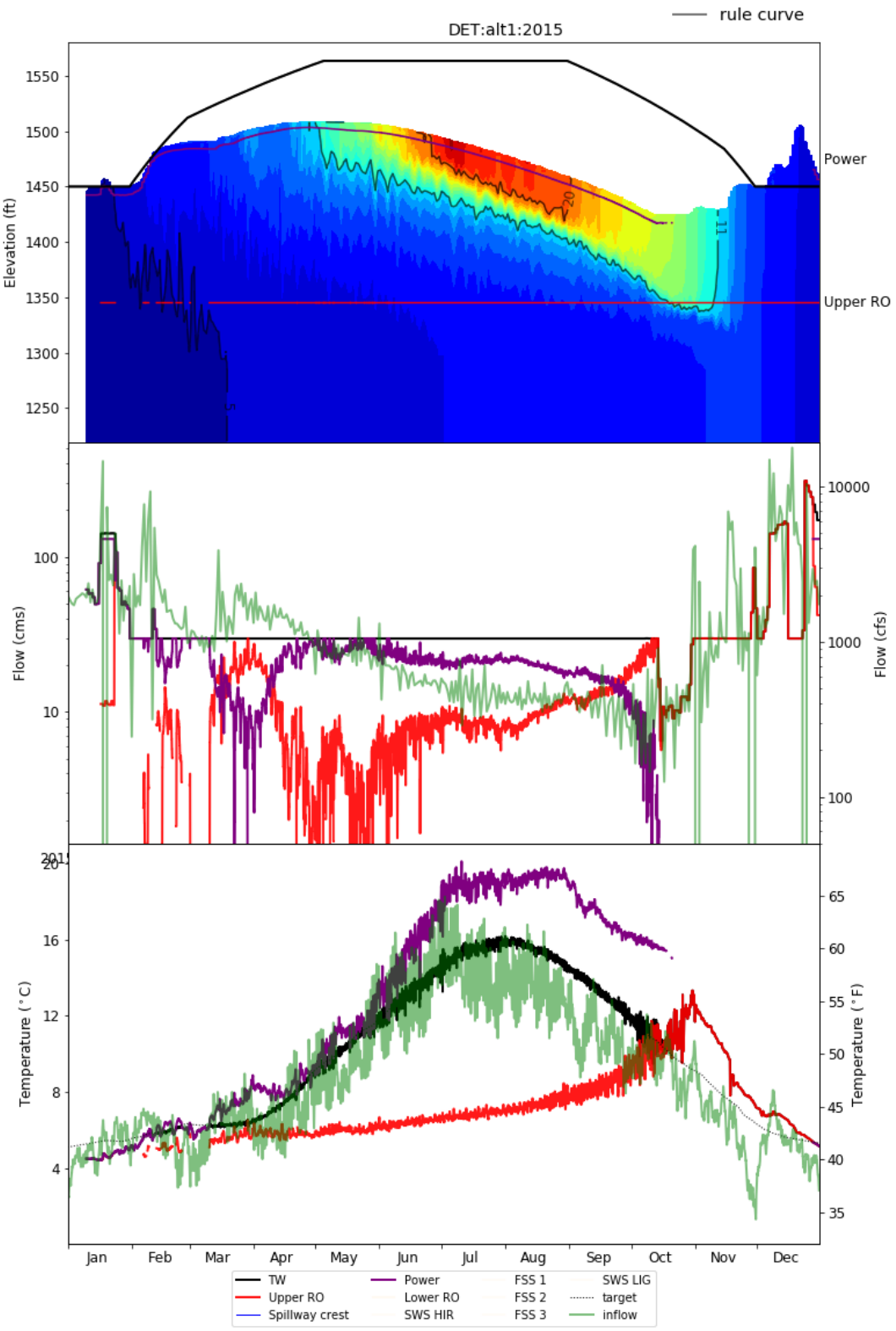


Figure 1-50. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under Alternative 1 in 2015.

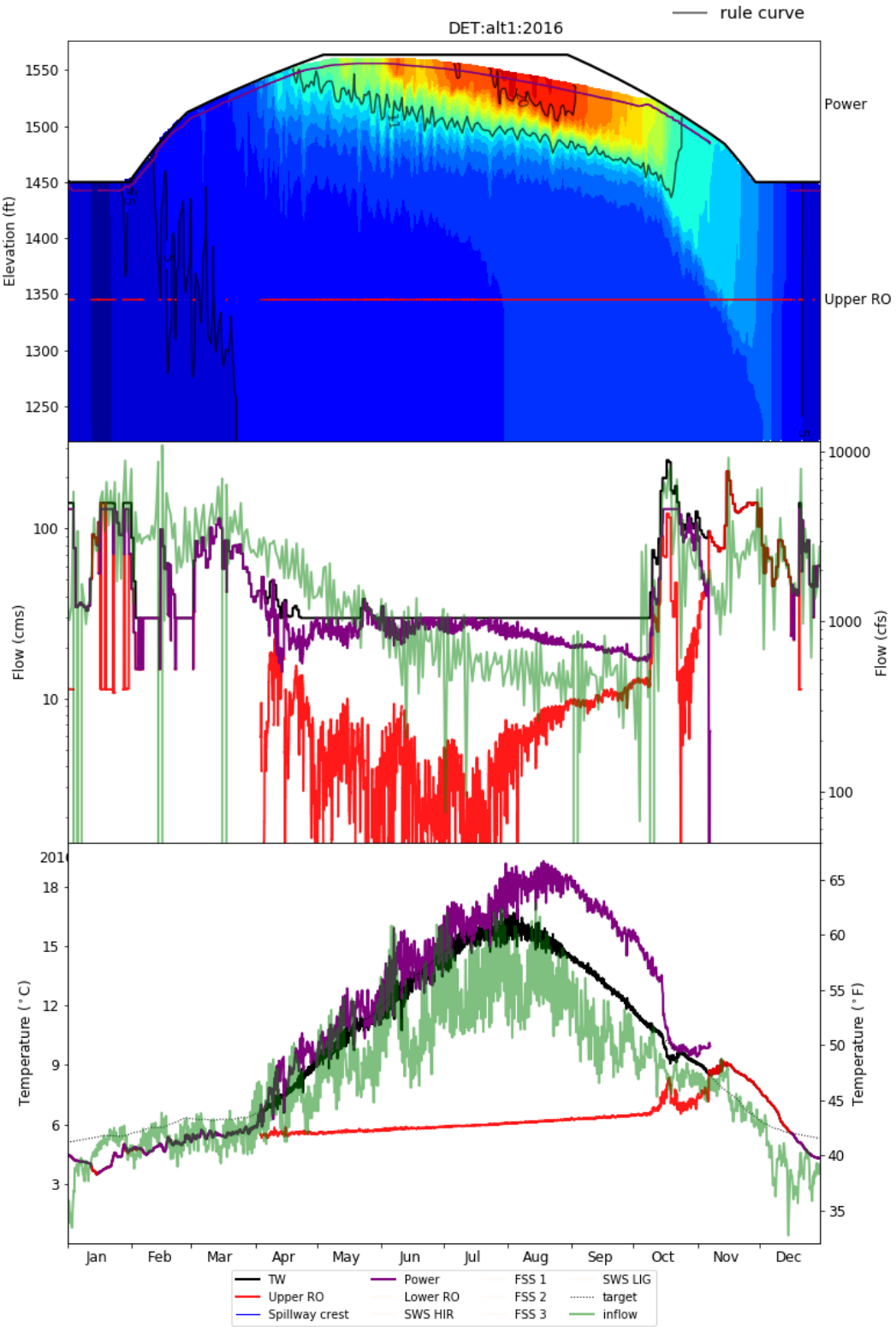


Figure 1-51. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under Alternative 1 in 2016.

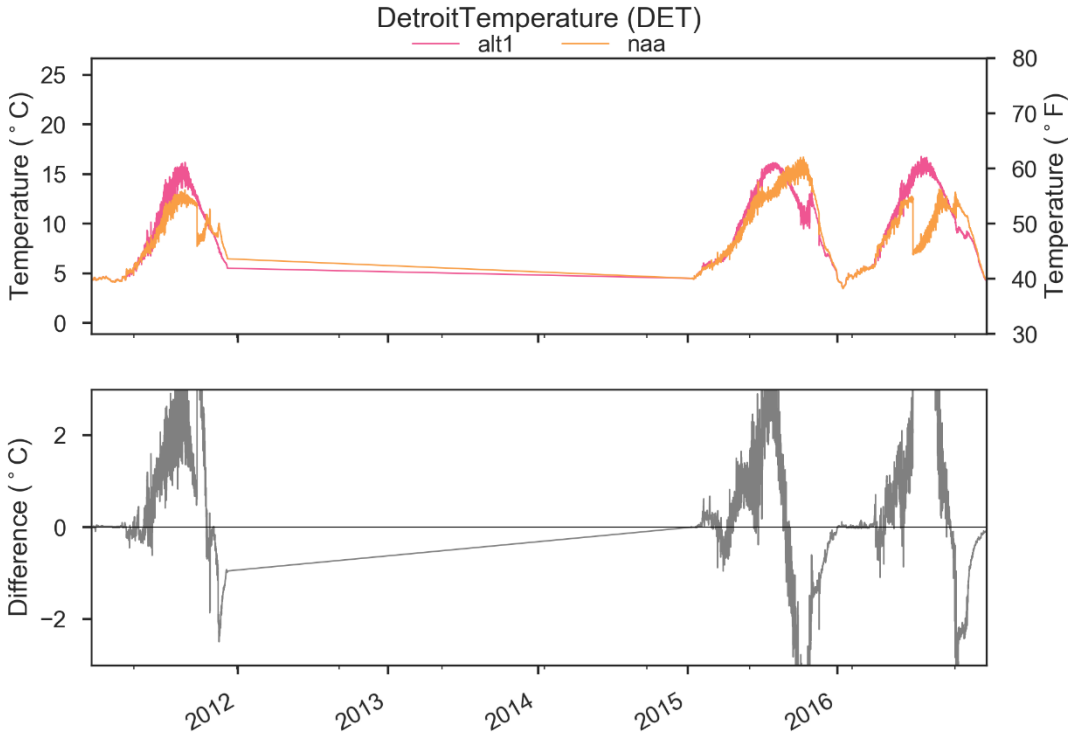


Figure 1-52. Comparison of DET Outflow Temperatures in NAA and Alternative 1.

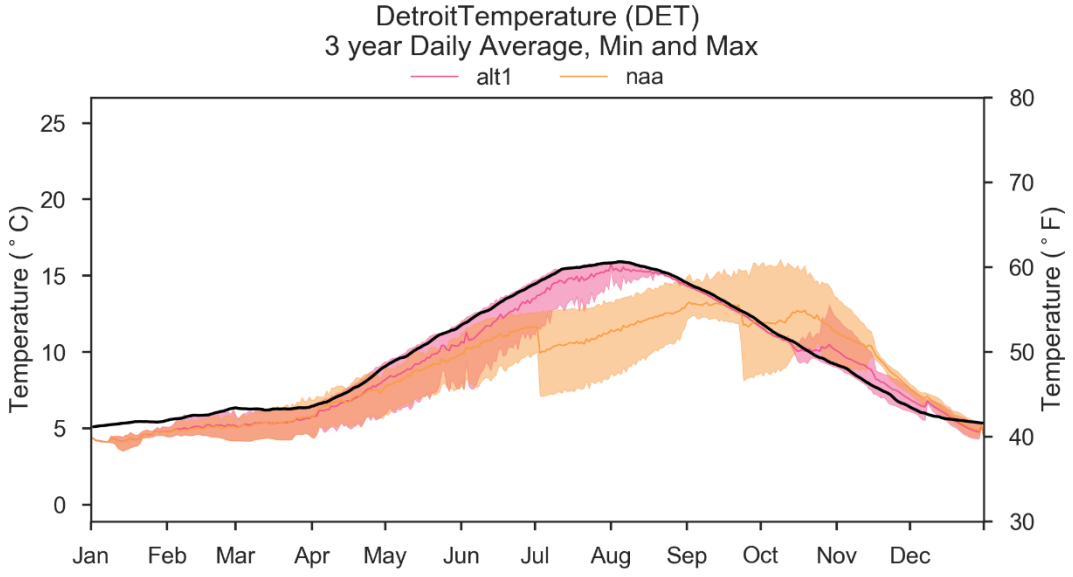


Figure 1-53. Comparison of DET 3-year average, min, max outflow temperatures in NAA and Alternative 1. Black line indicates temperature target.

1.5.2.2 South Santiam Dams

1.5.2.2.1 Green Peter

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Green Peter were generally increased in Alternative 1 compared to NAA in 2011, 2015, and 2016 aside from October-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-54, Figure 1-56). The proposed SWS and FSS in Alternative 1 allowed all outflow within powerhouse capacity (assumed at 4000 cfs) to be routed from a floating outlet through the Power outlets for temperature management, which generally matched NAA gate-specific operations related to temperature management (Figure 1-55).

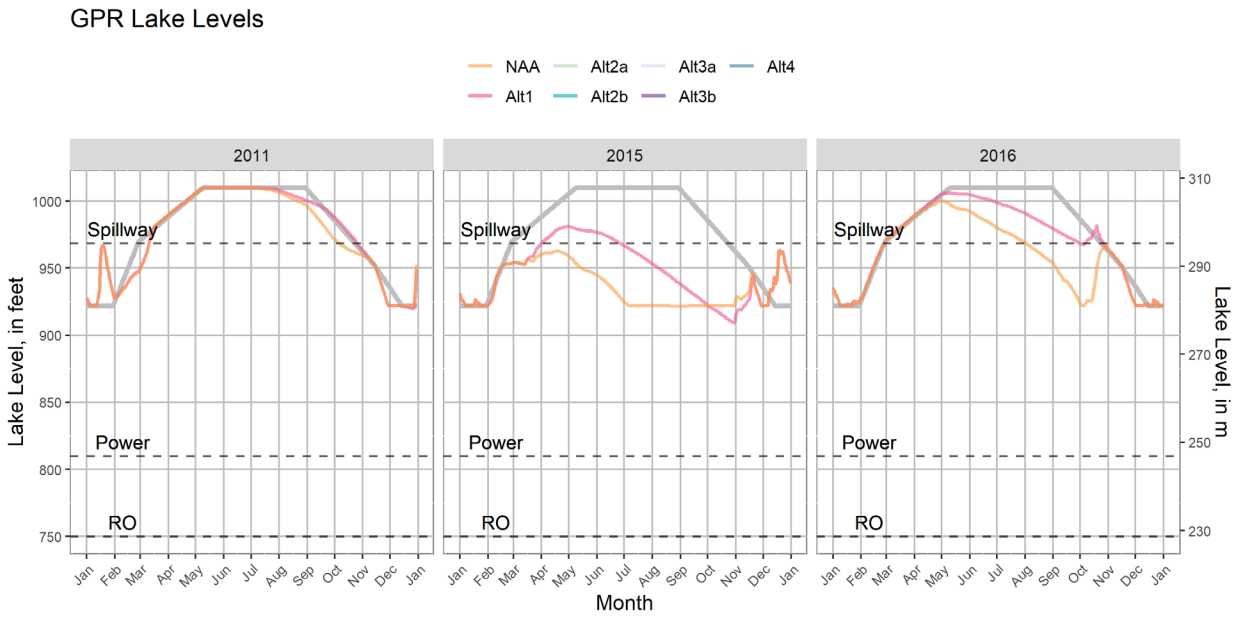


Figure 1-54. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 1 and NAA.

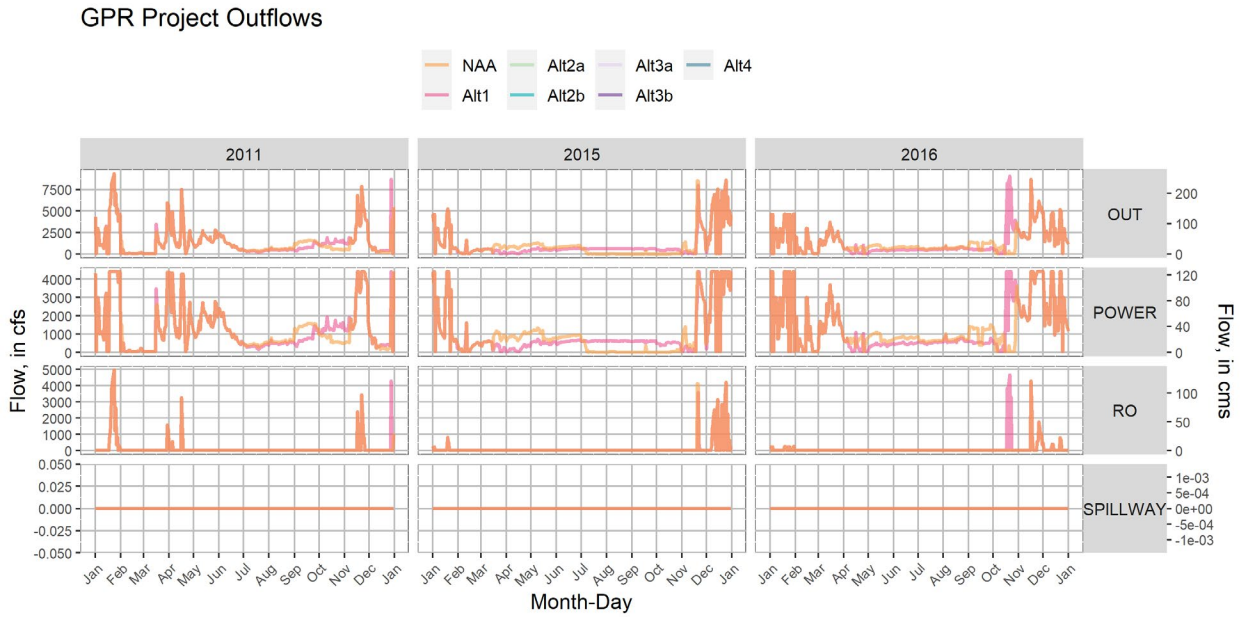


Figure 1-55. WV EIS HEC-ResSim Green Peter Dam gate-specific Outflows in 2011, 2015, and 2016 Under Alternative 1 and NAA.

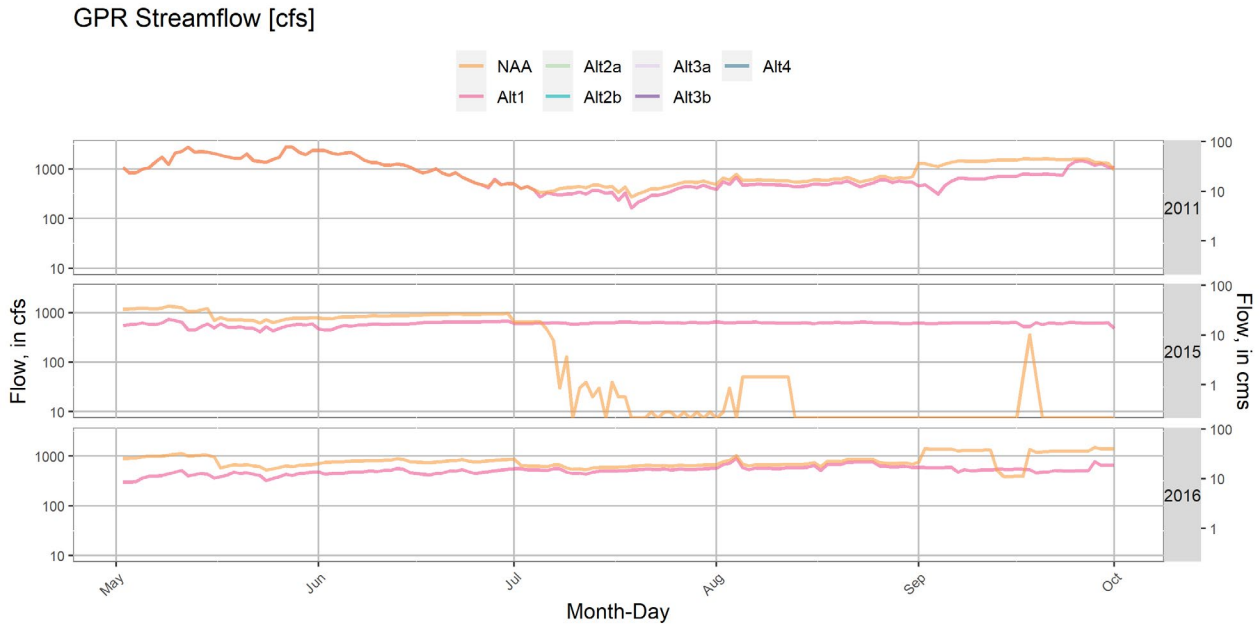


Figure 1-56. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 1 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-57, Figure 1-58, and Figure 1-59. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the Upper RO. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, this structure allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn (Figure 1-60, Figure 1-61).

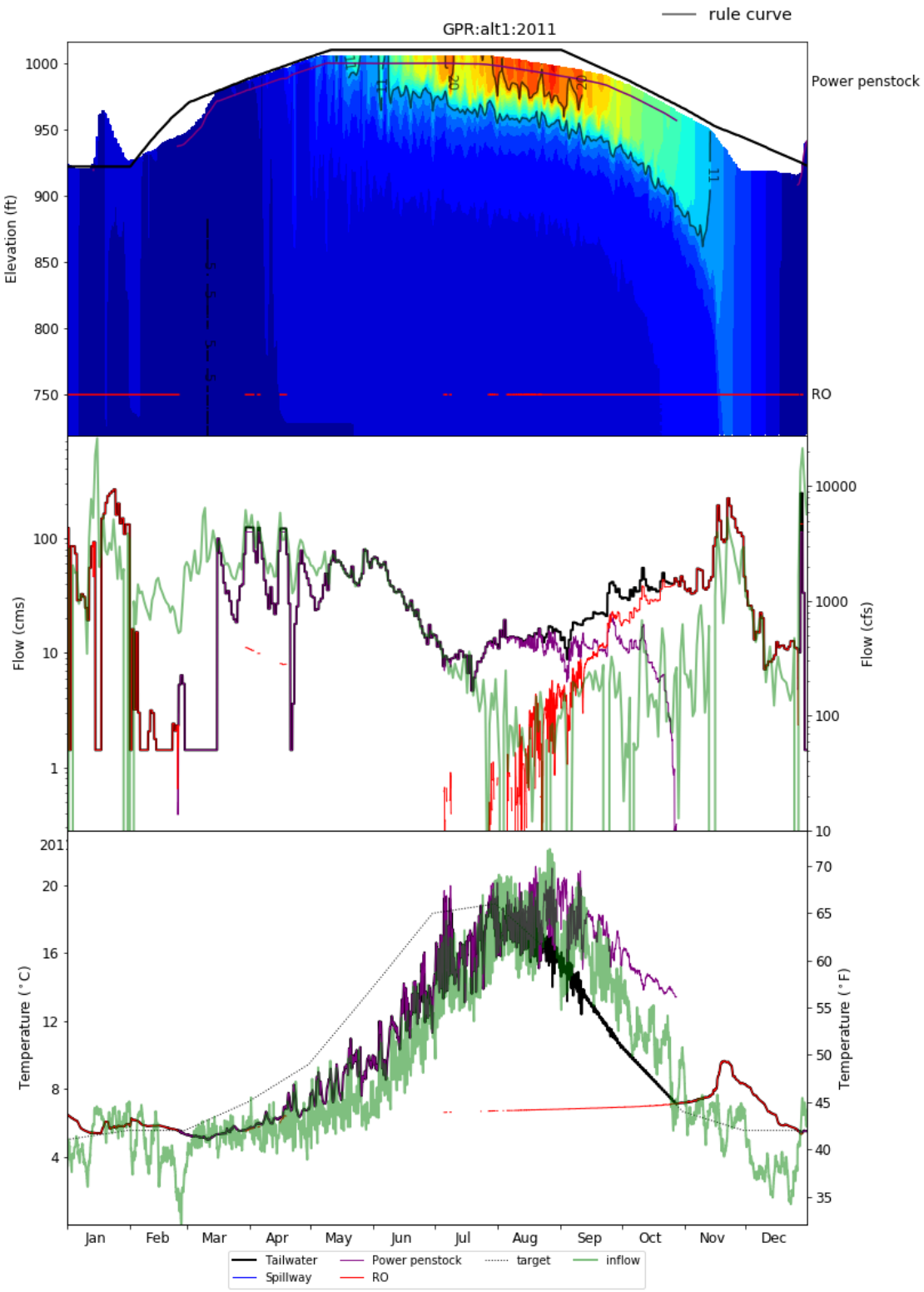


Figure 1-57. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 1 in 2011.

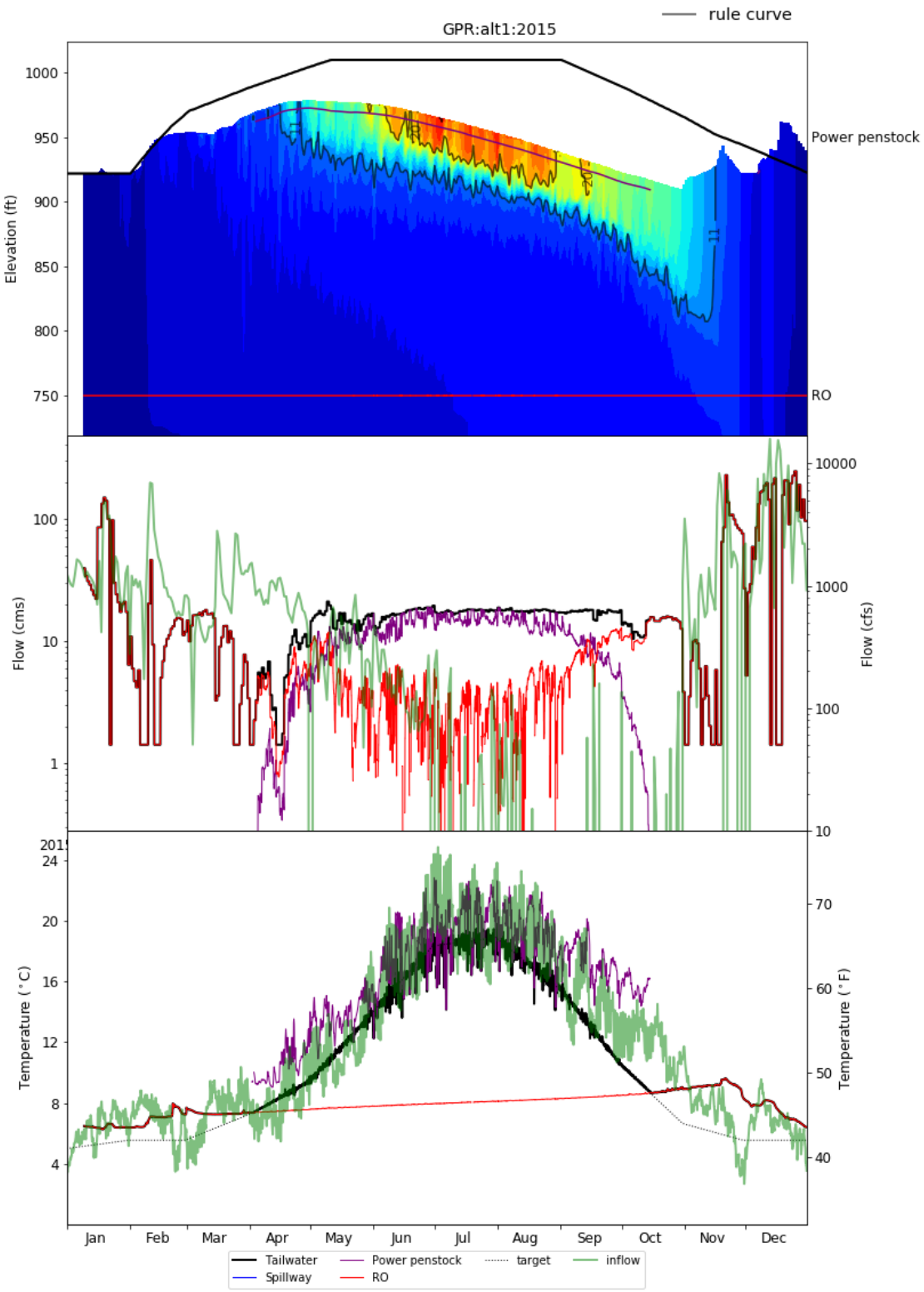


Figure 1-58. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 1 in 2015.

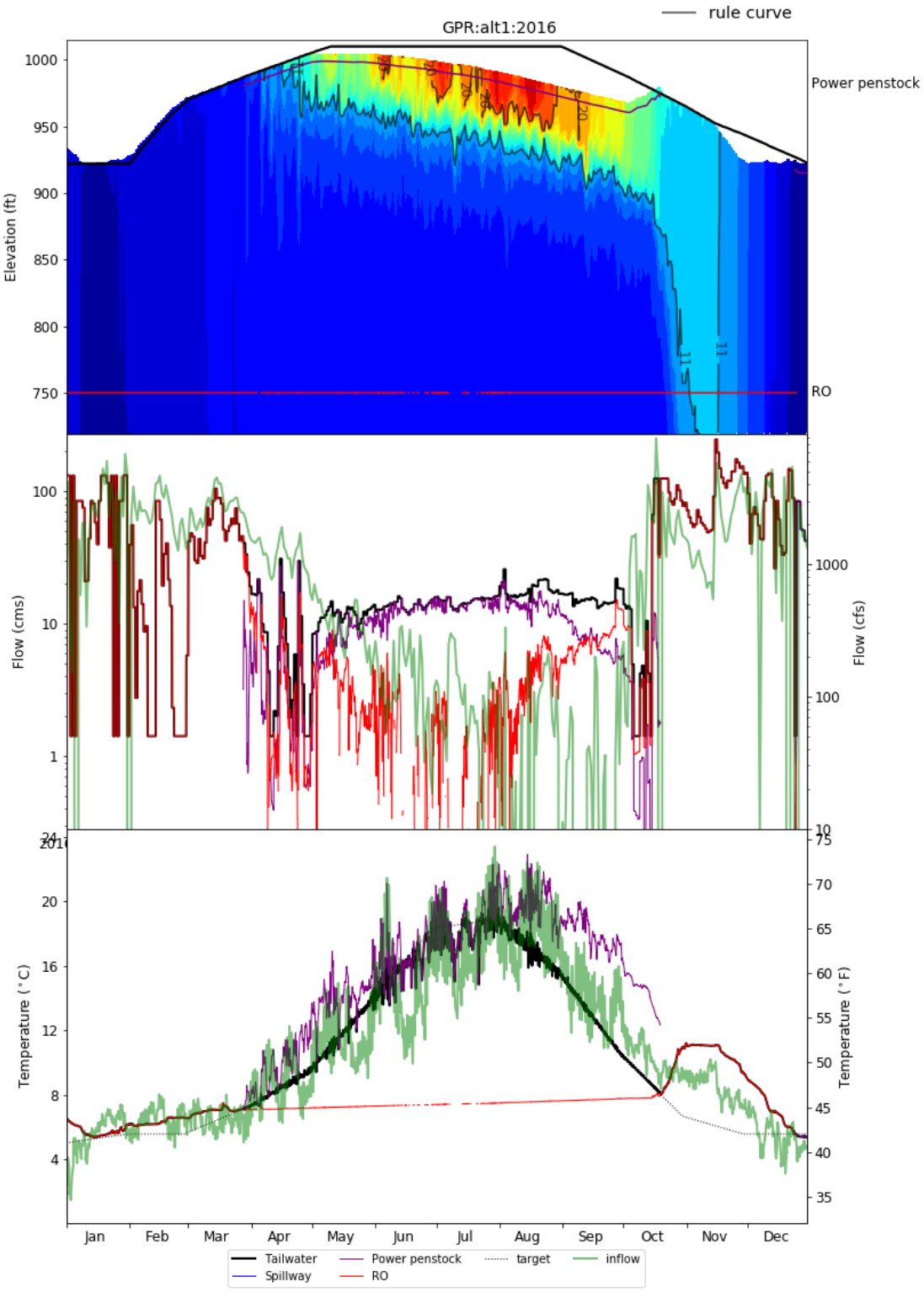


Figure 1-59. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 1 in 2016.

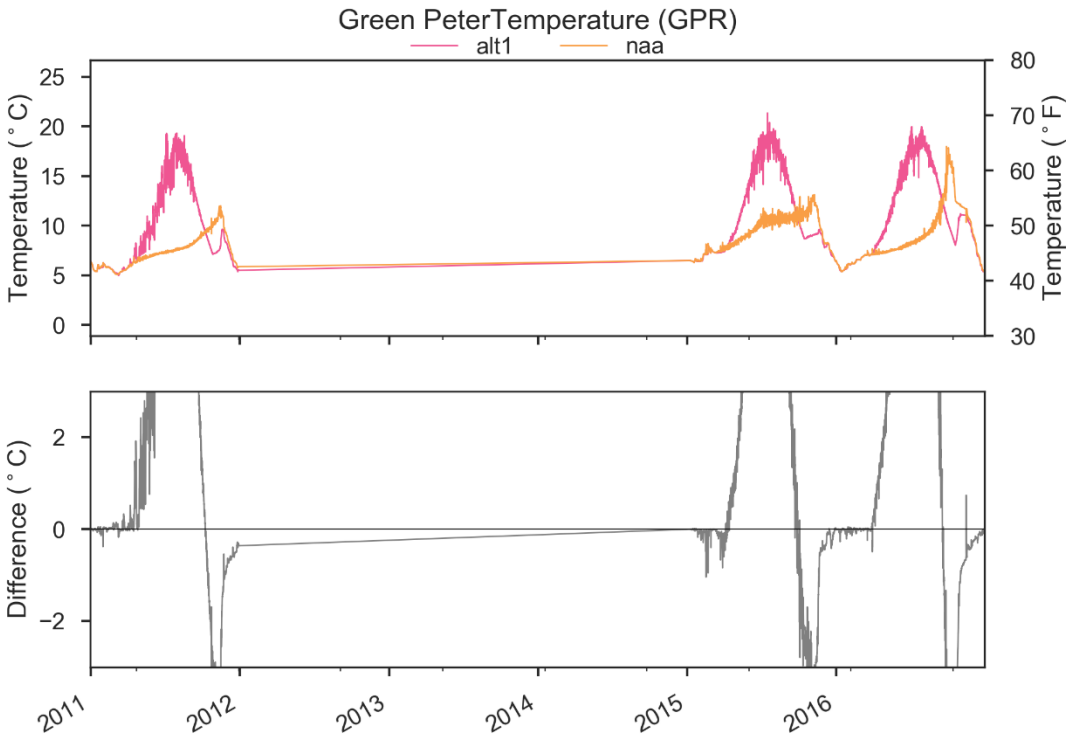


Figure 1-60. Comparison of GPR outflow temperatures in NAA and Alternative 1.

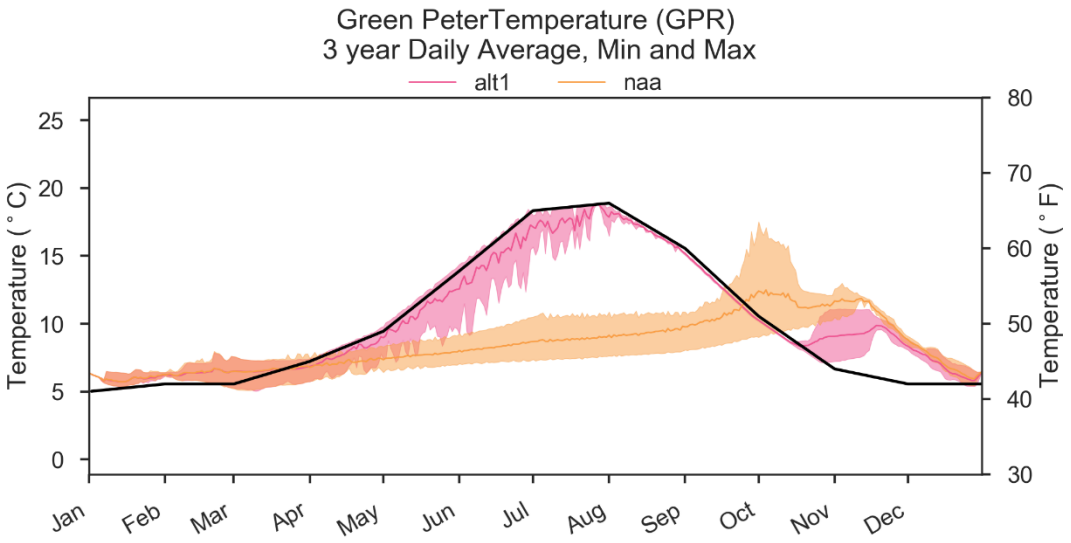


Figure 1-61. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black Line Indicates Temperature Target.

1.5.2.2.2 Foster

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Foster was generally similar in Alternative 1 compared to NAA in 2011 and 2016 but increased in 2015 in Alternative 1 compared to NAA (Figure 1-62, Figure 1-64). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam. The proposed modifications to the fish weir and FWWS in Alternative 1 resulted in lower outflow routed through the Power outlets for temperature management), especially during spring and summer compared to NAA (Figure 1-63).

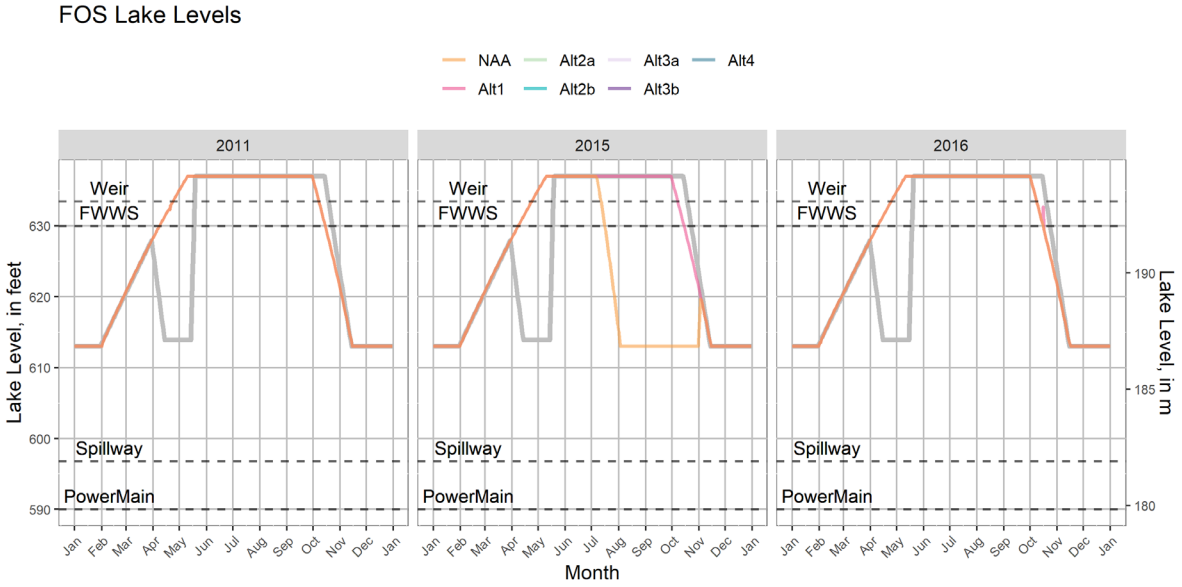


Figure 1-62. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA.

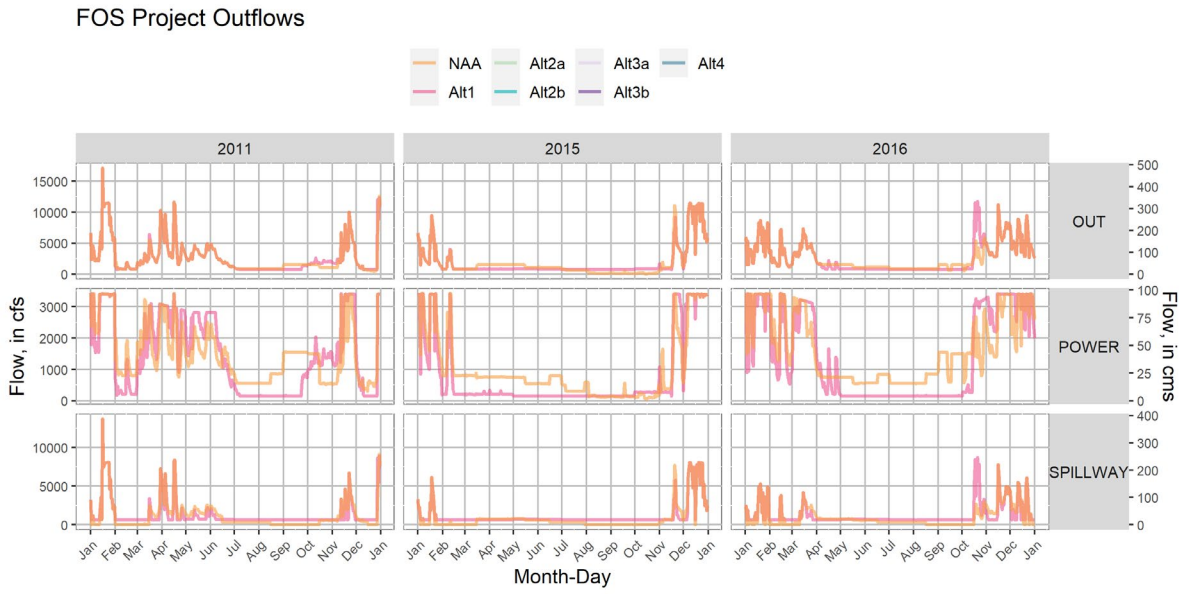


Figure 1-63. WV EIS HEC-ResSim Foster Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA.

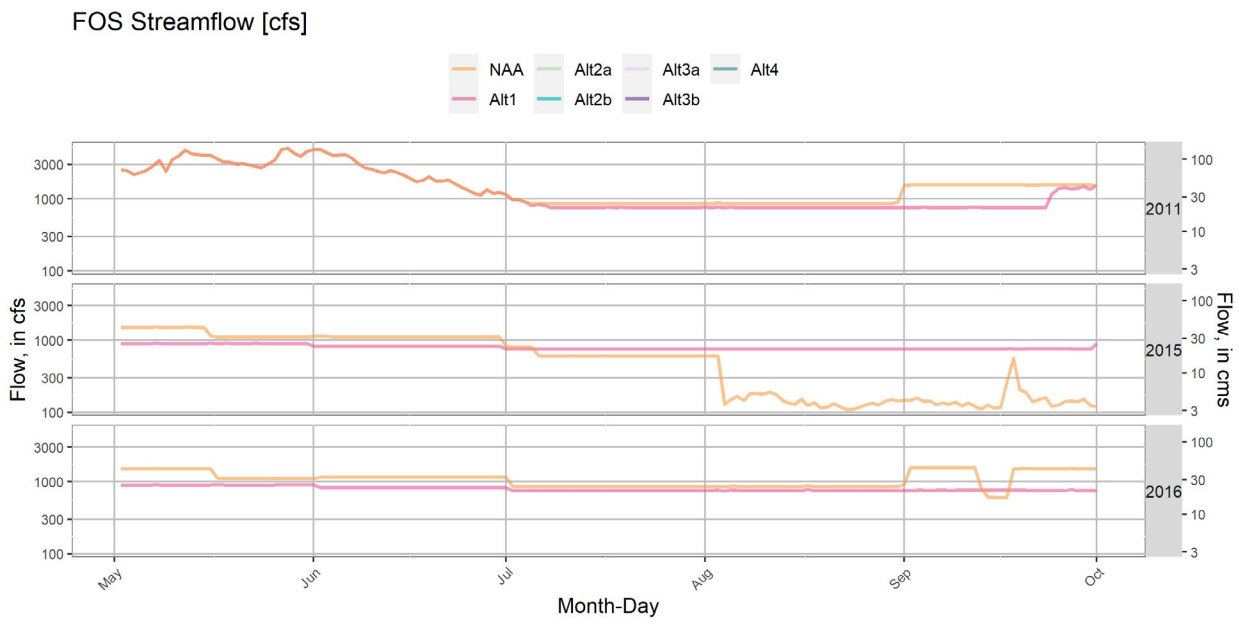


Figure 1-64. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-65, Figure 1-66, and Figure 1-67. Foster Lake temperature was affected by Green Peter Dam operations release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the temperature pattern (Sullivan and Rounds, 2021). Outflows from the proposed fish weir and FWWS resulted in warmer tailwater temperature in spring and summer compared to NAA and cooler than NAA in autumn (Figure 1-68, Figure 1-69).

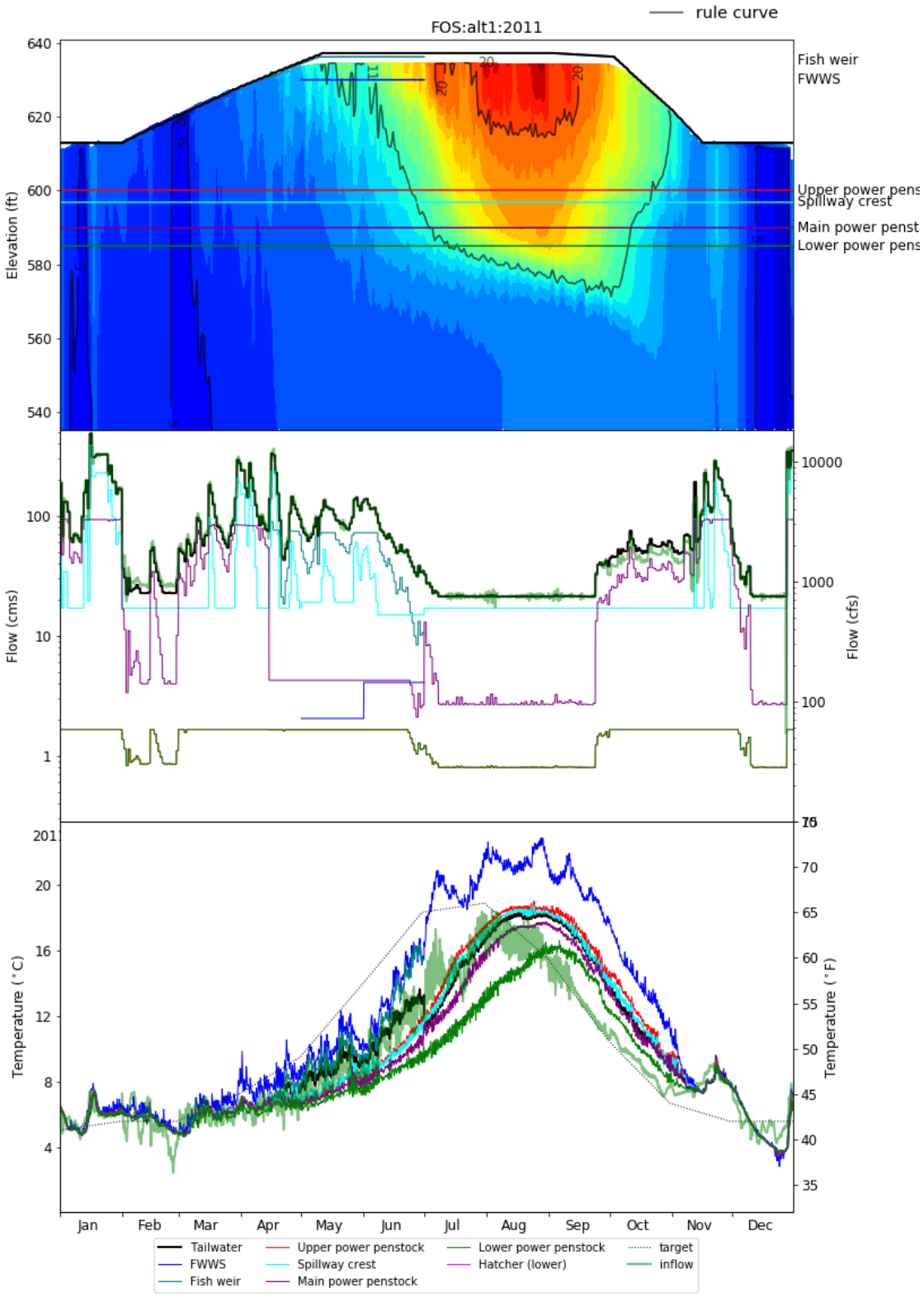


Figure 1-65. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS Under Alternative 1 in 2011.

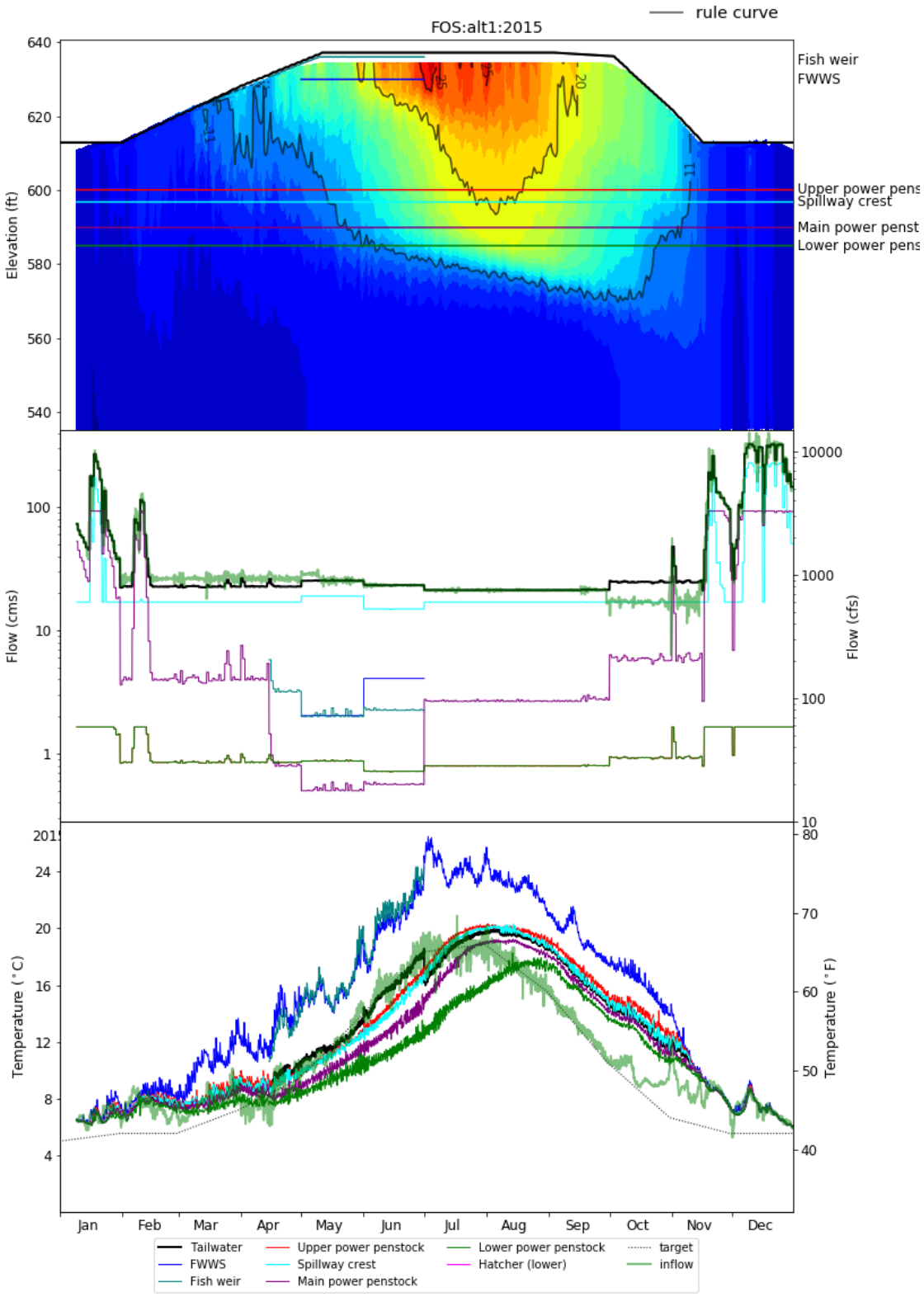


Figure 1-66. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS Under Alternative 1 in 2015.

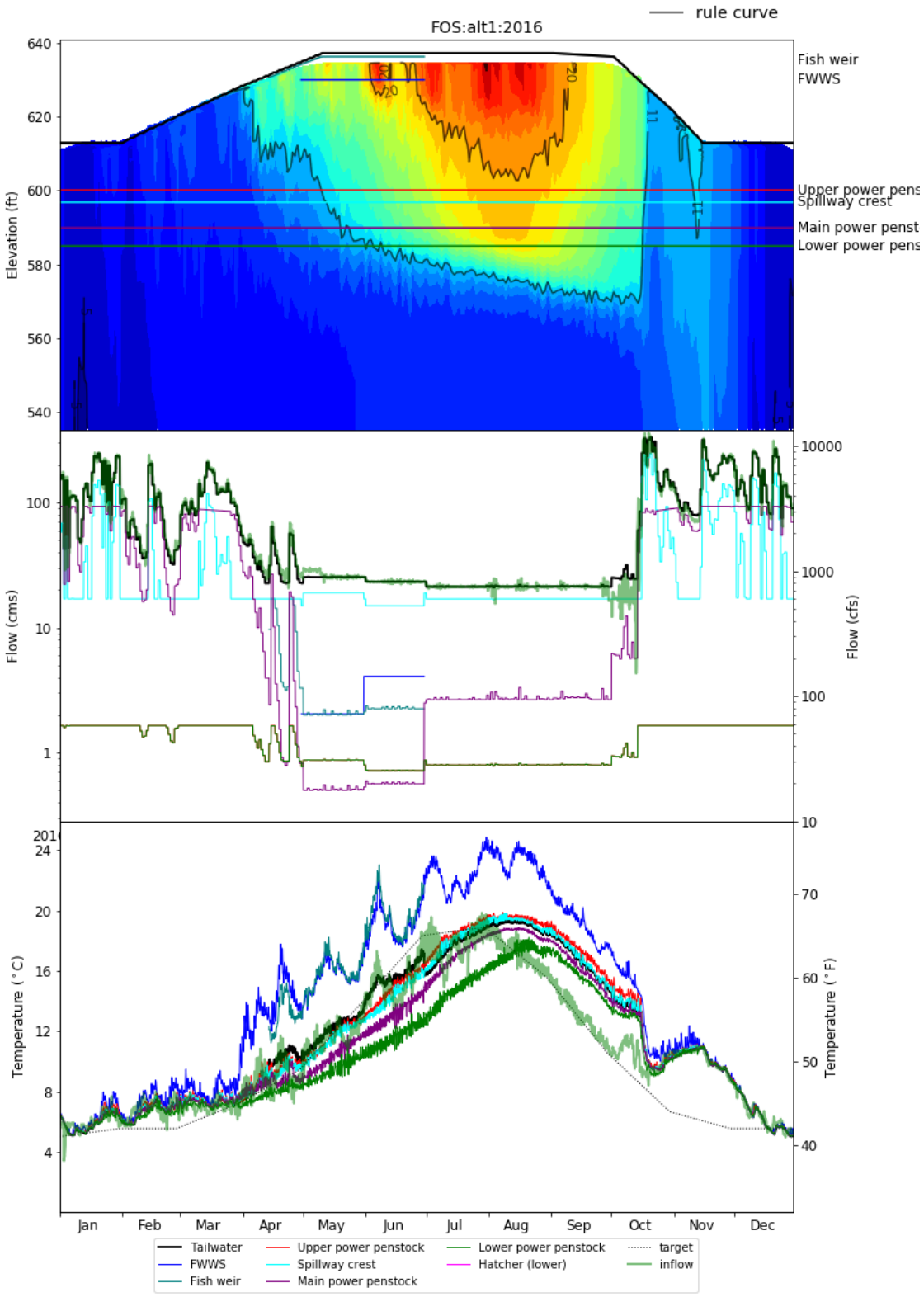


Figure 1-67. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS Under Alternative 1 in 2016.

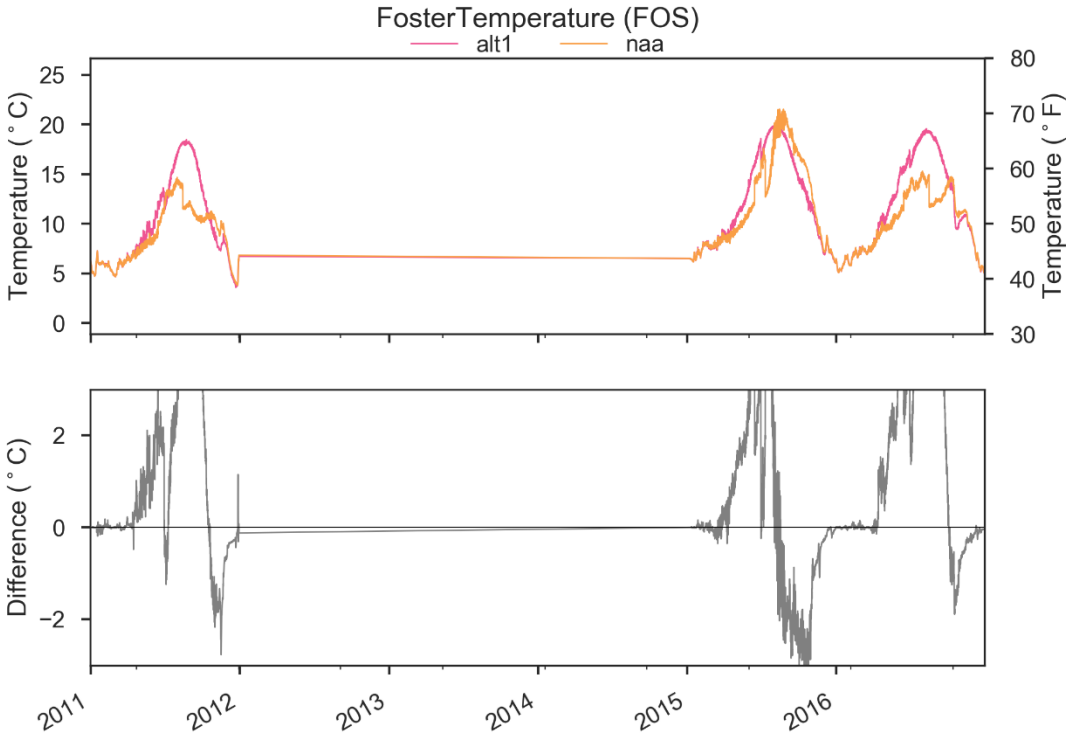


Figure 1-68. Comparison of FOS Outflow Temperatures in NAA and Alternative 1.

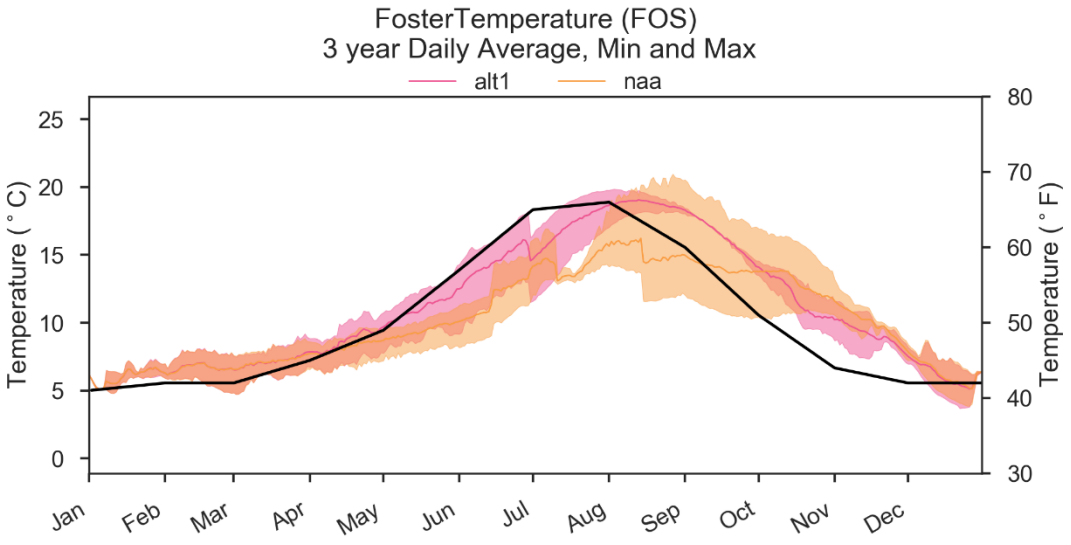


Figure 1-69. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black line indicates temperature target.

1.5.2.3 McKenzie Dams

1.5.2.3.1 Cougar

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Cougar Lake generally increased under Alternative 1 compared to NAA in 2015 and 2016 aside from September-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-70 and Figure 1-71). Increased storage coincided with reduced outflows during spring and increased outflows in summer during 2015 and 2016 (Figure 1-71). 2011 operations were generally similar in Alternative 1 and NAA at Cougar Lake.

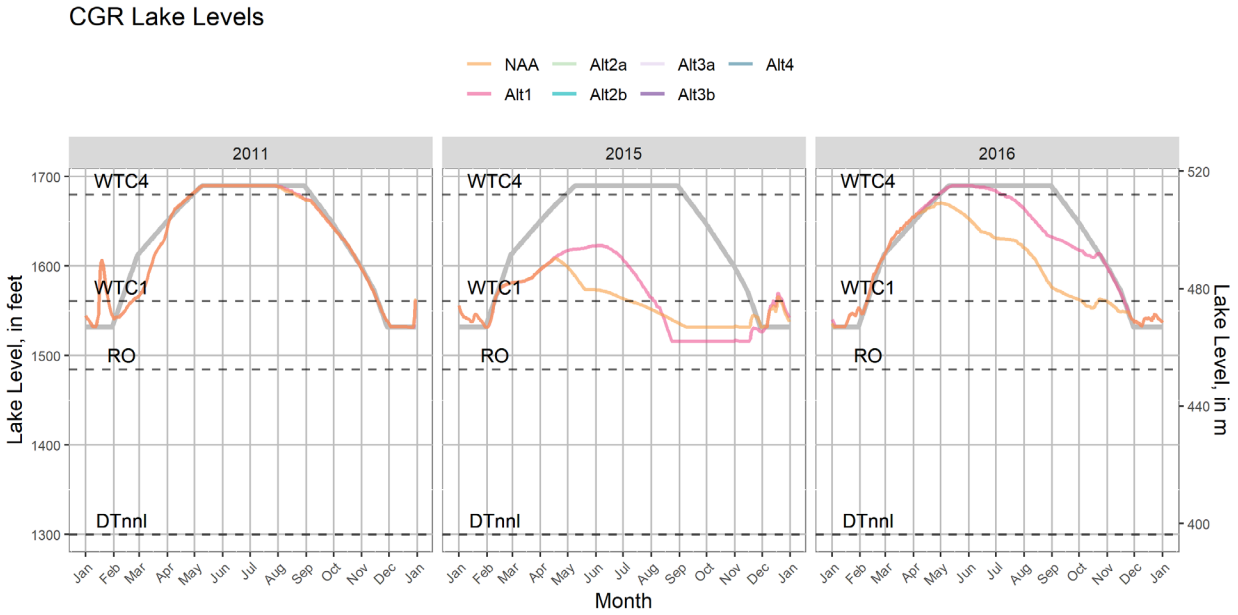


Figure 1-70. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA.

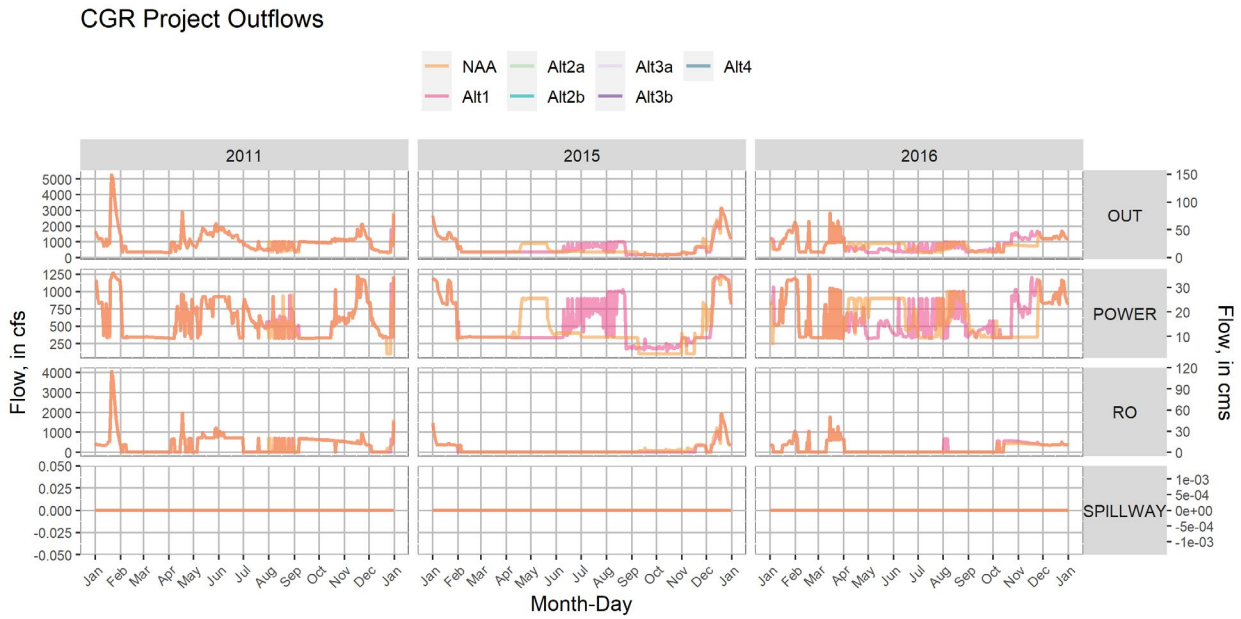


Figure 1-71. WV EIS HEC-ResSim Cougar Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA.

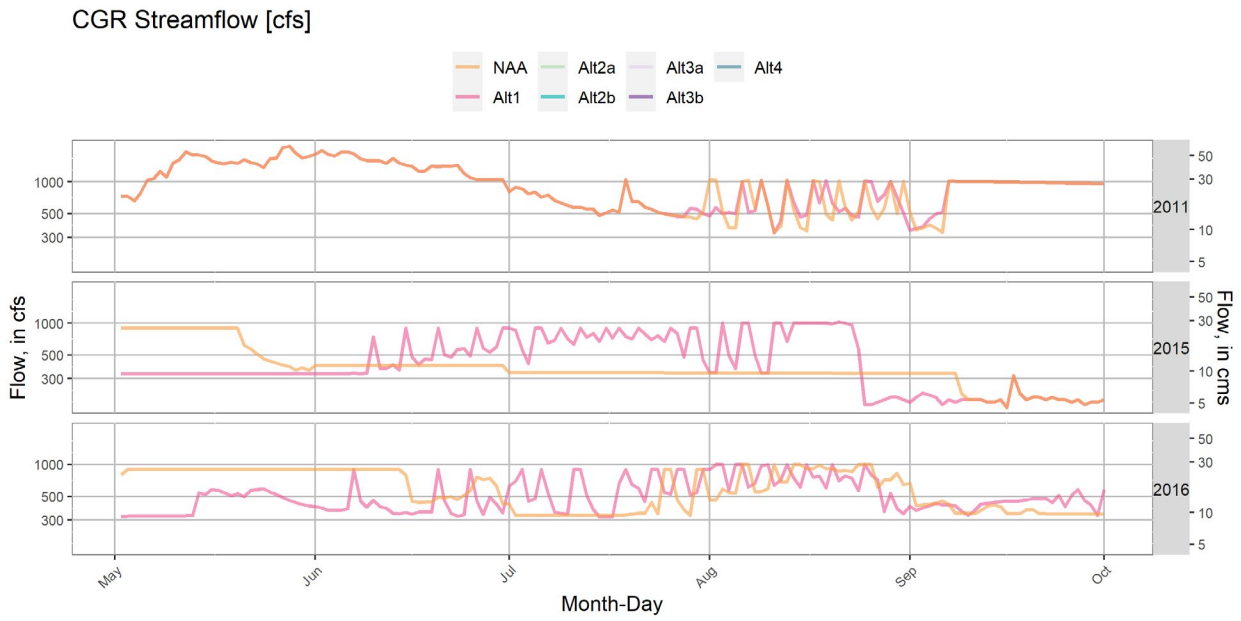


Figure 1-72. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Cougar Lake are shown in Figure 1-73, Figure 1-74, and Figure 1-75. Outflows from the existing temperature tower and proposed FSS resulted in similar tailwater temperature in Alternative 1 compared to NAA (Figure 1-76, Figure 1-77) aside from minor differences in each calendar year scenario that were likely linked to differences in lake levels. The addition of a FSS structure in Alternative 2a is not expected to have a large effect on the ability of the existing WTCT functionality with respect to temperature management (USACE, 2019a).

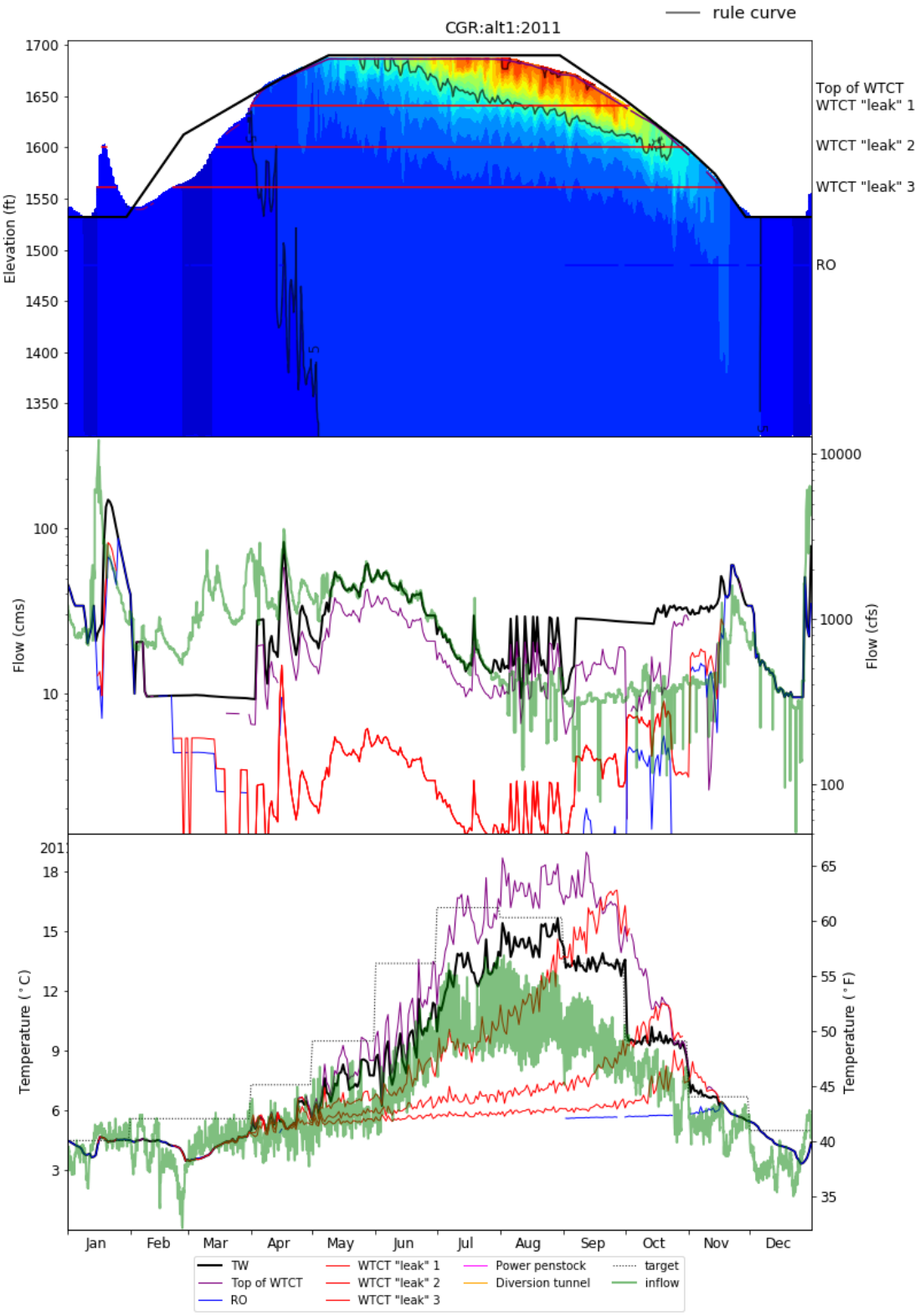


Figure 1-73. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 1 in 2011.

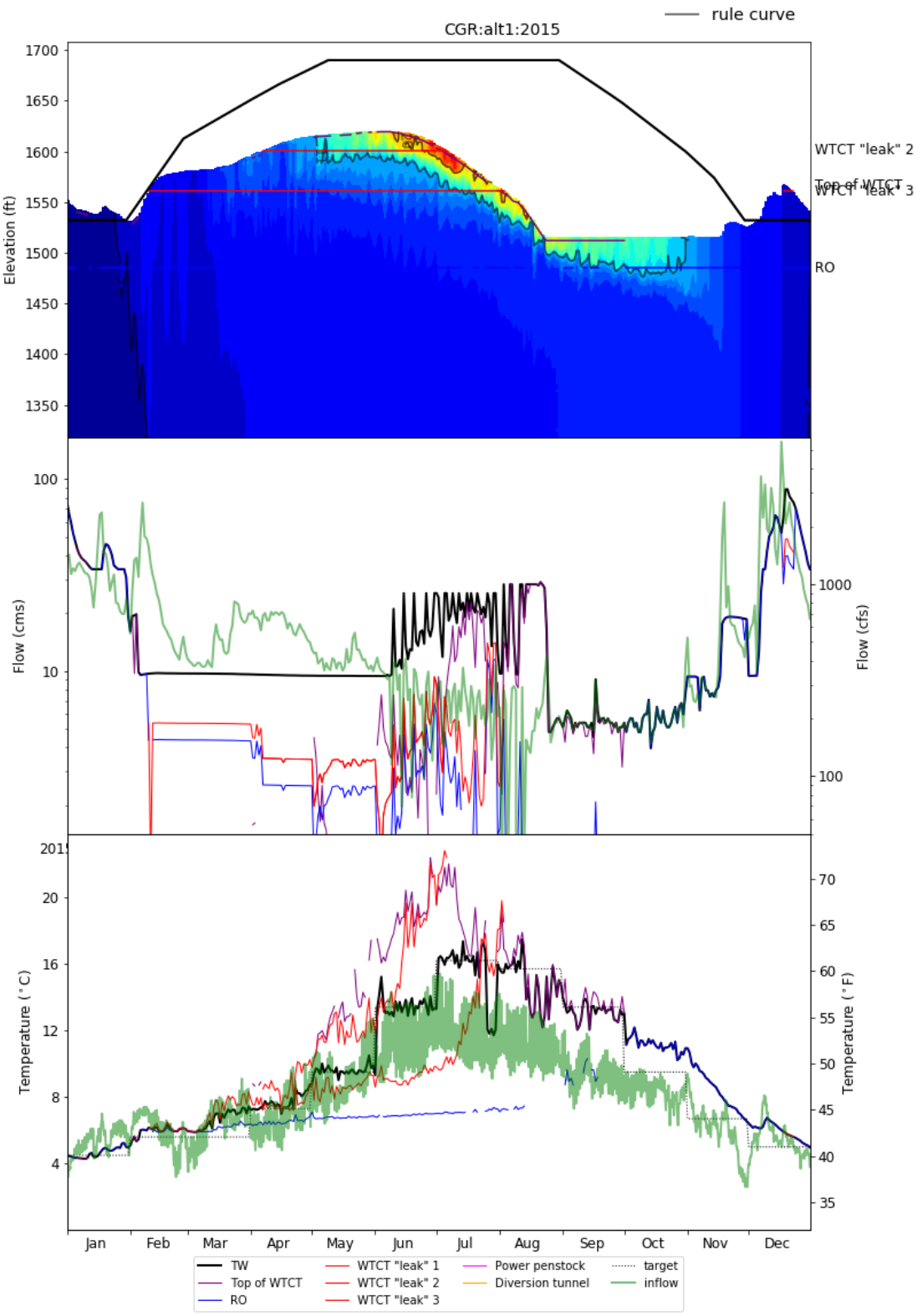


Figure 1-74. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 1 in 2015.

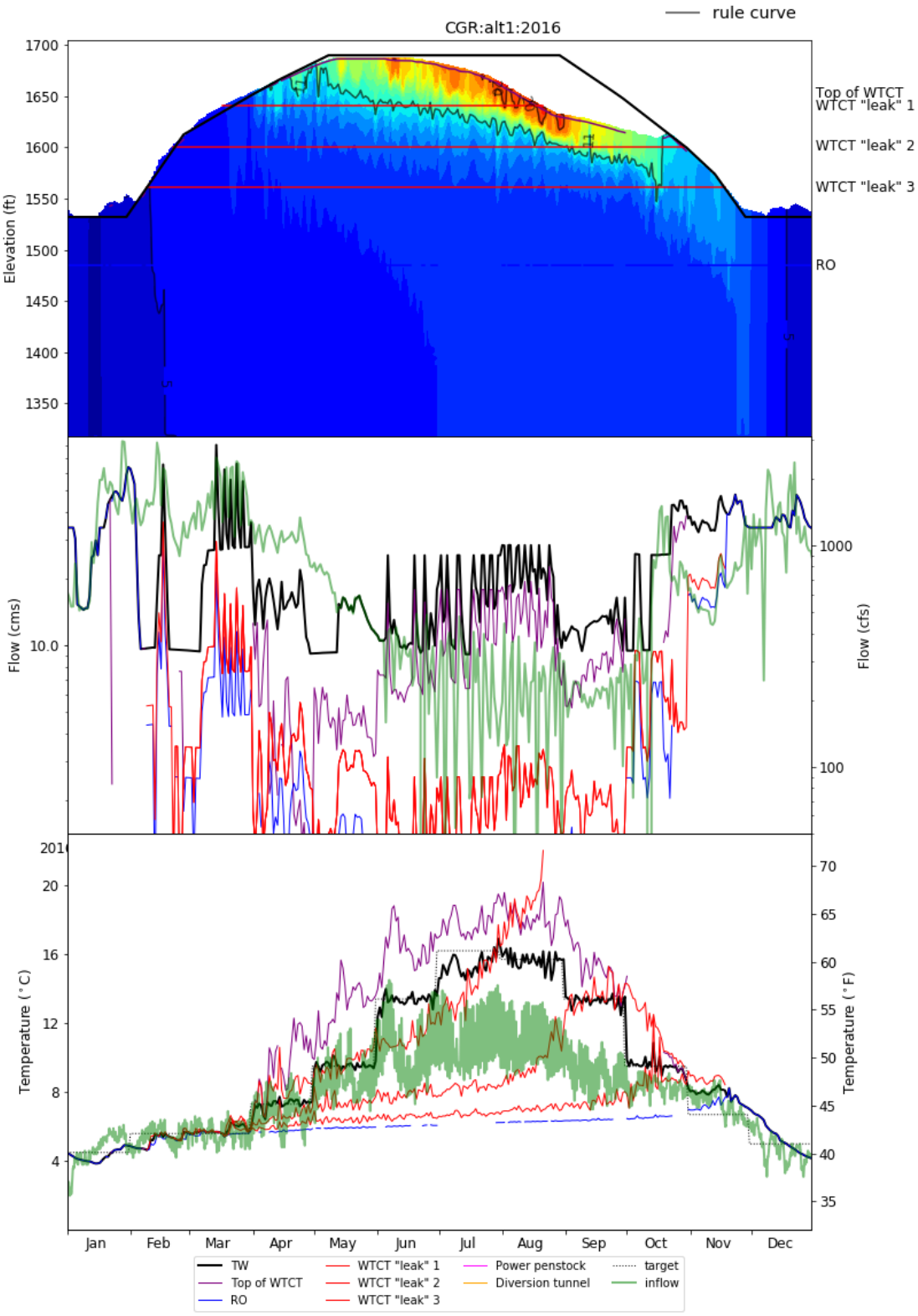


Figure 1-75. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 1 in 2016.

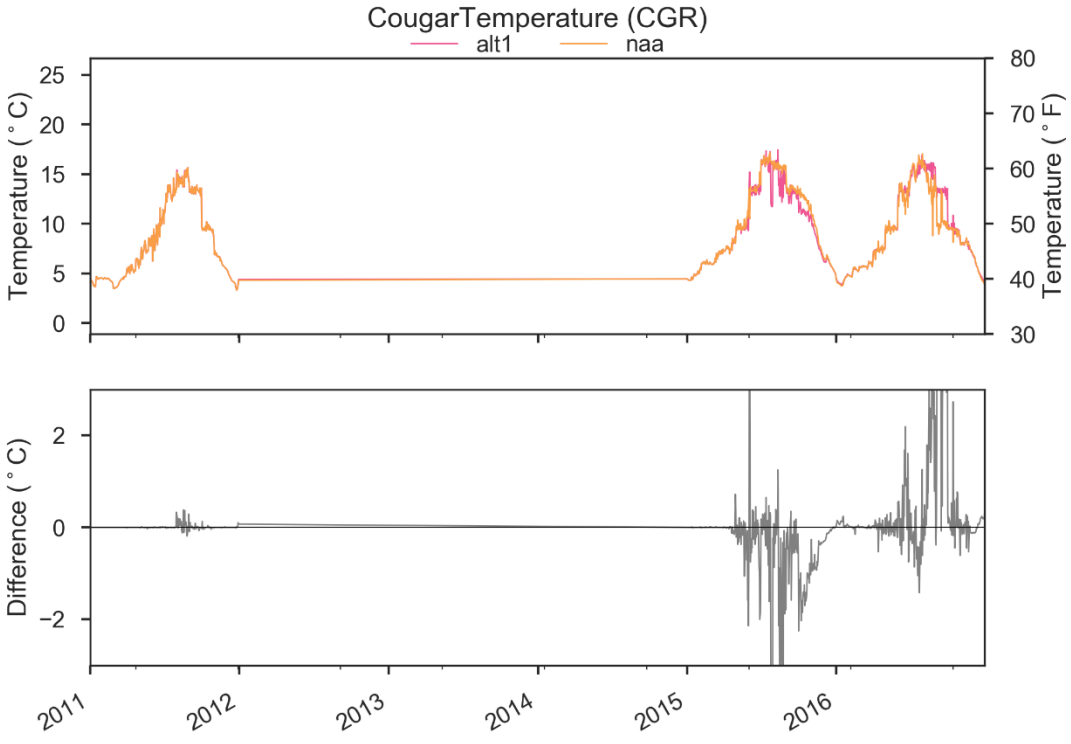


Figure 1-76. Comparison of CGR Outflow Temperatures in NAA and Alternative 1.

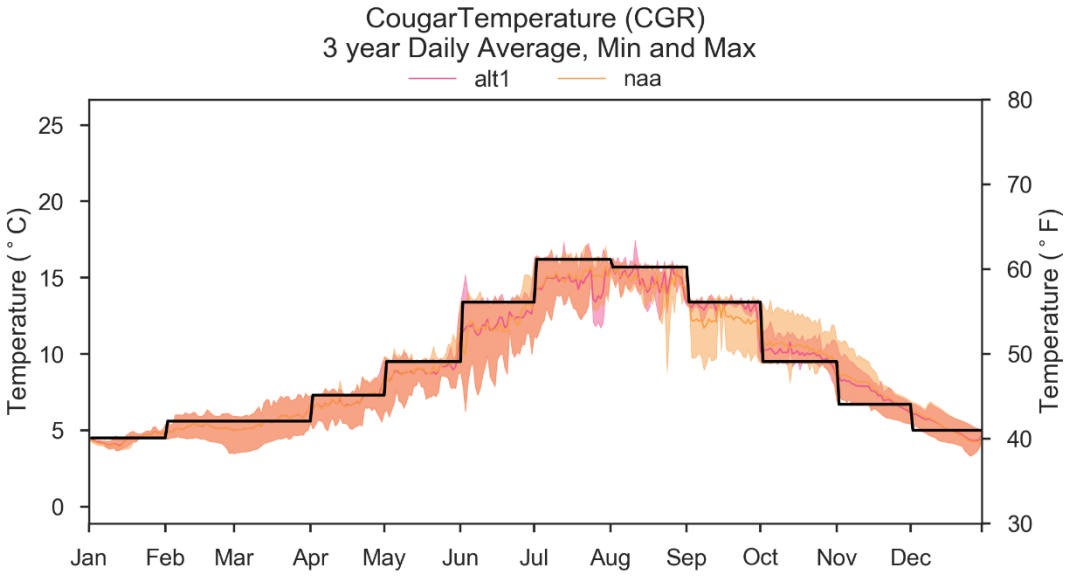


Figure 1-77 Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black line indicates temperature target.

1.5.2.4 Middle Fork Willamette Dams

1.5.2.4.1 Hills Creek

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Hills Creek Lake generally increased in Alternative 1 compared to NAA in 2015 and 2016 aside from August-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-78; Figure 1-80). The increased storage coincided with reduced outflows during spring and increased outflows in June-July during 2015 and July-October in 2016. (Figure 1-79). 2011 operations were generally similar in Alternative 1 and NAA at Hills Creek Lake.

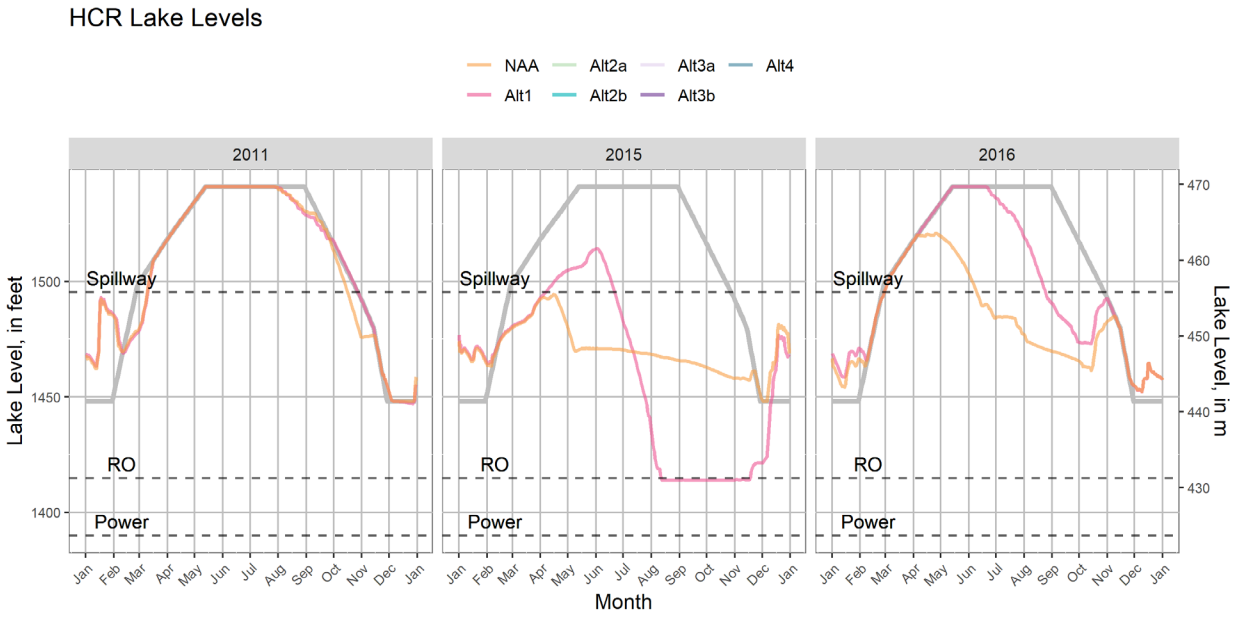


Figure 1-78. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA.



Figure 1-79. WV EIS HEC-ResSim Hills Creek Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA.

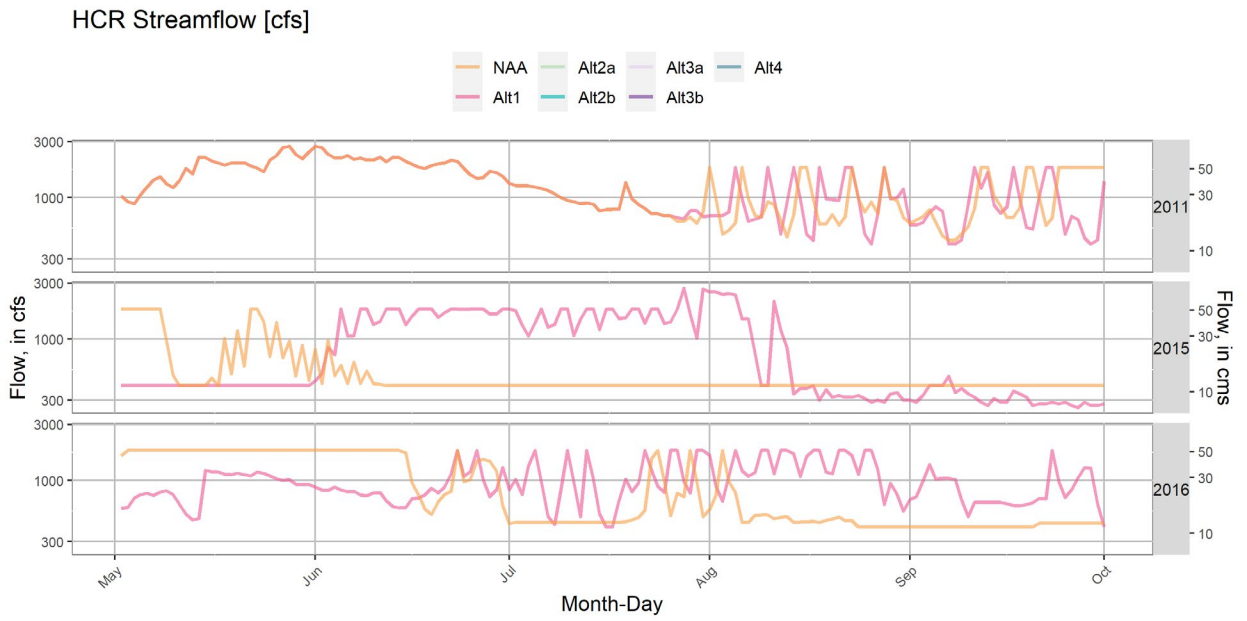


Figure 1-80. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 1 at Hills Creek Lake are shown in Figure 1-81, Figure 1-82, and Figure 1-83. The timing of the peak seasonal tailwater temperature under Alternative 1 occurred about one month earlier in 2015, which resulted in cooler tailwater temperature during autumn of that year compared to NAA (Figure 1-76, Figure 1-77). The 2016 outflow tailwater temperature in Alternative 1 was generally cooler than NAA in spring and summer but similar during autumn.

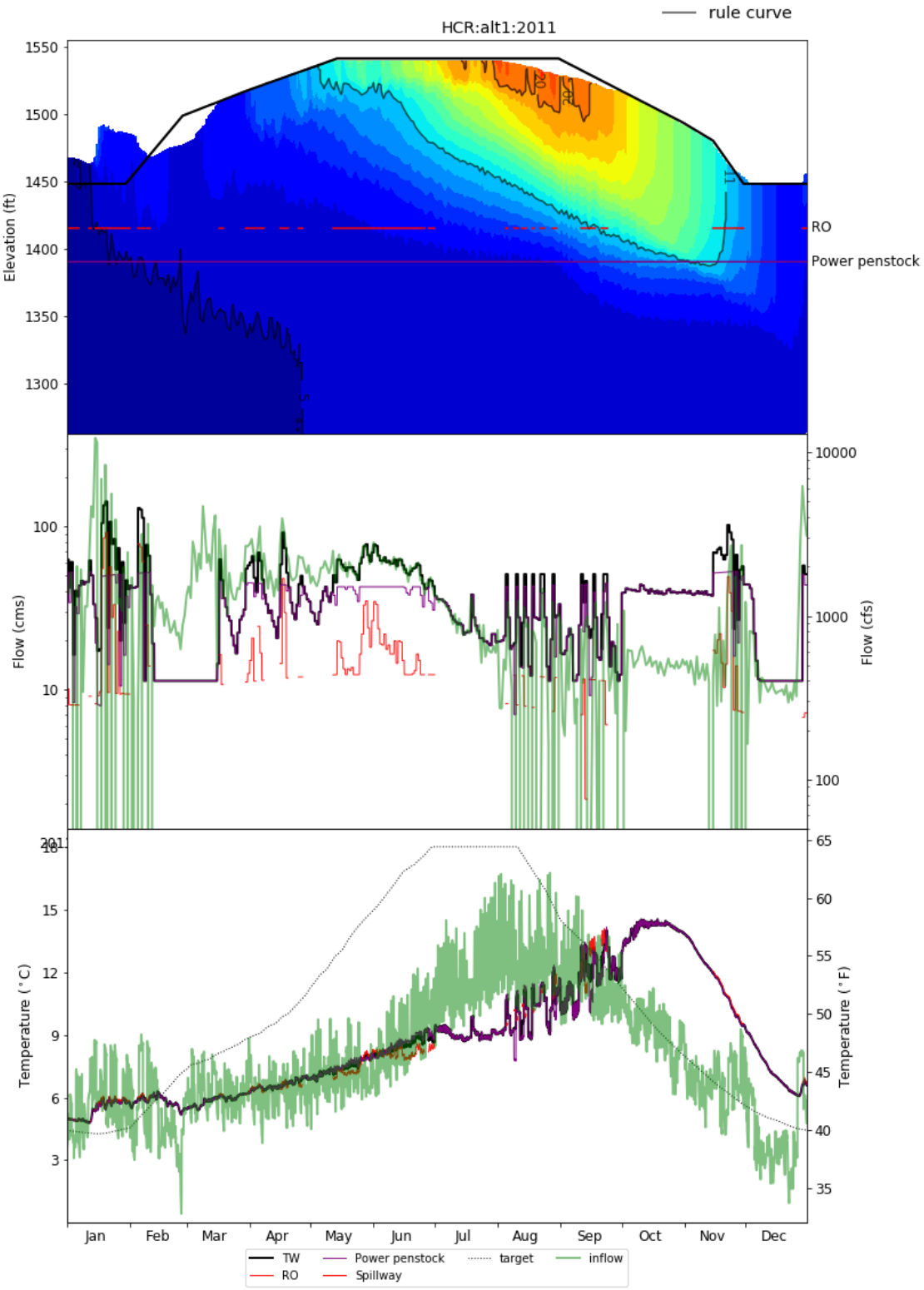


Figure 1-81. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 1 in 2011.

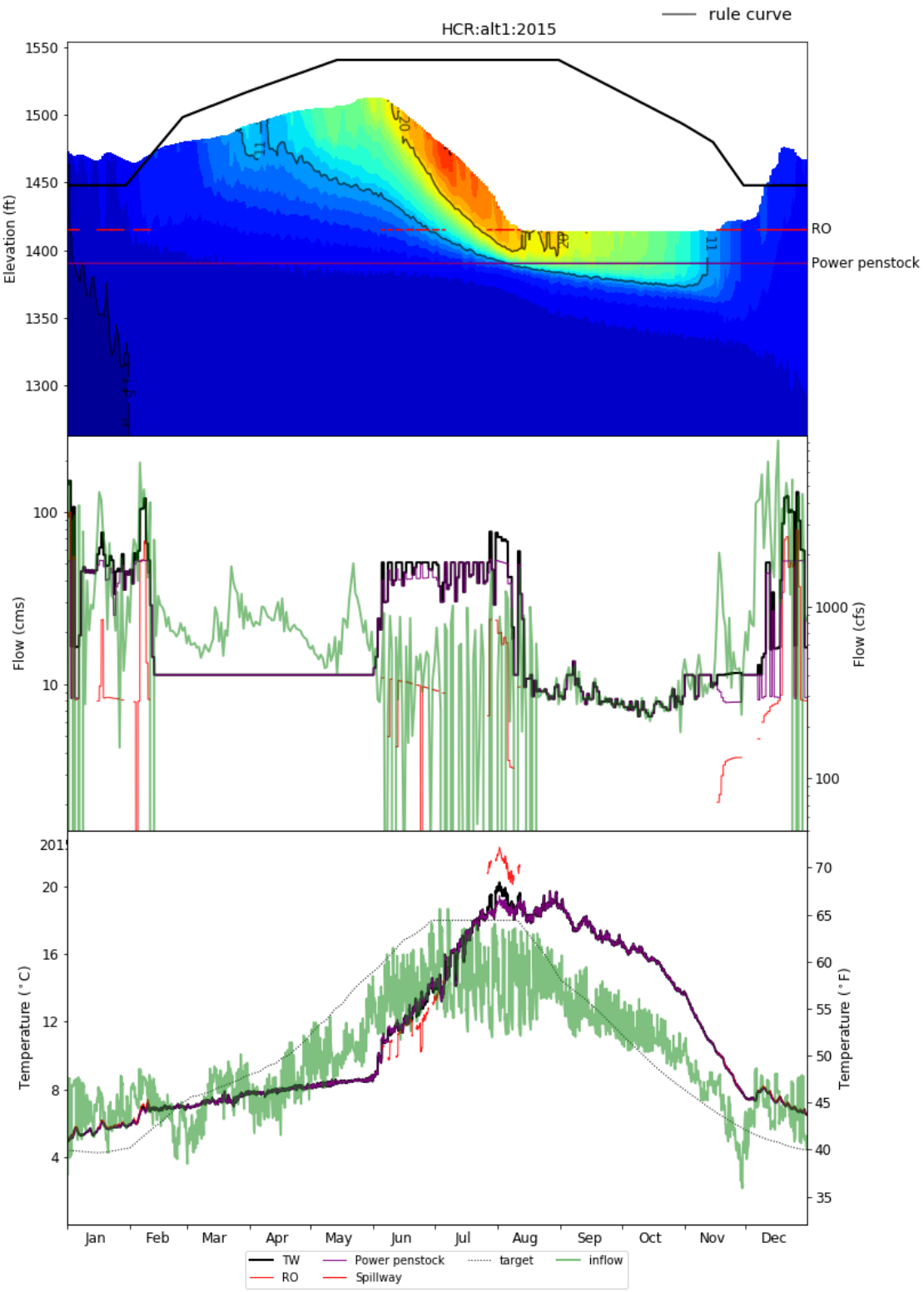


Figure 1-82. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 1 in 2015.

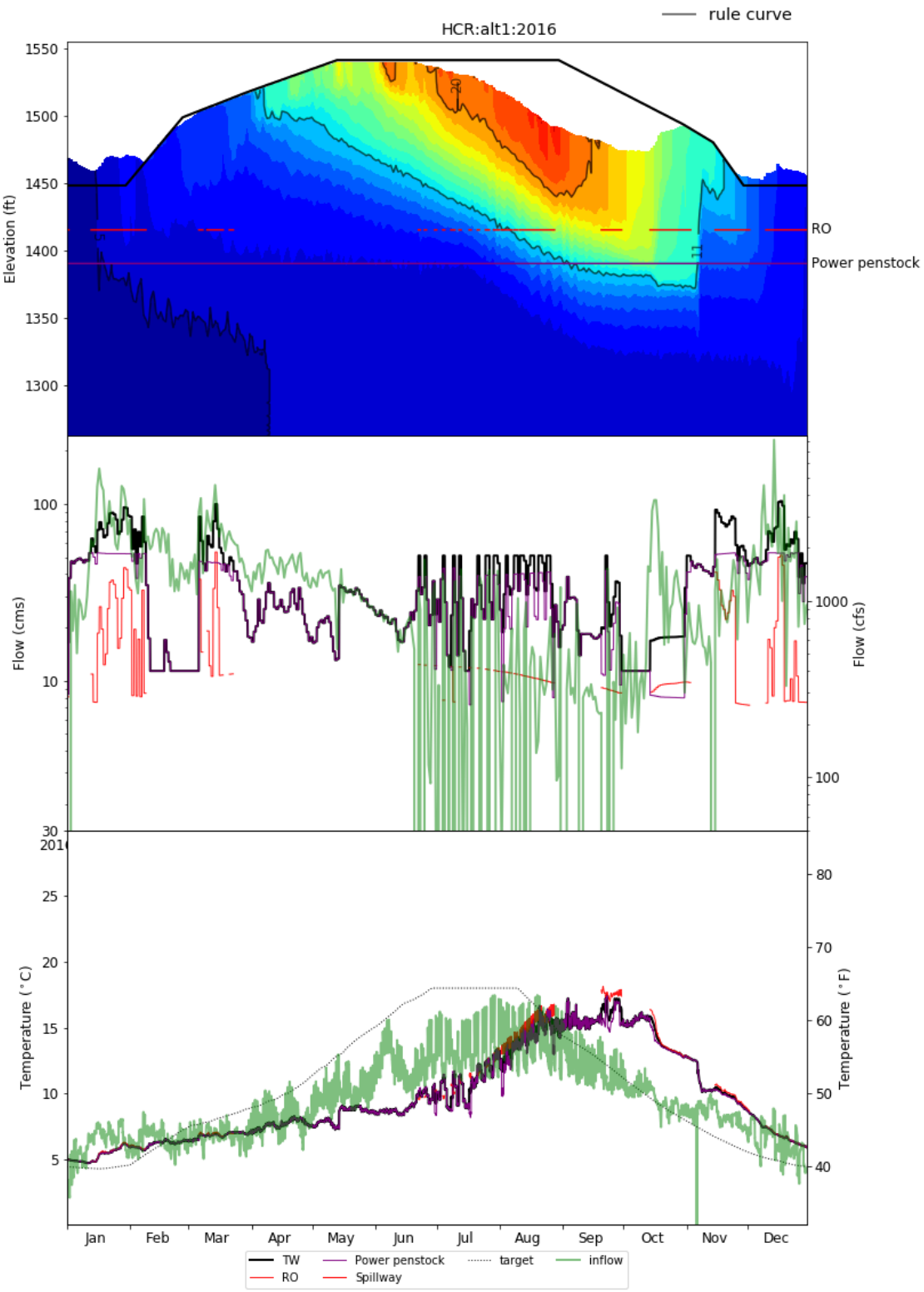


Figure 1-83. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 1 in 2016.

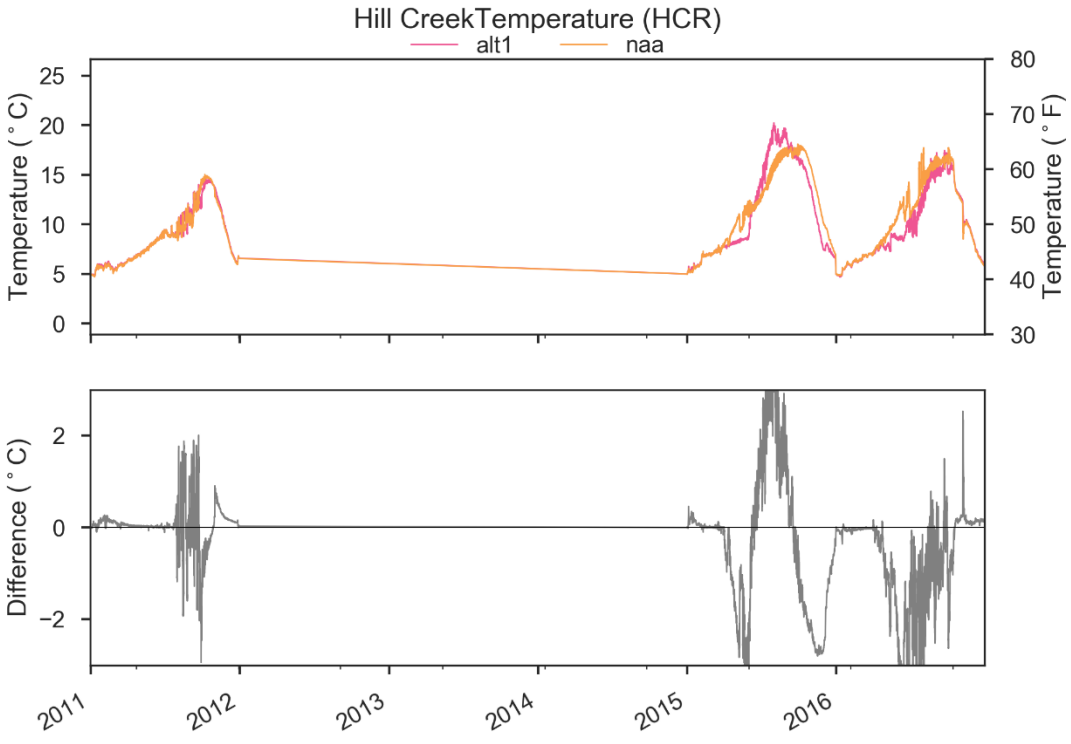


Figure 1-84. Comparison of HCR Outflow Temperatures in NAA and Alternative 1.

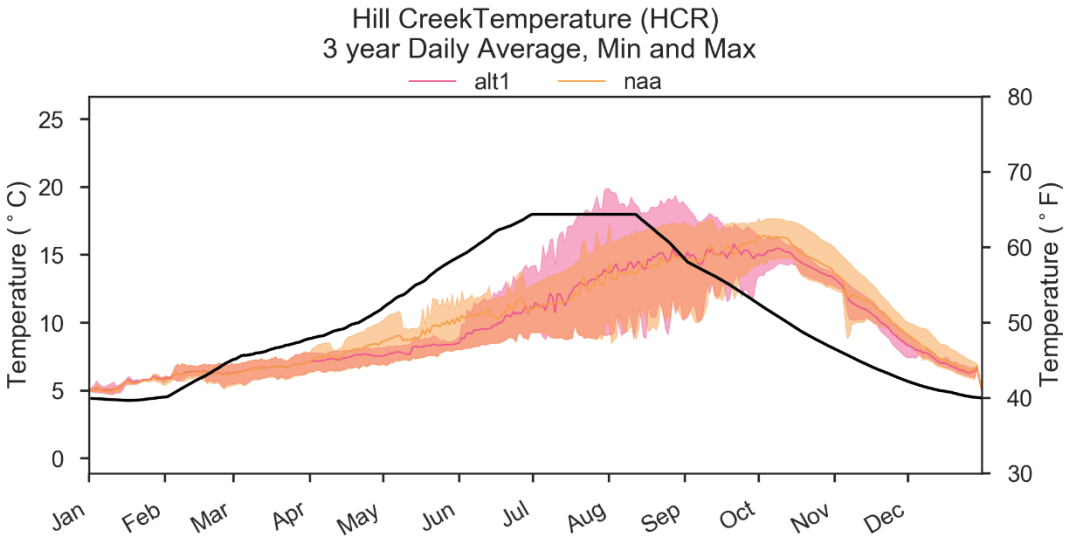


Figure 1-85. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black line indicates temperature target.

1.5.2.4.2 Lookout Point

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Lookout Point Lake were generally similar to NAA in 2011, 2015, and 2016 (Figure 1-86, Figure 1-88) aside from minor differences in timing of refill and release rates that were associated with upstream Hills Creek Dam operations. The proposed SWS and FSS in Alternative 1 allowed all outflow within powerhouse capacity (assumed at 6000 cfs) to be routed from a floating outlet through the Power outlets for temperature management (Figure 1-87).

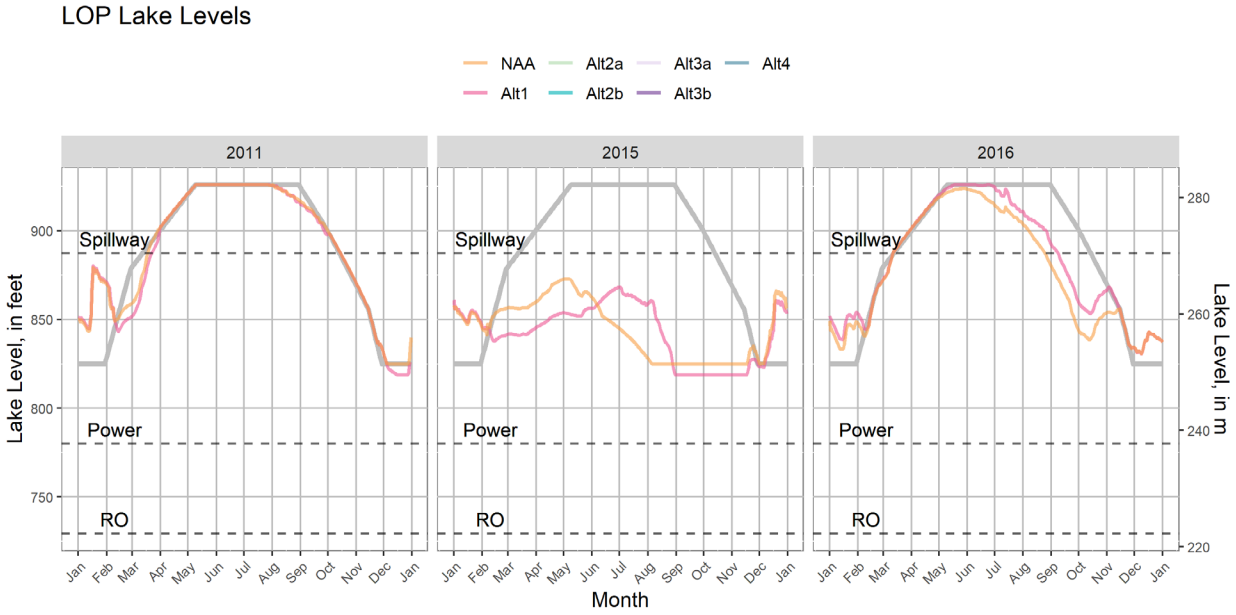


Figure 1-86. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA.

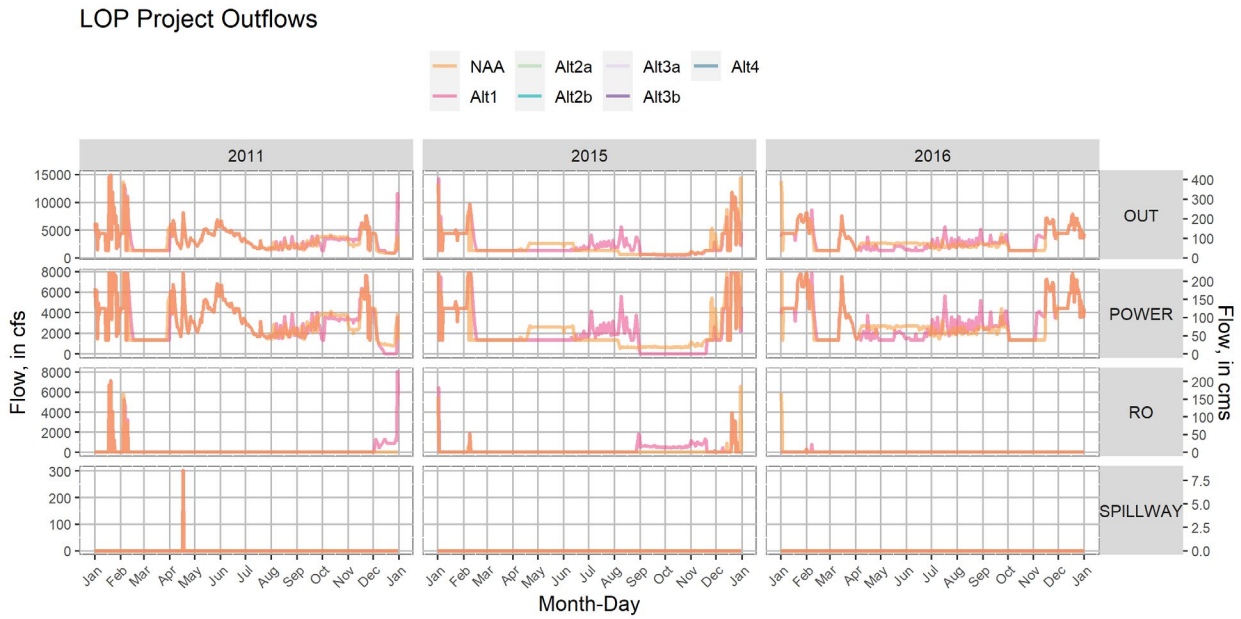


Figure 1-87. WV EIS HEC-ResSim Lookout Point Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA.

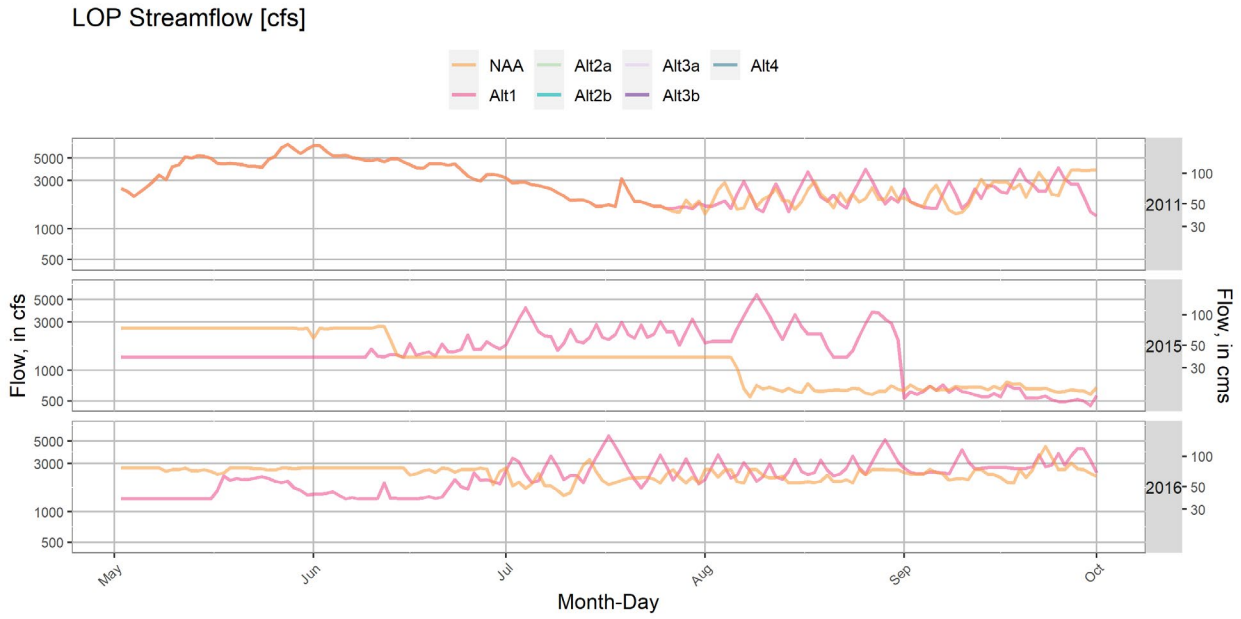


Figure 1-88. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year at Lookout Point Lake are shown in Figure 1-89, Figure 1-90, and Figure 1-91. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the RO. Tailwater release temperatures generally

matched the temperature target when sufficient warm or cool water was available. Generally, these proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn in 2011, 2015, and 2016 (Figure 1-92, Figure 1-93) as measured below Dexter Dam.

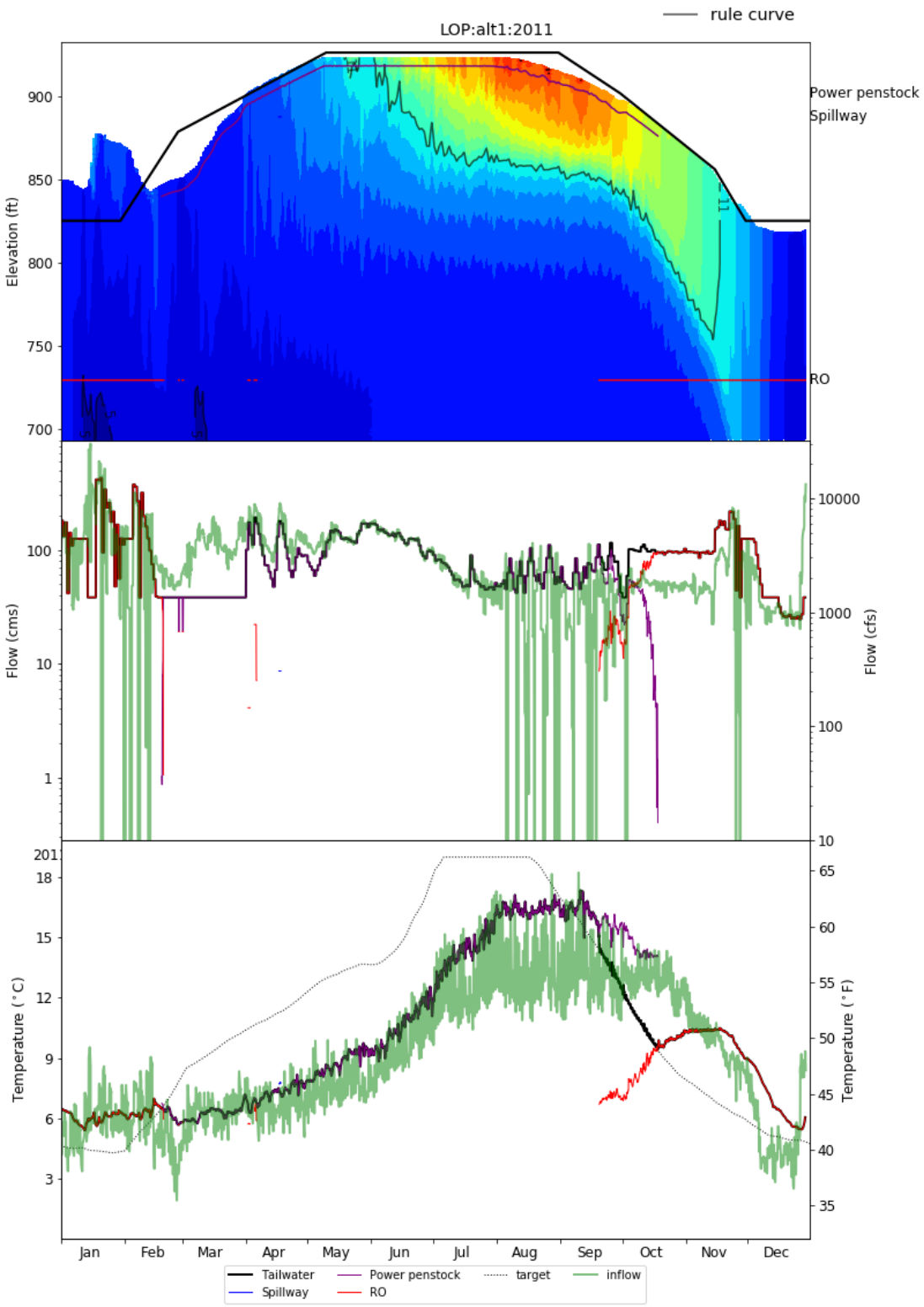


Figure 1-89. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 1 in 2011.

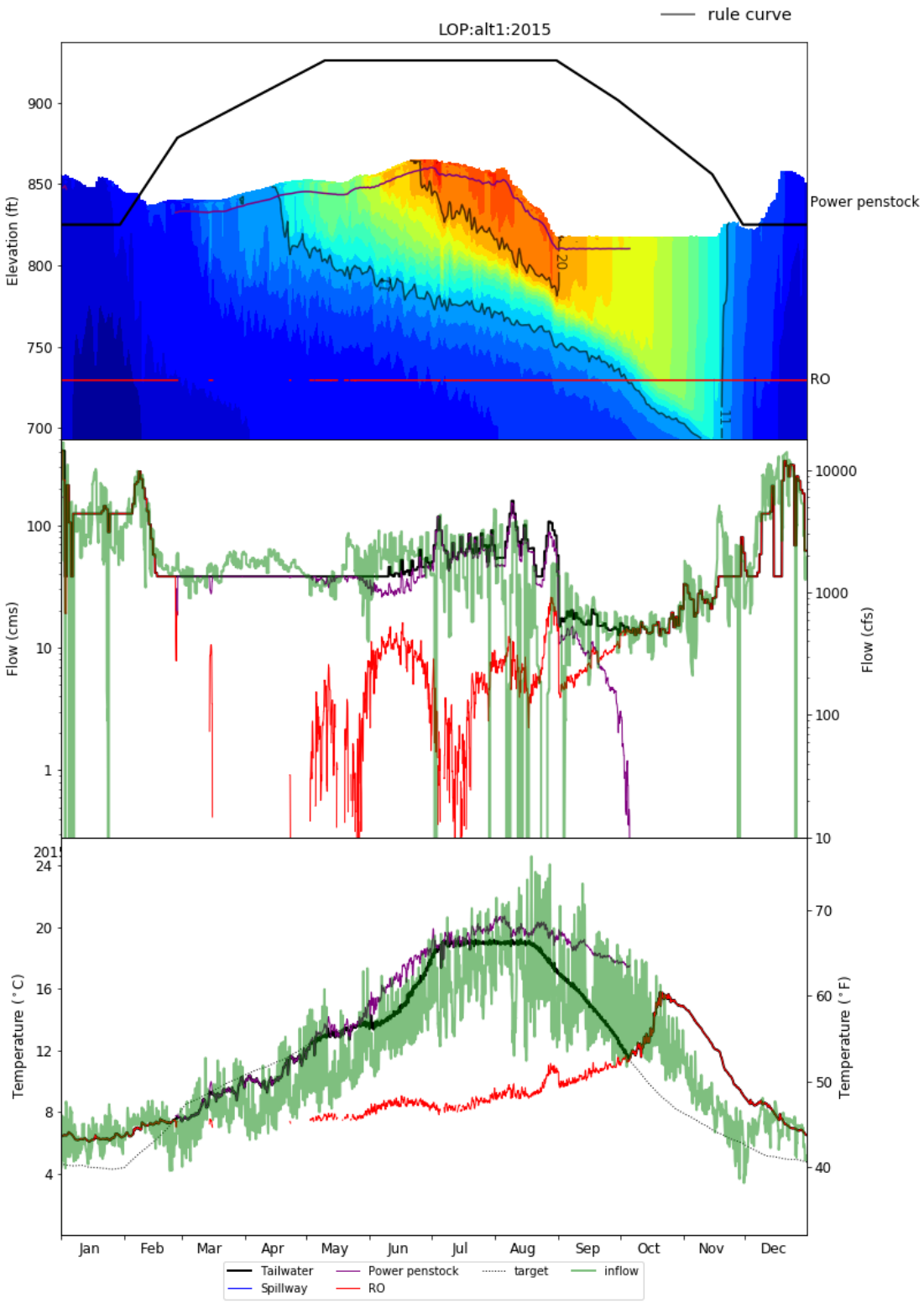


Figure 1-90. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 1 in 2015.

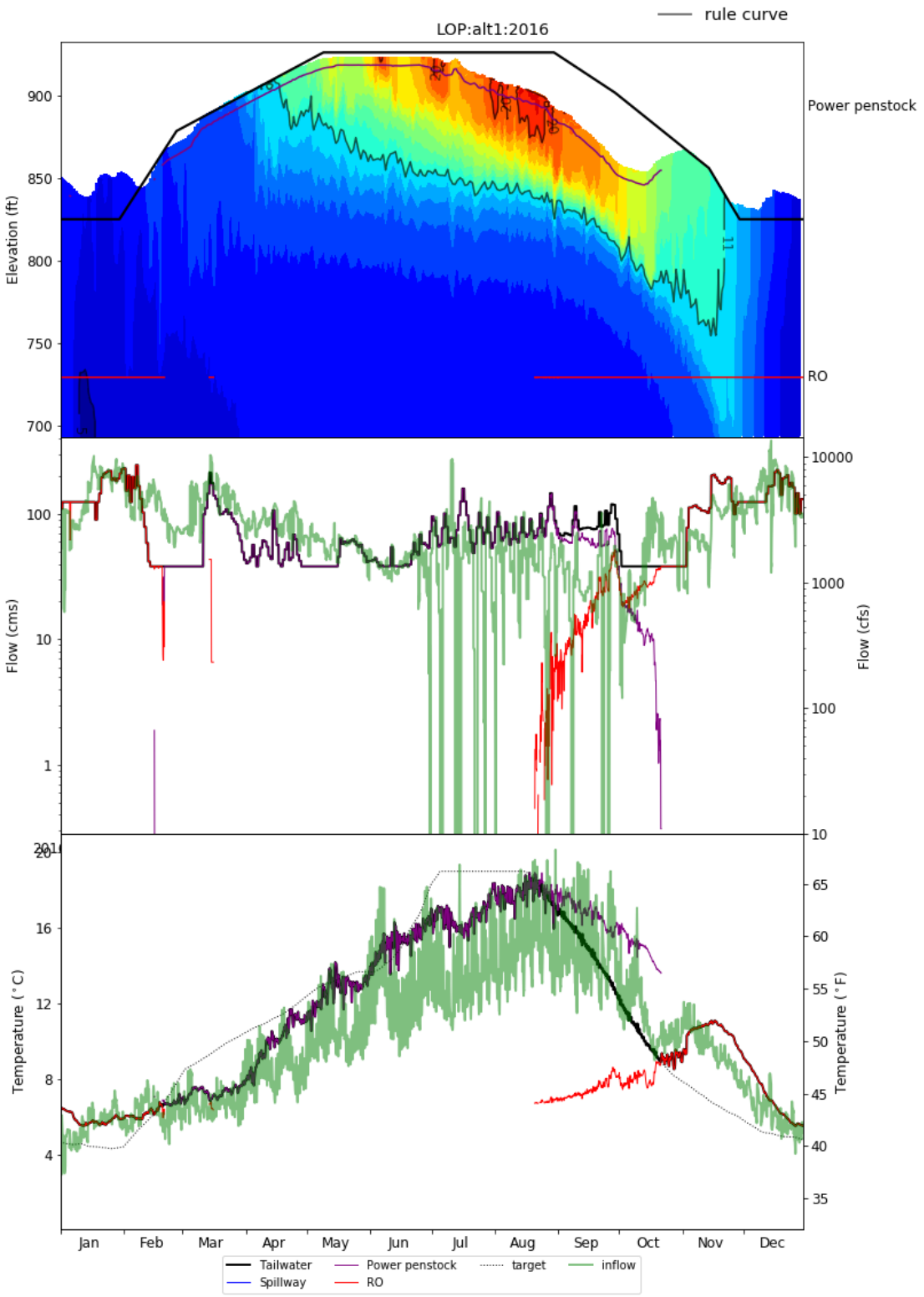


Figure 1-91. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 1 in 2016.

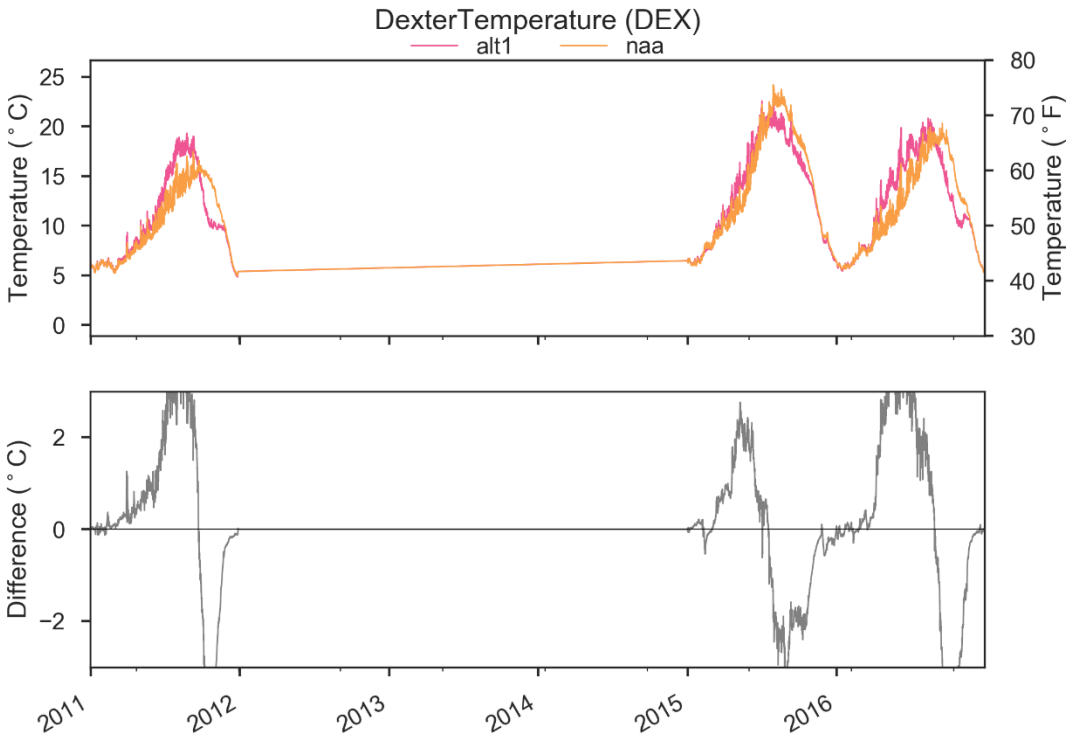


Figure 1-92. Comparison of DEX Outflow Temperatures in NAA and Alternative 1.

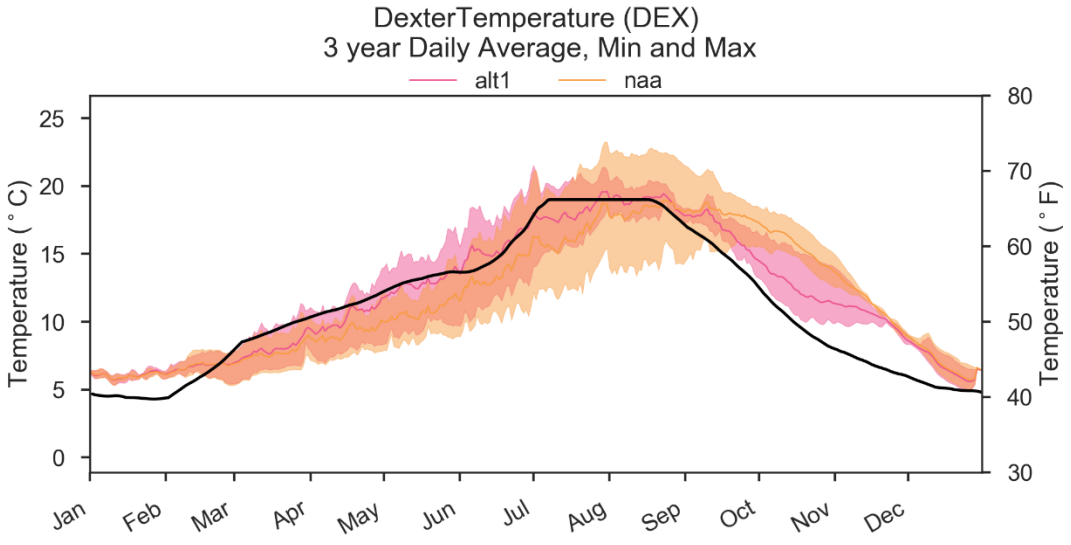


Figure 1-93. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black line indicates temperature target.

1.5.2.5 Mainstem Willamette River

Streamflow in the Mainstem Willamette River under Alternative 1 was generally lower from April to mid-June and higher from mid-June to mid-September compared with NAA (Figure 1-94). However, these flow differences were primarily in 2015 and responsive to the flow Measure 30 rules that increase dam outflows in advance of heat wave events (Figure 1-95). These flow changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (Figure 1-96, Figure 1-97). Water temperatures at Salem were also affected by upstream dam operations and proposed SWS-FSS structures, which likely contributed to warmer temperatures seen in 2011 and 2015 comparing Alternative 1 to NAA. Overall water temperature differences between Alternative 1 and NAA were less than 2 degrees Celsius.

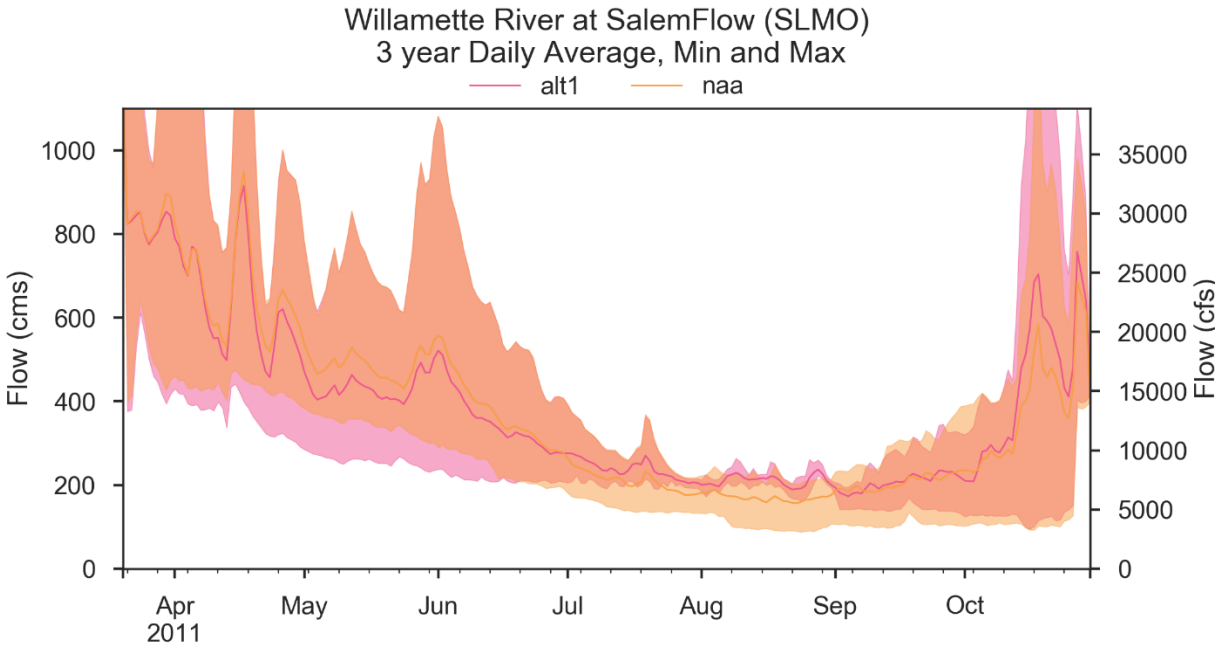


Figure 1-94. Streamflow comparison of Daily Average, Min, Max at Willamette River at SLMO under NAA and Alternative 1 conditions.

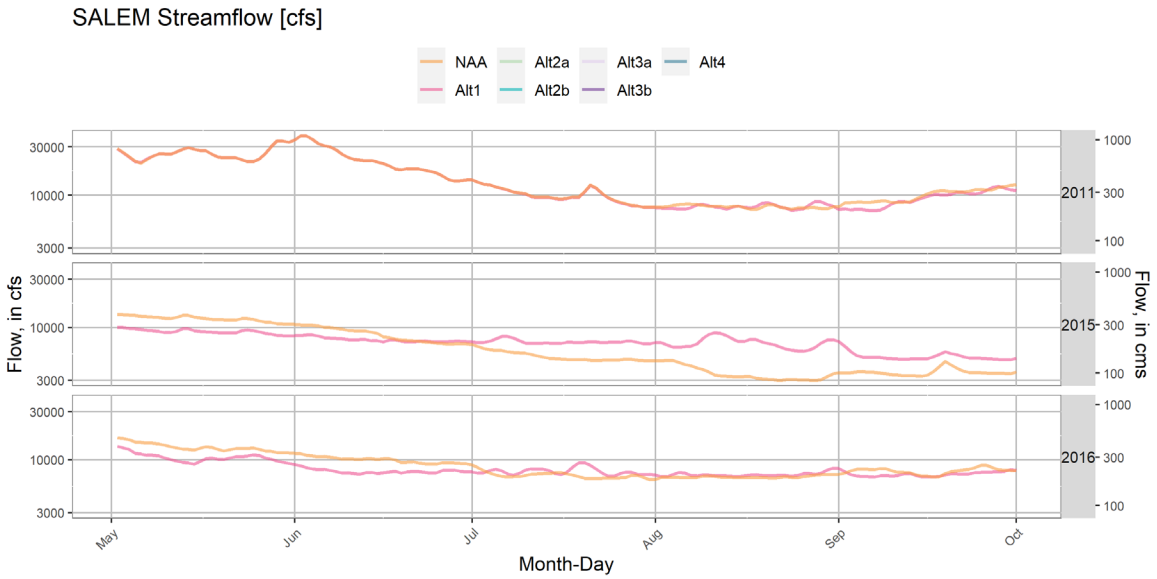


Figure 1-95. Streamflow Comparison Between Alternative 1 and NAA at Willamette River at SLMO.

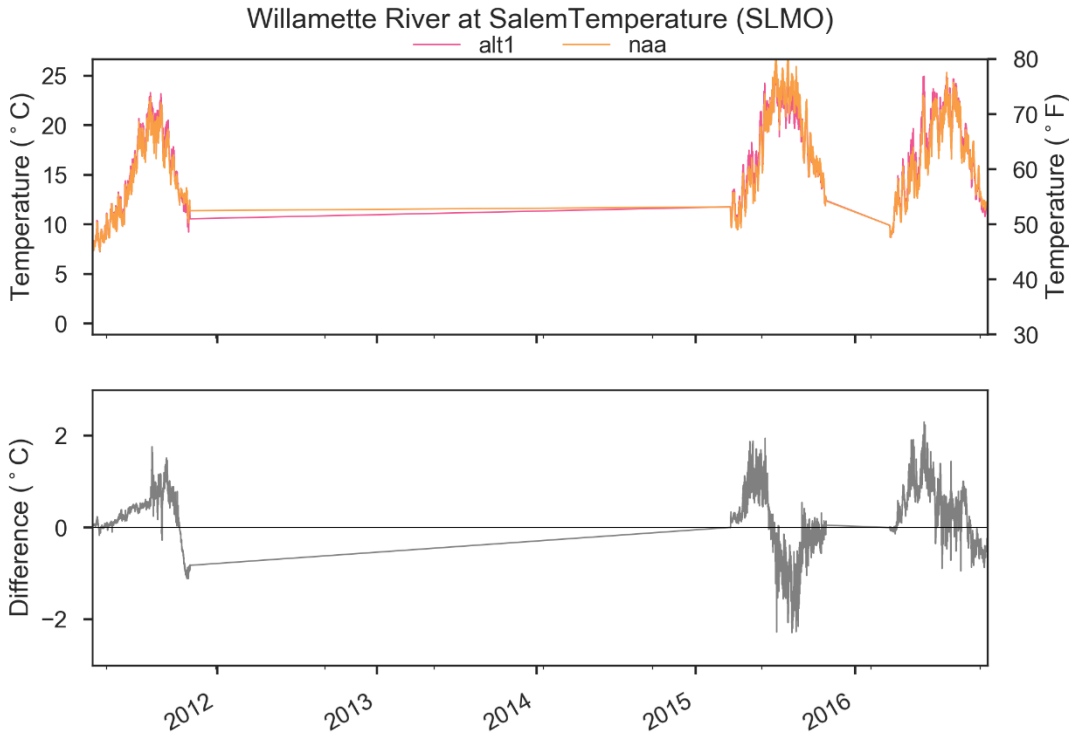


Figure 1-96. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 1.

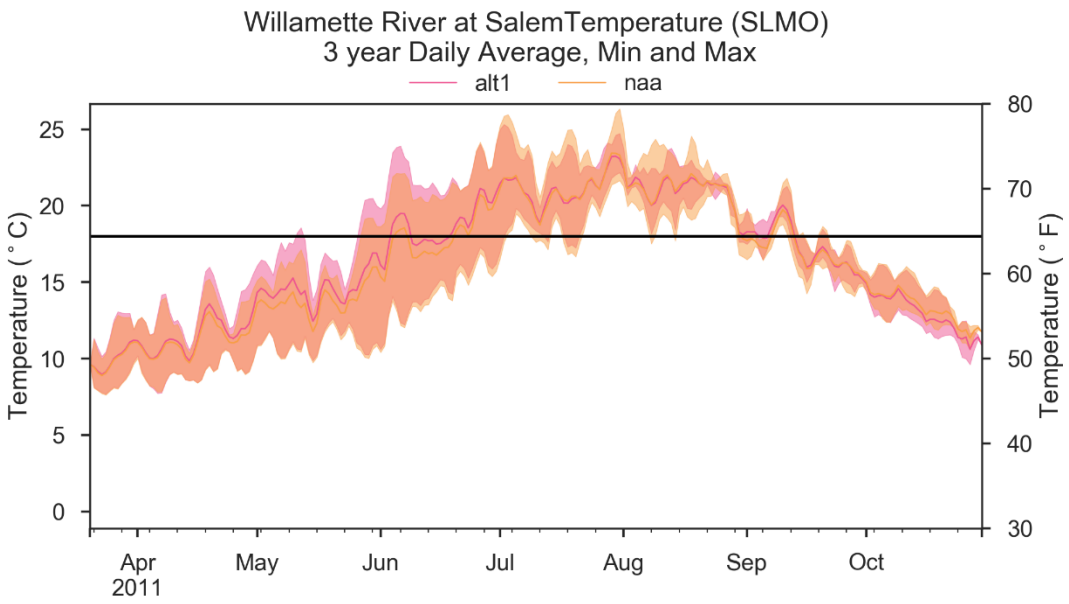


Figure 1-97. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1.

1.5.3 Alternative 2a – Hybrid Alternative

Alternative 2a measures that affected operations, lake storage, and water temperature included:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.
- Construct temperature control structure at Detroit.
- Deep fall drawdown to 35’ over the regulating outlet at Green Peter, use of RO in fall, use spillway for surface spill in spring and summer.
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.

1.5.3.1 North Santiam Dams

1.5.3.1.1 Detroit

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Detroit Lake generally increased under Alternative 2a compared to NAA in 2015 and 2016 aside from September-November in 2015, where the power pool was utilized for downstream flow augmentation (Figure 1-98, Figure 1-99, Figure 1-100). The increased storage coincided with reduced outflows during spring and increased outflows in summer during 2015 and 2016 comparing Alternative 2a to NAA. Total outflow in 2011 was generally similar in Alternative 2a and NAA at Detroit Lake. The proposed SWS and FSS in Alternative 2a allowed all outflow within powerhouse capacity (assumed at 4600 cfs) to be routed from a floating outlet through the Power outlets for temperature management, rather than the Spillway or URO flow for temperature management that was used in NAA (Figure 1-99).

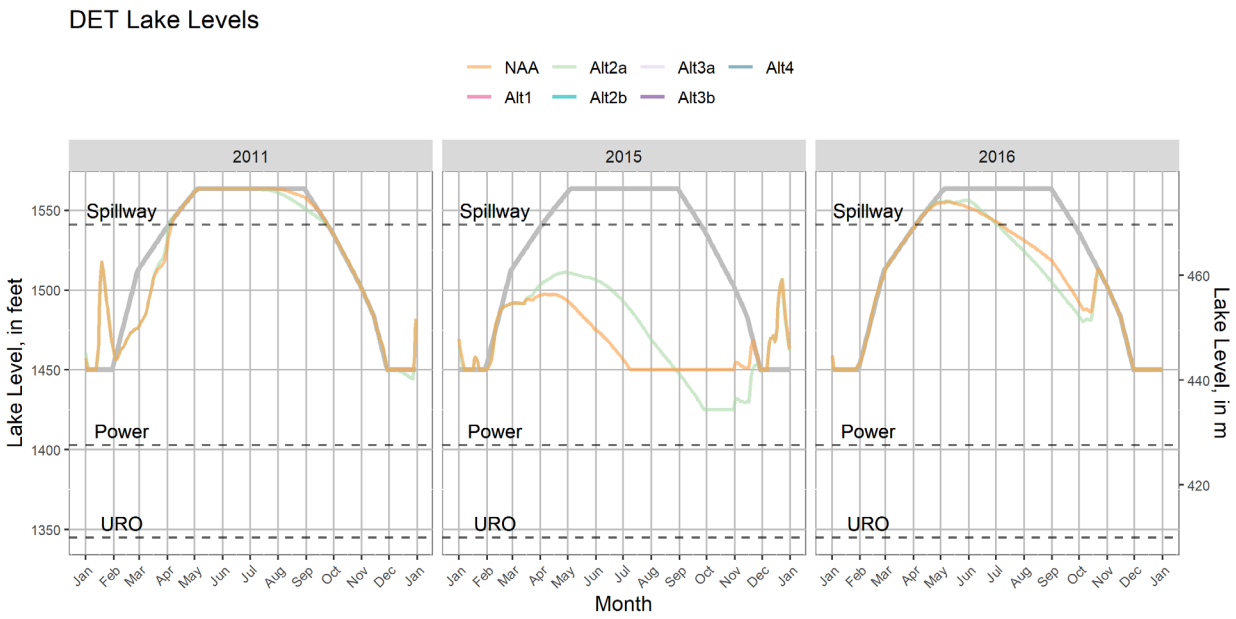


Figure 1-98. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA.

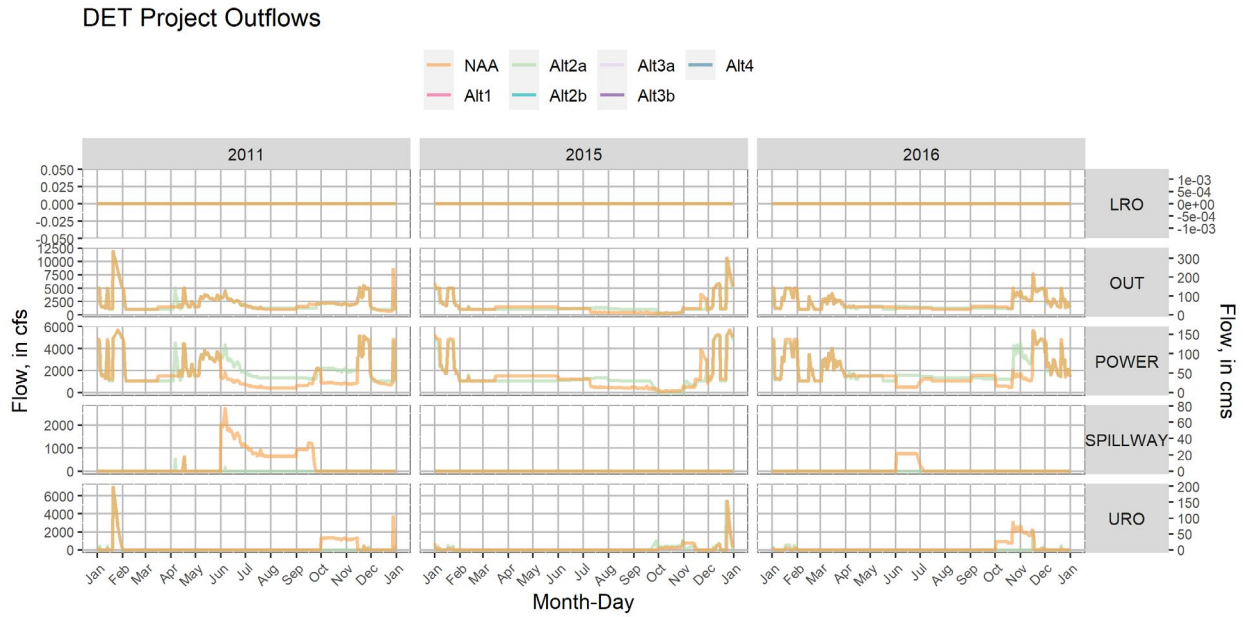


Figure 1-99. WV EIS HEC-ResSim gate-specific outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA.

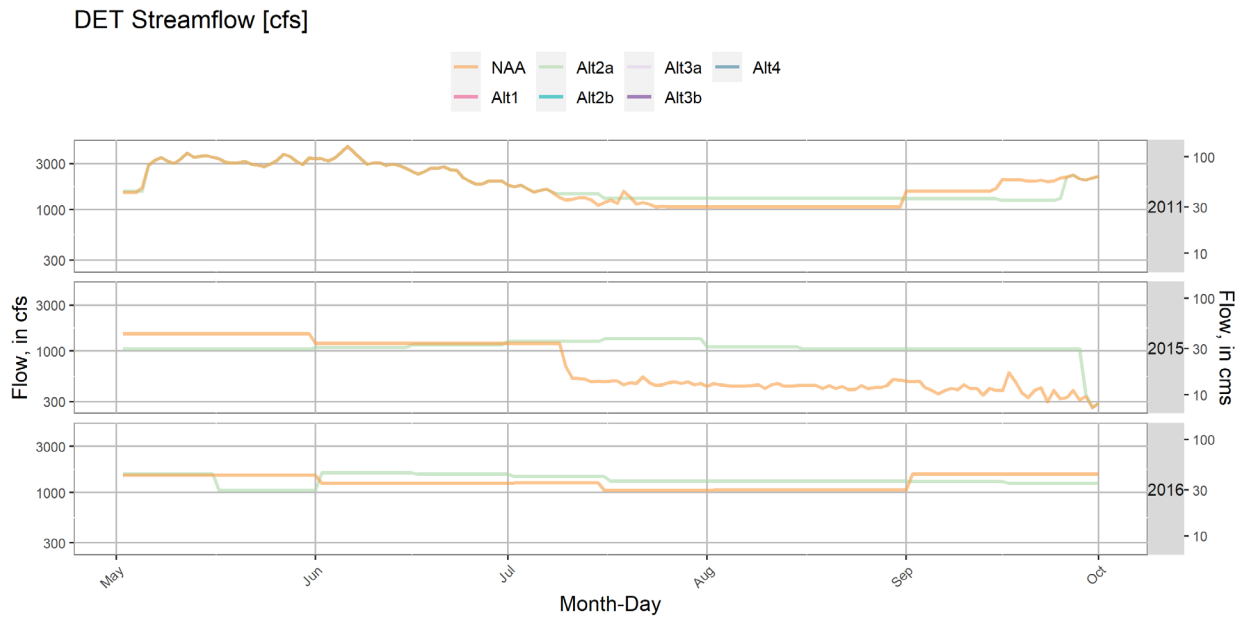


Figure 1-100. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-101, Figure 1-102, and Figure 1-103. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the Upper RO. Tailwater release temperatures

generally matched the temperature target when sufficient warm or cool water was available. Generally, the proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn (Figure 1-104, Figure 1-105).

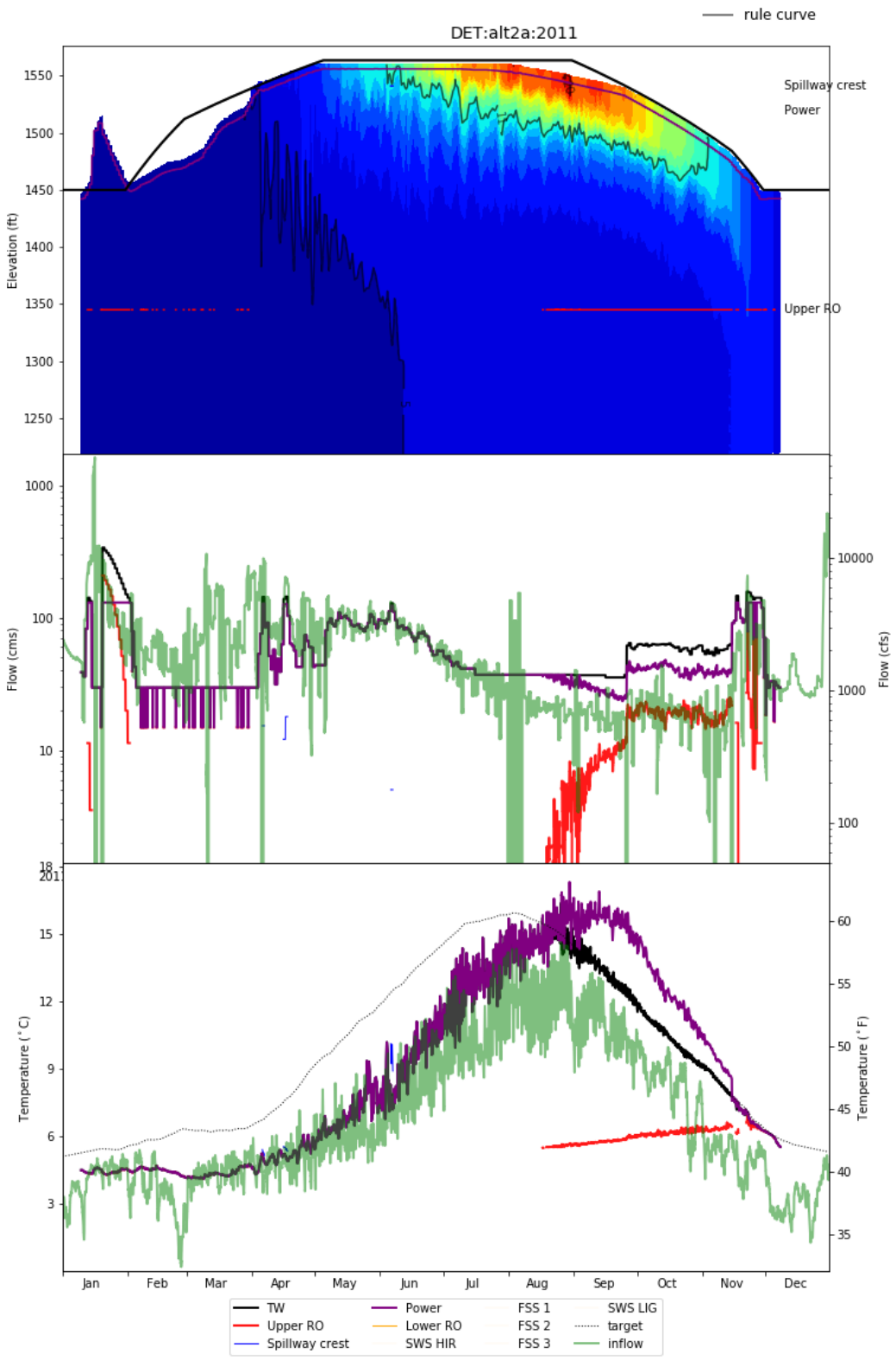


Figure 1-101. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2a in 2011.

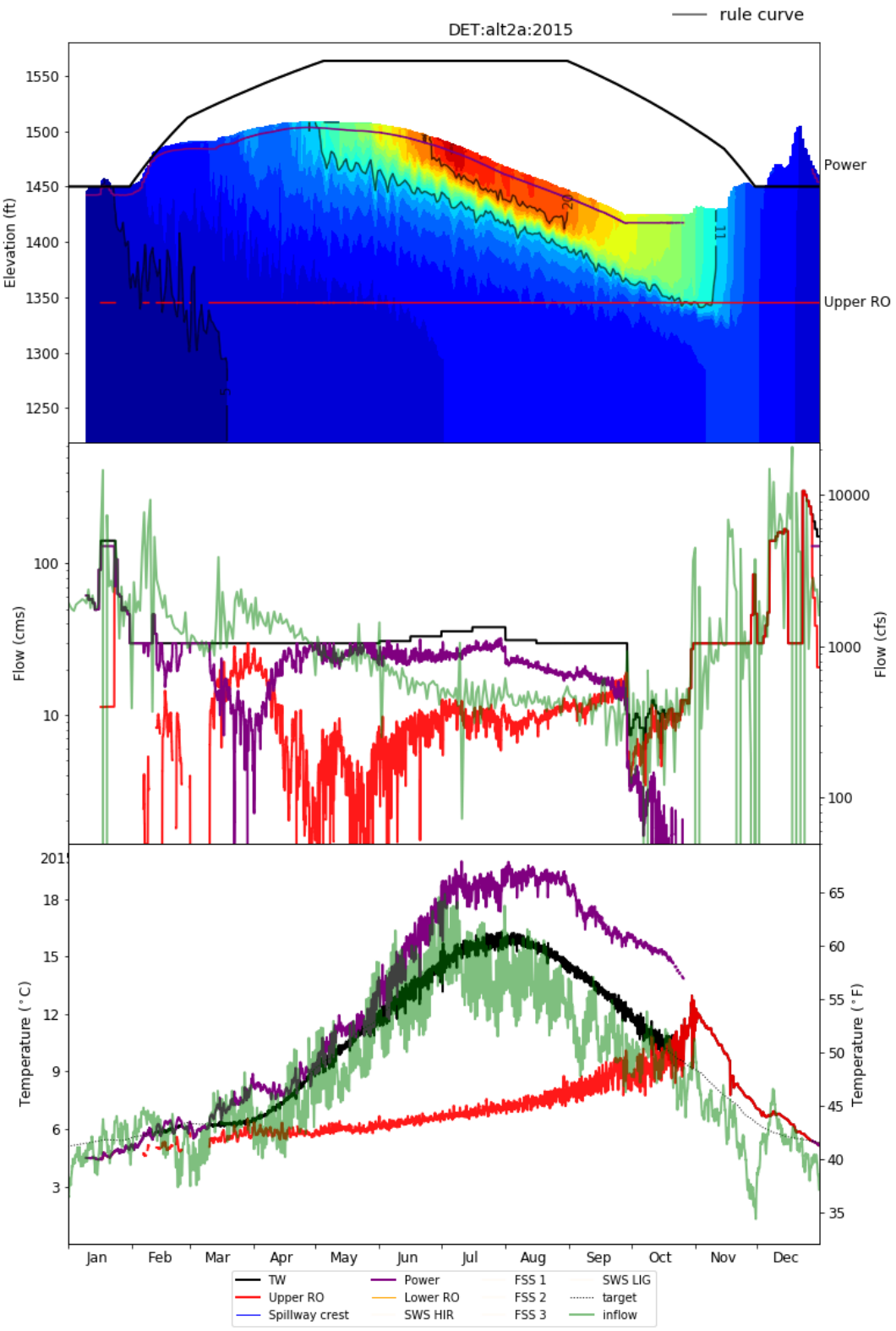


Figure 1-102. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2a in 2015.

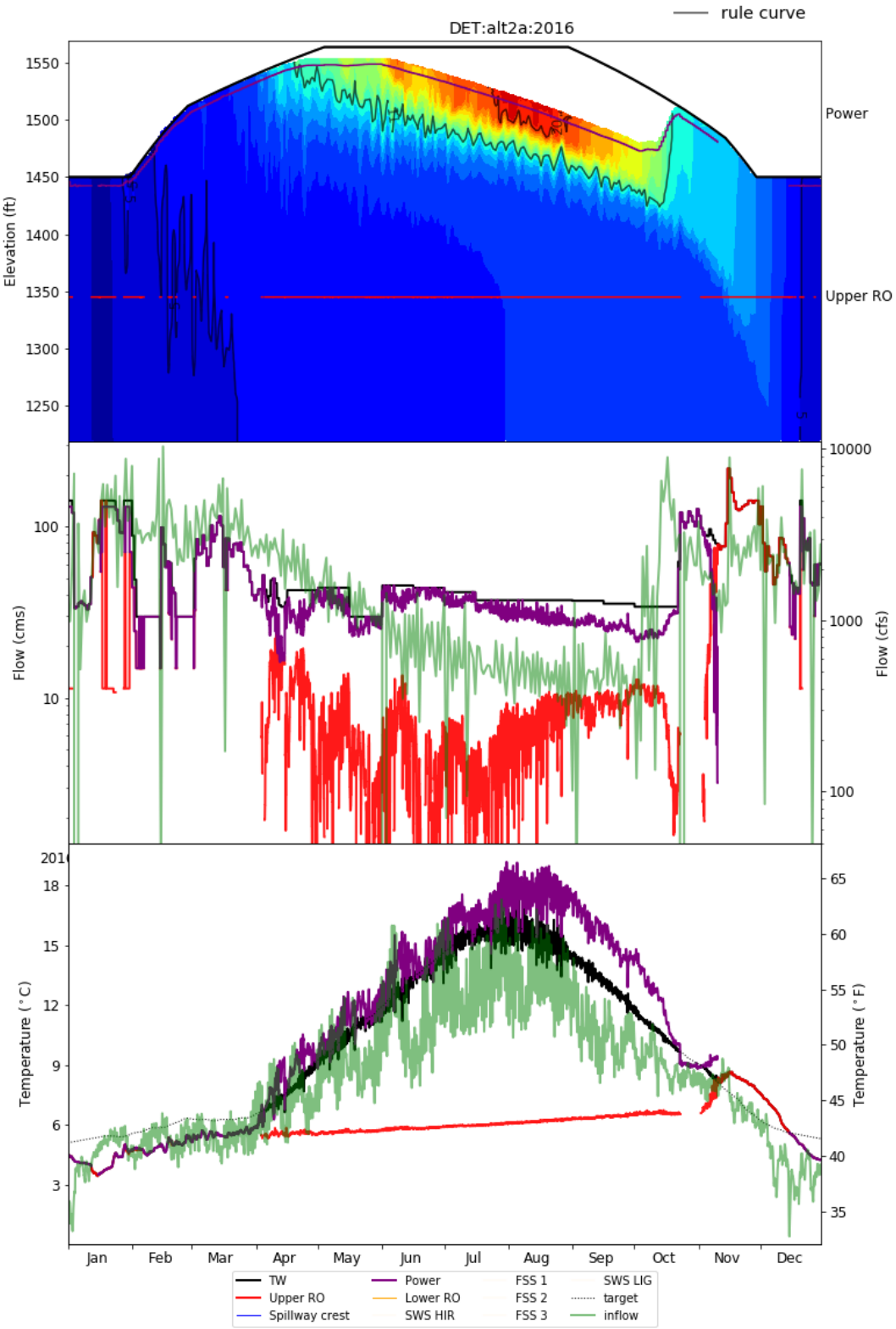


Figure 1-103. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2a in 2016.

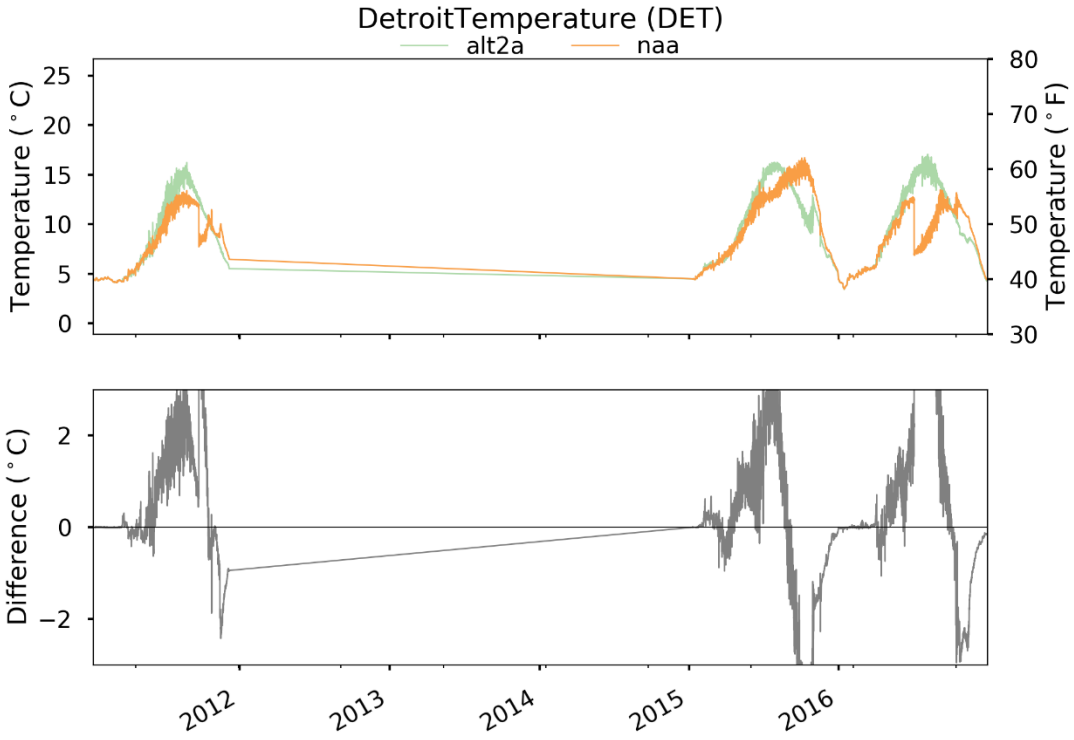


Figure 1-104. Comparison of DET Outflow Temperatures in NAA and Alternative 2a.

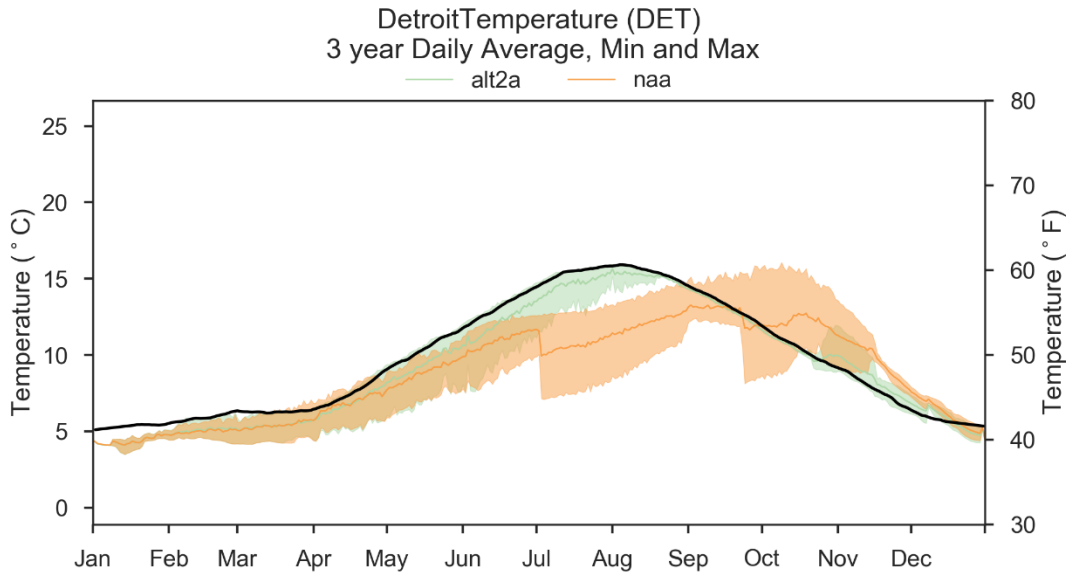


Figure 1-105. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target.

1.5.3.2 South Santiam Dams

1.5.3.2.1 Green Peter

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Green Peter were generally similar in Alternative 2a and NAA in 2011, 2015, and 2016 aside from October-December when a drawdown for fish passage RO operation occurred (Figure 1-106, Figure 1-107, Figure 1-108). Some increased storage in 2015 coincided with reduced outflows during spring and increased outflows in July-October. The proposed operational temperature management through the spillway (during spring/summer) and RO (during autumn) in Alternative 2a resulted in decreased power outflow compared to NAA (Figure 1-107).

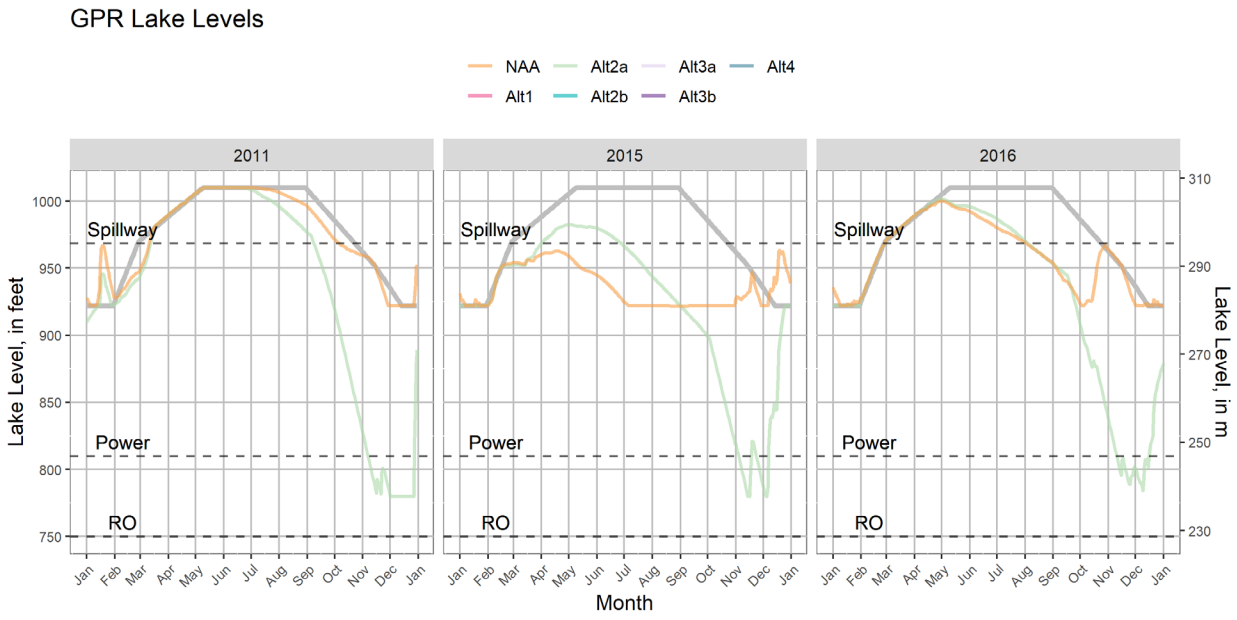


Figure 1-106. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA.

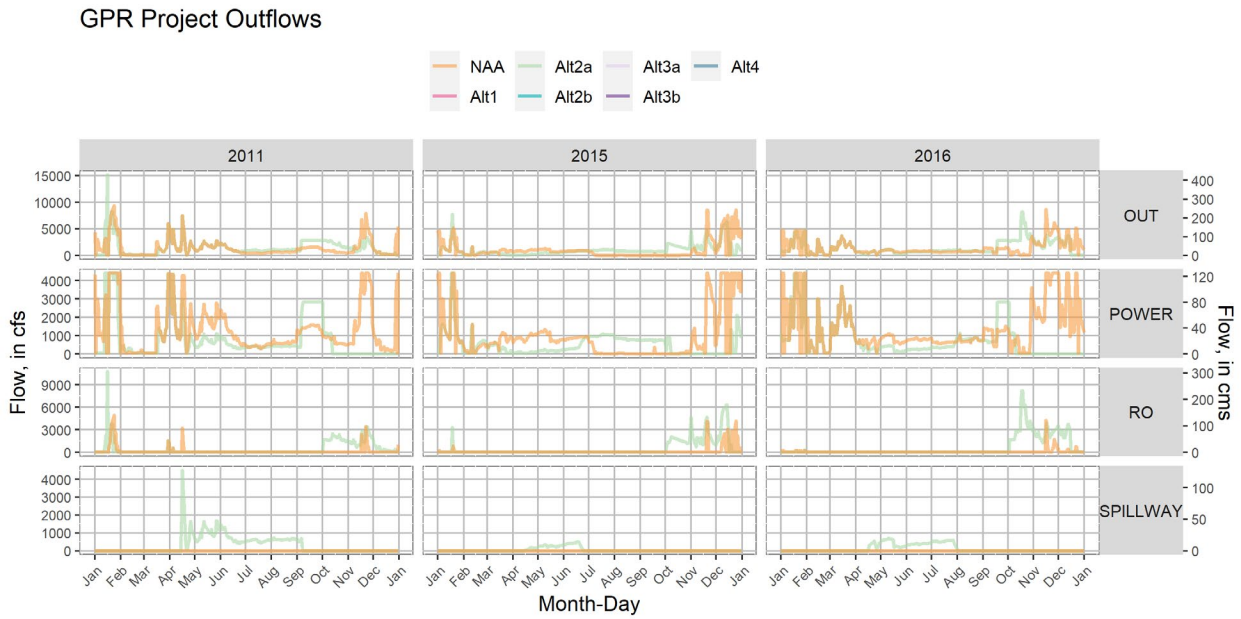


Figure 1-107. WV EIS HEC-ResSim Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA.

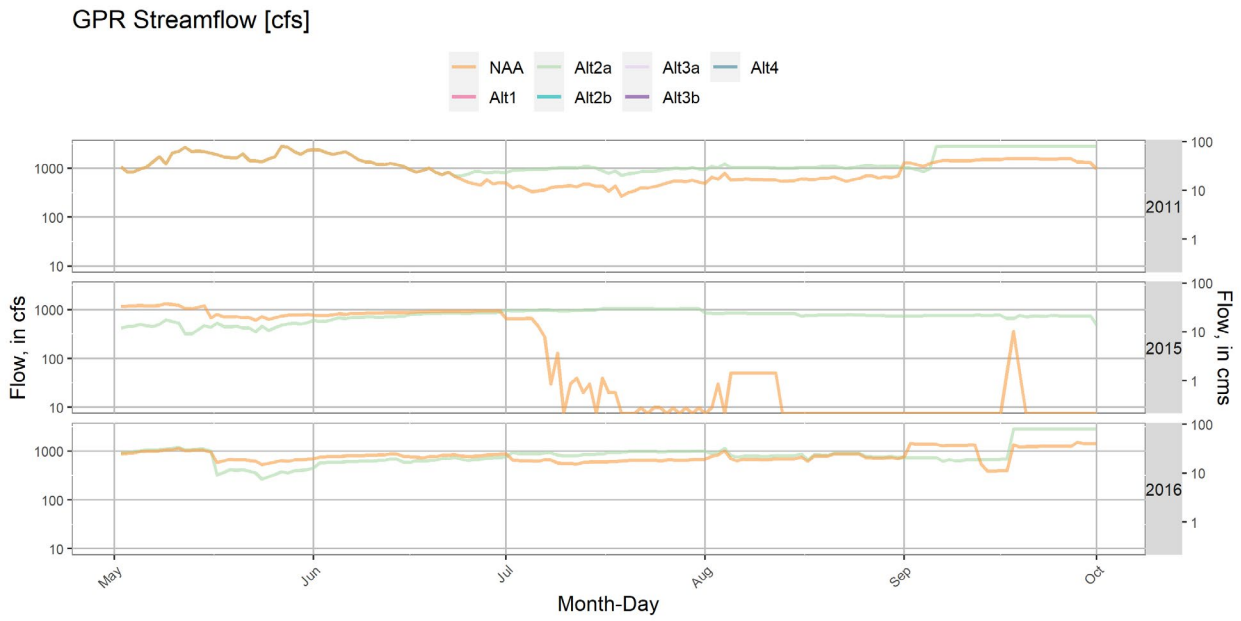


Figure 1-108. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-109, Figure 1-110, and Figure 1-111. Alternative 2a included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during

autumn to mix non-power releases with relatively deep power penstock releases to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and those outlets were submerged (available for use). Spillway access was limited in some years (2015 especially), which led to an abrupt drop in tailwater temperature when spillway access ended in mid-summer of those years. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam (Figure 1-112, Figure 1-113). Generally, the autumn fish passage operation (drawdown to the RO) resulted in cooler autumn temperatures (November-December) compared to NAA (Figure 1-113).

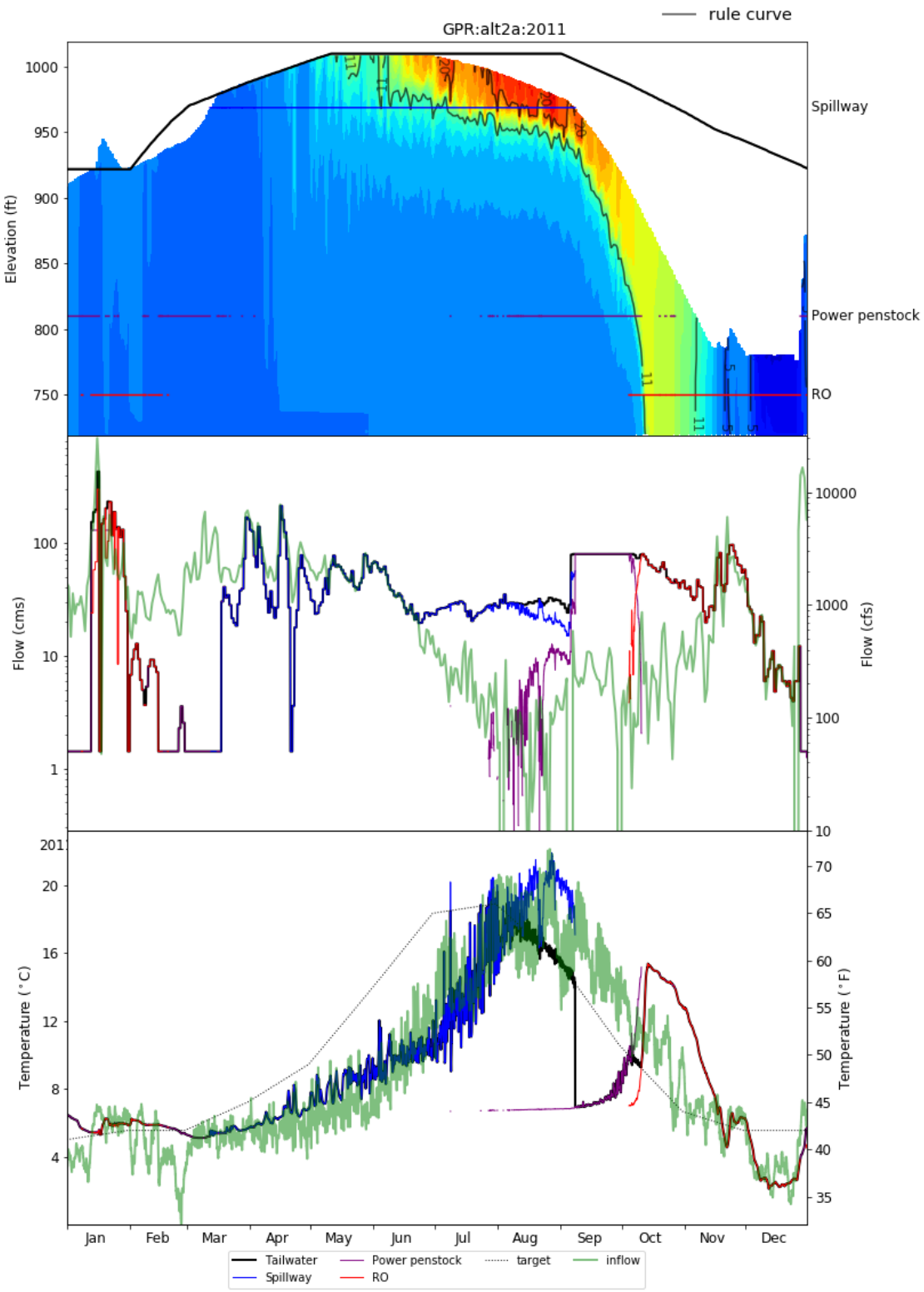


Figure 1-109. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2a in 2011.

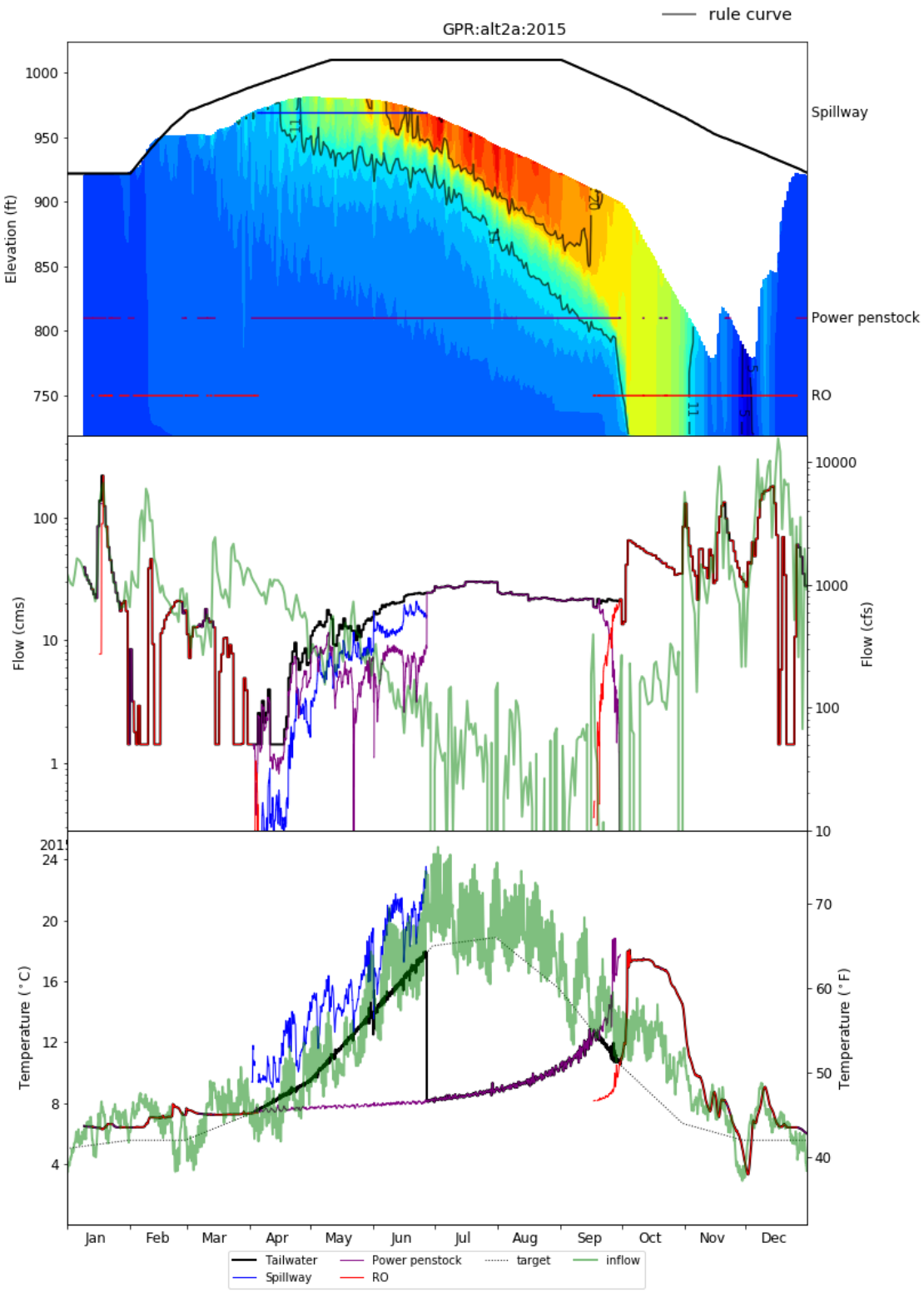


Figure 1-110. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2a in 2015.

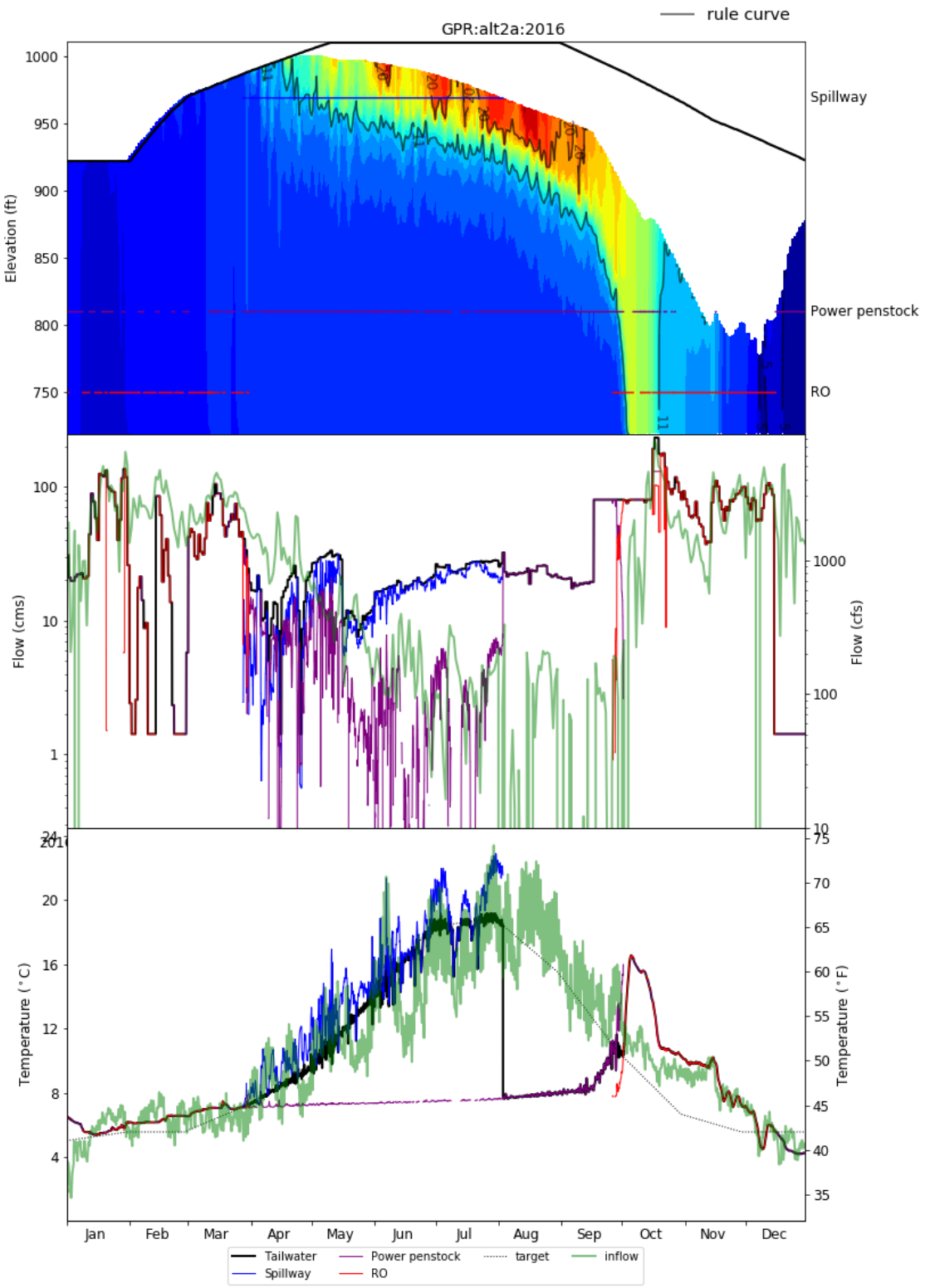


Figure 1-111. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2a in 2016.

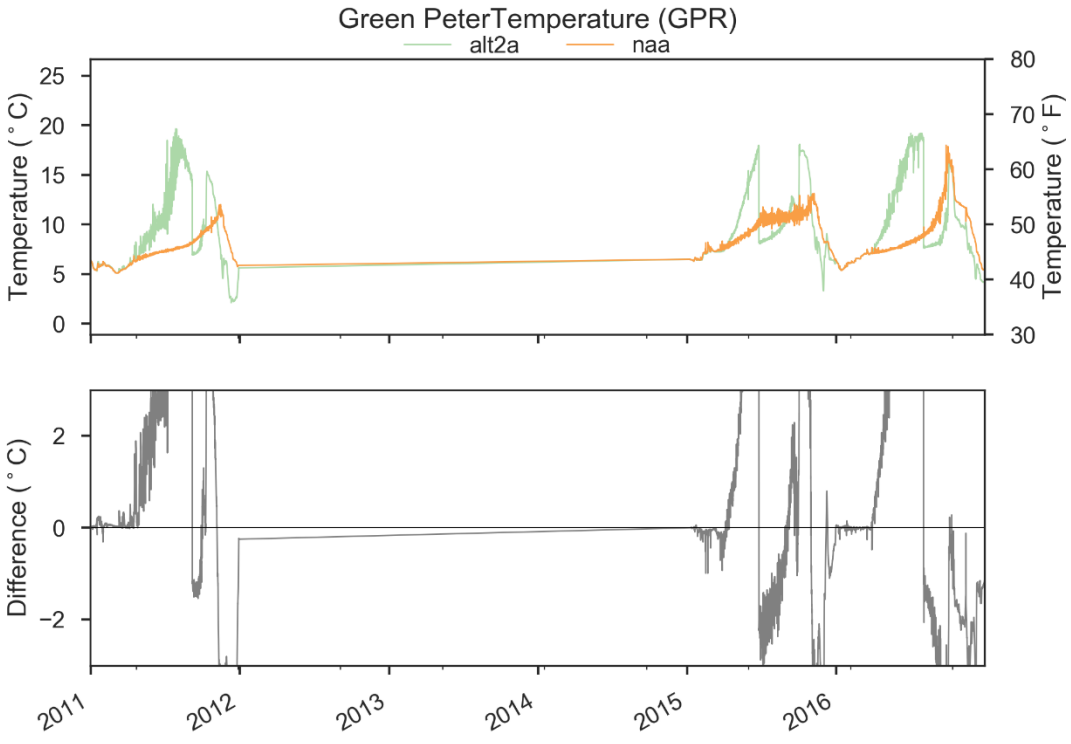


Figure 1-112. Comparison of GPR outflow temperatures in NAA and Alternative 2a.

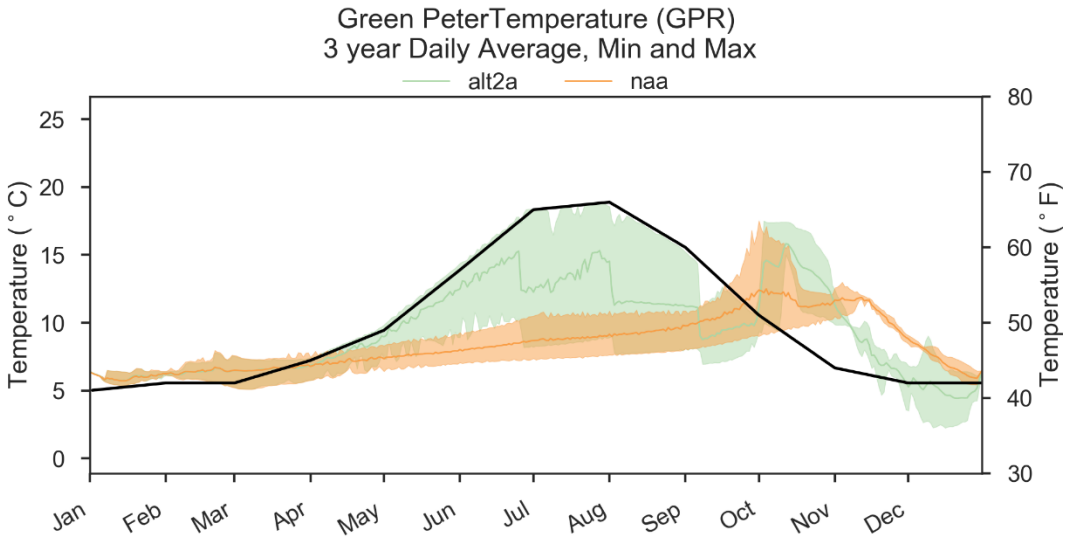


Figure 1-113. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target.

1.5.3.2.2 Foster

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Foster were generally similar under Alternative 2a compared to NAA in 2011 and 2016 but increased in 2015 in Alternative 2a compared to NAA (Figure 1-114, Figure 1-116). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam. The proposed modifications to the fish weir and FWWS in Alternative 2a resulted in lower outflow routed through the Power outlets for temperature management, especially during spring and summer compared to NAA (Figure 1-115).

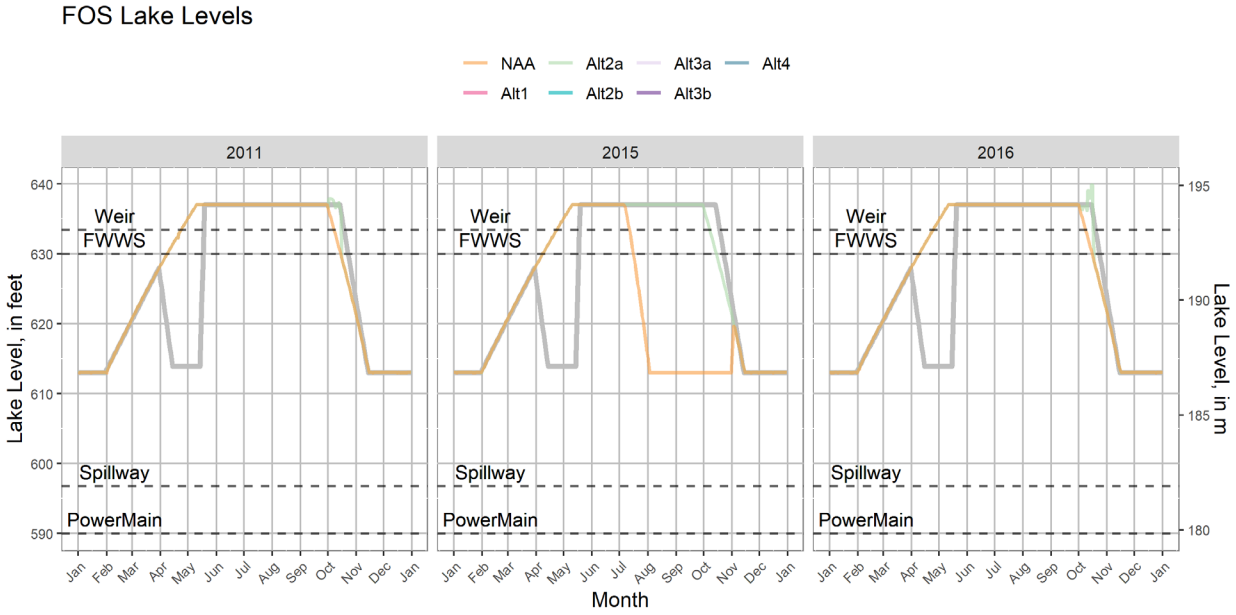


Figure 1-114. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA.

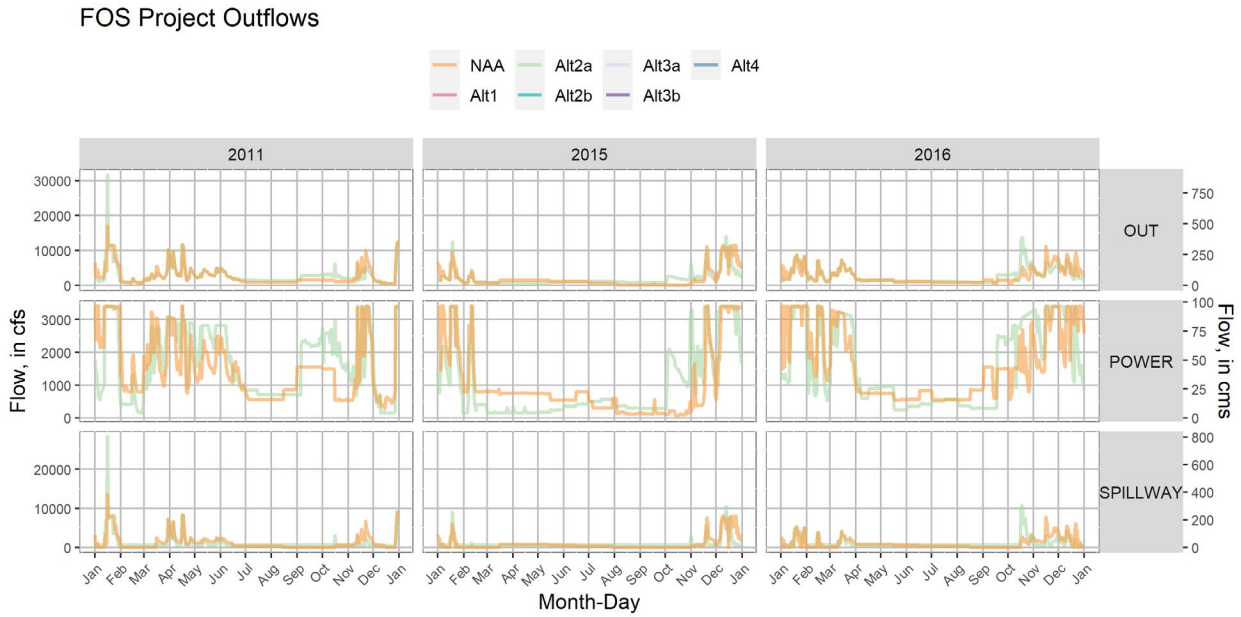


Figure 1-115. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alernative 2a and NAA.

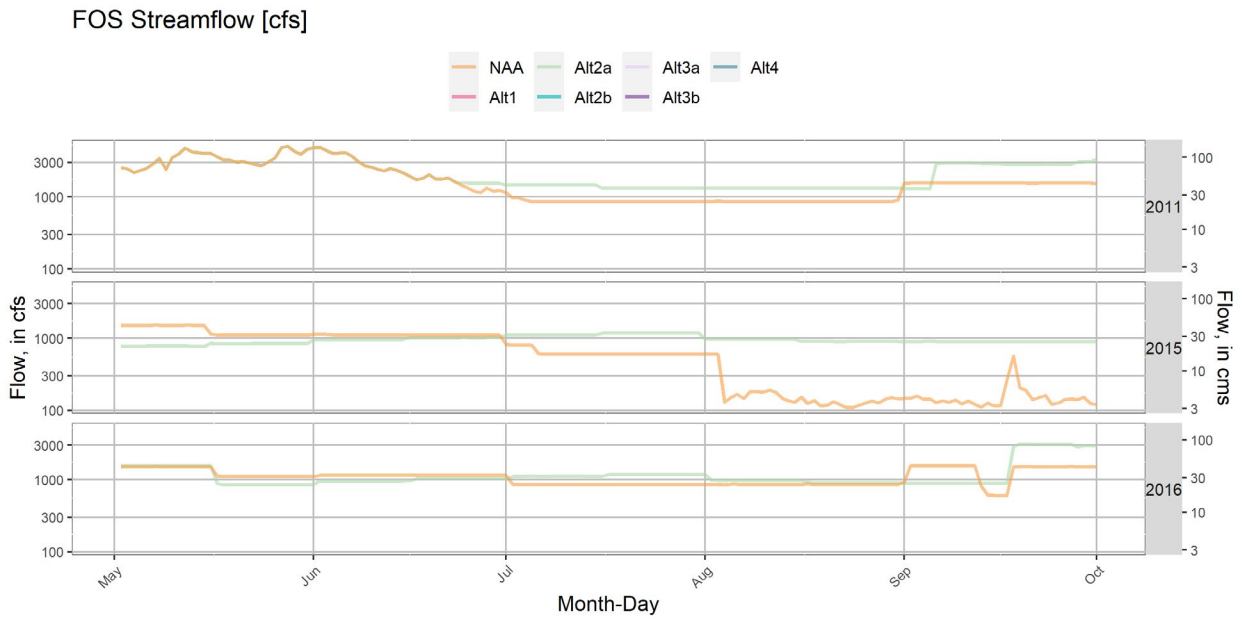


Figure 1-116. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-117, Figure 1-118, and Figure 1-119. Foster Lake temperature was affected by Green Peter Dam operations release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in

the temperature pattern (Sullivan and Rounds, 2021). Outflows from the proposed fish weir and FWWS combined with warmer spillway releases from Green Peter upstream resulted in warmer tailwater temperature in spring and summer compared to NAA (Figure 1-120, Figure 1-121). Generally, the autumn fish passage operation (drawdown to the RO at Green Peter) resulted in cooler autumn temperatures (November-December) compared to NAA downstream of Foster Dam.

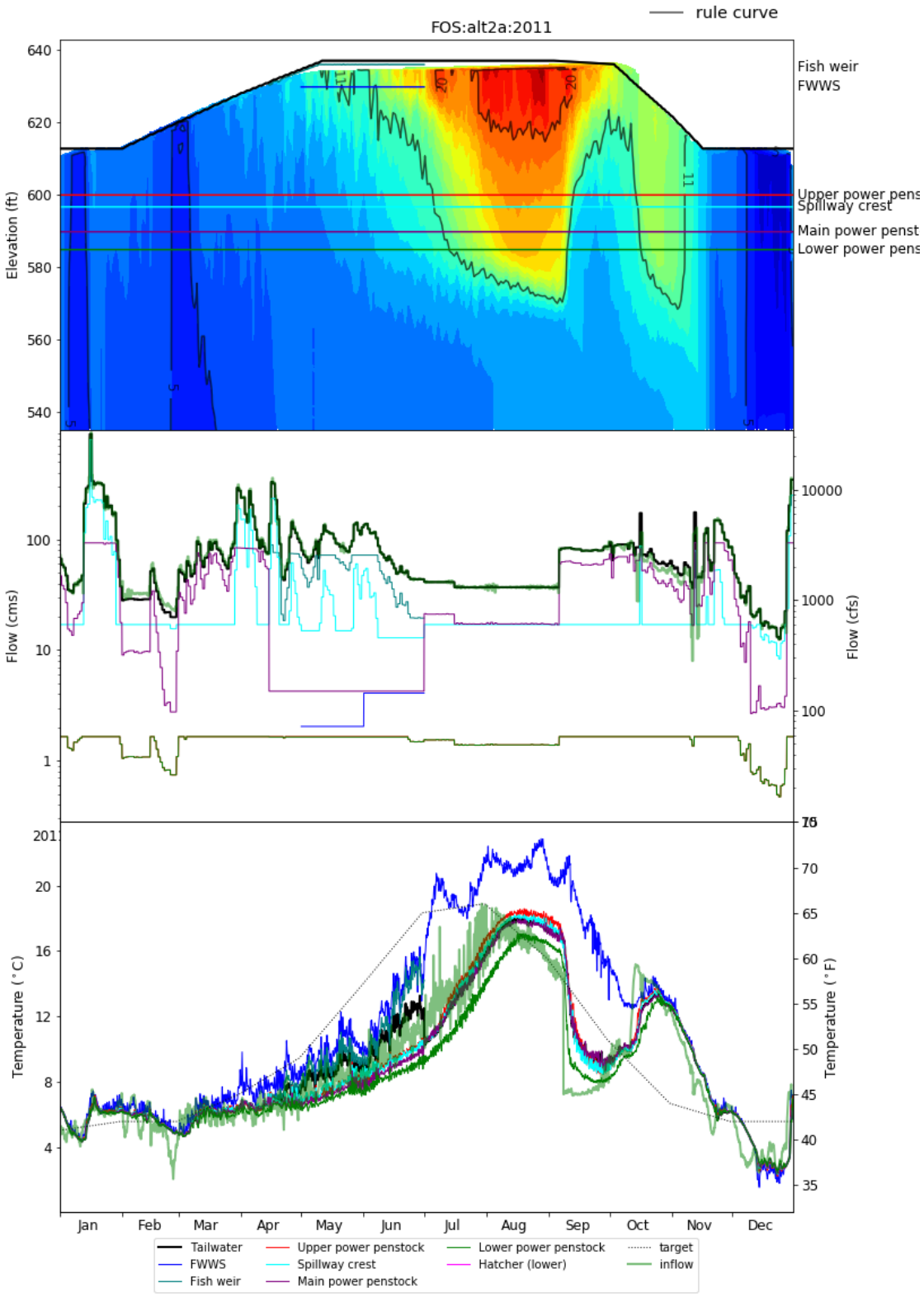


Figure 1-117. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2a in 2011.

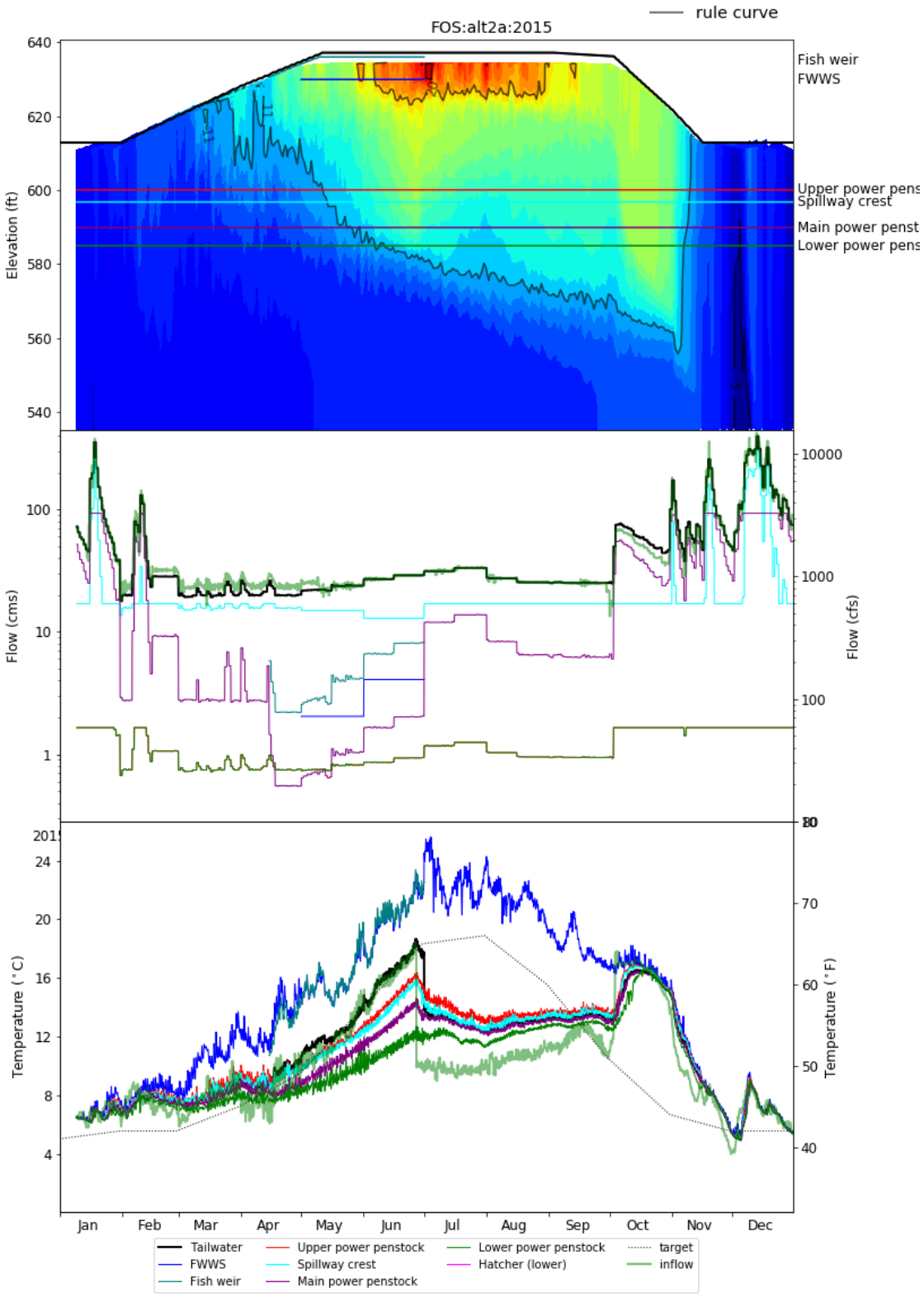


Figure 1-118. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2a in 2015.

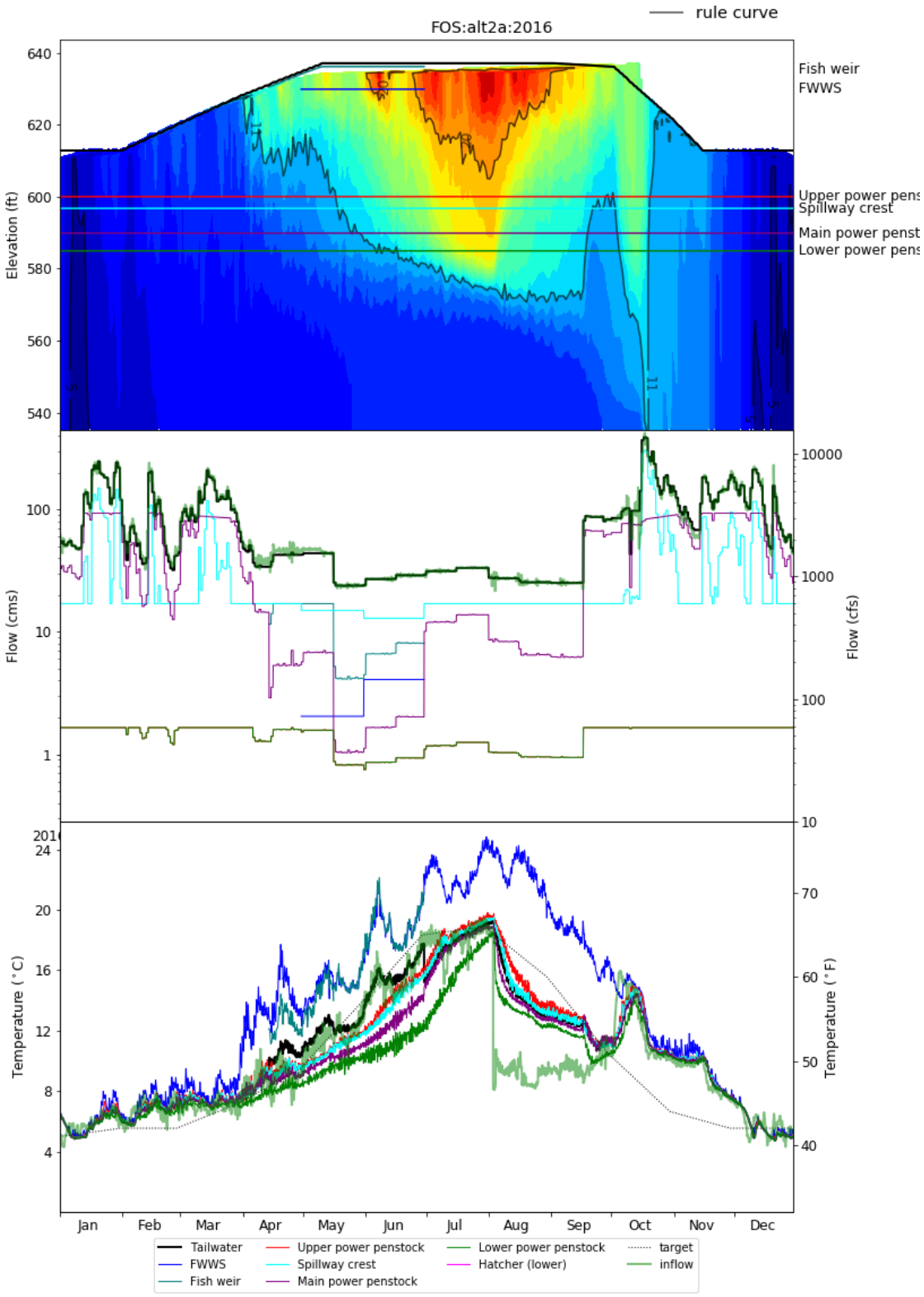


Figure 1-119. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2a in 2016.

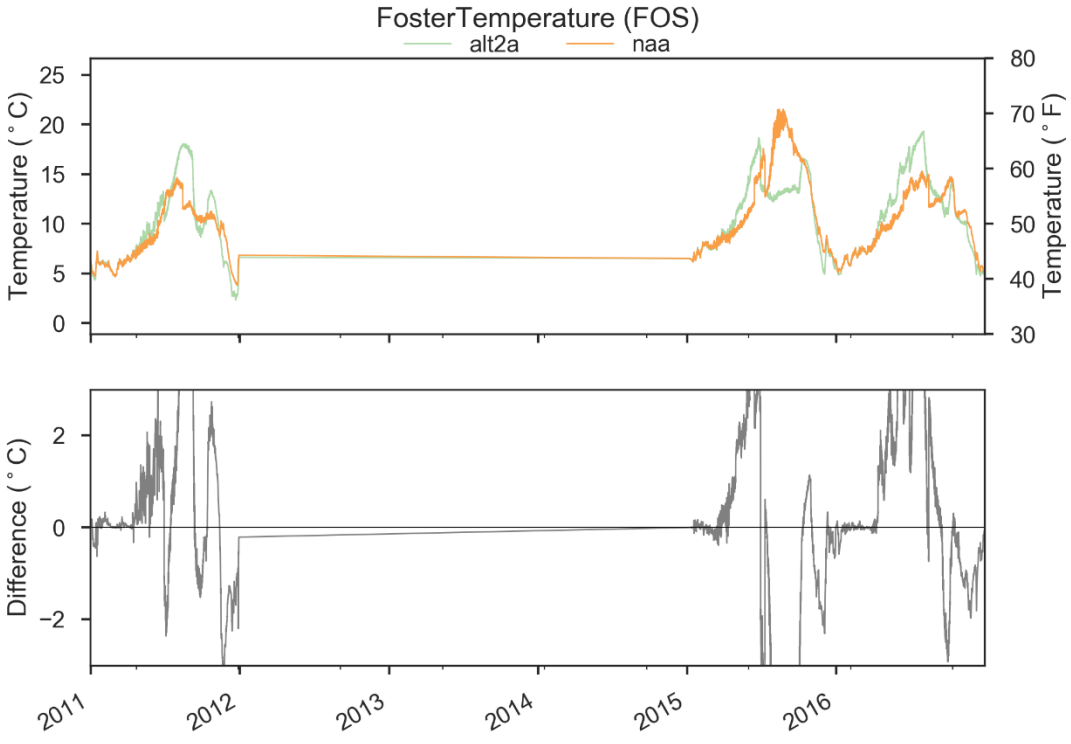


Figure 1-120. Comparison of FOS Outflow Temperatures in NAA and Alternative 2a.

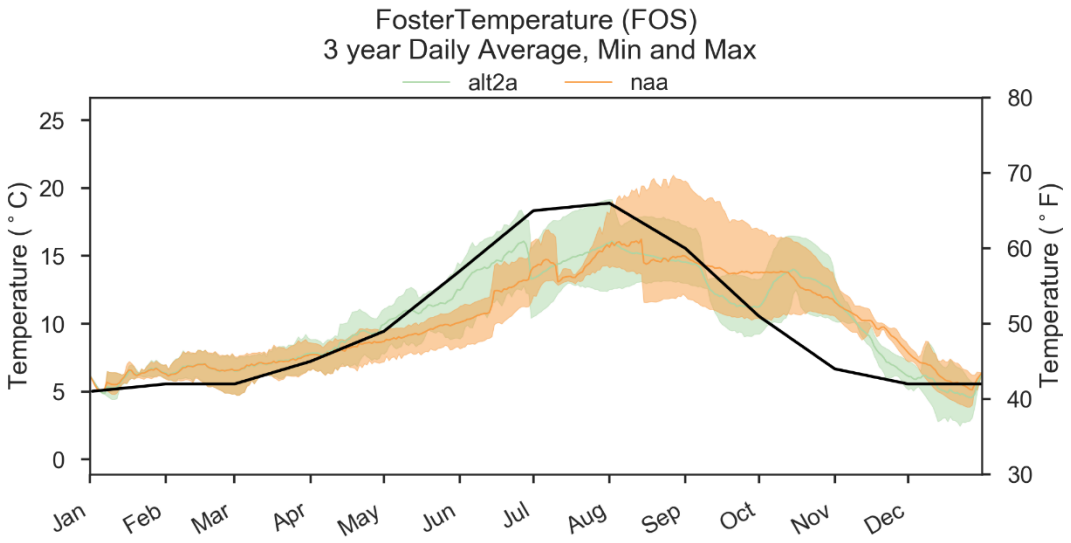


Figure 1-121. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target.

1.5.3.3 McKenzie Dams

1.5.3.3.1 Cougar

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Cougar Lake generally increased under Alternative 2a compared to NAA in 2015 and 2016 aside from September-November in 2015 where the power pool was utilized for downstream flow augmentation when available (Figure 1-122, Figure 1-123, Figure 1-124). The increased storage coincided with reduced outflows during spring and increased outflows in summer (while the lake was above minimum lake elevation rules set in HEC-ResSim) during 2015 and 2016 comparing Alternative 2a to NAA (Figure 1-123). 2011 operations were generally similar in Alternative 2a and NAA at Cougar Lake.

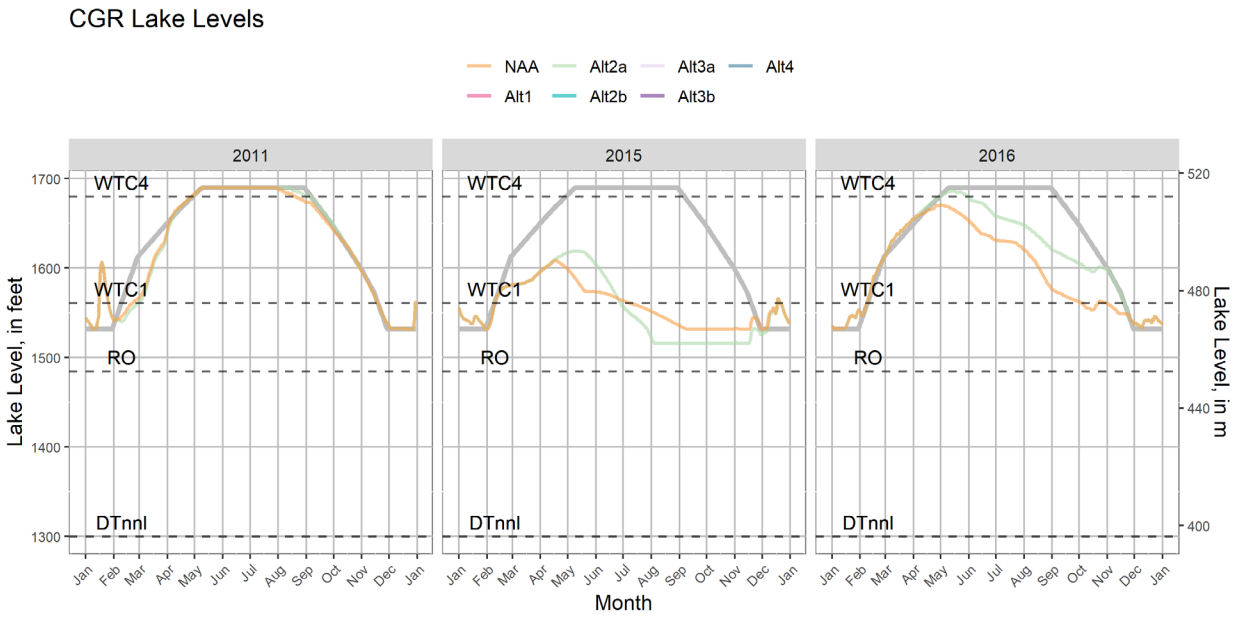


Figure 1-122. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 under Alternative 2a and NAA.

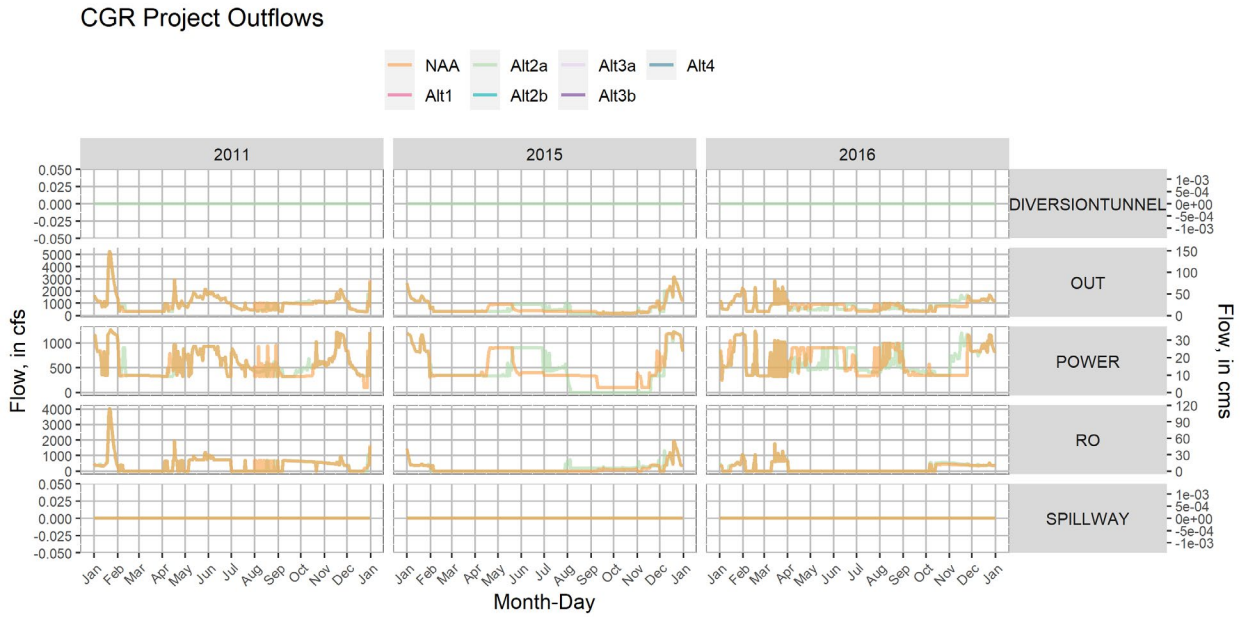


Figure 1-123. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA.

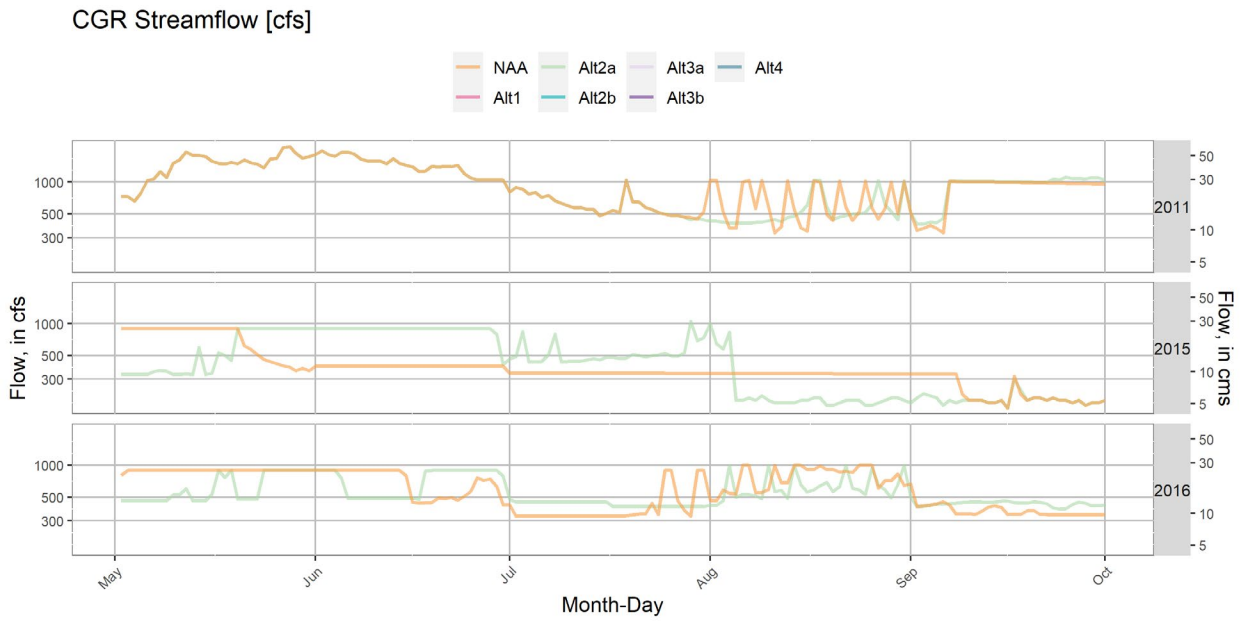


Figure 1-124. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Cougar Lake are shown in Figure 1-125, Figure 1-126, and Figure 1-127. Outflows from the existing temperature tower and proposed FSS resulted in similar tailwater temperature in Alternative 2a compared to NAA (Figure 1-128 and Figure 1-129) aside

from minor differences in each calendar year scenario that were likely linked to differences in lake levels and the shift in timing of when the lake was drafted below the bottom usable elevation of the WTCT. The addition of a FSS structure in Alternative 2a is not expected to have a large effect on the ability of the existing WTCT functionality with respect to temperature management (USACE, 2019a).

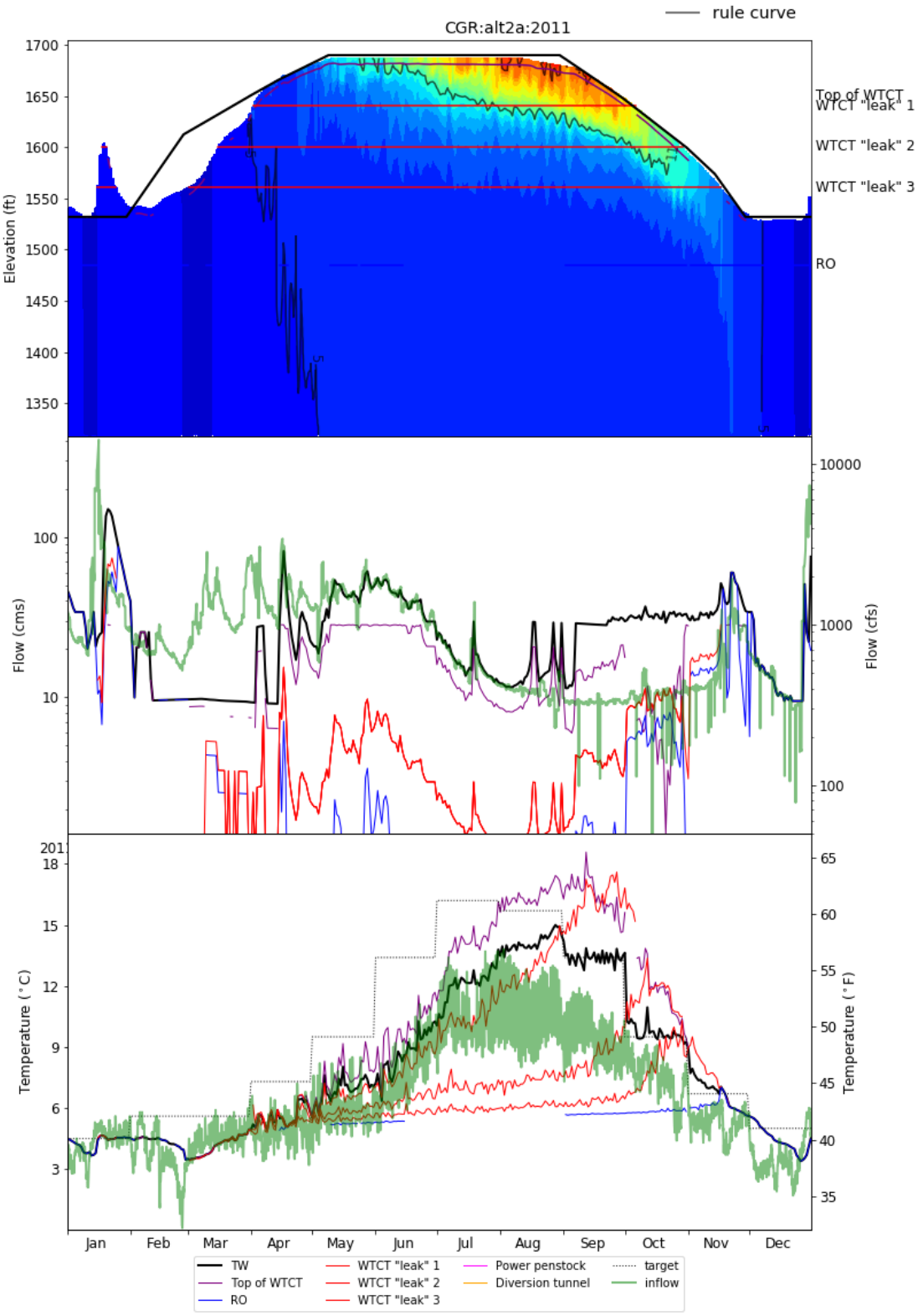


Figure 1-125. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2a in 2011.

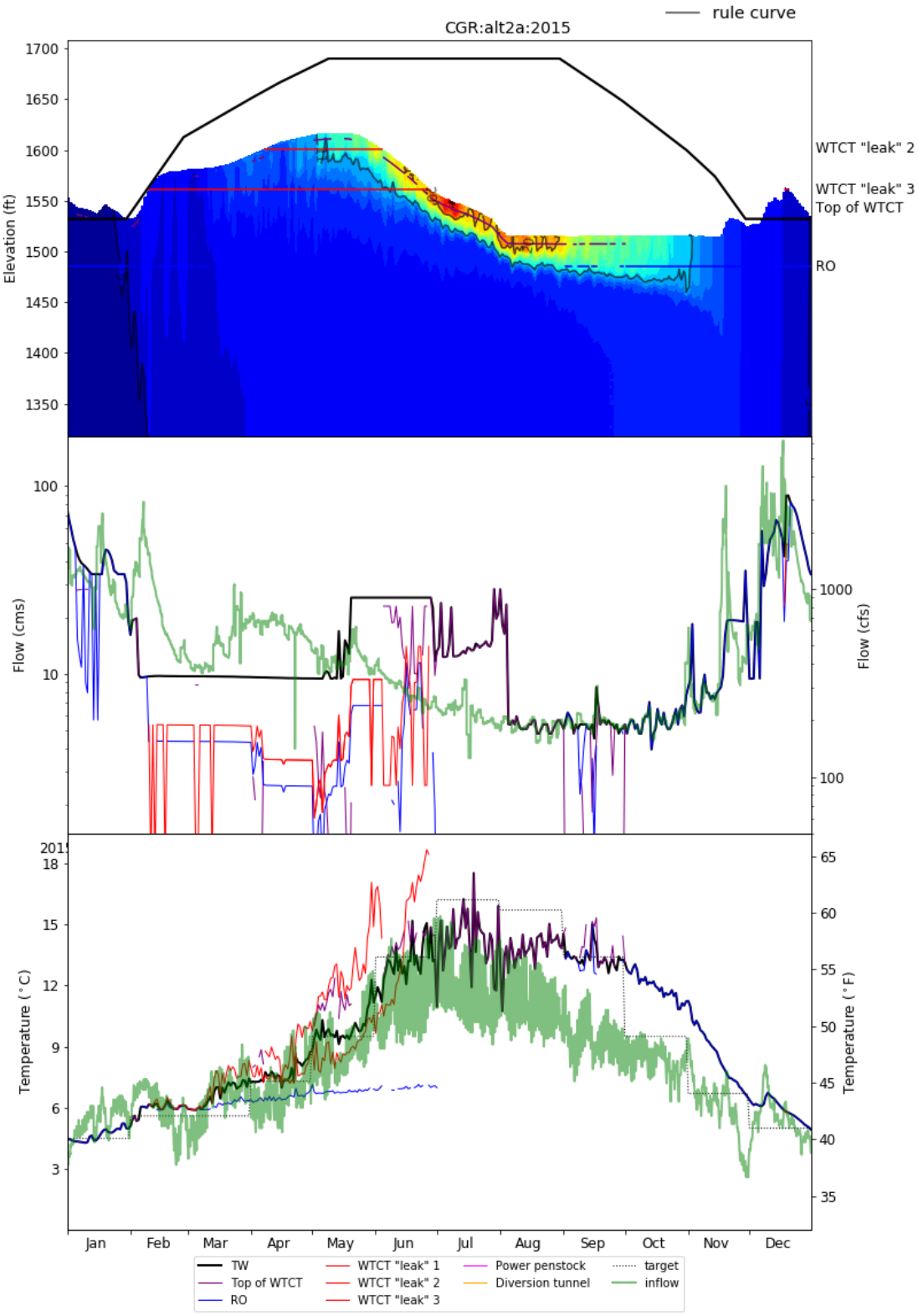


Figure 1-126. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2a in 2015.

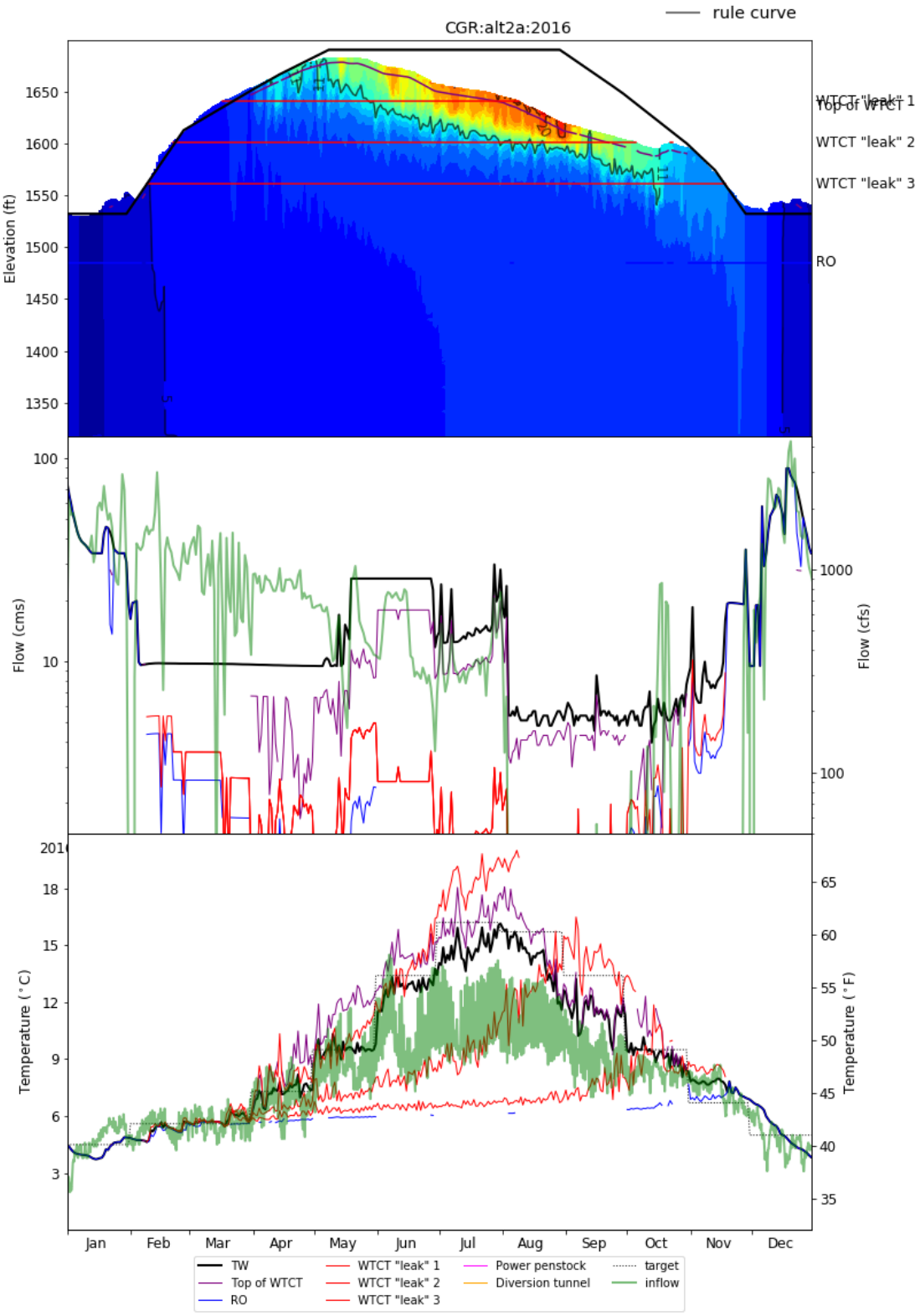


Figure 1-127. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2a in 2016.

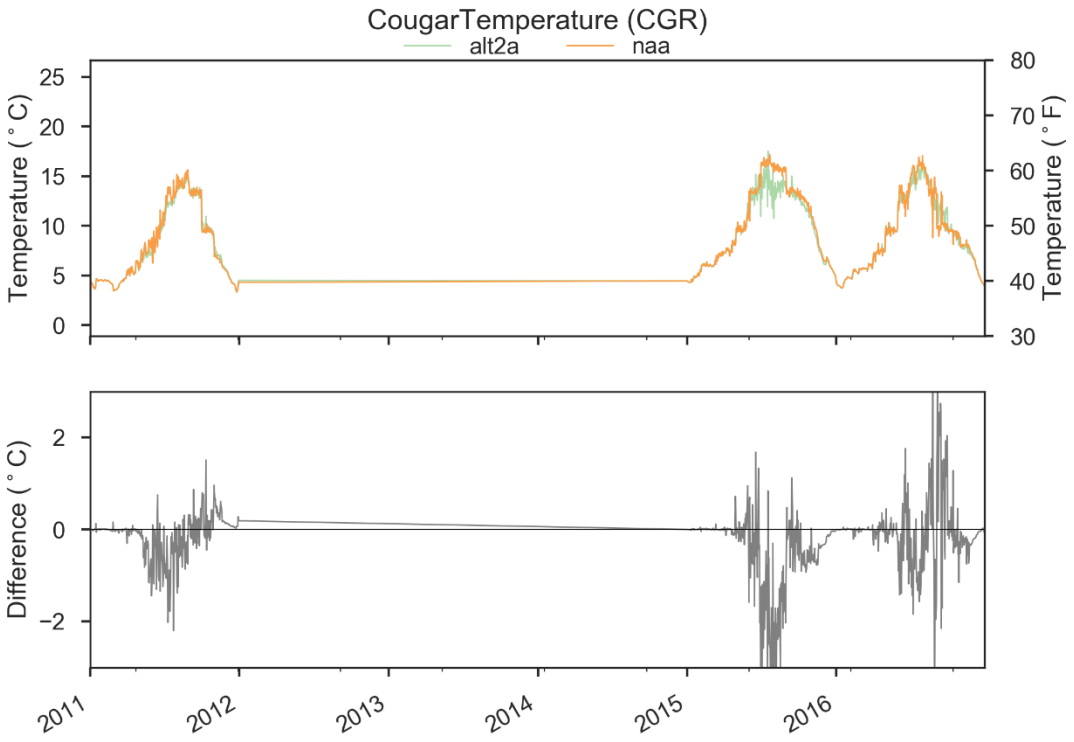


Figure 1-128. Comparison of CGR outflow temperatures in NAA and Alternative 2a.

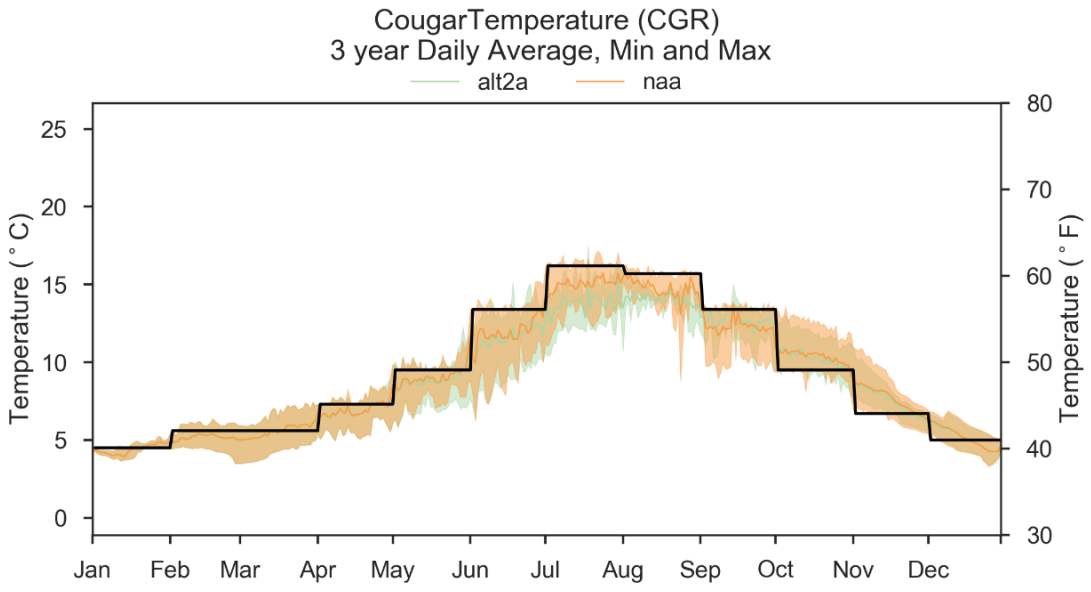


Figure 1-129. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target.

1.5.3.4 Middle Fork Willamette Dams

1.5.3.4.1 Hills Creek

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Hills Creek Lake generally increased under Alternative 2a compared to NAA in 2015 and 2016 aside from August-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-130, Figure 1-131, and Figure 1-132). The increased storage coincided with reduced outflows during spring and increased outflows in June-August during 2015 and August-October in 2016 comparing Alternative 2a to NAA (Figure 1-131). 2011 operations were generally similar in Alternative 2a and NAA at Hills Creek Lake.

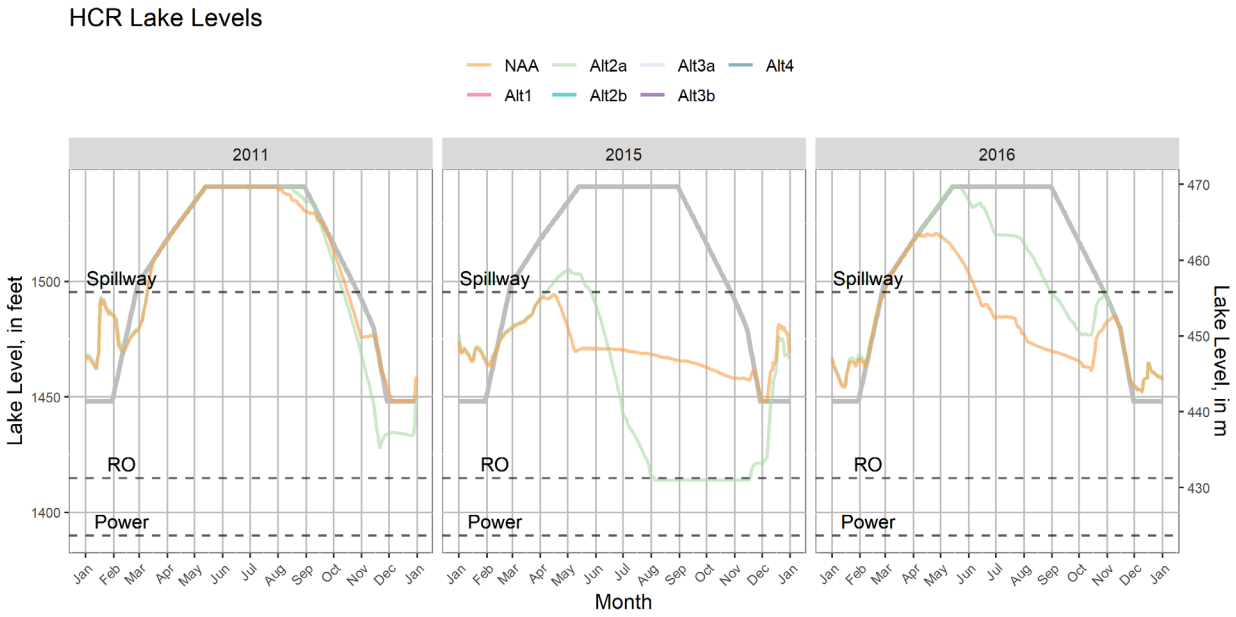


Figure 1-130. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA.

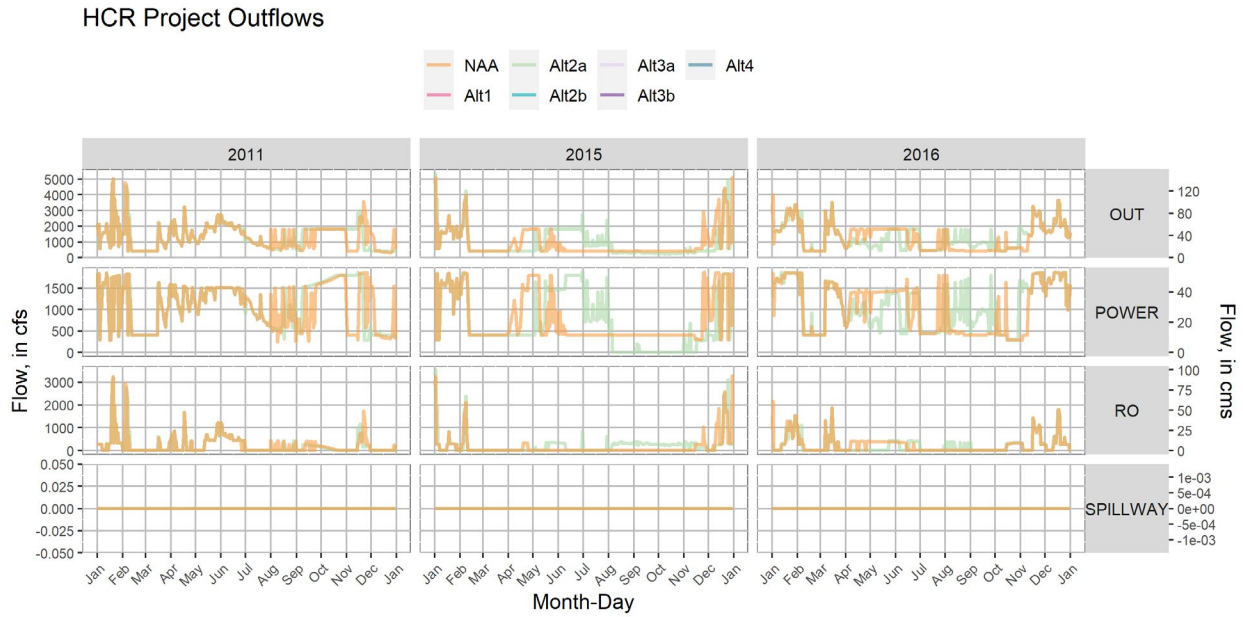


Figure 1-131. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 2a and NAA.

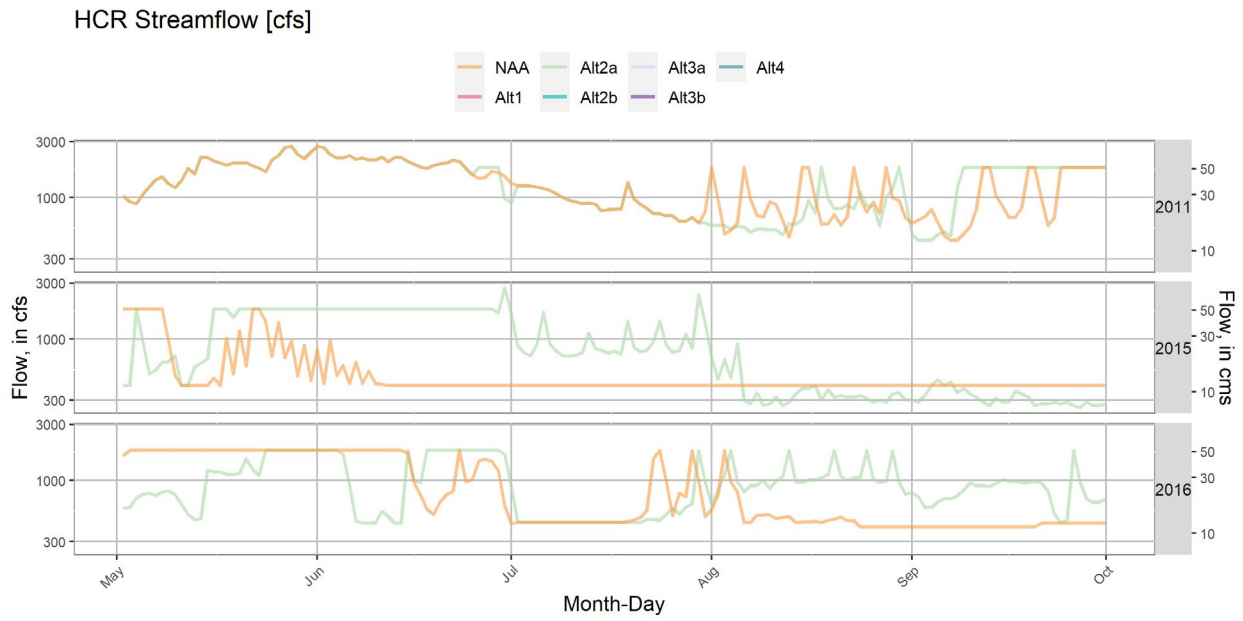


Figure 1-132. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 under Alternative 2a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 2a at Hills Creek Lake are shown in Figure 1-133, Figure 1-134, and Figure 1-135. The timing of the seasonal peak in outflow tailwater temperature in Alternative 2a was higher in magnitude and occurred about one month earlier in 2015, which

resulted in cooler tailwater temperature during autumn of that year compared to NAA (Figure 1-136, Figure 1-137). The 2016 outflow tailwater temperature in Alternative 2a was generally cooler than NAA in spring and summer but similar during autumn.

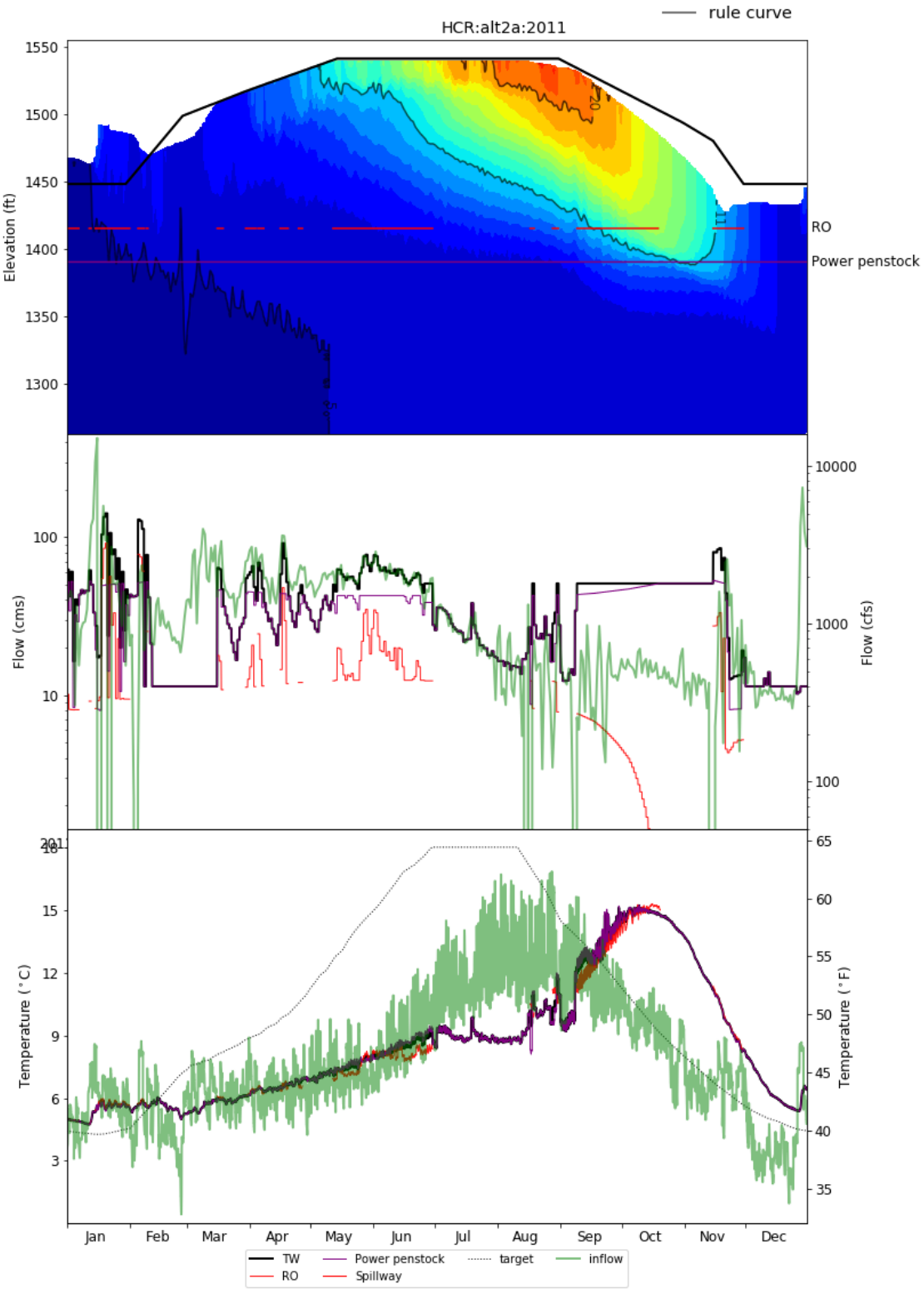


Figure 1-133. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2a in 2011.

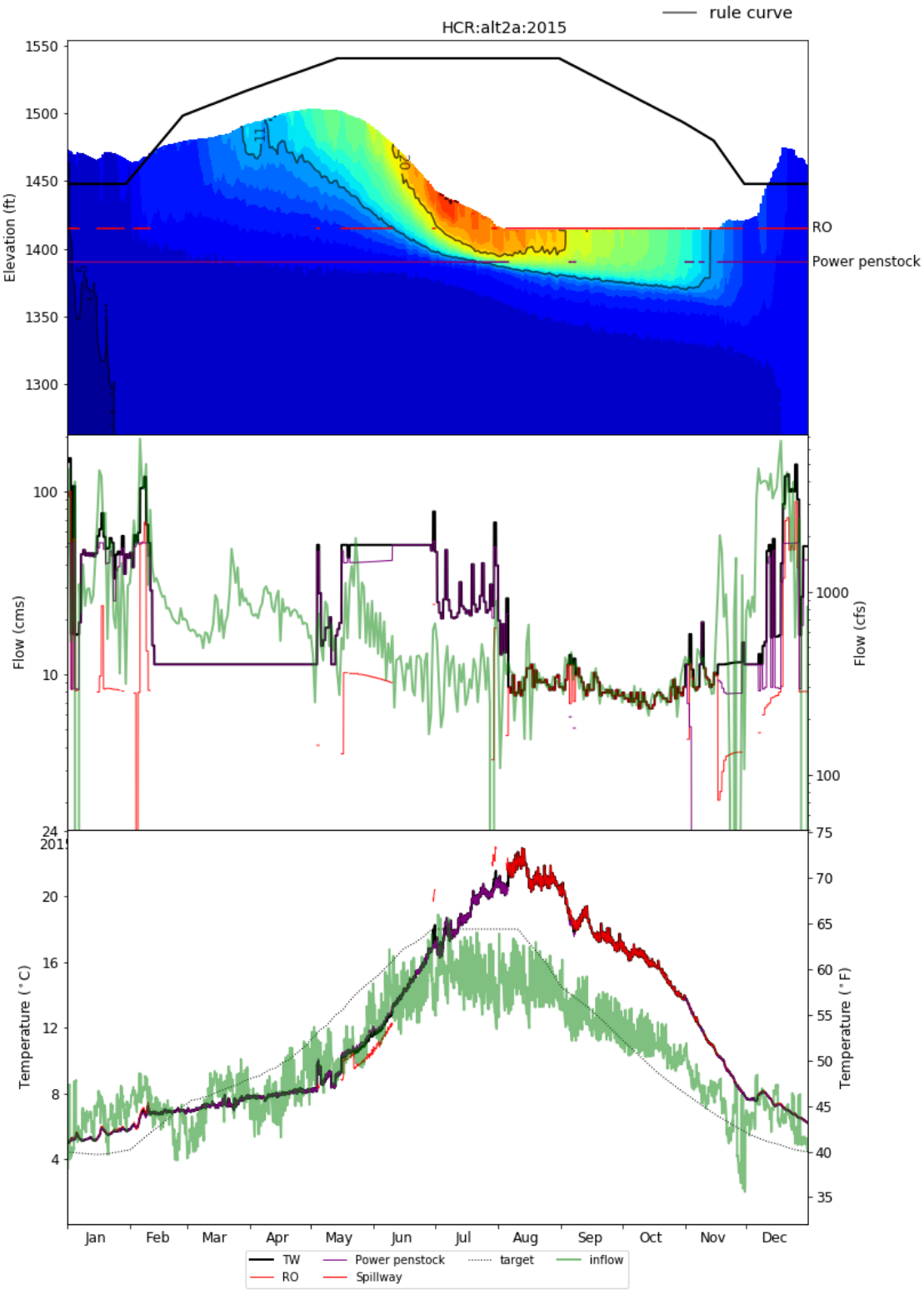


Figure 1-134. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2a in 2015.

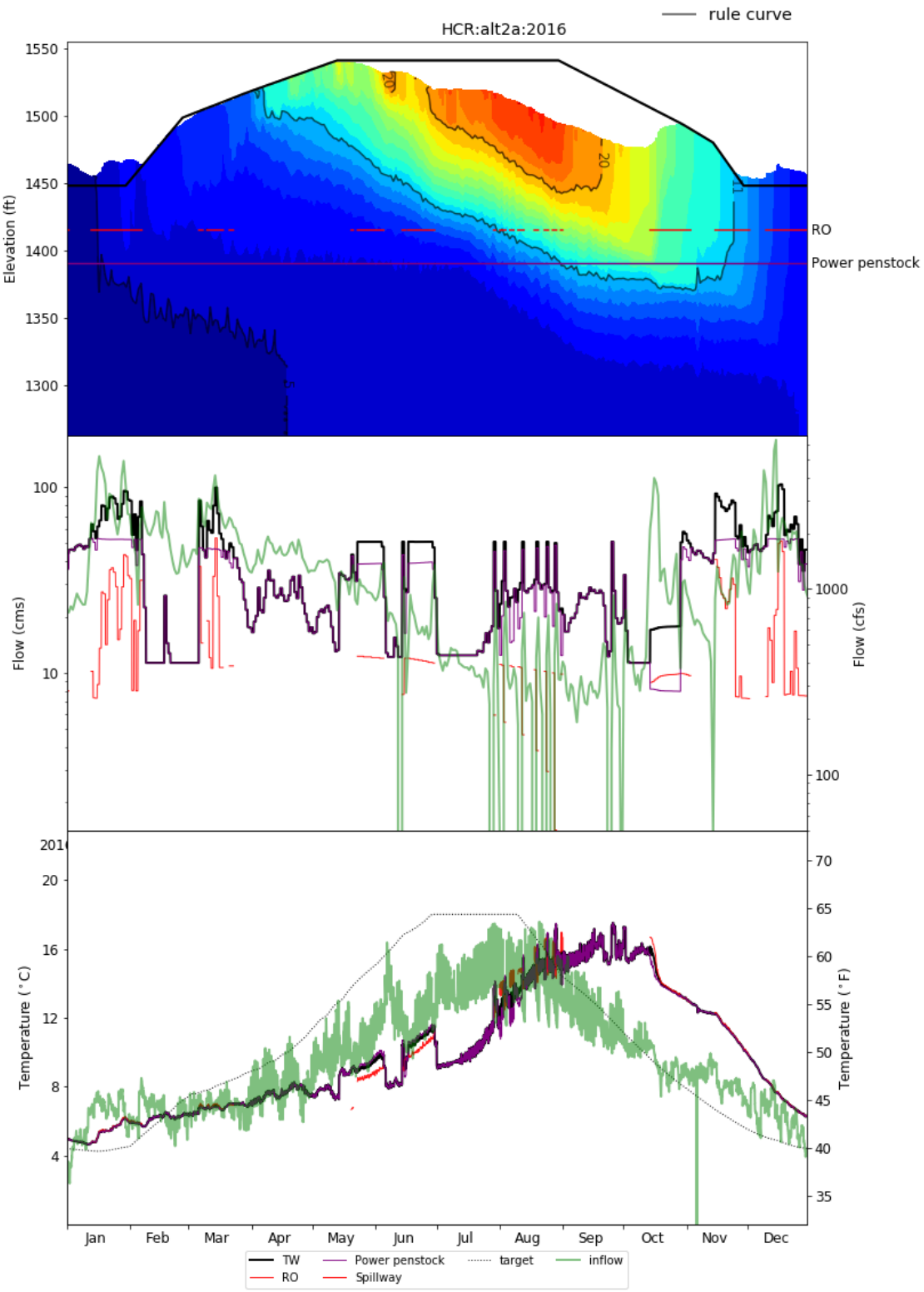


Figure 1-135. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2a in 2016.

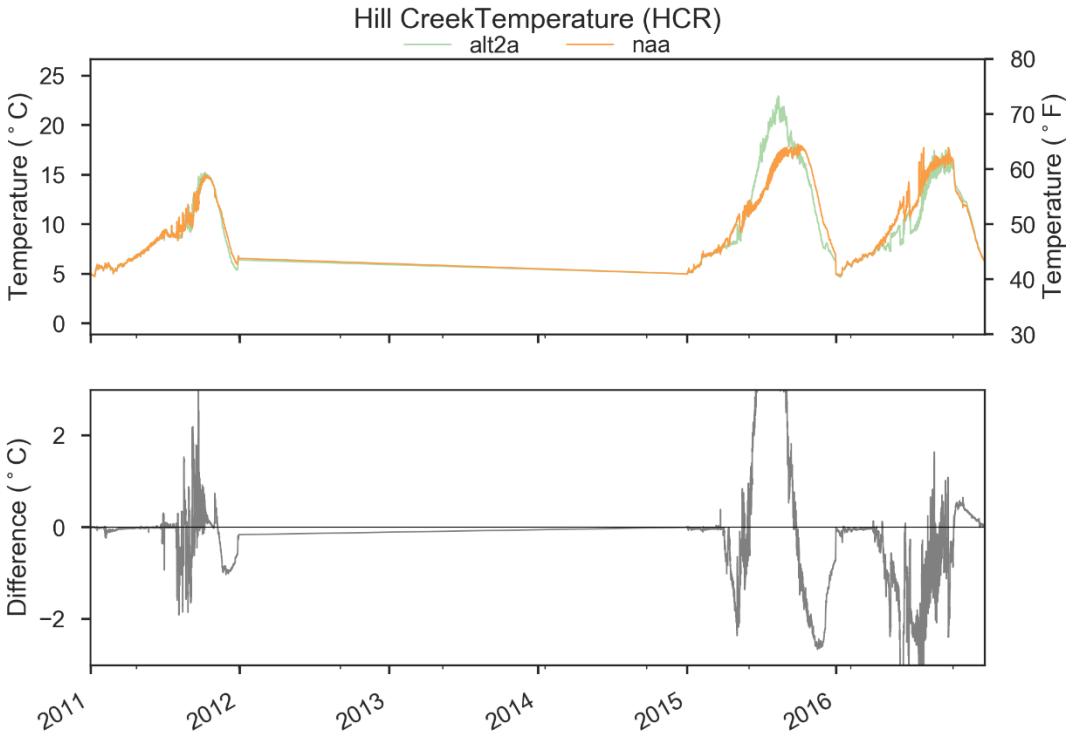


Figure 1-136. Comparison of HCR Outflow Temperatures in NAA and Alternative 2a.

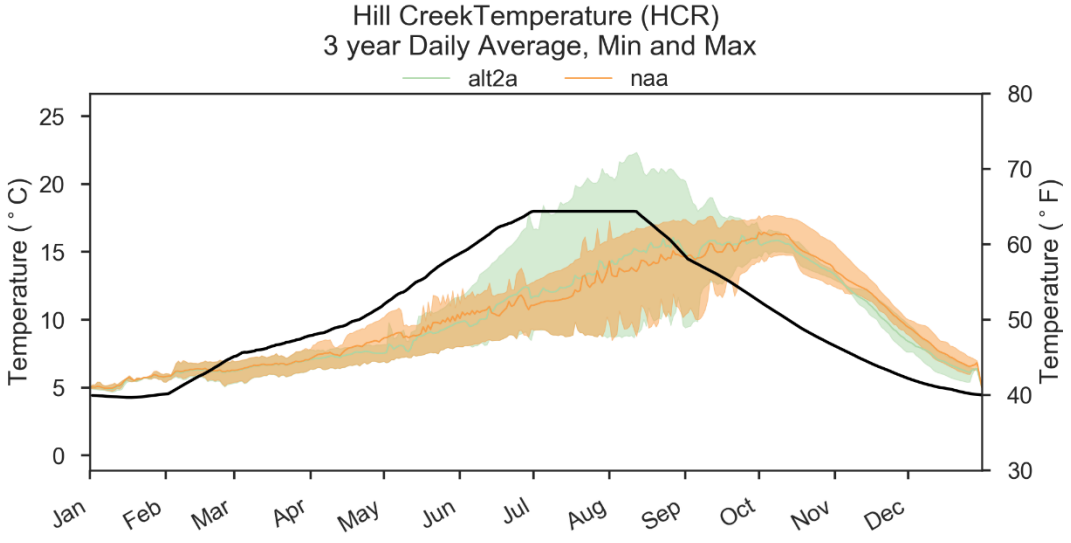


Figure 1-137. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target.

1.5.3.4.2 Lookout Point

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Lookout Point Lake was generally similar to NAA in 2011, 2015, and 2016 (Figure 1-138, Figure 1-139, Figure 1-140) aside from minor differences in timing of refill and release rates that were associated.

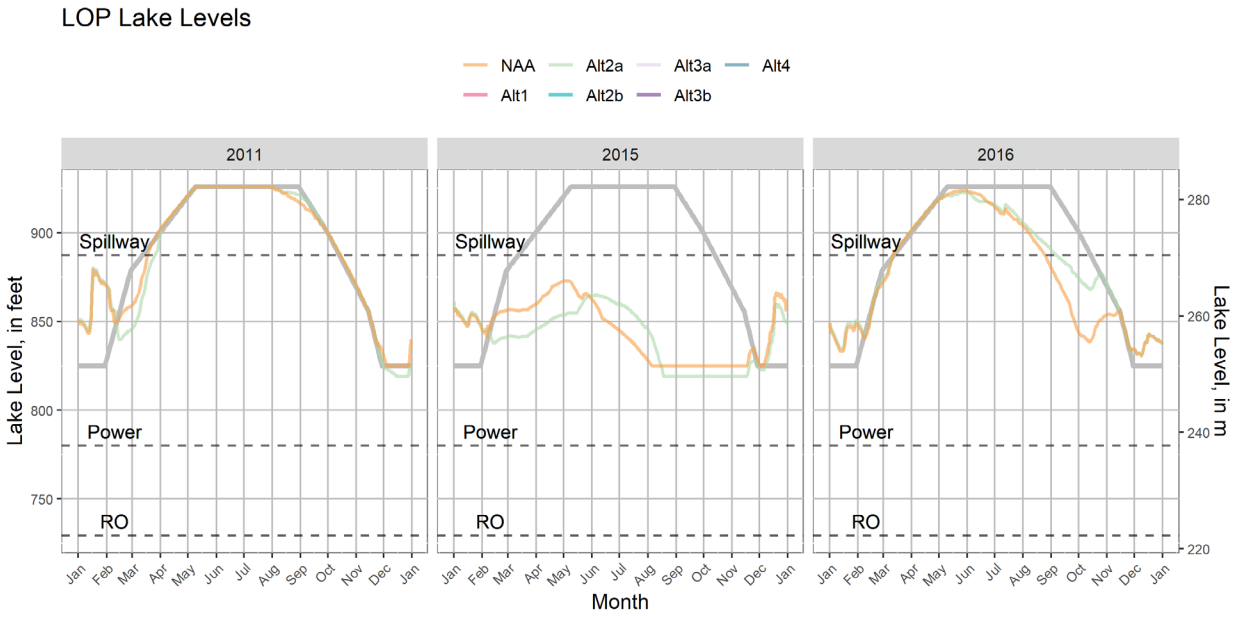


Figure 1-138 WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA.

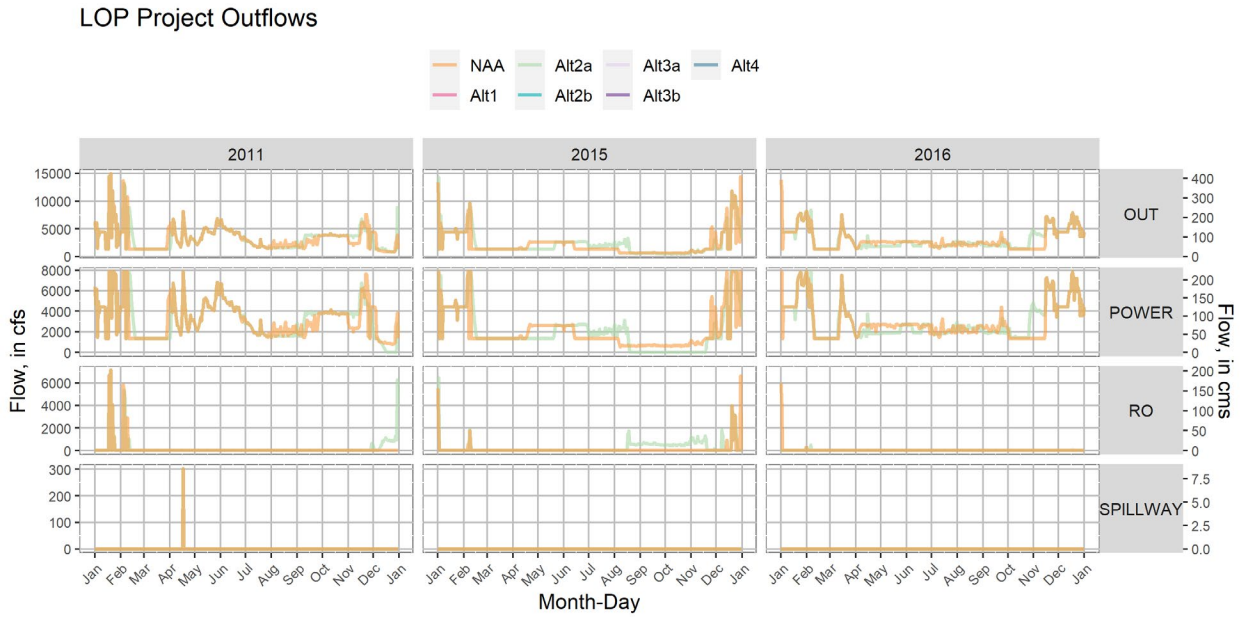


Figure 1-139. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA.

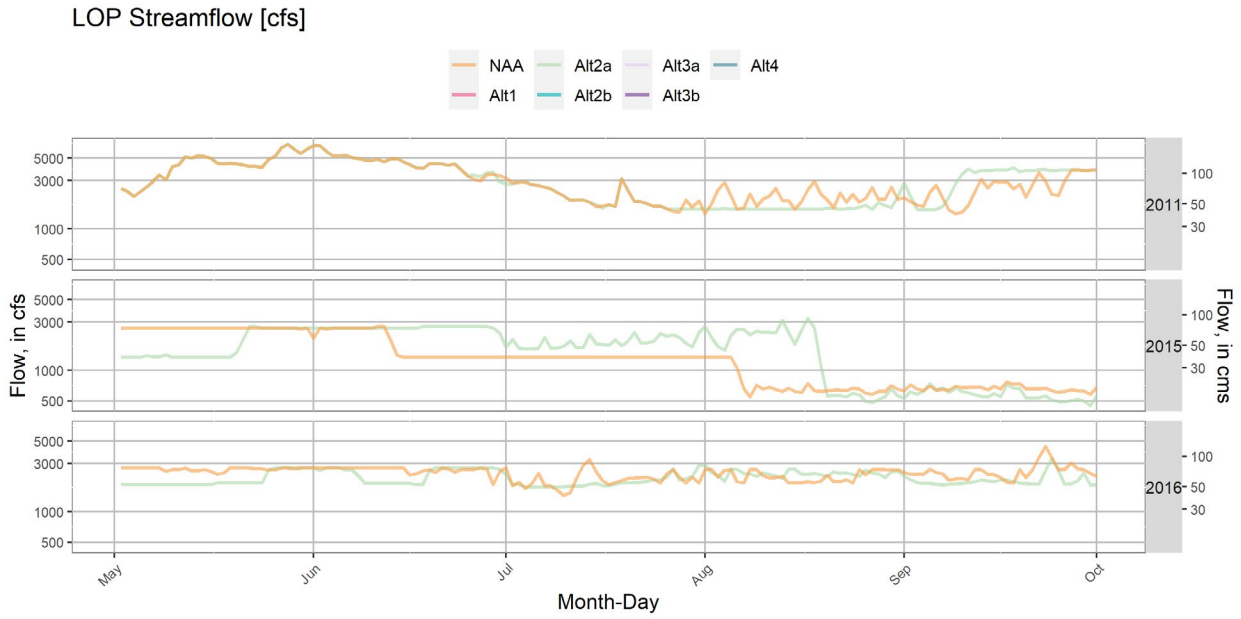


Figure 1-140. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Lookout Point Lake are shown in Figure 1-141, Figure 1-142, and Figure 1-143. The effect of the proposed FSC (and attraction pumps intended for fish collection) in Lookout Point Lake is currently assumed to have minimal effect on release temperature from

the relatively deep Lookout Point Penstocks, but has potential to result in mixing thermal layering and de-stratification in the forebay of Lookout Point Lake. Simulating this effect on water temperature was beyond the scope of the WV EIS. Generally, temperatures downstream of LOP-DEX were similar to NAA, aside from short-term differences in late summer of 2015 likely related to upstream Hills Creek operations (Figure 1-144, Figure 1-145).

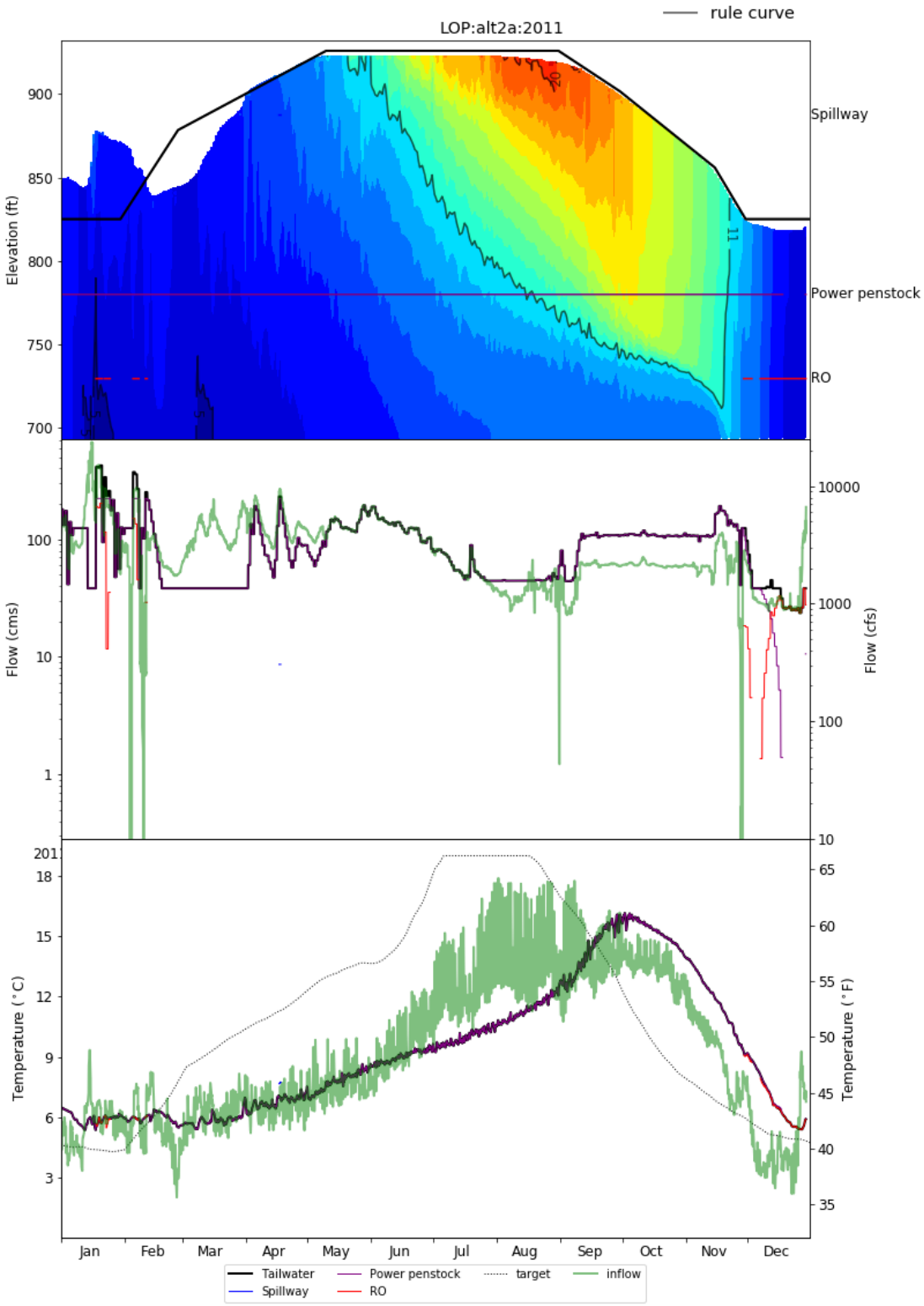


Figure 1-141. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2a in 2011.

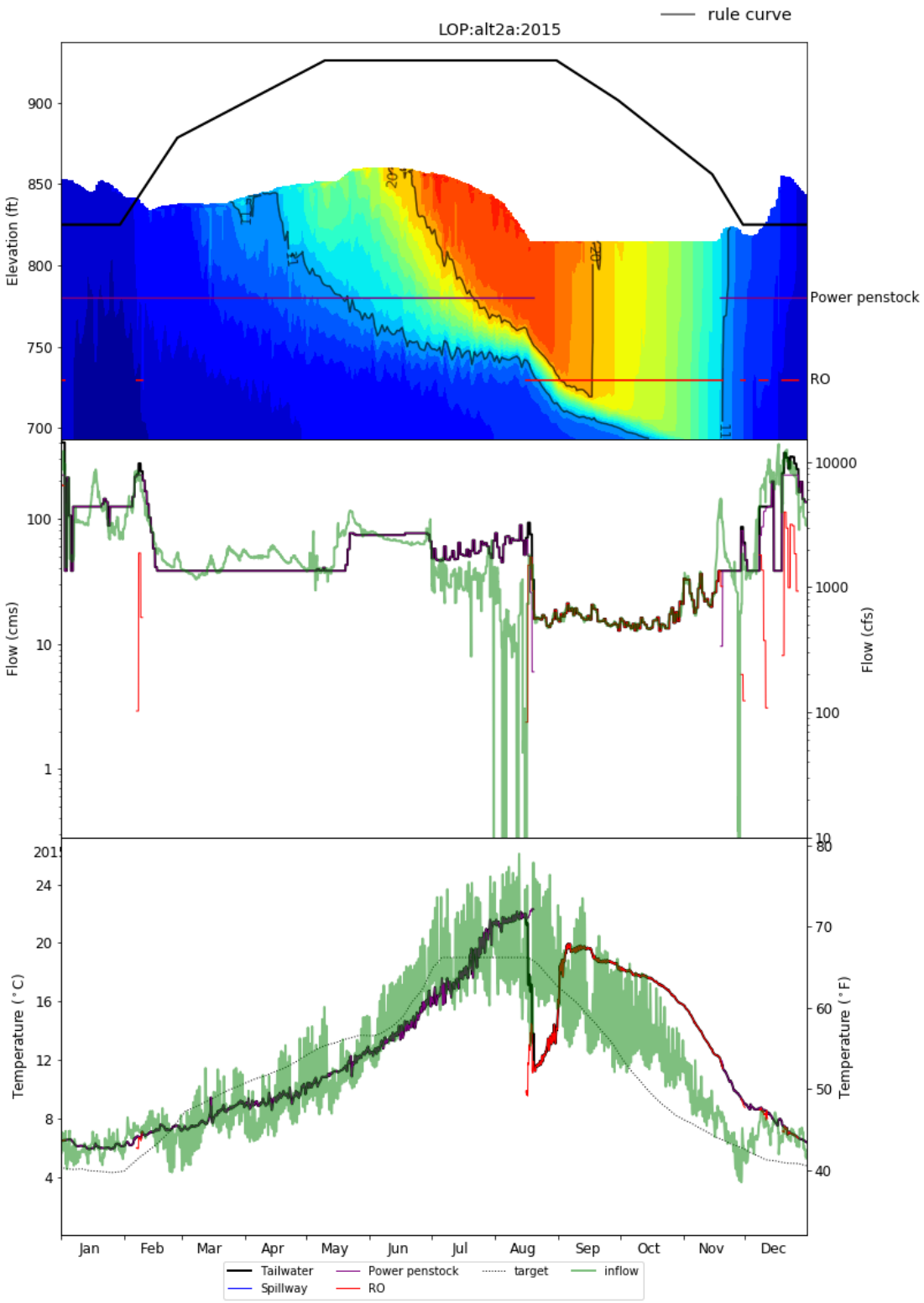


Figure 1-142. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2a in 2015.

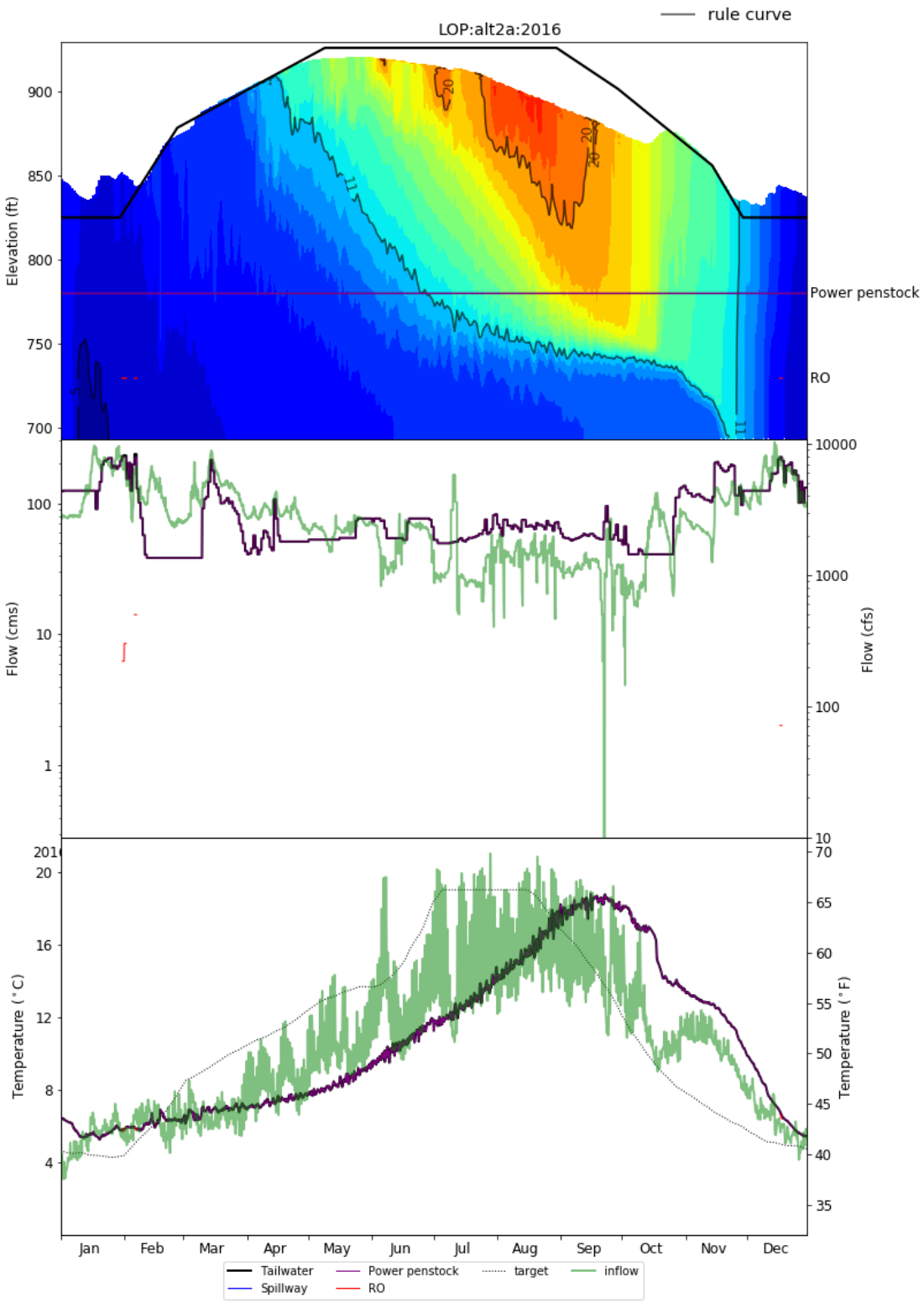


Figure 1-143. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2a in 2016.

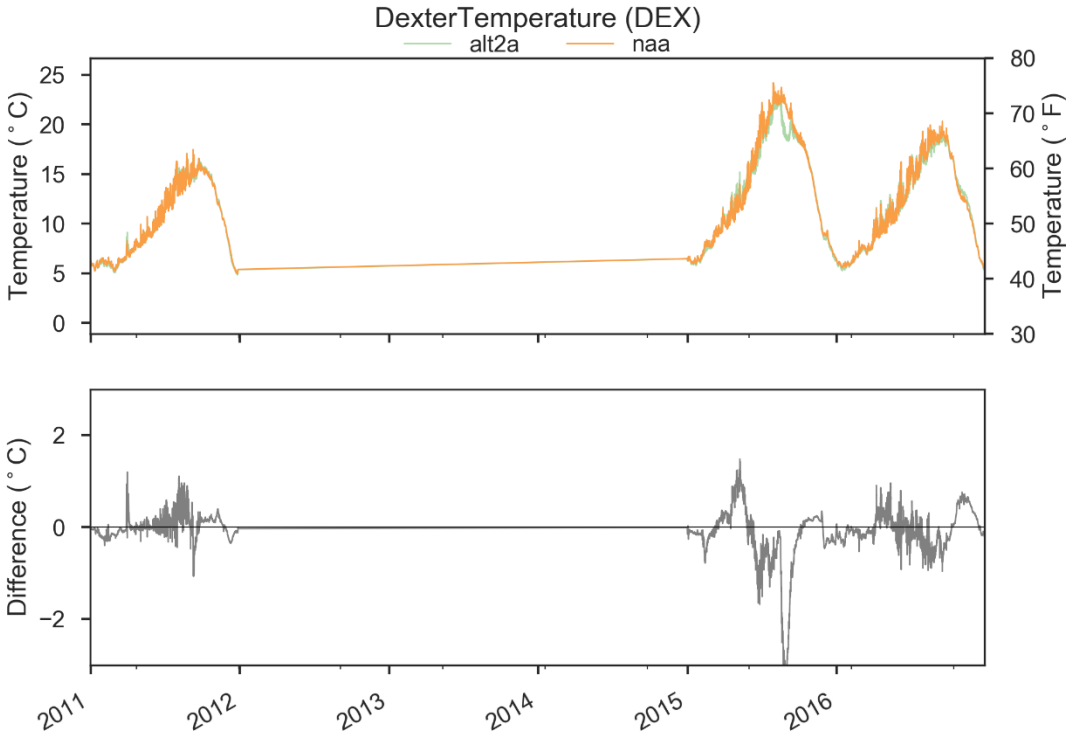


Figure 1-144. Comparison of DEX Outflow Temperatures in NAA and Alternative 2a.

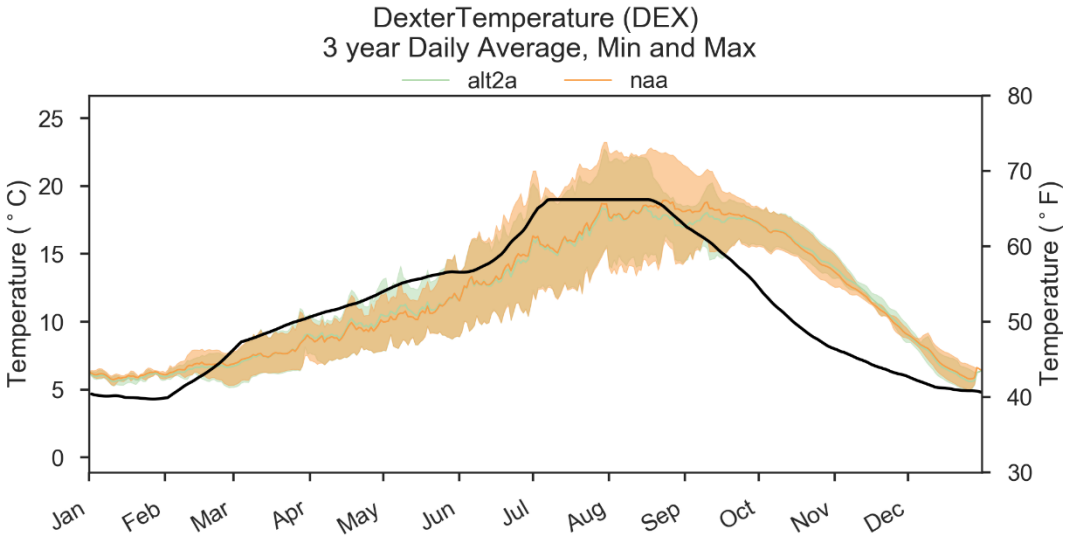


Figure 1-145 Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target.

1.5.3.5 Mainstem Willamette River

Streamflow on the mainstem Willamette River under Alternative 2a was generally lower from April to mid-June and higher from mid-June to mid-September compared with NAA (Figure 1-146). However, these flow differences were primarily in 2015 and responsive to the flow Measure 30 rules that increase dam outflows in advance of heat wave events (Figure 1-147). These flow changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (Figure 1-148 and Figure 1-149). Water temperatures at Salem were also affected by upstream dam operations and the proposed SWS-FSS structure at Detroit Dam, which likely contributed to warmer temperatures seen in 2011 and 2015 under Alternative 2a. Overall water temperature differences between Alternative 2a and NAA were less than 2 degrees Celsius.

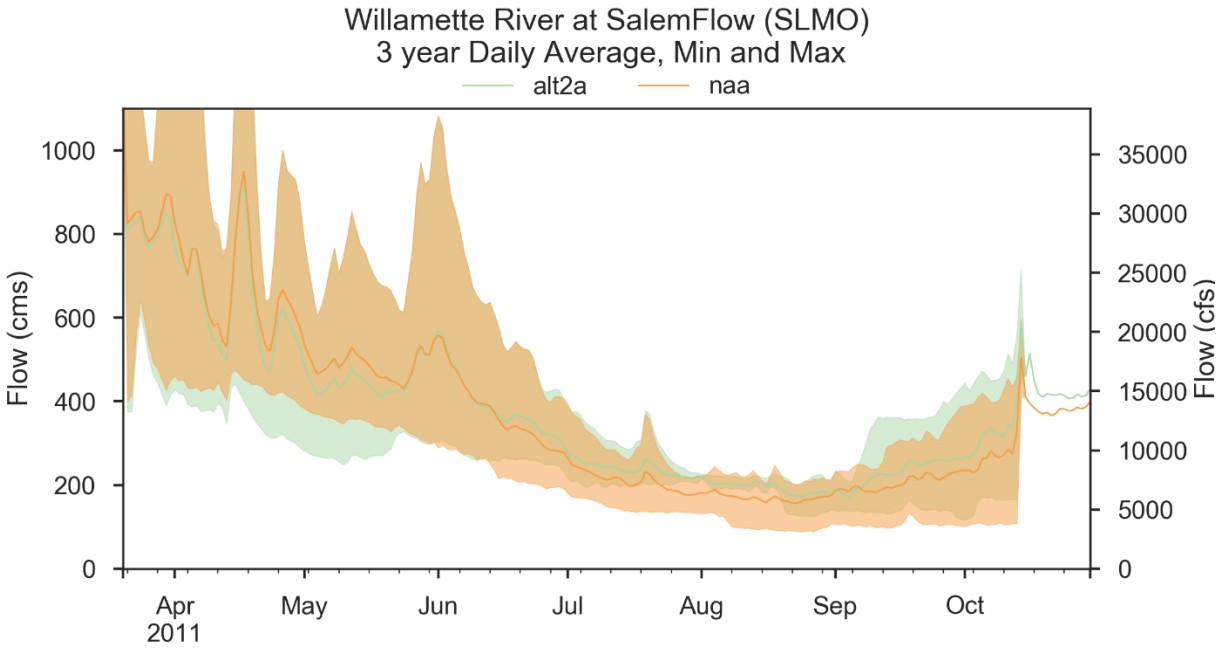


Figure 1-146. Streamflow Comparison of Average, Min, and Max Willamette River at SLMO under NAA and Alternative 2a Conditions.

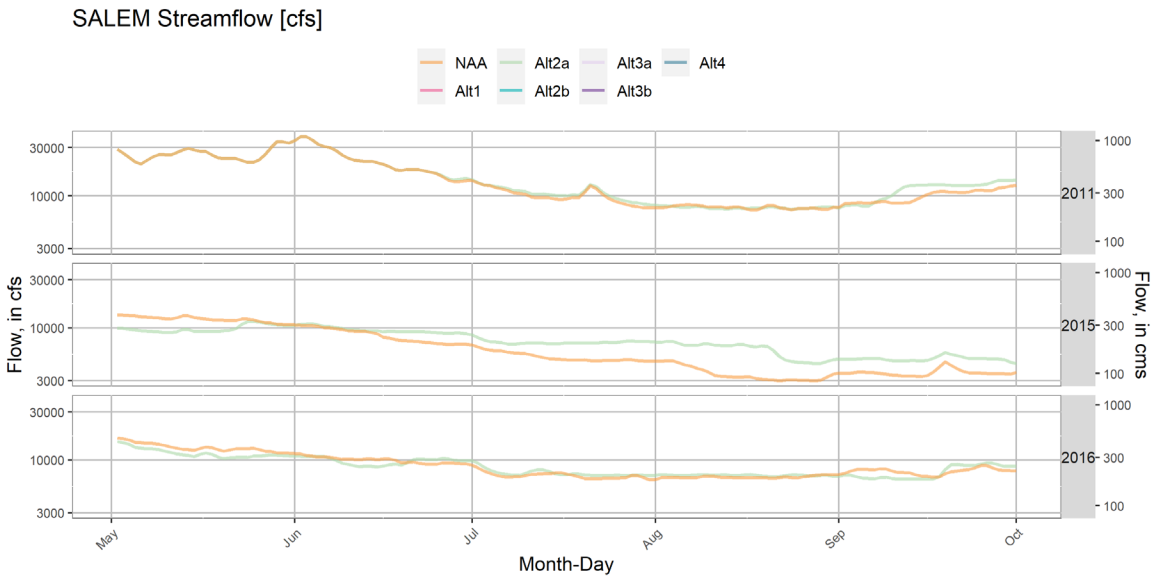


Figure 1-147. Streamflow Comparison Between Alternative 2a and NAA at Willamette River at SLMO.

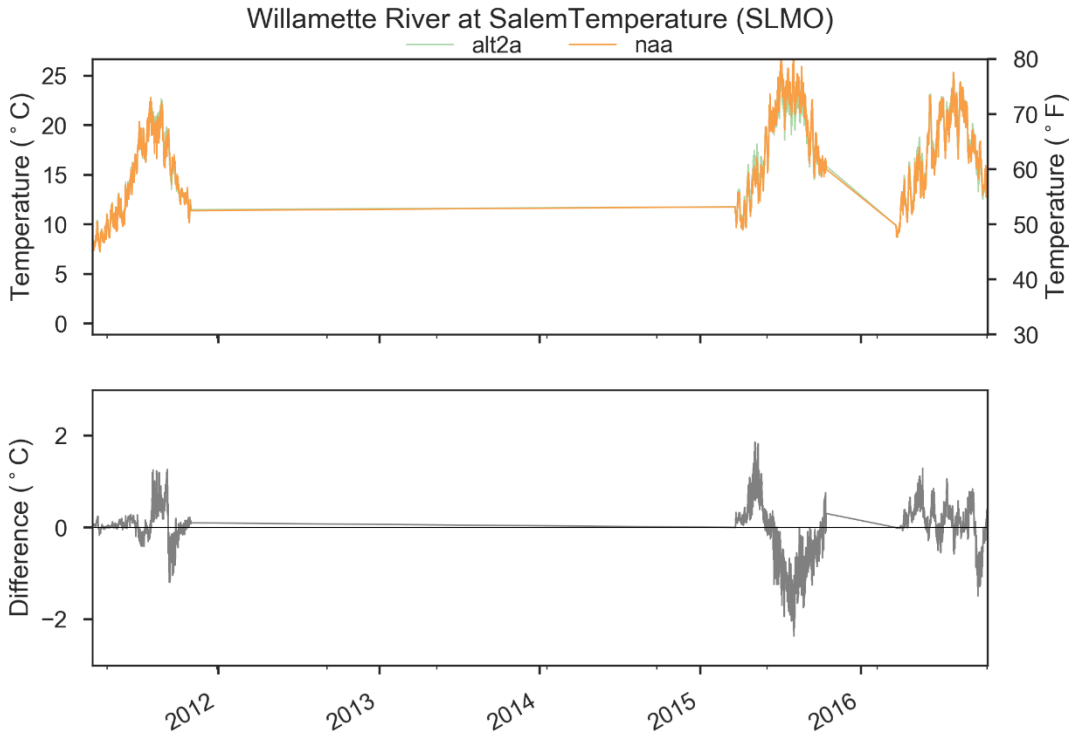


Figure 1-148. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 2a.

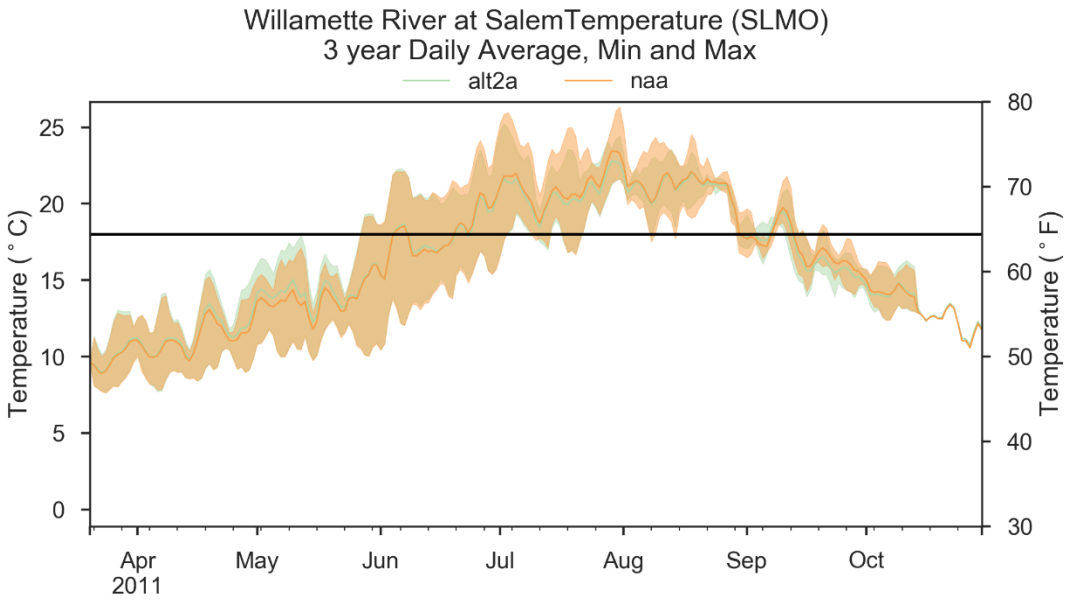


Figure 1-149. Comparison of Willamette River at SLMO 3-year Average, Min, Max Outflow Temperatures in NAA and Alternative 2a.

1.5.4 Alternative 2b – Hybrid Alternative

Alternative 2b measures that affected operations, lake storage, and water temperature included:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.
- Construct temperature control structure at Detroit.
- Deep fall drawdown to 35’ over the regulating outlet at Green Peter, use of RO in fall, use spillway for surface spill in spring and summer.
- Deep spring and fall drawdown to 30 feet over the diversion tunnel at Cougar, with a limited refill window between June 15th and November 15th (essentially a delayed refill).
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.

1.5.4.1 North Santiam Dams

1.5.4.1.1 Detroit

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Detroit Lake generally increased under Alternative 2b compared to NAA in 2015 and 2016 aside from September-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-150, Figure 1-151, and Figure 1-152). The increased storage coincided with reduced outflows during spring (e.g., April-May of 2015) and increased outflows in summer (July-September in 2015, June-Aug in 2016) under Alternative 2b. Total outflow in 2011 was generally similar in Alternative 2b and NAA at Detroit Lake. The proposed SWS and FSS in Alternative 2b allowed all outflow within powerhouse capacity (assumed at 4600 cfs) to be routed from a floating outlet through the Power outlets for temperature management, rather than the Spillway or URO flow for temperature management that was used in NAA (Figure 1-151).

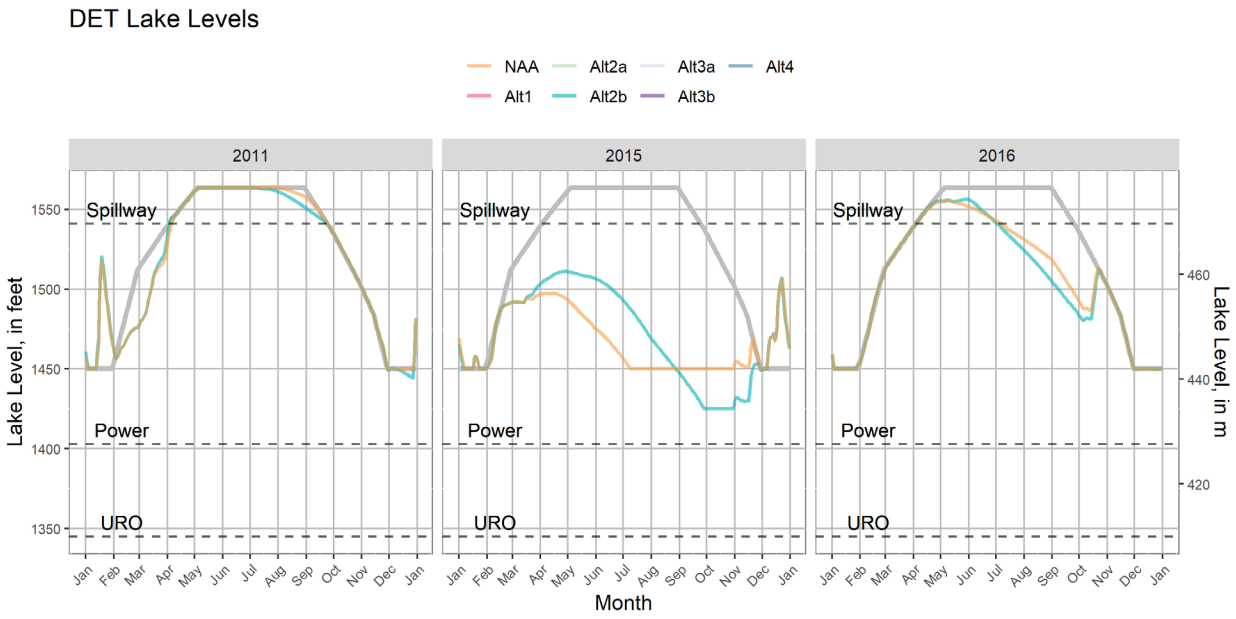


Figure 1-150. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 Under Alternative 2b and NAA.

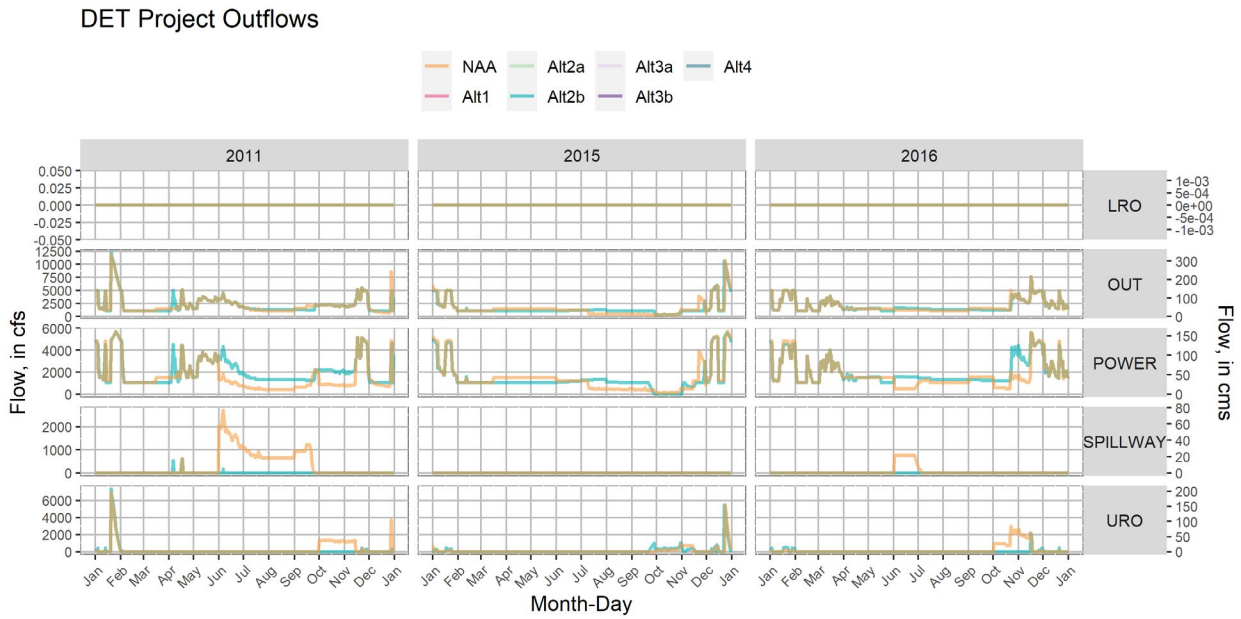


Figure 1-151. WV EIS HEC-ResSim Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2b and NAA.

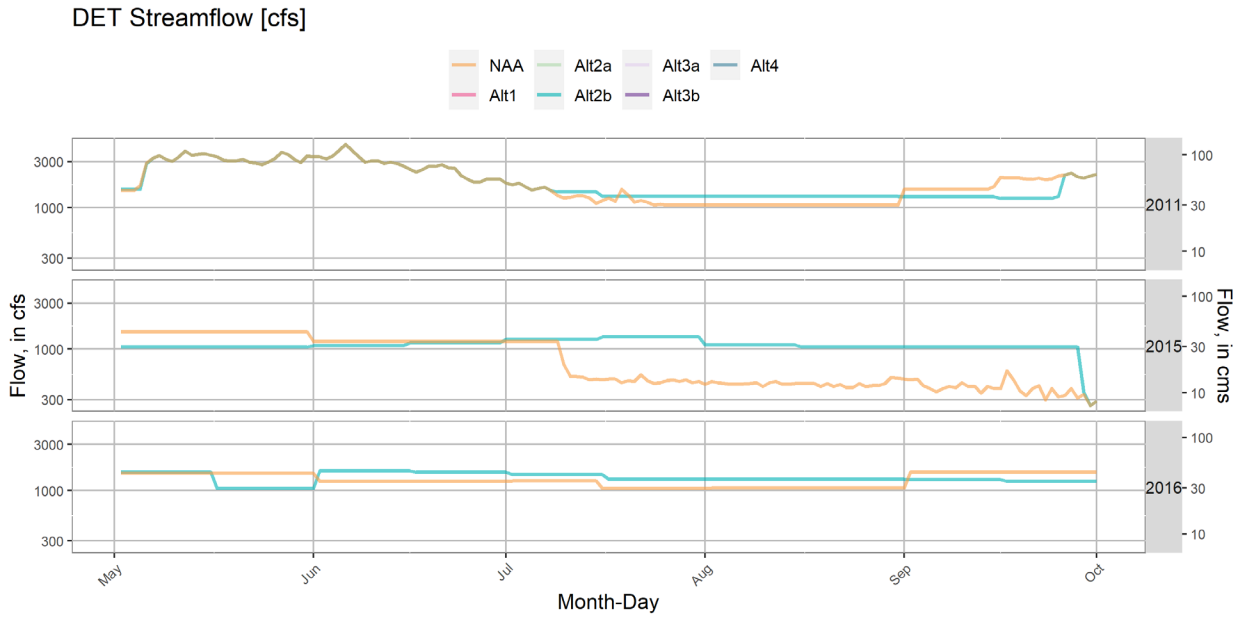


Figure 1-152. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 Under Alternative 2b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-153, Figure 1-154, and Figure 1-155. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the Upper RO. Tailwater release temperatures

generally matched the temperature target when sufficient warm or cool water was available. Generally, the proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn (Figure 1-156, Figure 1-157).

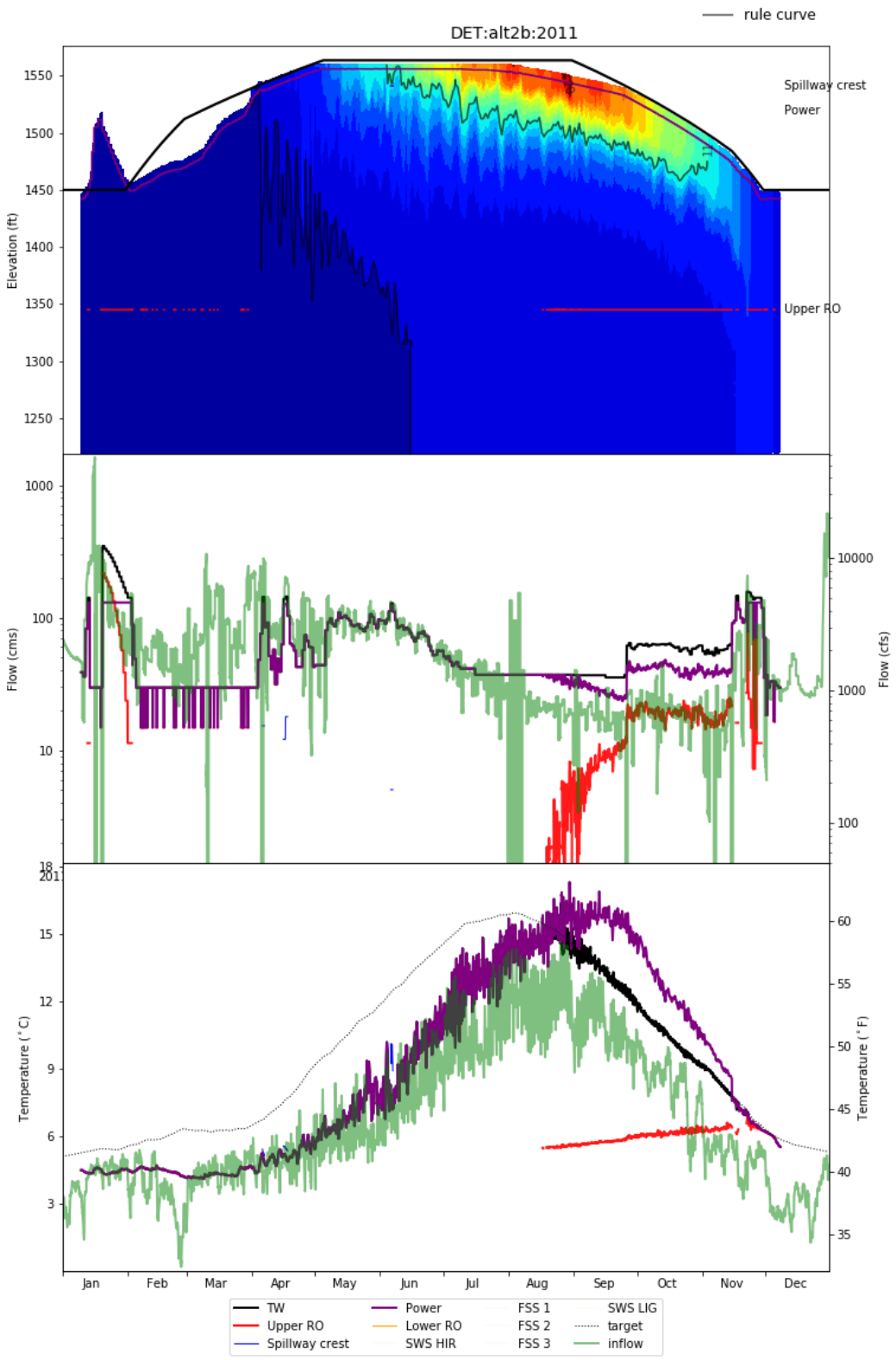


Figure 1-153. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2b in 2011.

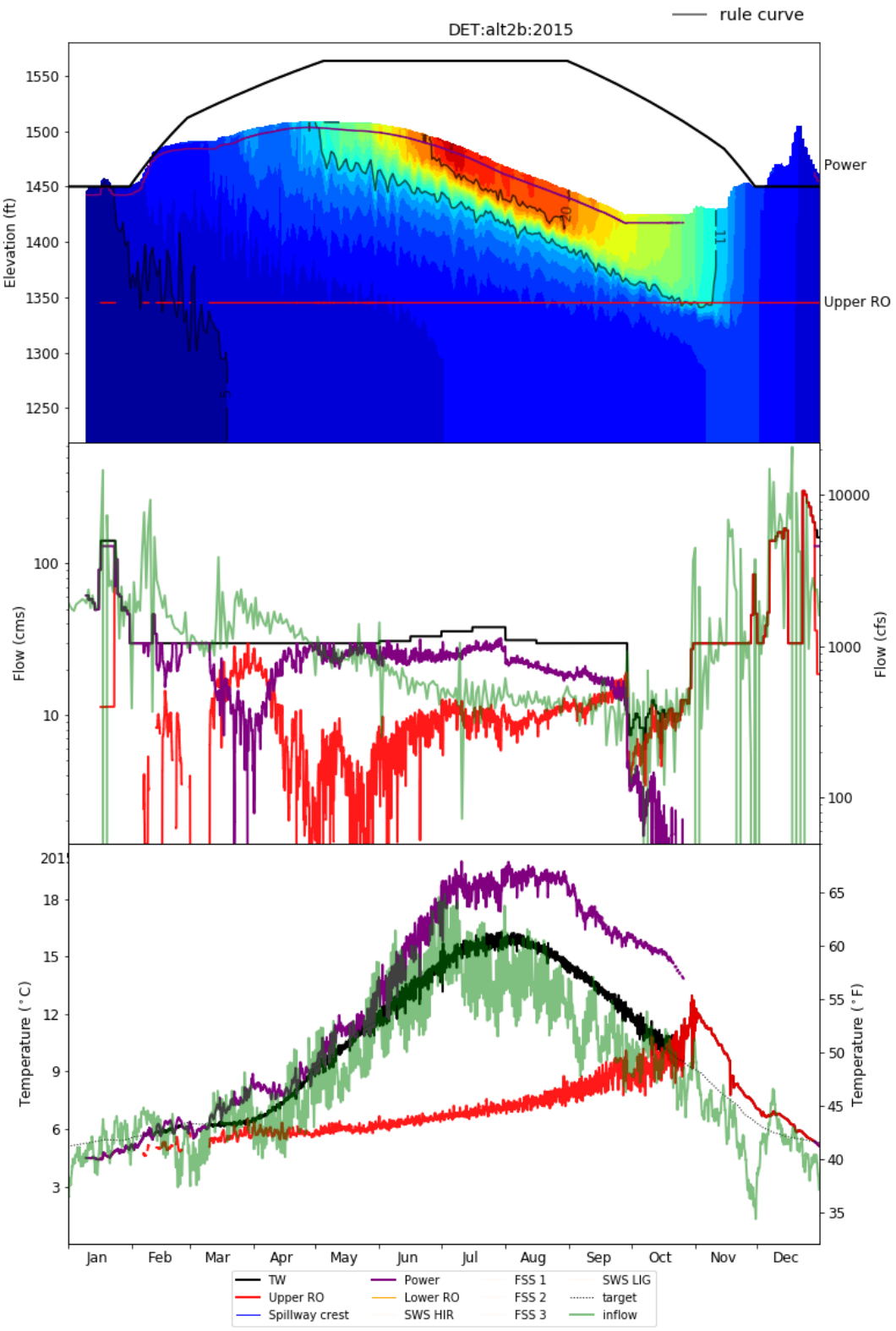


Figure 1-154. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2b in 2015.

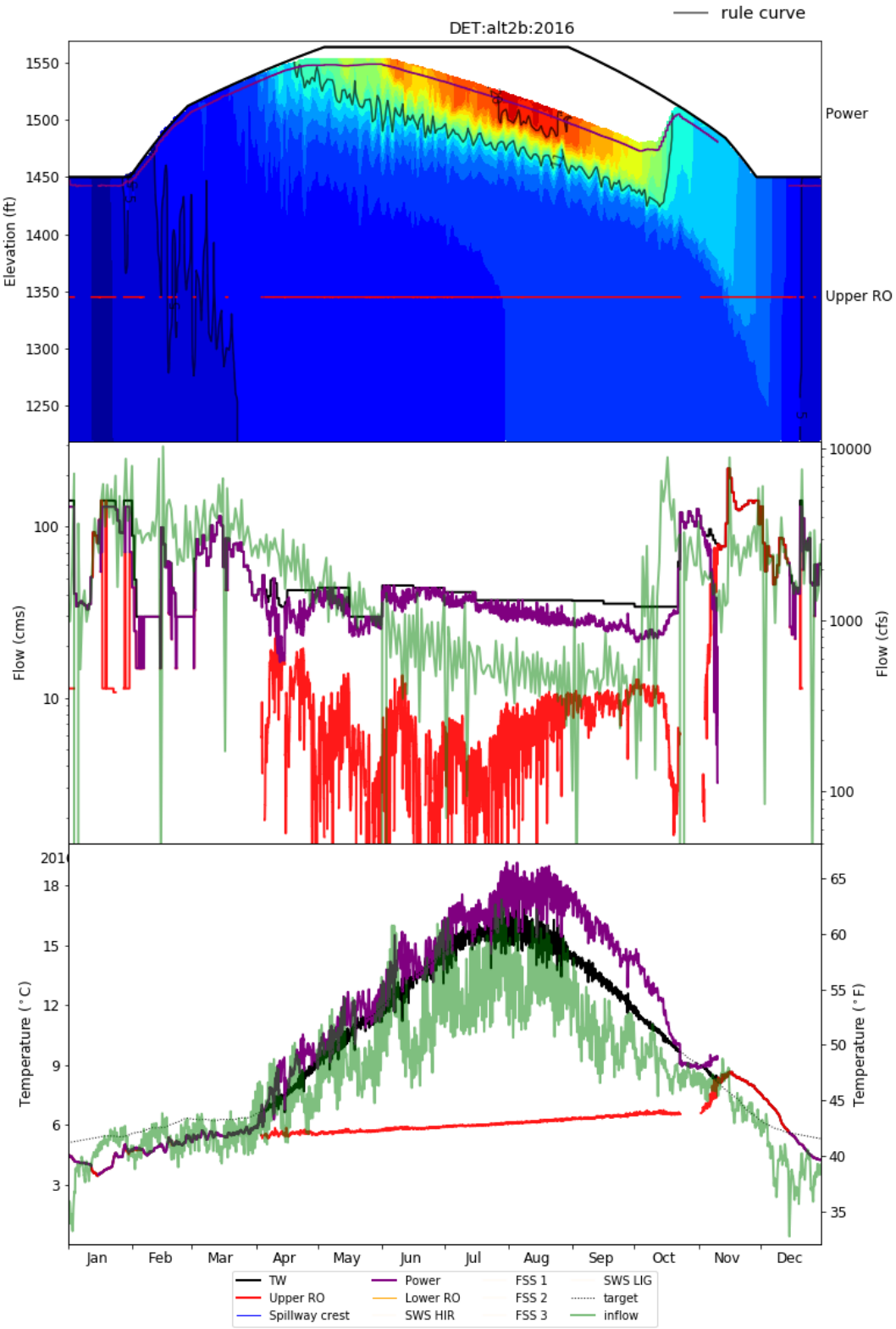


Figure 1-155. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2b in 2016.

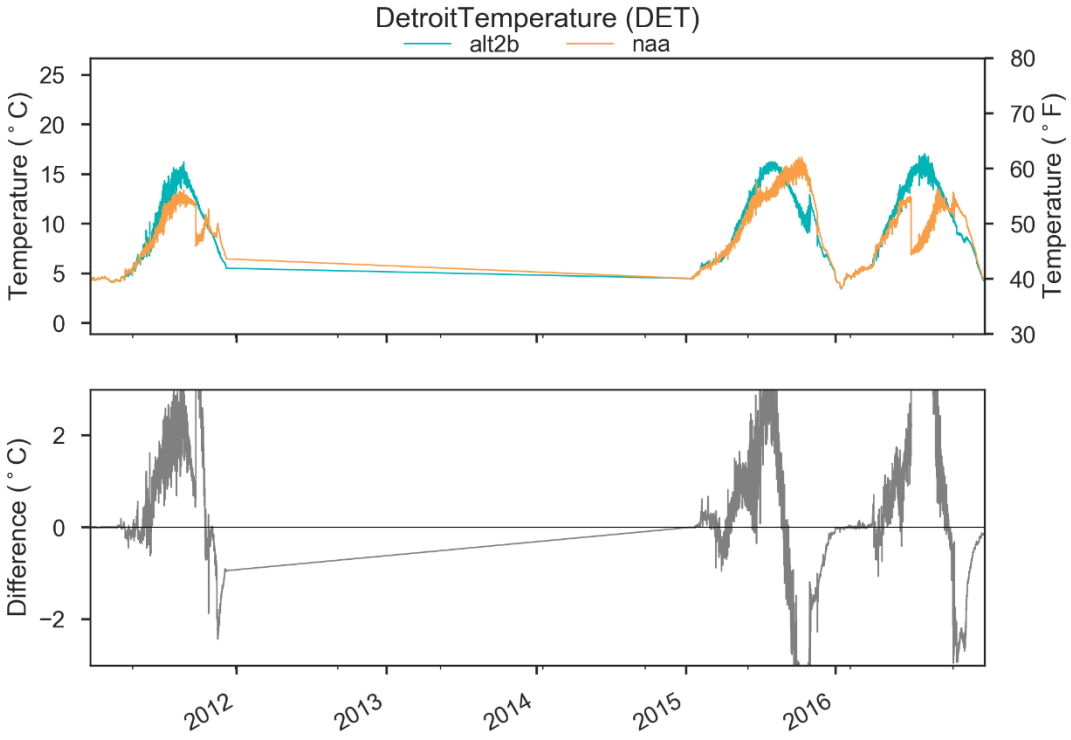


Figure 1-156. Comparison of DET outflow temperatures in NAA and Alternative 2b.

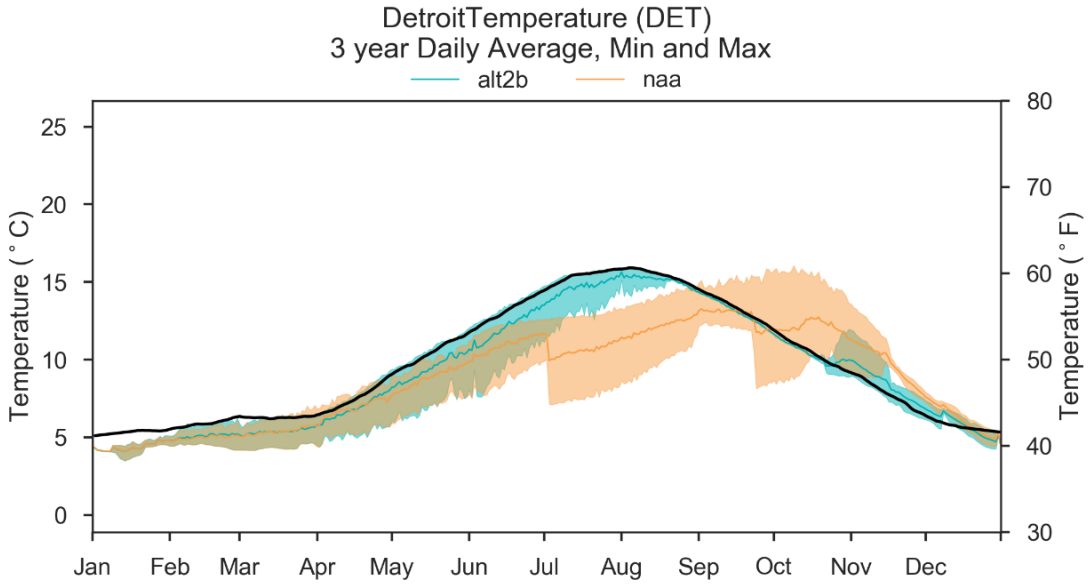


Figure 1-157. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target.

1.5.4.2 South Santiam Dams

1.5.4.2.1 Green Peter

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Green Peter were generally similar under Alternative 2b and NAA in 2011, 2015, and 2016 aside from October-November during RO drawdown for fish passage(Figure 1-158, Figure 1-159, and Figure 1-160). Some increased storage in 2015 coincided with reduced outflows during spring and increased outflows in July-October comparing Alternative 2b to NAA. 2011 and 2016 operations were generally similar in Alternative 2b and NAA at Green Peter Lake January-June but followed increased outflows in July-October to draft the lake for fish passage operations through the ROs in autumn. The proposed operational temperature management through the spillway (during spring/summer) and RO (during autumn) in Alternative 2b led to increased outflow from these outlets and decreased power outflow compared to NAA (Figure 1-159).

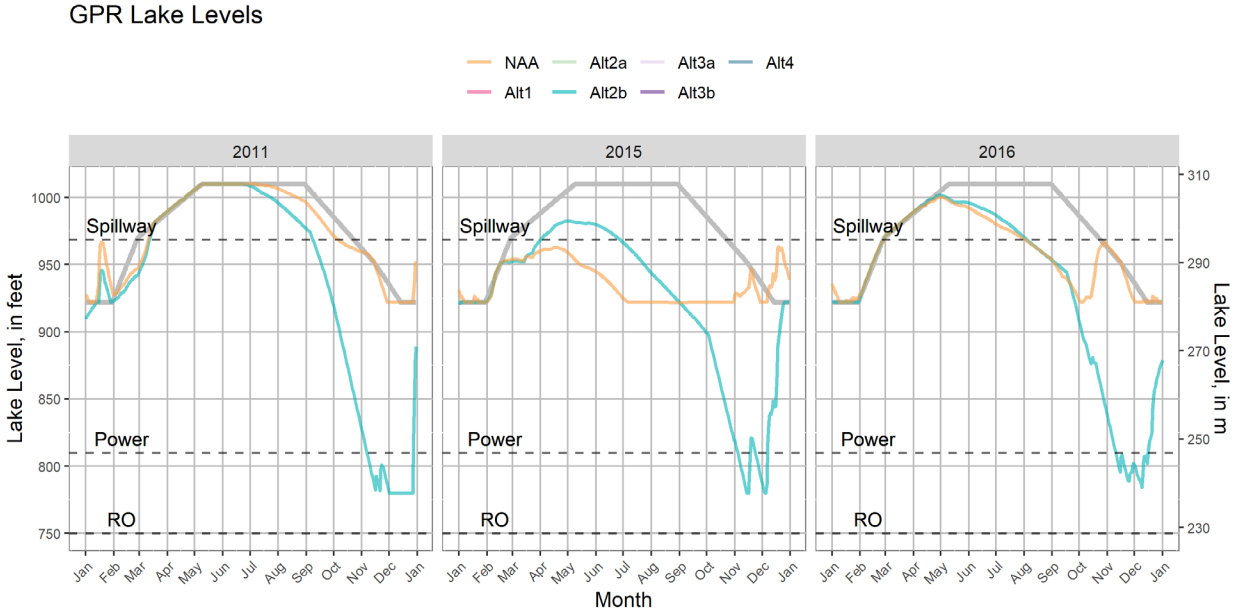


Figure 1-158. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 2b and NAA.

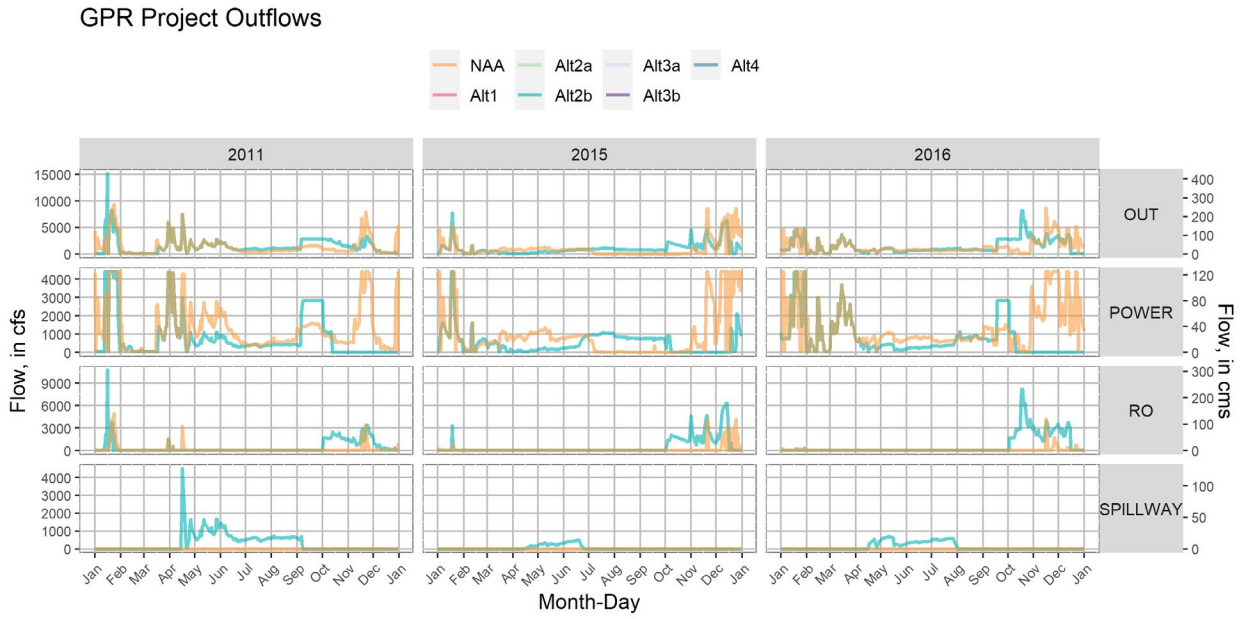


Figure 1-159. WV EIS HEC-ResSim Green Peter Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 2b and NAA.

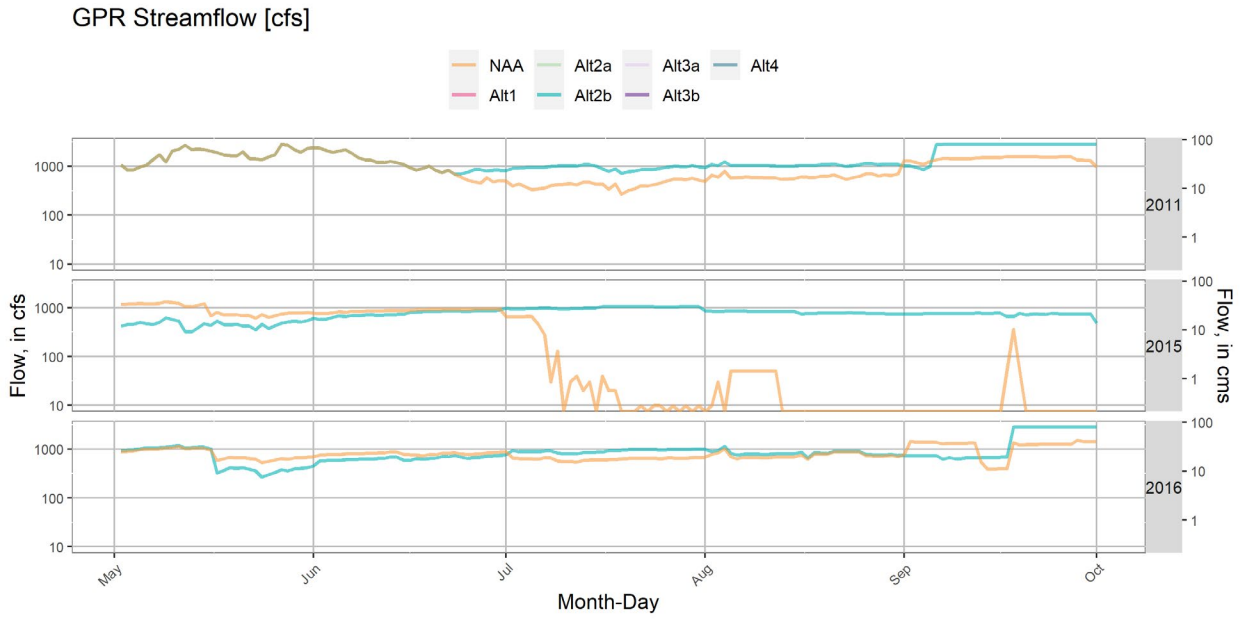


Figure 1-160. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-161, Figure 1-162, and Figure 1-163 . Alternative 2b included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during

autumn to mix releases from these non-power releases with relatively deep power penstock releases in an attempt to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available, and those outlets were submerged. Spillway access was limited in some years (2015 especially), which led to an abrupt drop in tailwater temperature when spillway access ended in mid-summer of those years. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam (Figure 1-164, Figure 1-165). Generally, the autumn fish passage operation (drawdown to the RO) resulted in cooler autumn temperatures (November-December) compared to NAA (Figure 1-165).

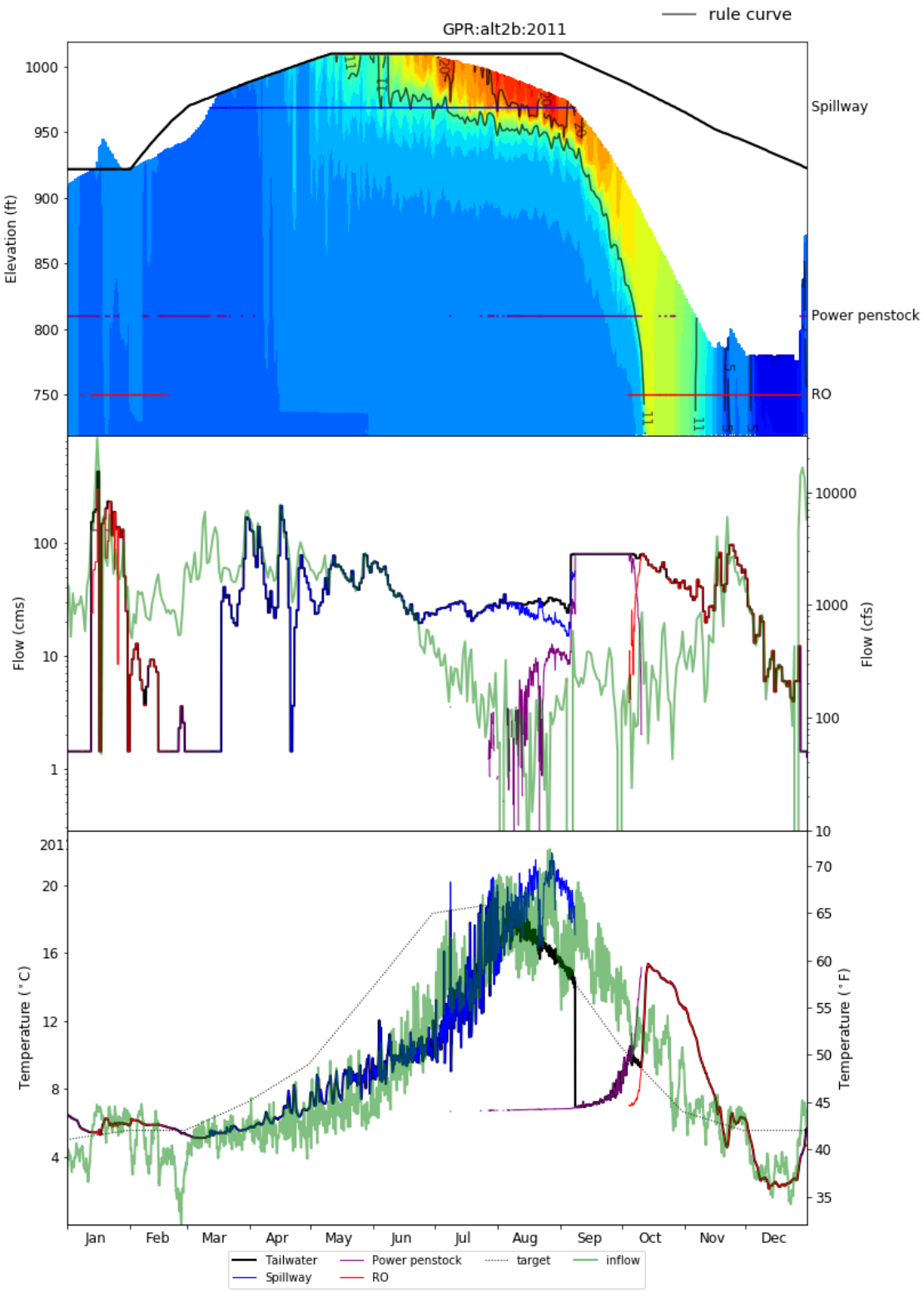


Figure 1-161. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2b in 2011.

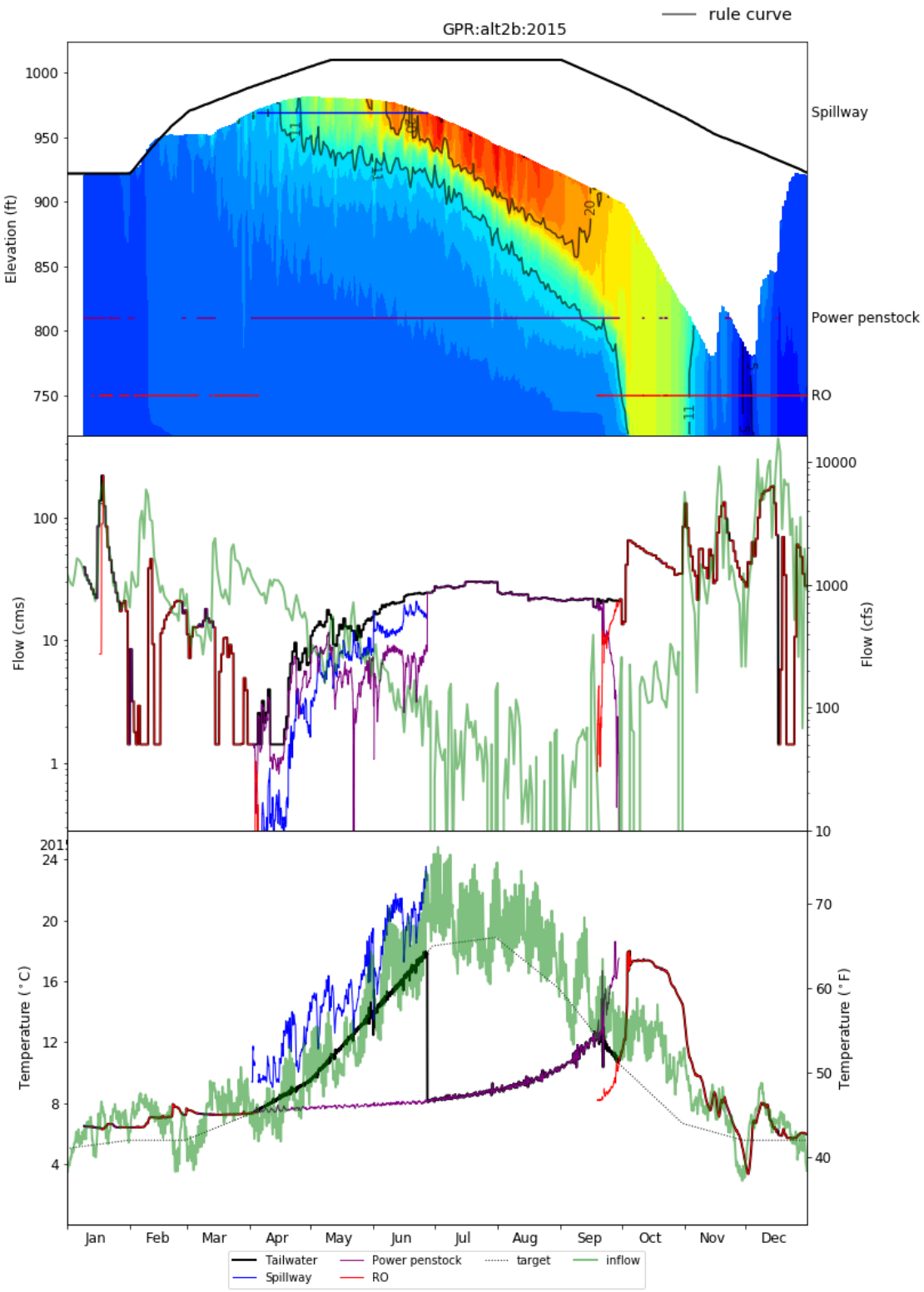


Figure 1-162. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2b in 2015.

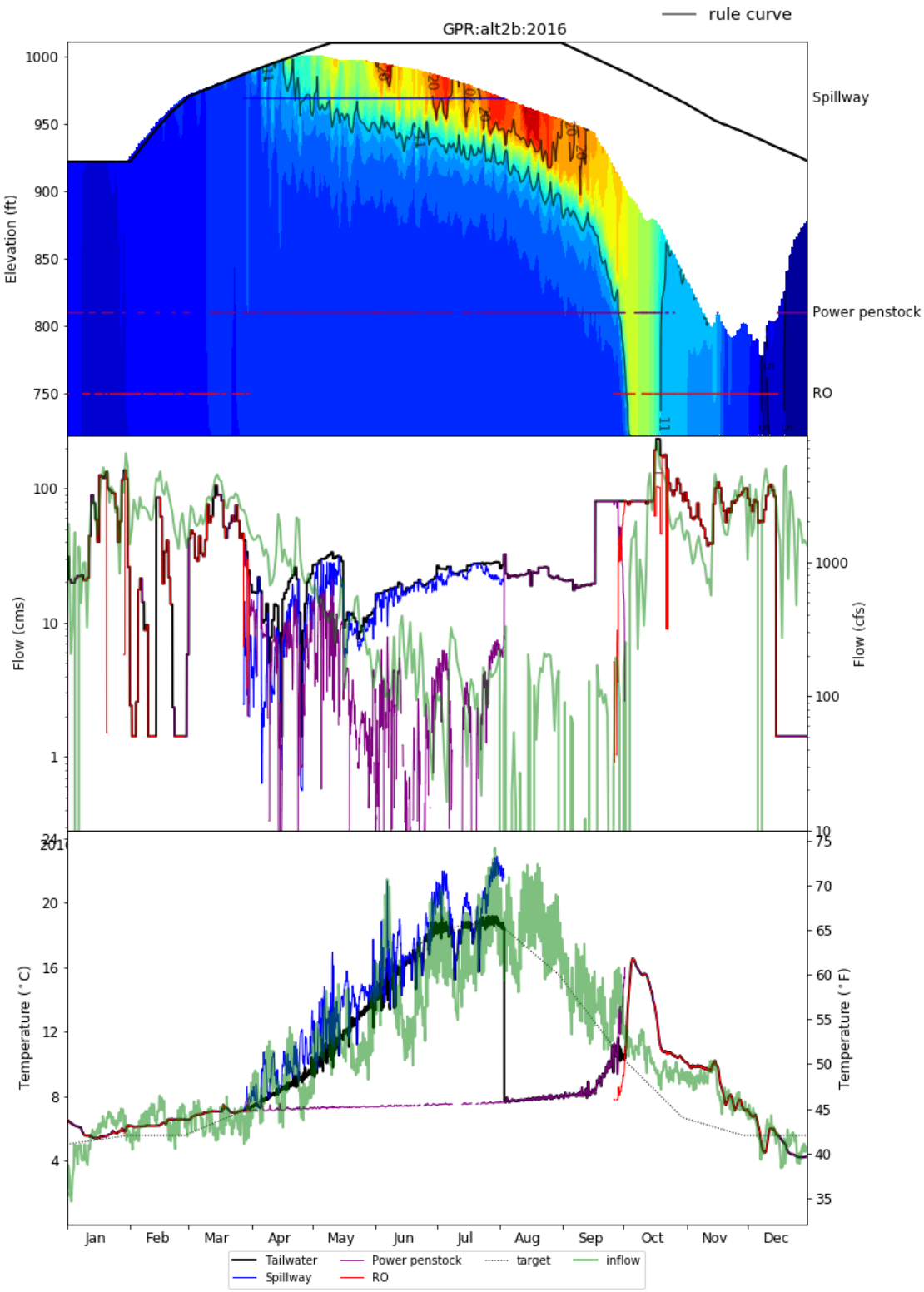


Figure 1-163. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2b in 2016.

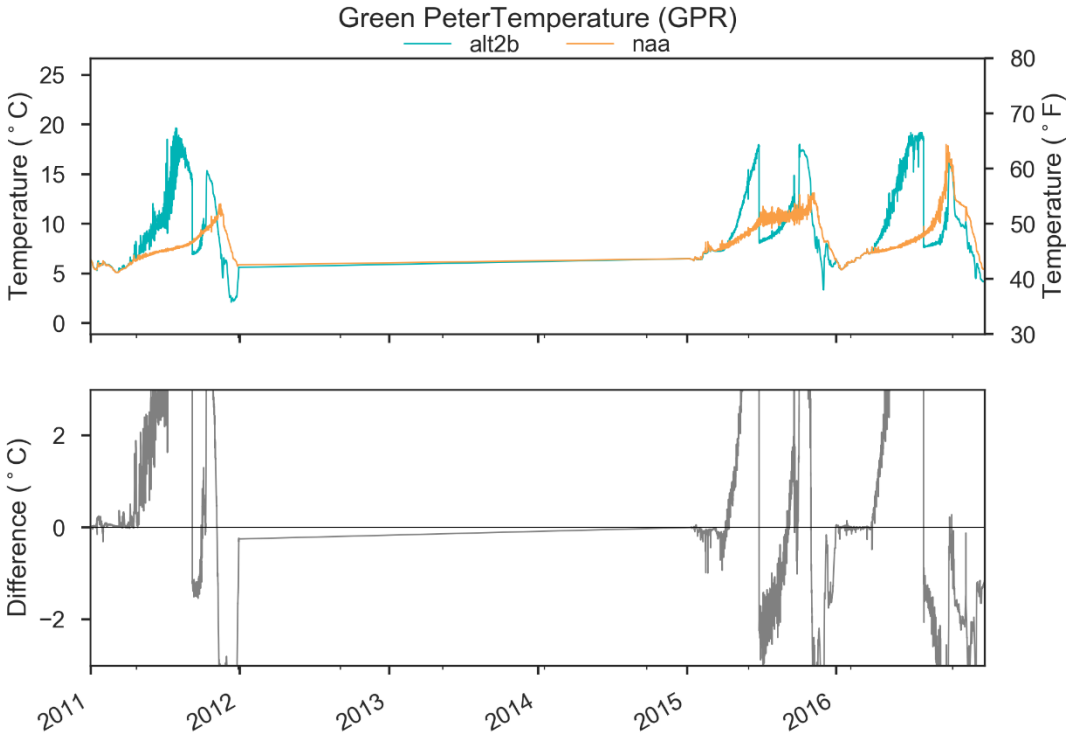


Figure 1-164. Comparison of GPR Outflow Temperatures in NAA and Alternative 2b.

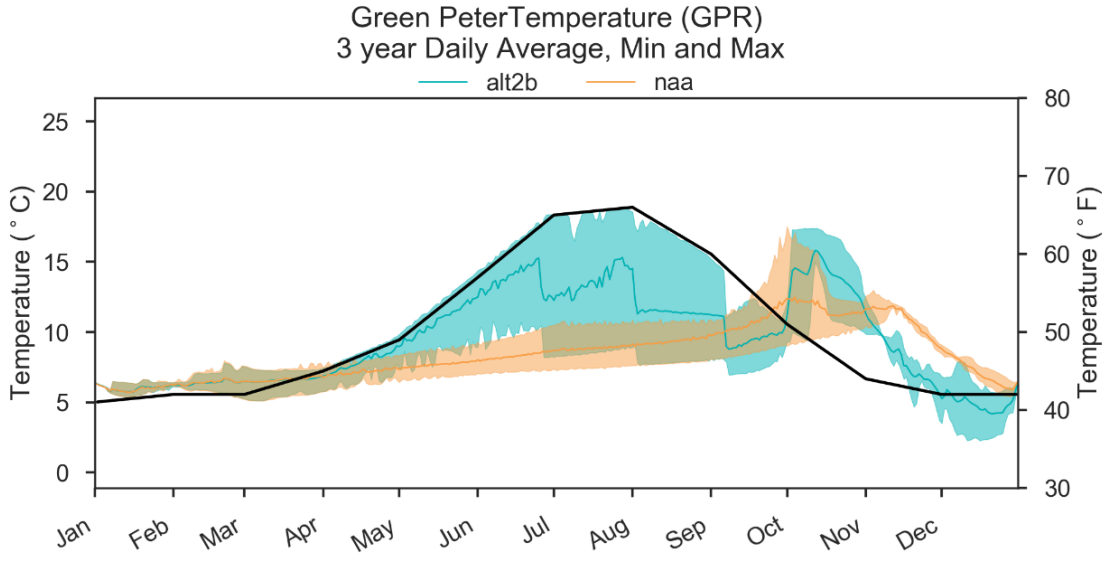


Figure 1-165. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target.

1.5.4.2.2 Foster

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Foster was generally similar in Alternative 2b compared to NAA in 2011 and 2016 but increased in 2015 in Alternative 2b compared to NAA (Figure 1-166, Figure 1-167, and Figure 1-168). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam. The proposed modifications to the fish weir and FWWS in Alternative 2b resulted in lower outflow routed through the Power outlets for temperature management, especially during spring and summer compared to NAA (Figure 1-167).

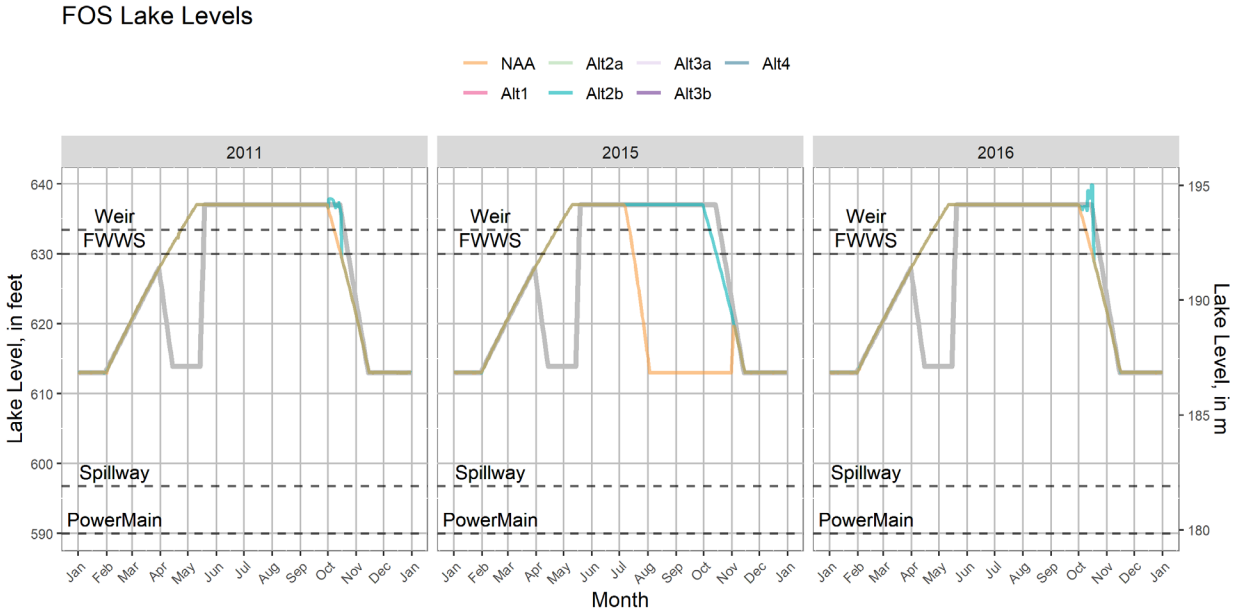


Figure 1-166. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 under Alternative 2b and NAA.

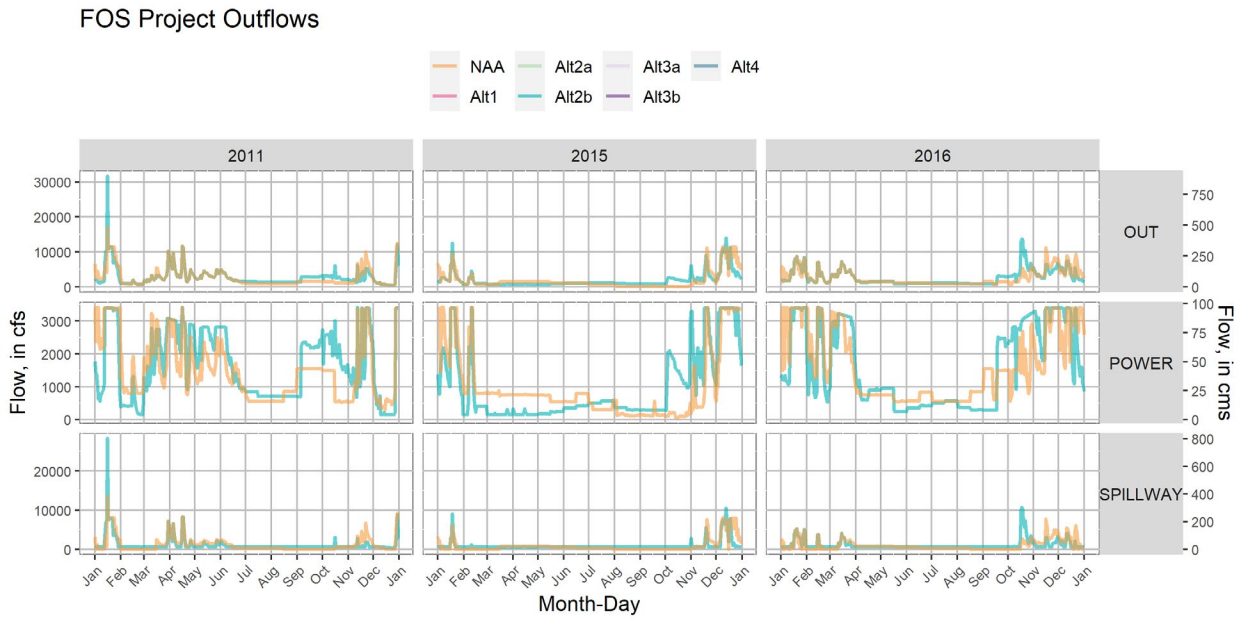


Figure 1-167. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2b and NAA.

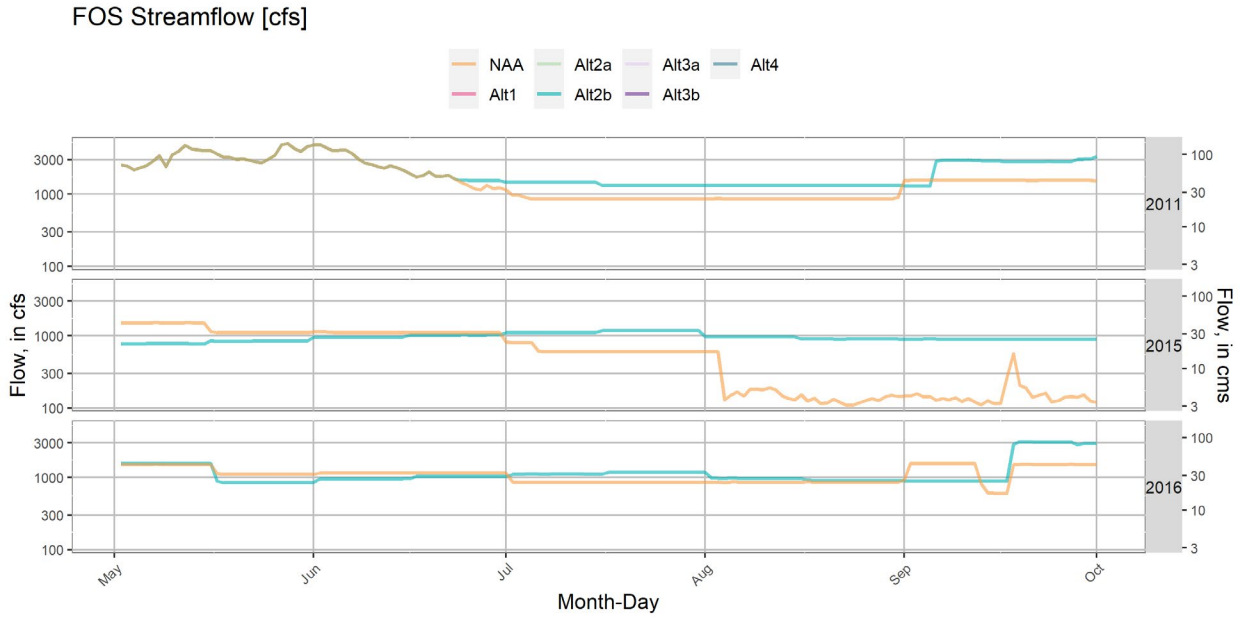


Figure 1-168. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-169, Figure 1-170, and Figure 1-171. Foster Lake temperature was affected by Green Peter Dam operations release temperatures,

generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the temperature pattern (Sullivan and Rounds, 2021). Outflows from the proposed fish weir and FWWS combined with warmer spillway releases from Green Peter upstream resulted in warmer tailwater temperature in spring and summer compared to NAA (Figure 1-172, Figure 1-173). Generally, the autumn fish passage operation (drawdown to the RO at Green Peter) resulted in cooler autumn temperatures (November-December) compared to NAA downstream of Foster Dam.

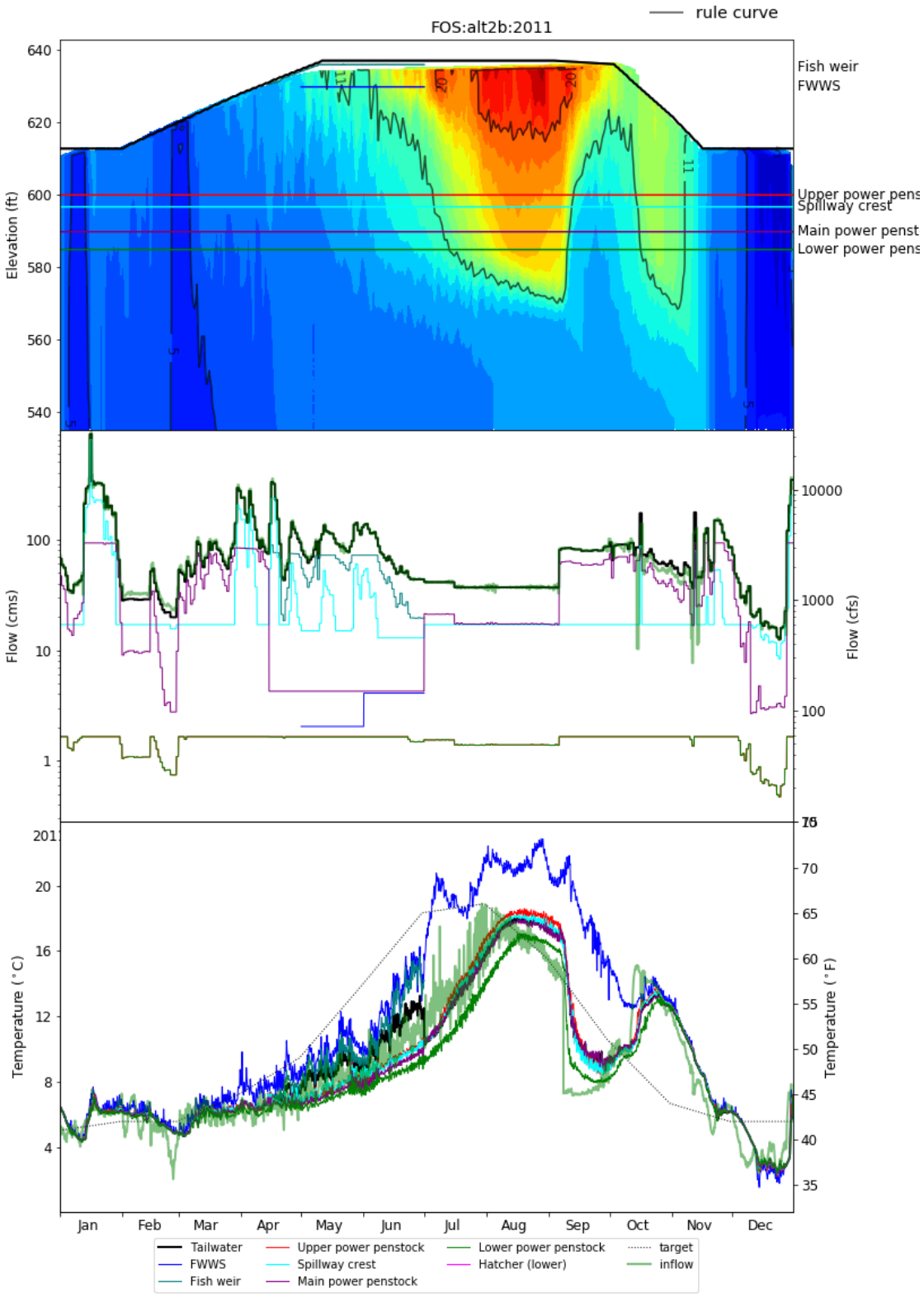


Figure 1-169. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2b in 2011.

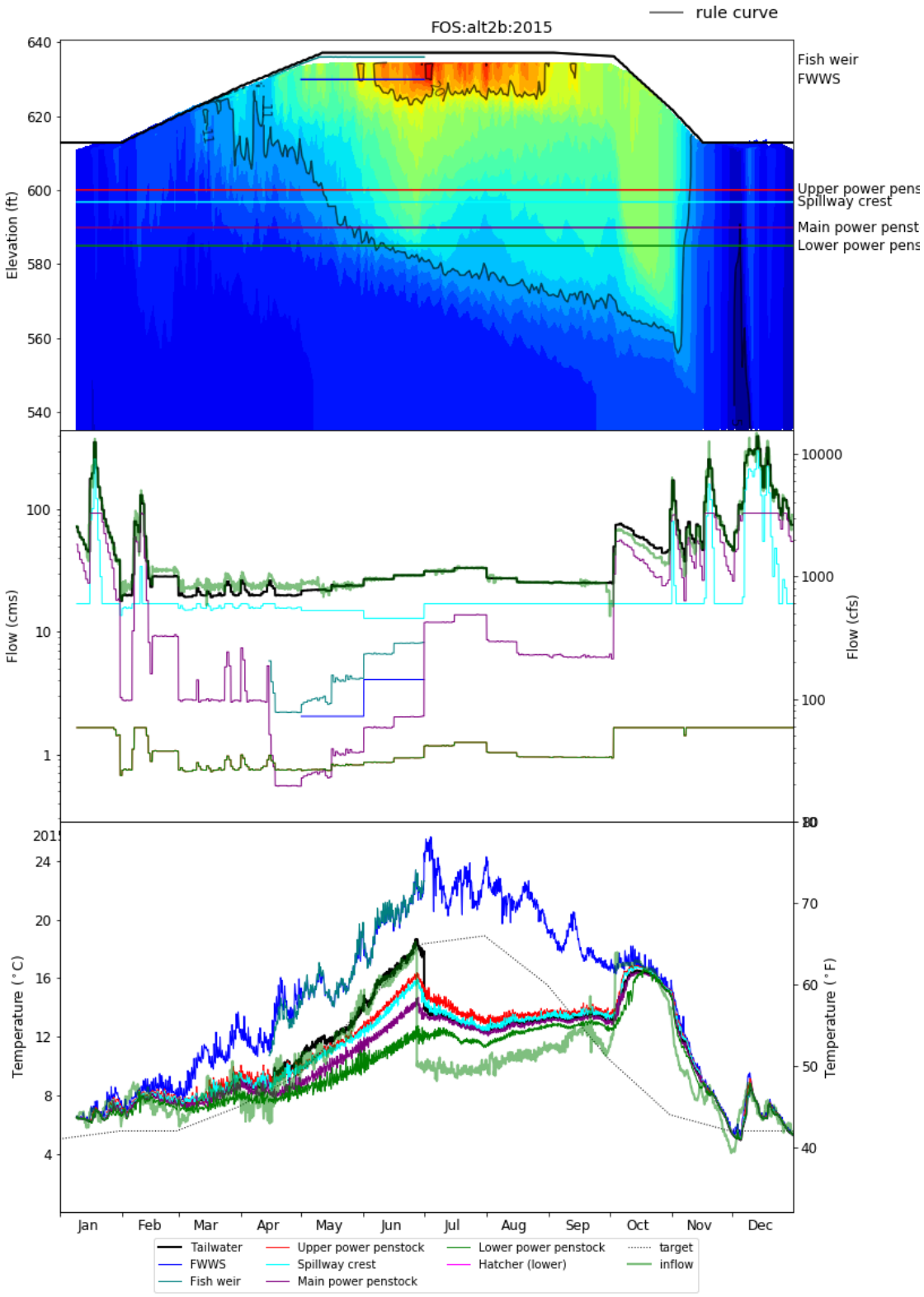


Figure 1-170. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2b in 2015.

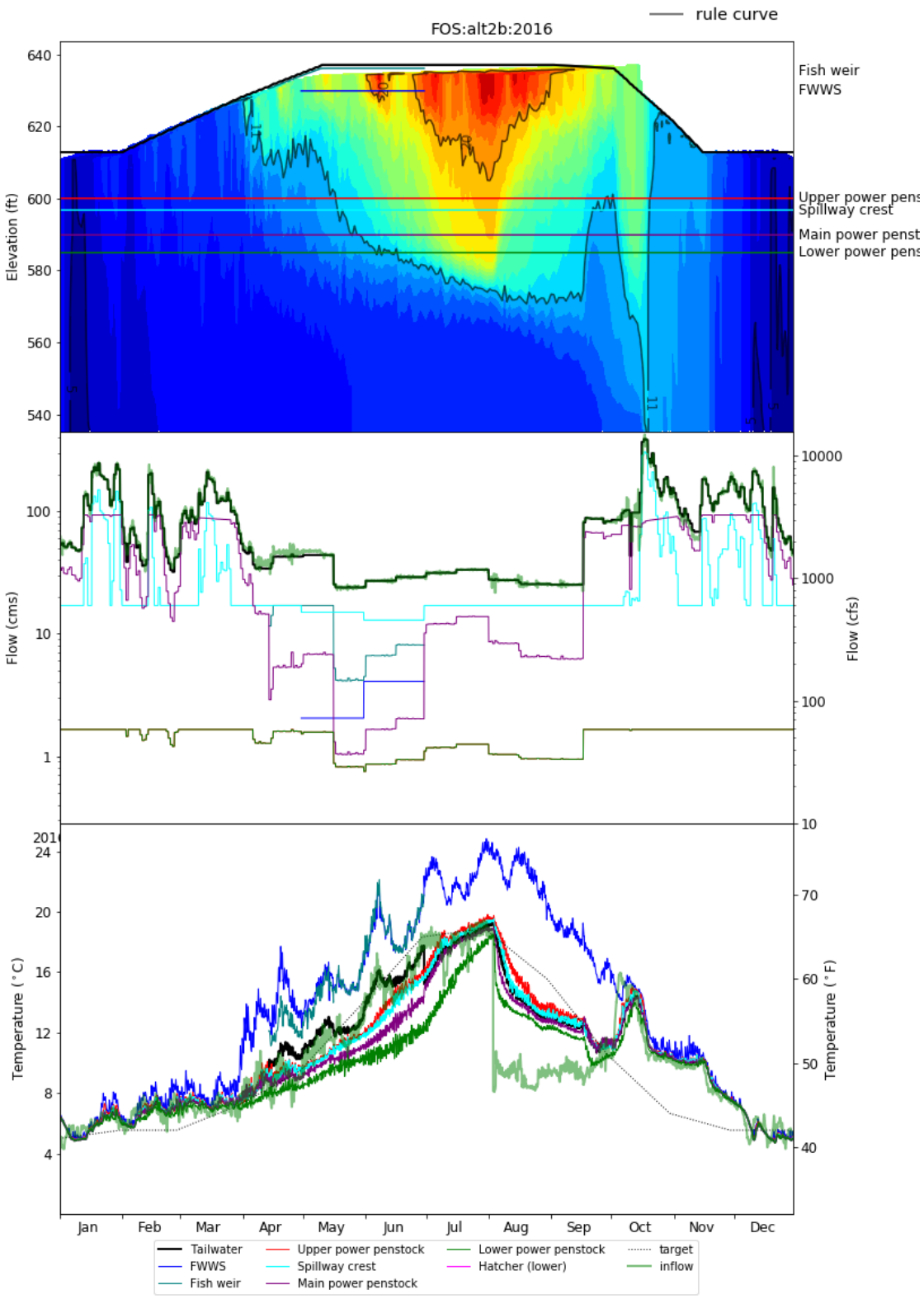


Figure 1-171. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2b in 2016.

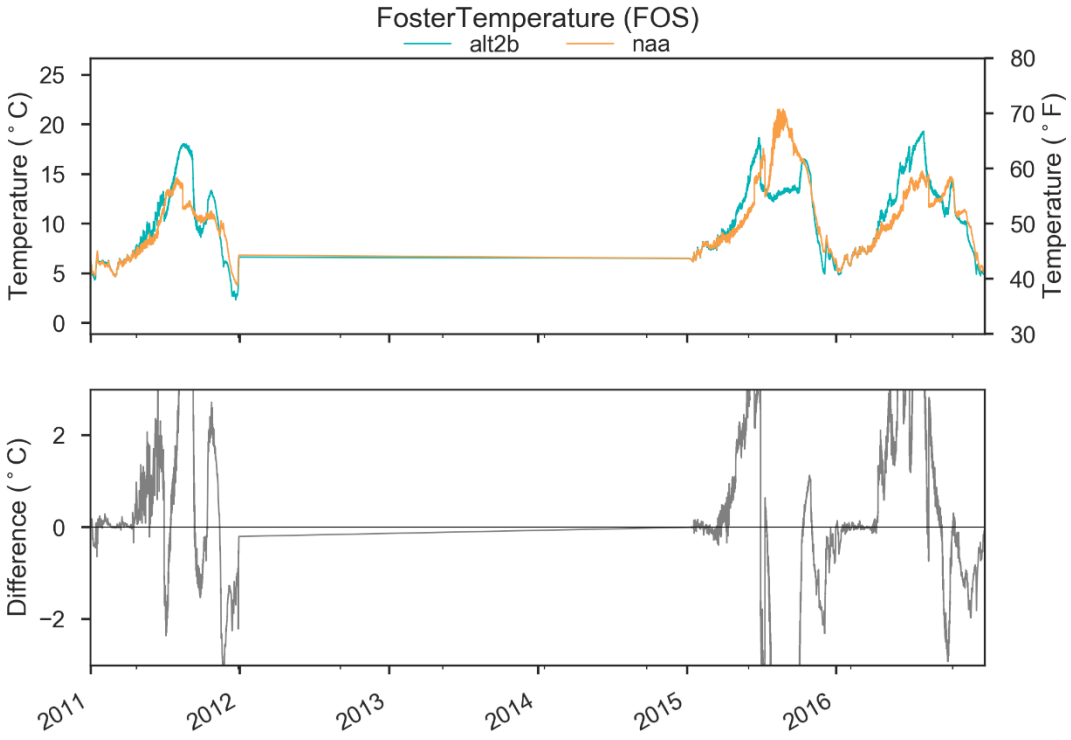


Figure 1-172. Comparison of FOS outflow temperatures in NAA and Alternative 2b.

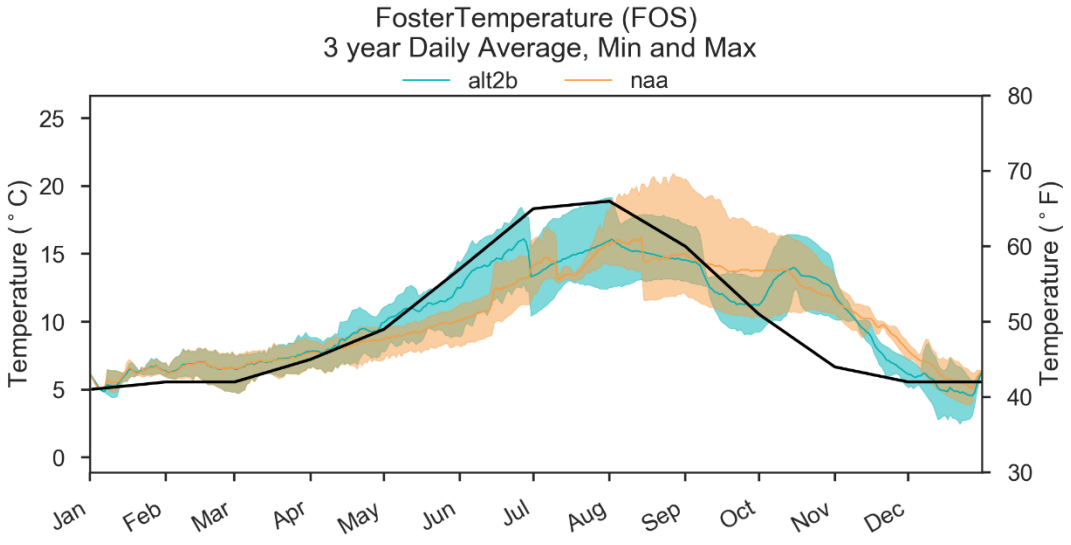


Figure 1-173. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black line indicates temperature target.

1.5.4.3 McKenzie Dams

1.5.4.3.1 Cougar

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Cougar Lake decreased under in Alternative 2b compared to NAA in 2011, 2015, and 2016 to allow for proposed fish passage operations through the diversion tunnel (Figure 1-174, Figure 1-175, Figure 1-176). The decreased storage coincided with reduced outflows during spring and summer (Figure 1-176). Outflows were primarily routed through the diversion tunnel in Alternative 2b, except when the lake refilled to about 30 feet above the RO intake (e.g., 2011).

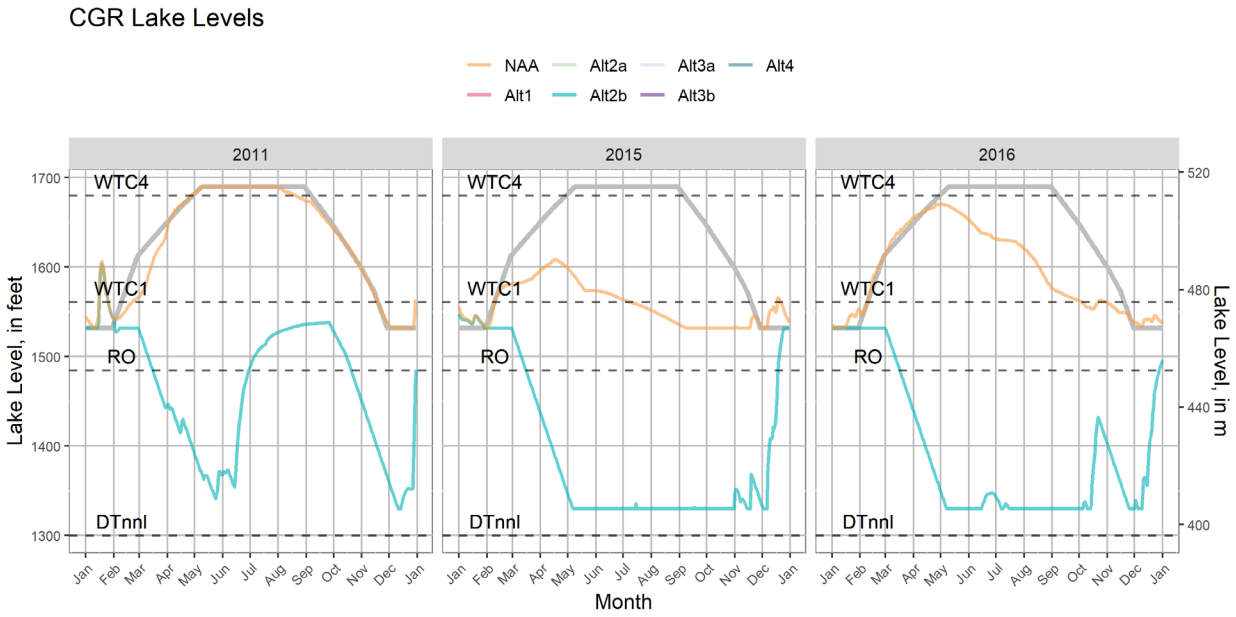


Figure 1-174. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 2b and NAA.

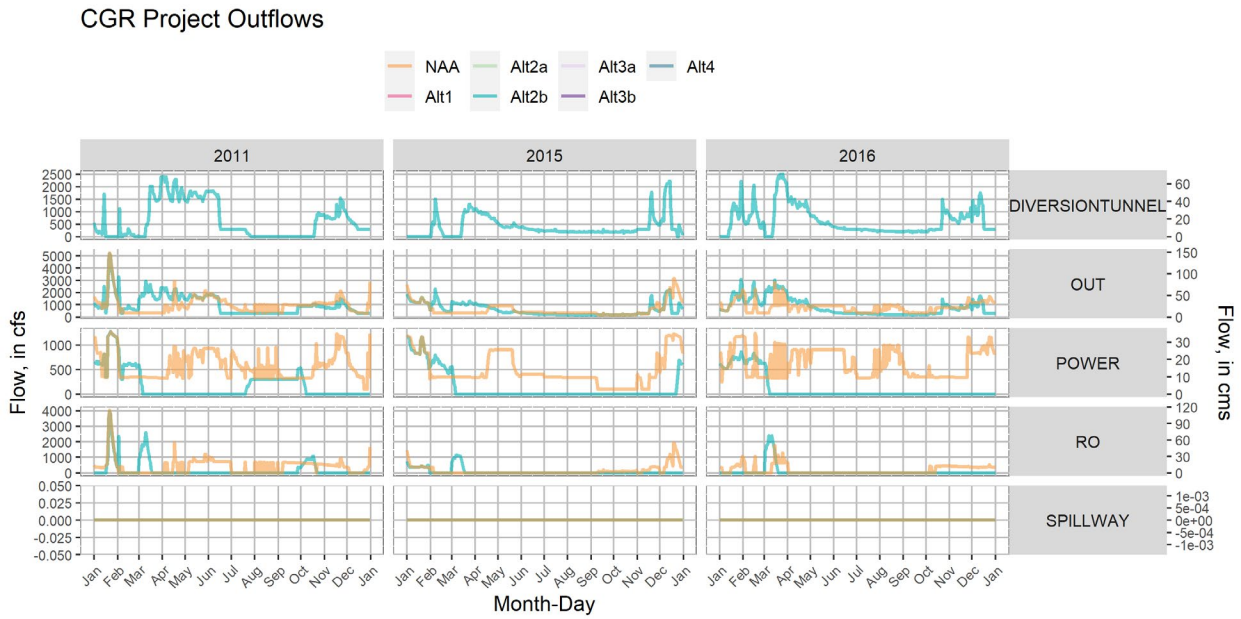


Figure 1-175. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2b and NAA.

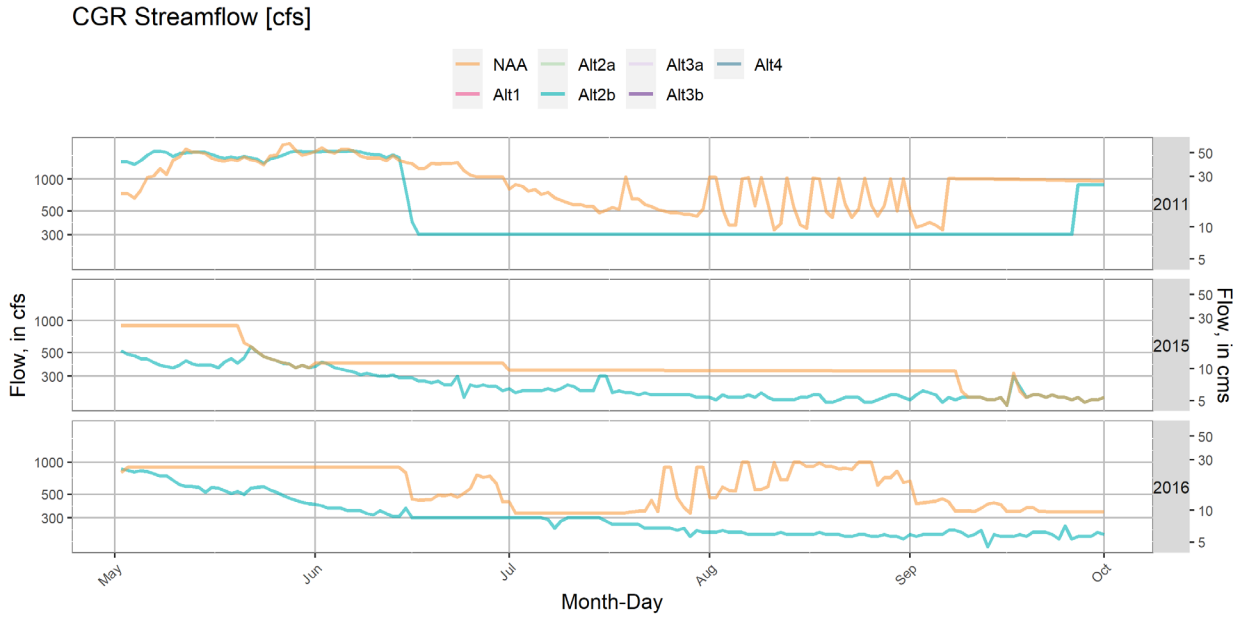


Figure 1-176. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Cougar Lake are shown in Figure 1-177, Figure 1-178, and Figure 1-179. Outflow temperatures from Cougar Dam in Alternative 2b were cooler than NAA year-round in 2011, 2015, and 2016 as the lake surface area, volume, and residence time was reduced (Figure 1-180 and Figure 1-181).

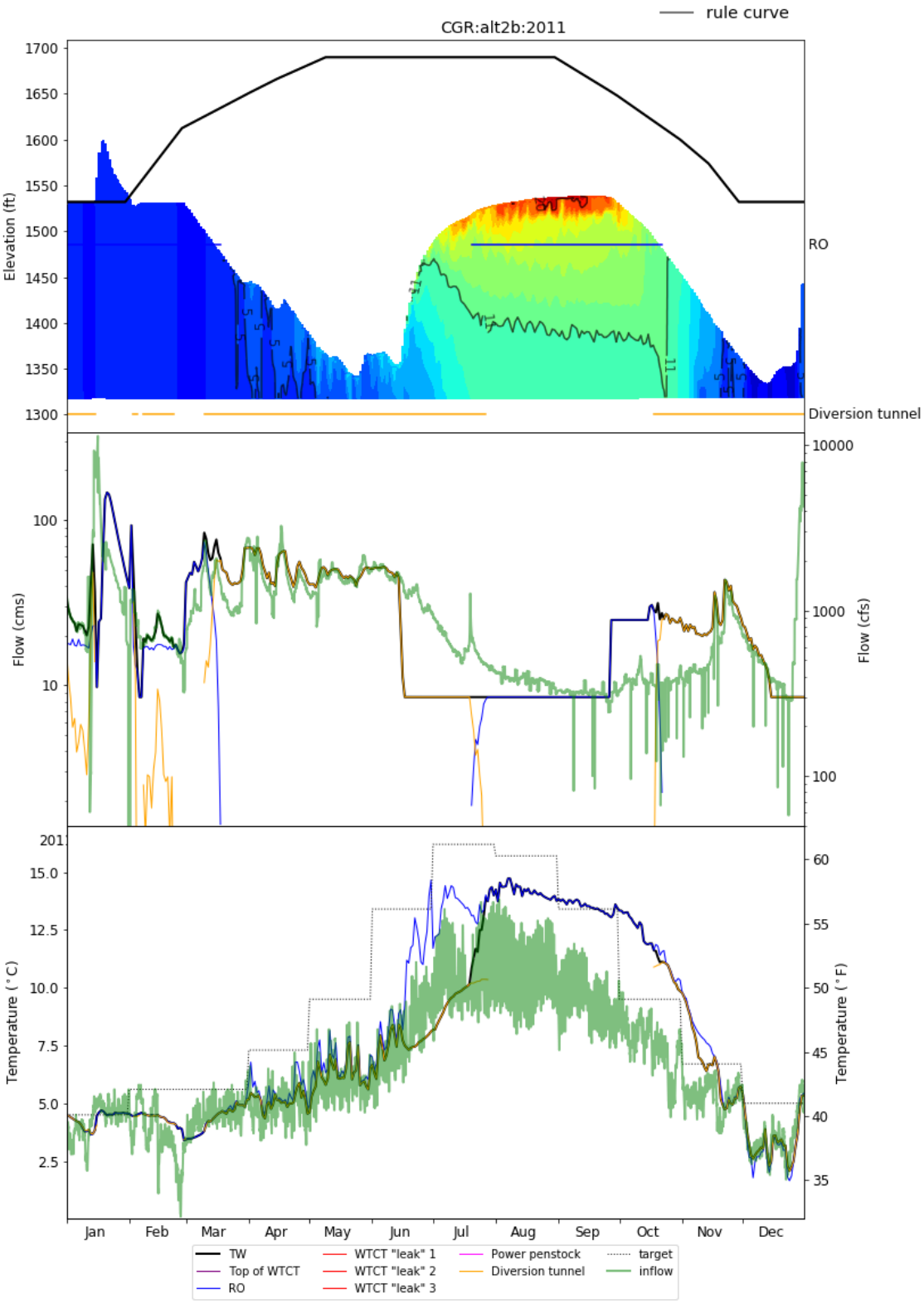


Figure 1-177. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2b in 2011.

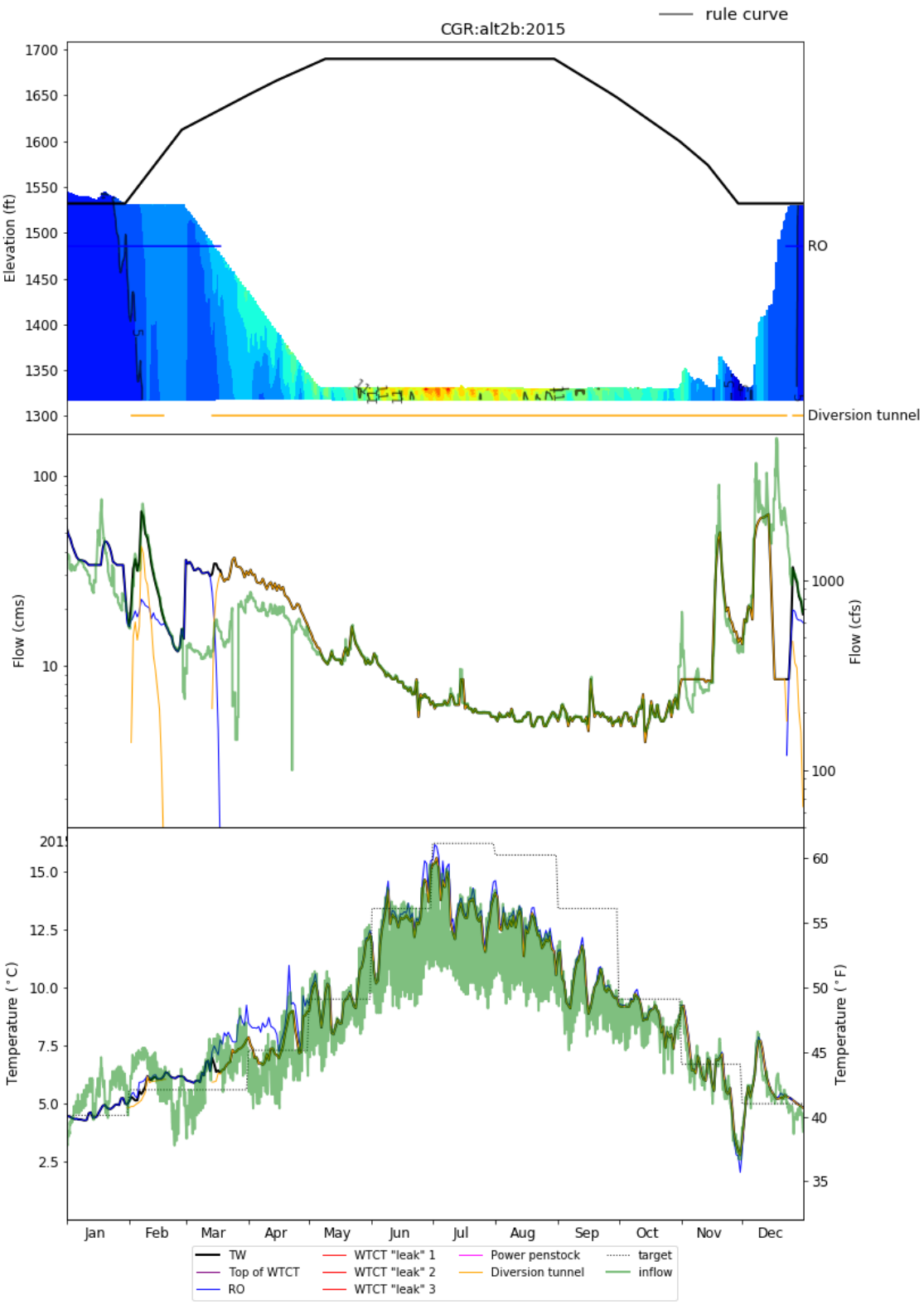


Figure 1-178. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2b in 2015.

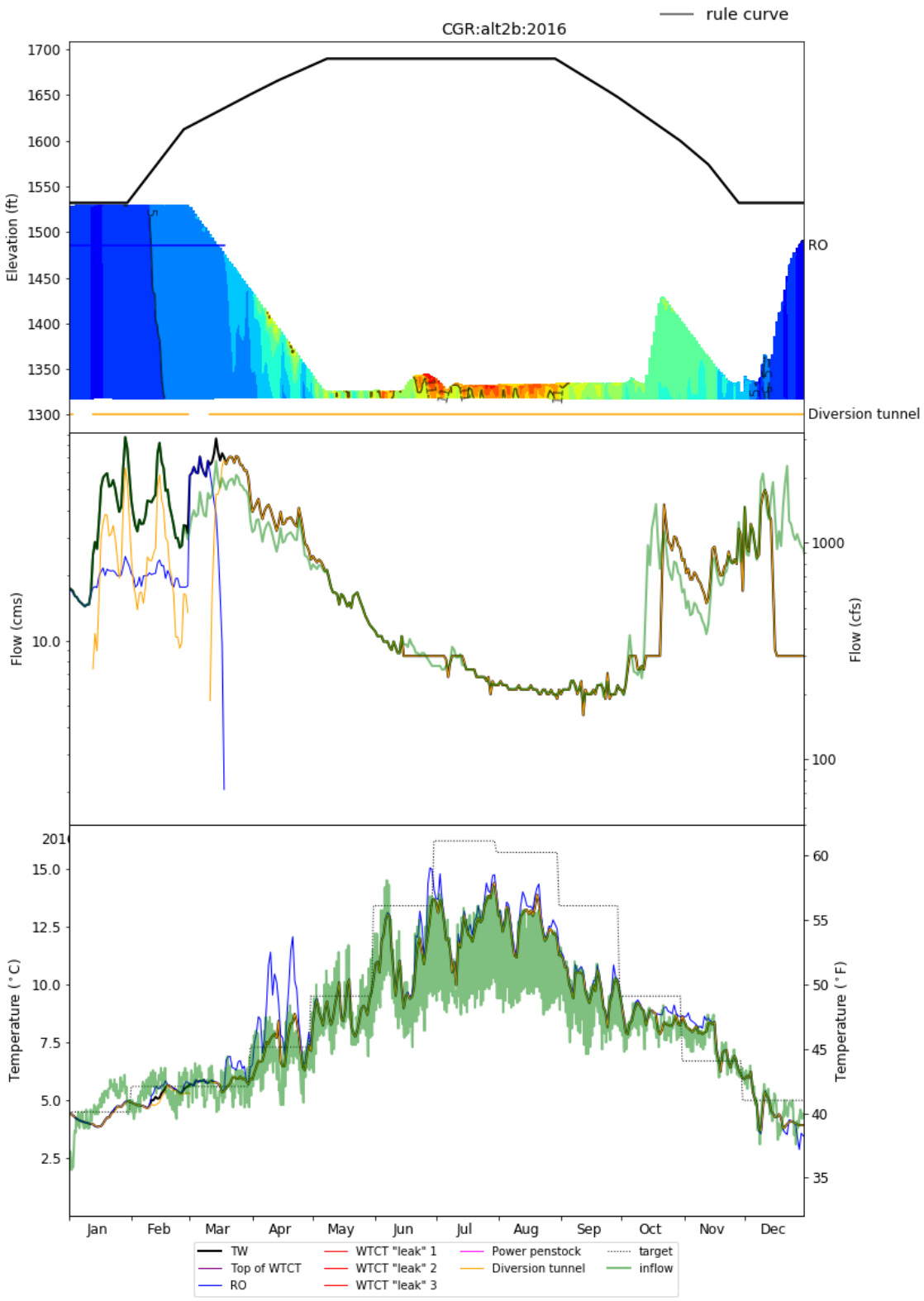


Figure 1-179. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2b in 2016.

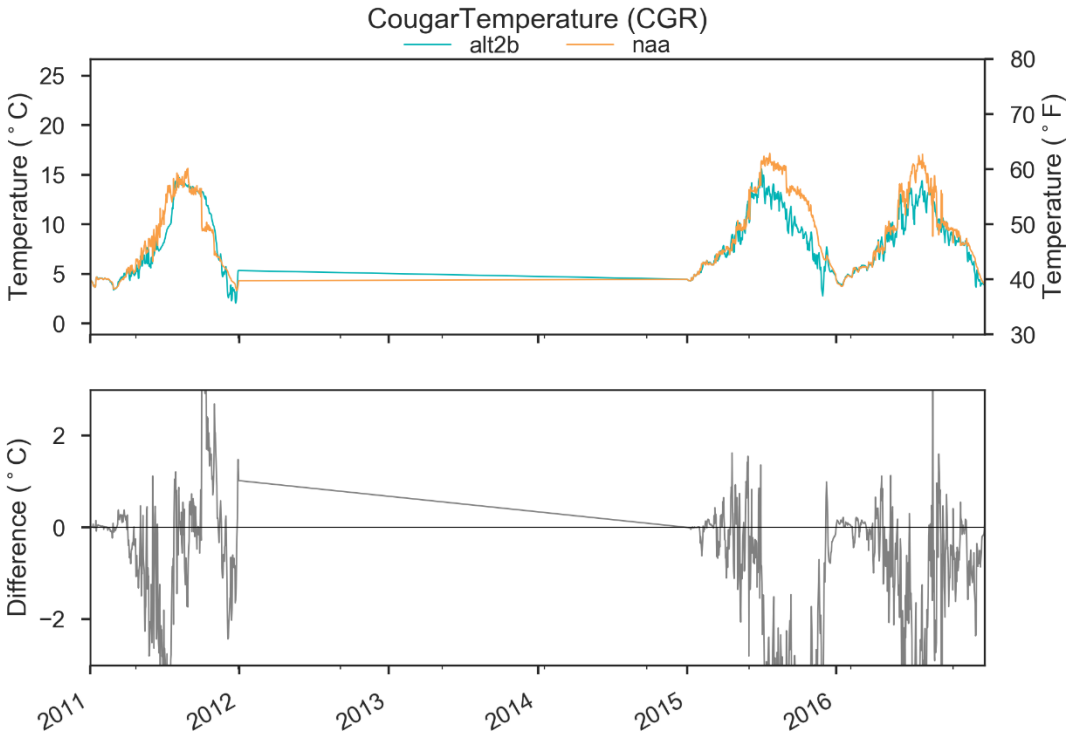


Figure 1-180. Comparison of CGR Outflow Temperatures in NAA and Alternative 2b.

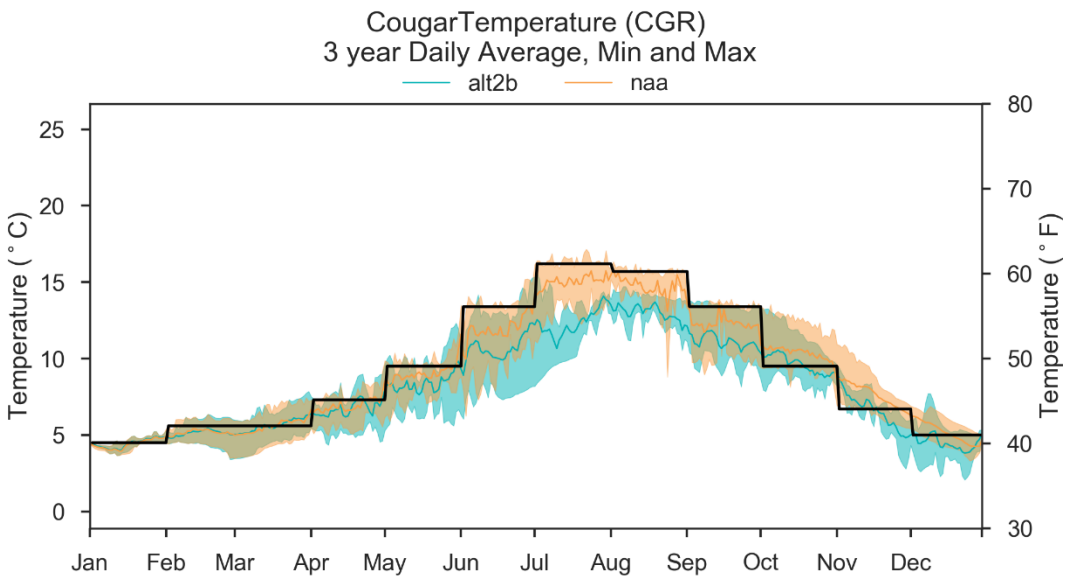


Figure 1-181. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target.

1.5.4.4 Middle Fork Willamette Dams

1.5.4.4.1 Hills Creek

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Hills Creek Lake generally increased under Alternative 2b compared to NAA in 2015 and 2016 except for August-November, 2015, when the power pool was utilized for downstream flow augmentation (Figure 1-182, Figure 1-183, and Figure 1-184). The increased storage coincided with reduced outflows during spring and increased outflows in May-July during 2015 and August-October in 2016 (Figure 1-183). 2011 operations were generally similar in Alternative 2b and NAA at Hills Creek Lake.

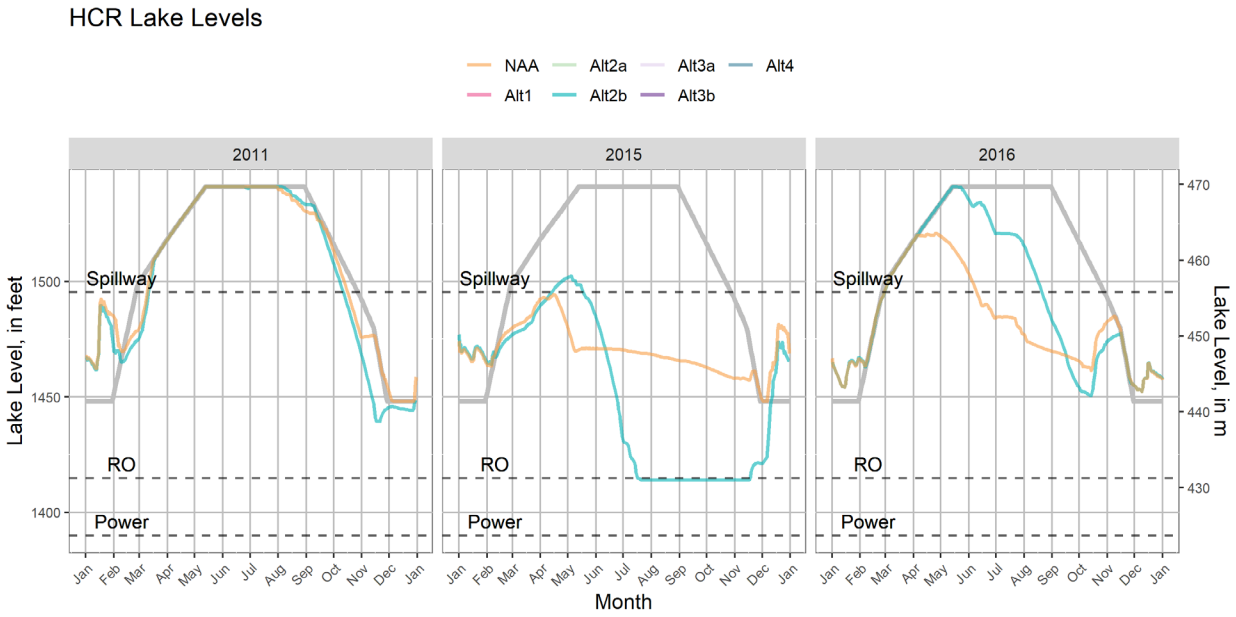


Figure 1-182. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 under Alternative 2b and NAA.

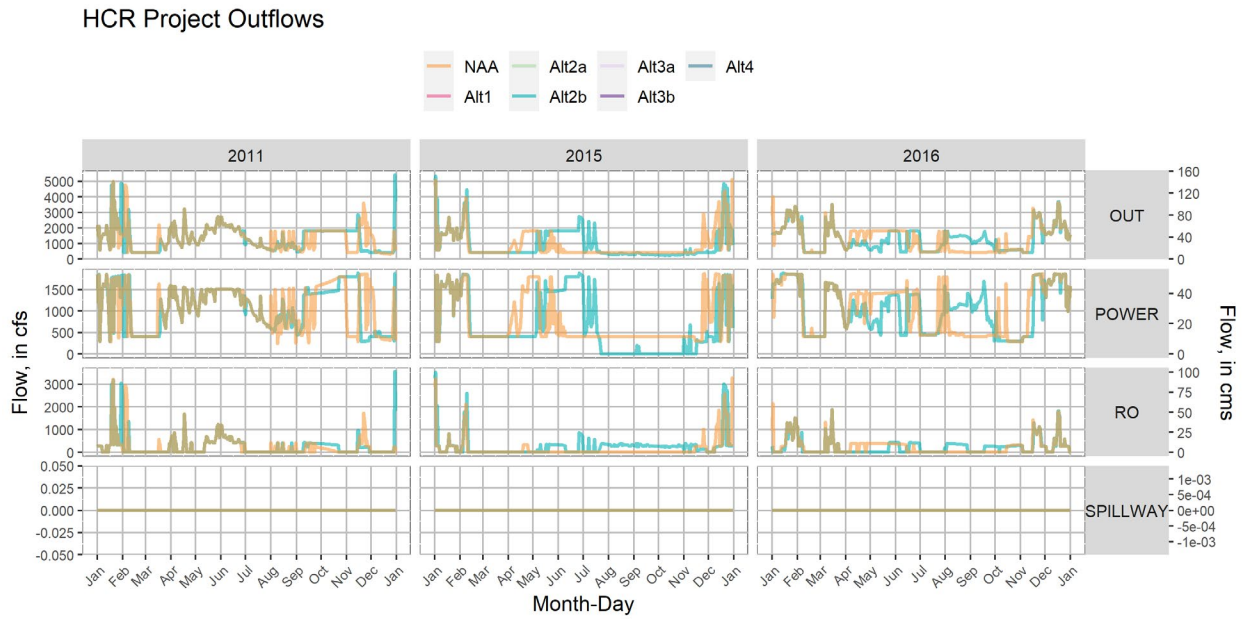


Figure 1-183. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 2b and NAA.

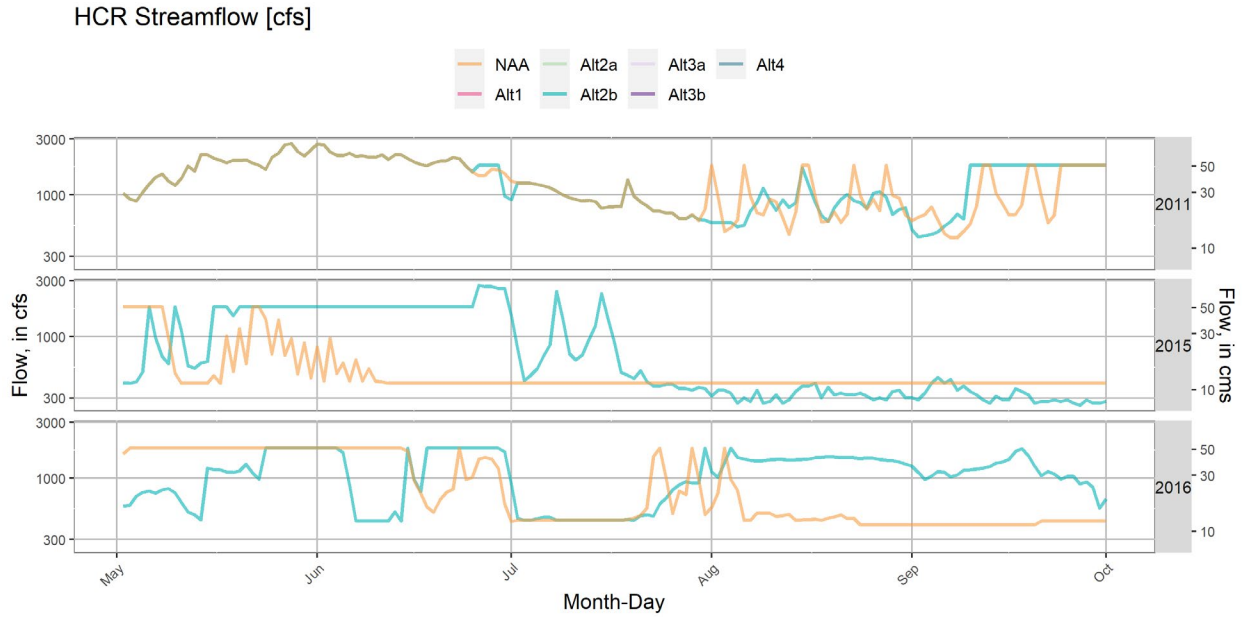


Figure 1-184. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 under Alternative 2b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 2b at Hills Creek Lake are shown in Figure 1-185, Figure 1-186, and Figure 1-187. The seasonal peak tailwater temperature under Alternative 2b was

higher and occurred about one month earlier in 2015, which resulted in cooler tailwater temperature during autumn of that year compared to NAA (Figure 1-188, Figure 1-189). 2016 outflow tailwater temperature in Alternative 2b was generally cooler than NAA in spring and summer but similar during autumn. Hills Creek tailwater temperatures in 2011 were generally similar in Alternative 2b and NAA.

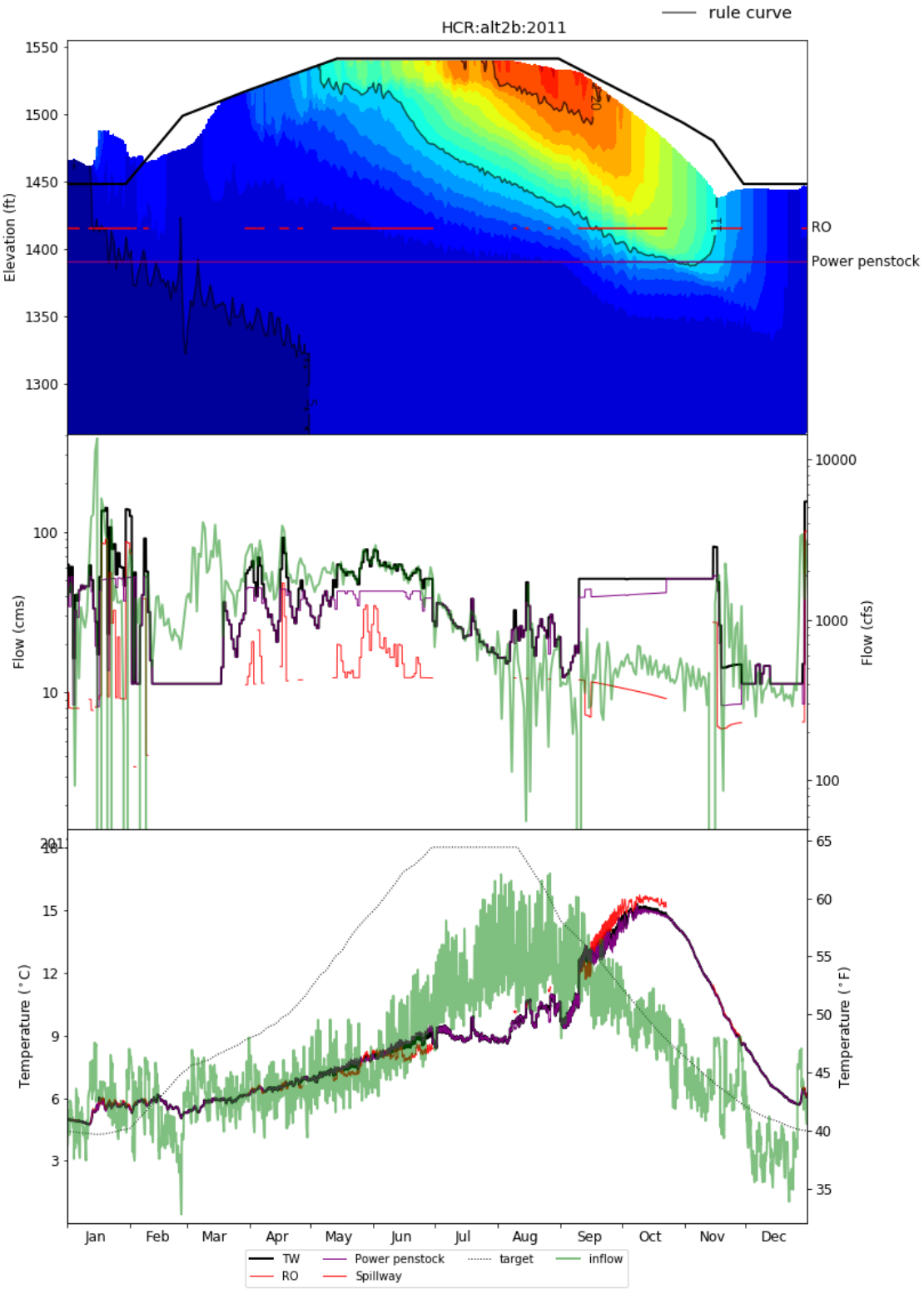


Figure 1-185. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2b in 2011.

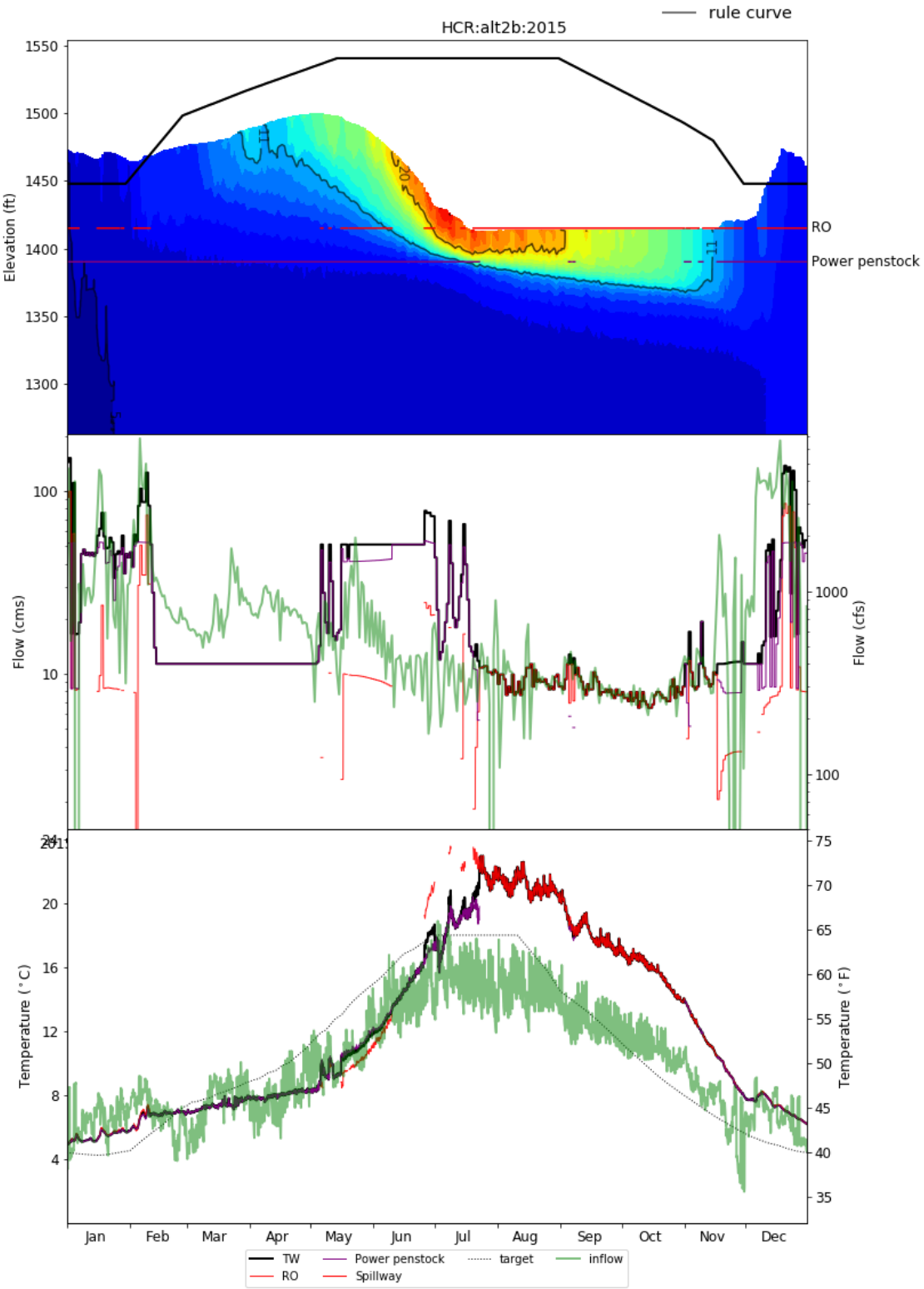


Figure 1-186. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2b in 2015.

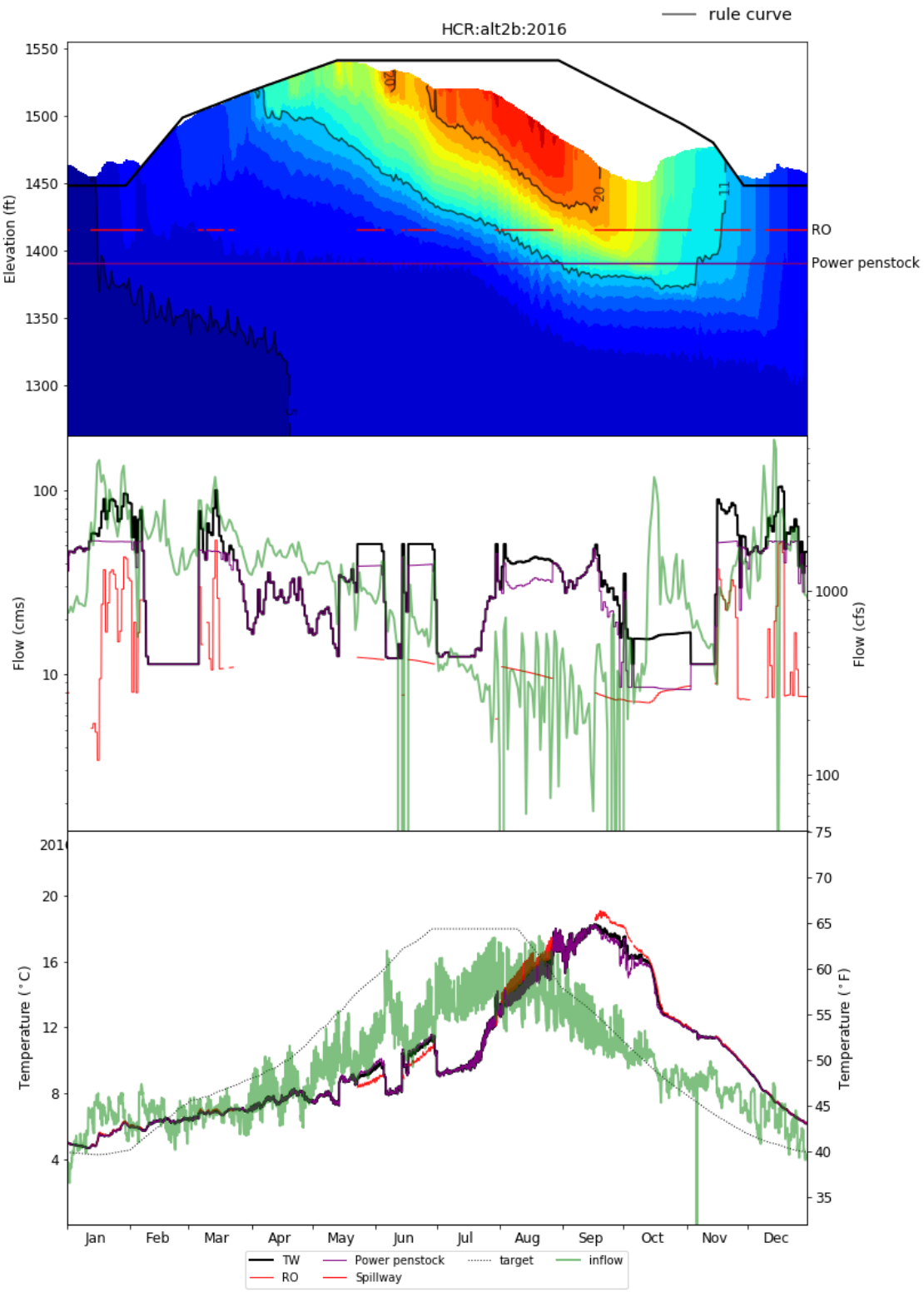


Figure 1-187. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2b in 2016.

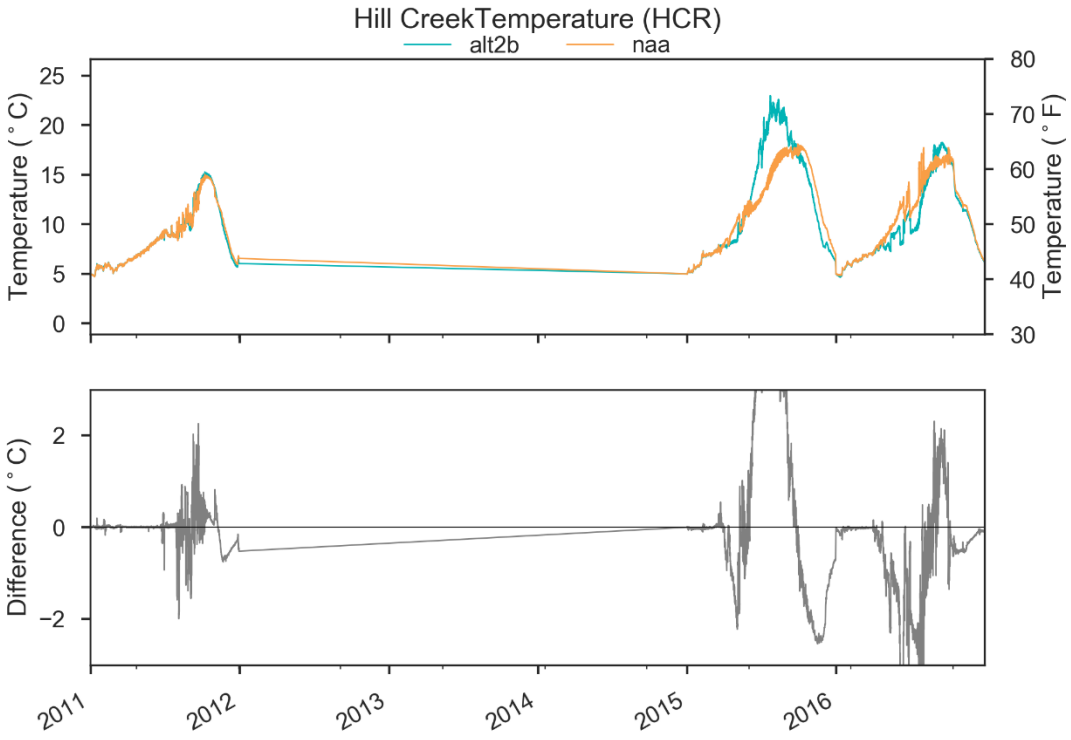


Figure 1-188. Comparison of HCR outflow temperatures in NAA and Alternative 2b.

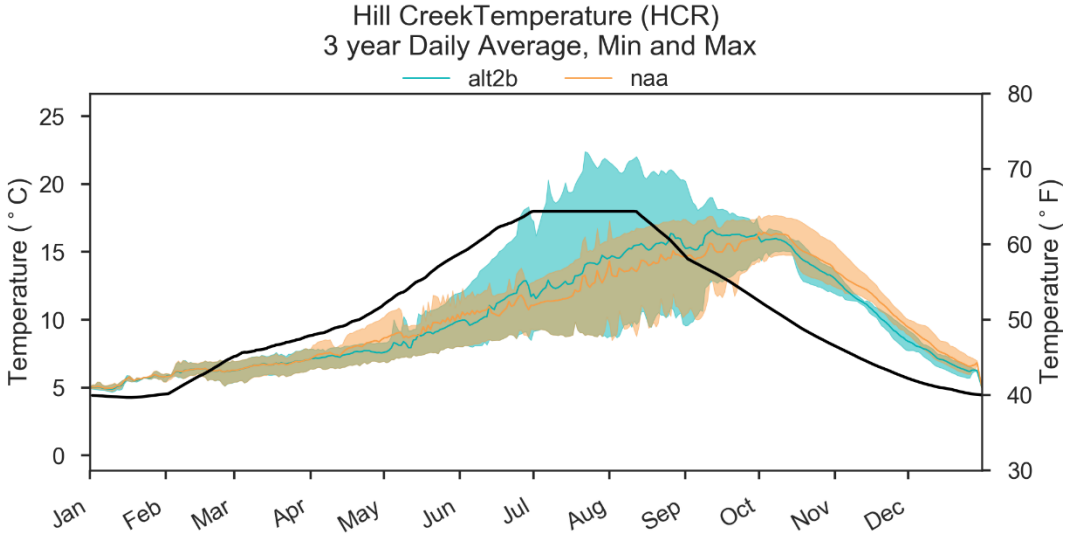


Figure 1-189. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target.

1.5.4.4.2 Lookout Point

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Lookout Point Lake was generally similar to NAA in 2011, 2015, and 2016 (Figure 1-190, Figure 1-191, and Figure 1-192) aside from minor differences in timing of refill and release rates that were associated with upstream Hills Creek Dam operations.

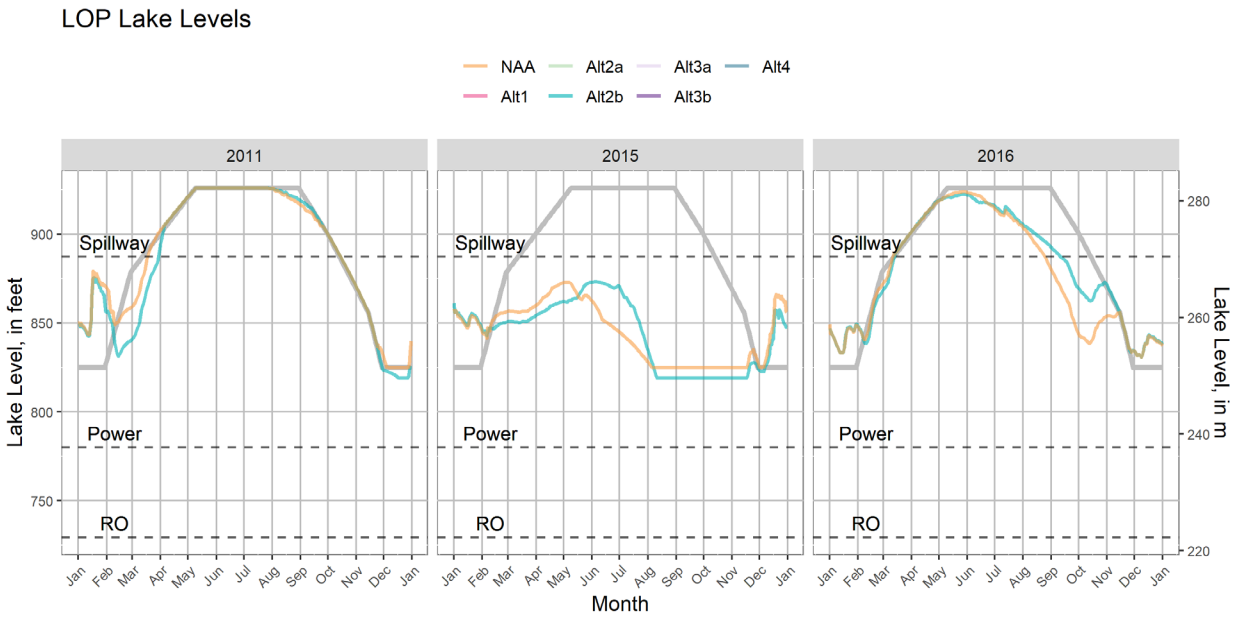


Figure 1-190. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 2b and NAA.

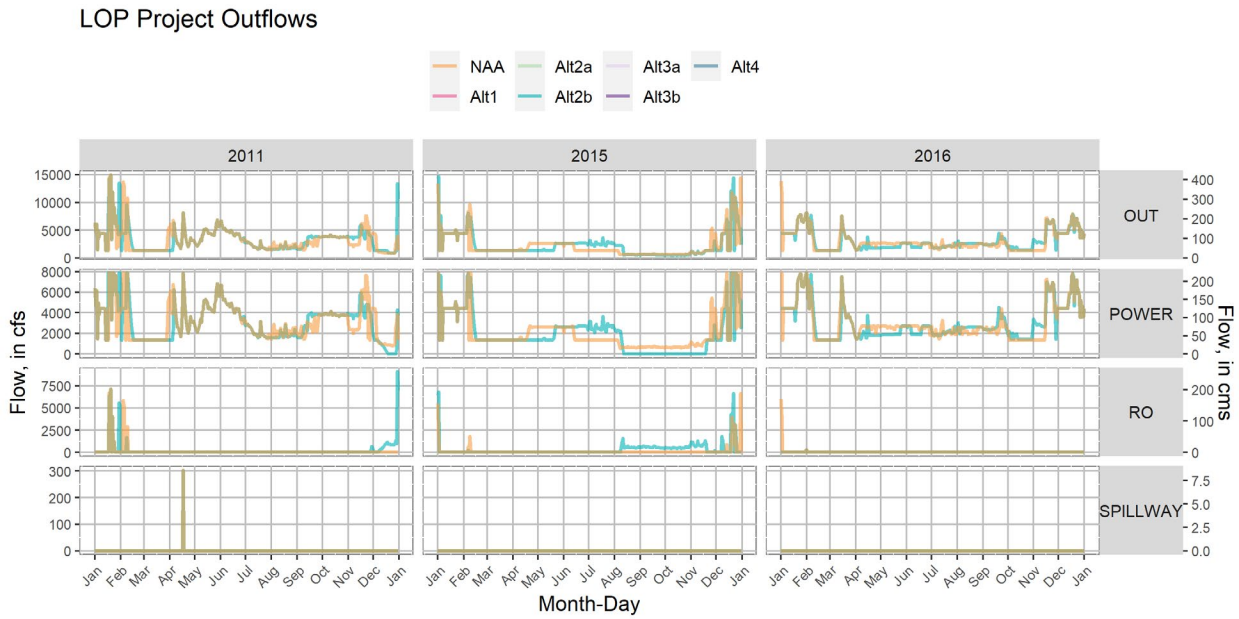


Figure 1-191. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 2b and NAA.

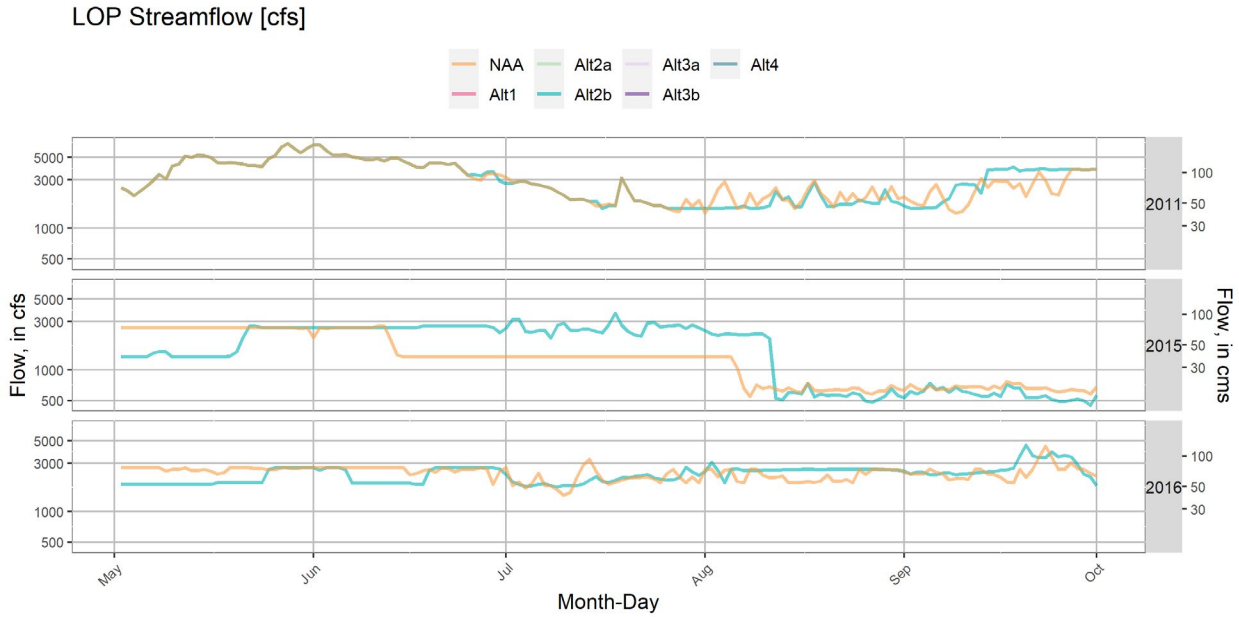


Figure 1-192. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 2b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Lookout Point Lake are shown in Figure 1-193, Figure 1-194, and Figure 1-195. The proposed FSC (and attraction pumps intended for fish collection) in Lookout

Point Lake is currently assumed to have minimal effect on release temperature from the relatively deep Lookout Point Penstocks, but has potential to result in mixing thermal layering and de-stratification in the forebay of Lookout Point Lake. Simulating this effect on water temperature was beyond the scope of the WV EIS. Generally, temperatures downstream of LOP-DEX were similar to NAA, aside from short-term differences in late summer of 2015 likely related to upstream Hills Creek operations (Figure 1-196, Figure 1-197).

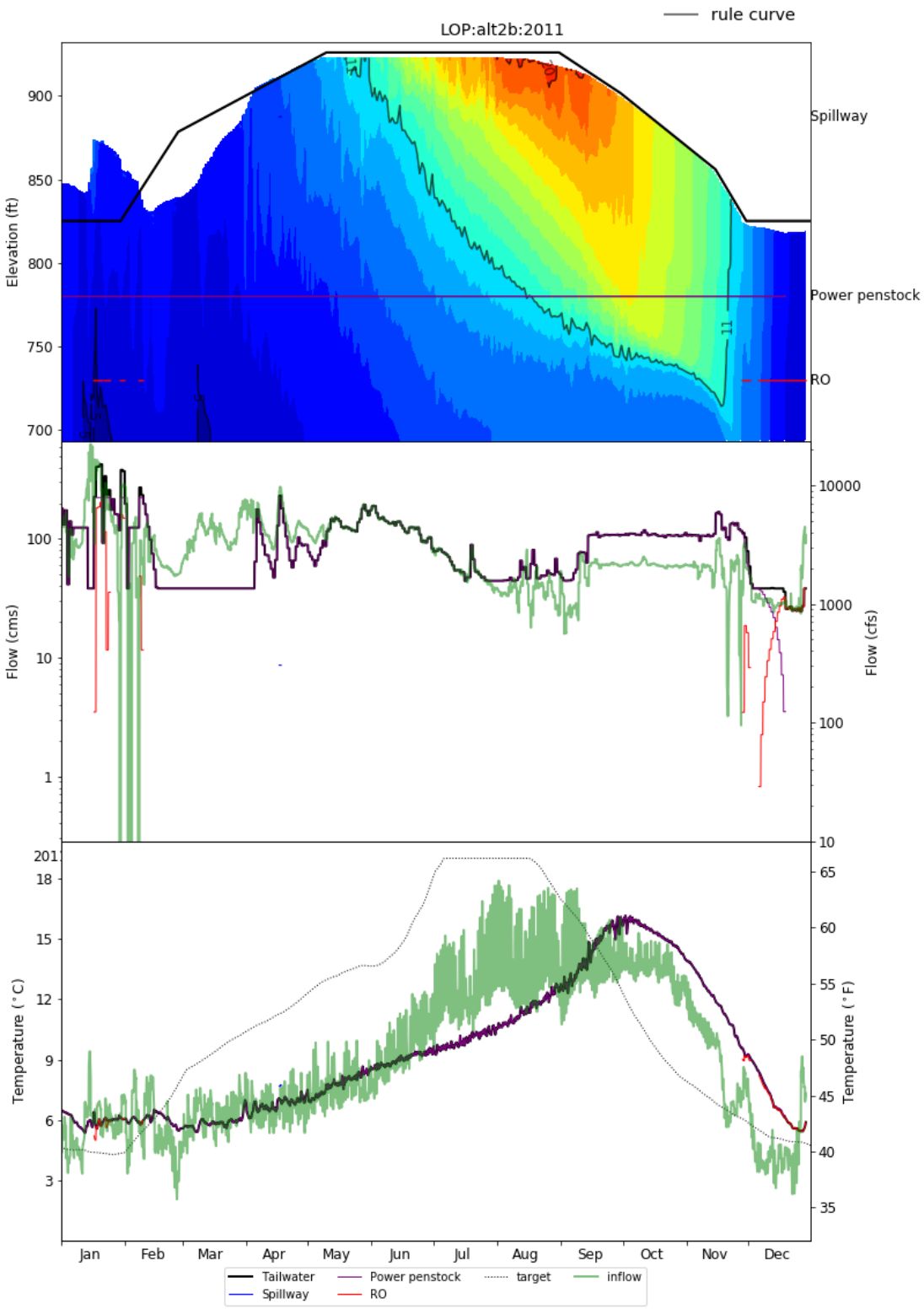


Figure 1-193. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2b in 2011.

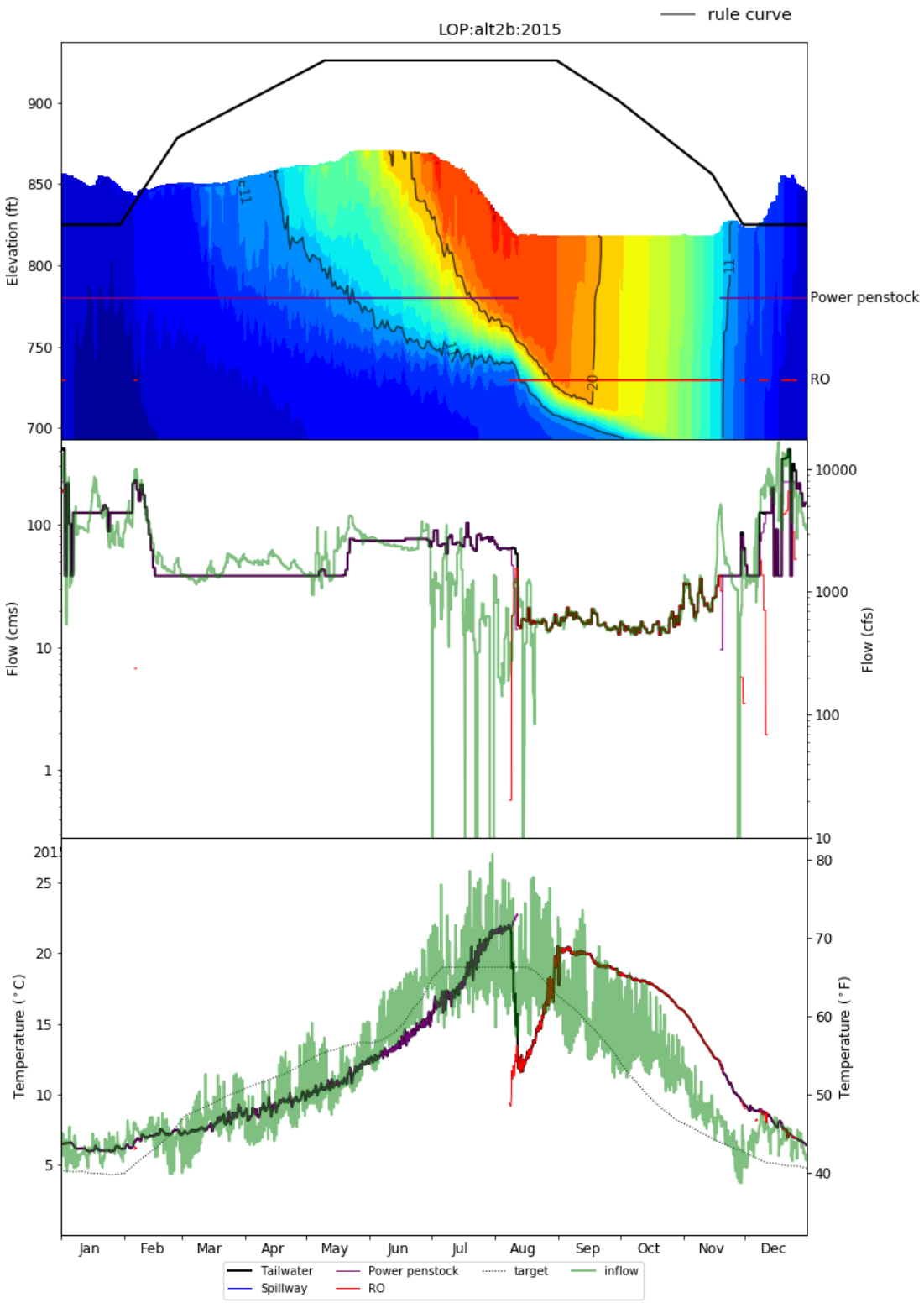


Figure 1-194. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2b in 2015.

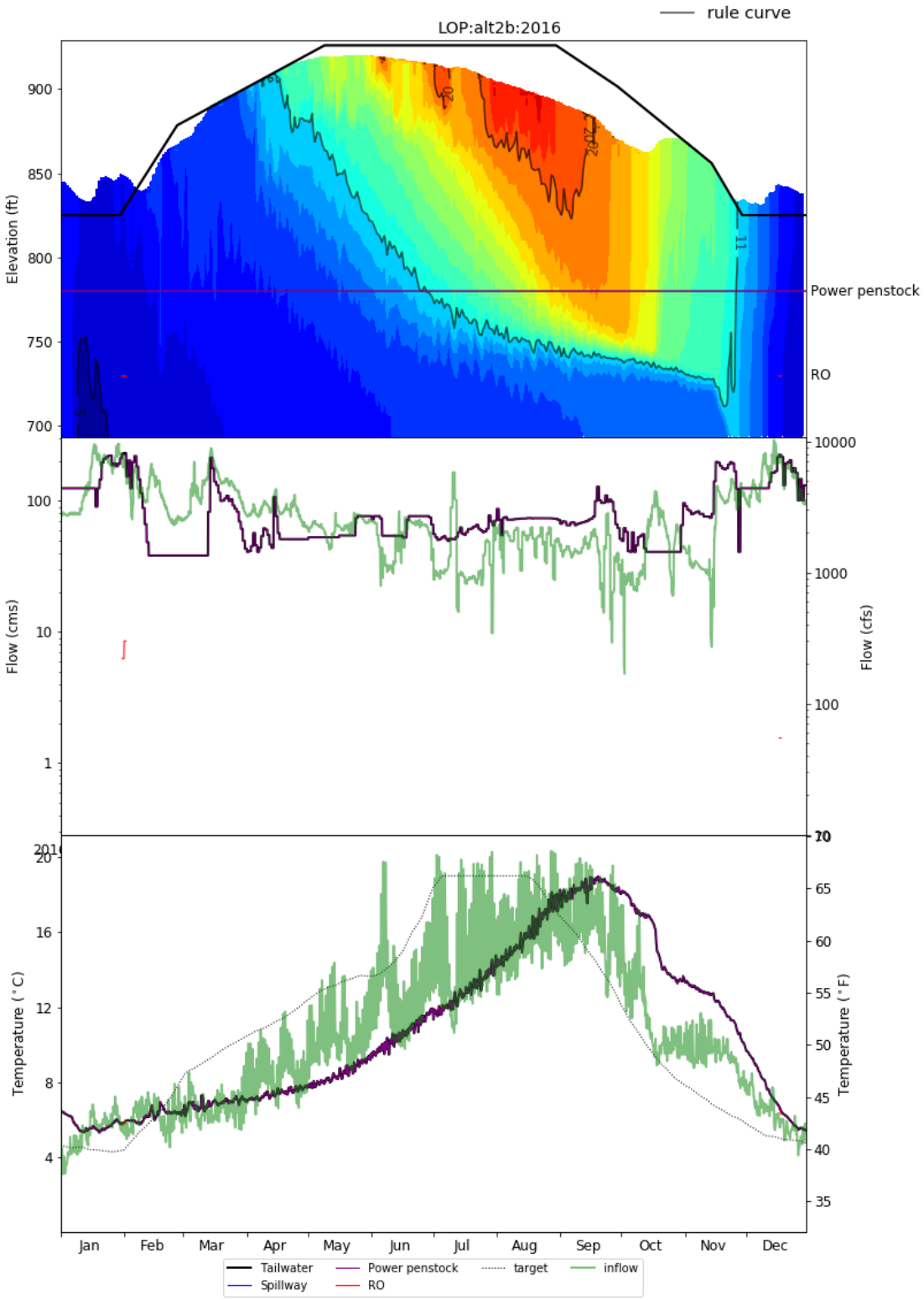


Figure 1-195. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2b in 2016.

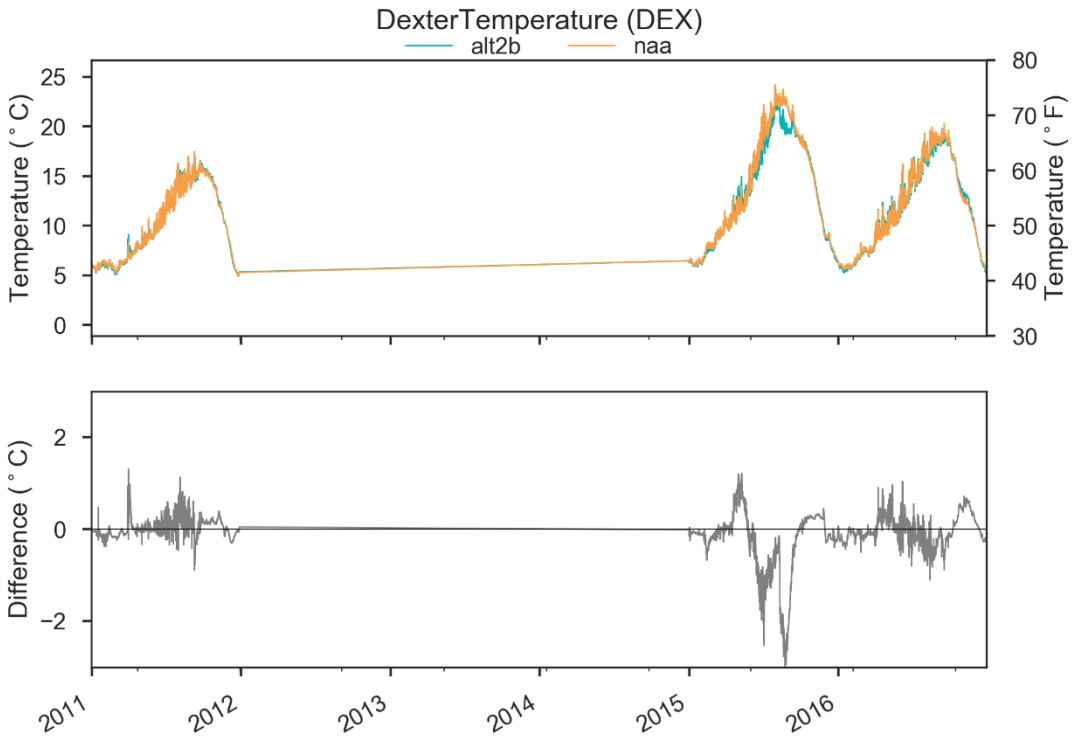


Figure 1-196. Comparison of DEX Outflow Temperatures in NAA and Alternative 2b.

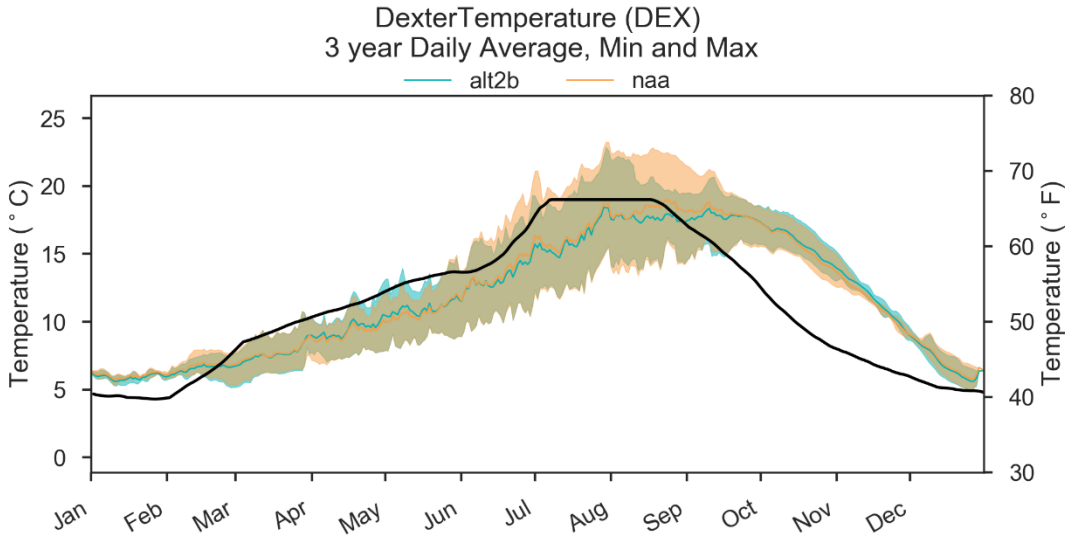


Figure 1-197. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target.

1.5.4.5 Mainstem Willamette River

Streamflow under Alternative 2b was generally lower from April to mid-June and higher from mid-June to mid-September compared with NAA (Figure 1-198).

As explained in the Hydrologic and Hydraulic Processes section, under Measure 30b Res-Sim determines whether to use the max or minimum flow target in half-month increments based on whether a reservoir is above or below 90% of rule curve (Table 1-7) throughout the refill period. On June 1 of each year, Res-Sim determines whether to use the max or minimum flow target for the rest of the conservation season in each tributary under Measure 30b (Alternative 2b, 5). For the three years, 2011, 2015, and 2016, only 2015 was below 90% rule curve on June 1, which triggered the lower minimum flow target (Table 1-7). When comparing observed water surface elevations and Res-Sim, it is important to be aware that Res-Sim does not reduce flows as real-time operations staff and WATER team stakeholders are able to do (as seen in the observed data records).

Table 1-7 Percent of Rule Curve Fill Level in Alternative 2b

Major Storage Reservoir	2011	2015	2016
Detroit	> 90% except Feb 16 - April 15	< 90% except Feb 16 - Feb 29	> 90% except May 16 - May 30
Green Peter	> 90% except Feb 16 - April 1	< 90% except Feb 16 - Feb 29	> 90% except May 16 - May 30
Cougar	< 90% all year	< 90% all year	< 90% all year
Lookout Point	> 90% except Feb 16 - April 1	< 90% except Feb 16 - Feb 29	> 90% except Feb 16 - Mar 16

However, these flow differences were primarily in 2015 and responsive to the Measure 30b dam outflow increases in advance of heat wave events (Figure 1-199). These flow changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (Figure 1-200, Figure 1-201).

Water temperatures at Salem were also affected by upstream dam operations and the proposed SWS-FSS structure at Detroit Dam, which likely contributed to warmer temperatures seen in 2011 and 2015 comparing Alternative 2b to NAA. Overall water temperature differences between Alternative 2b and NAA were less than 2 degrees Celsius.

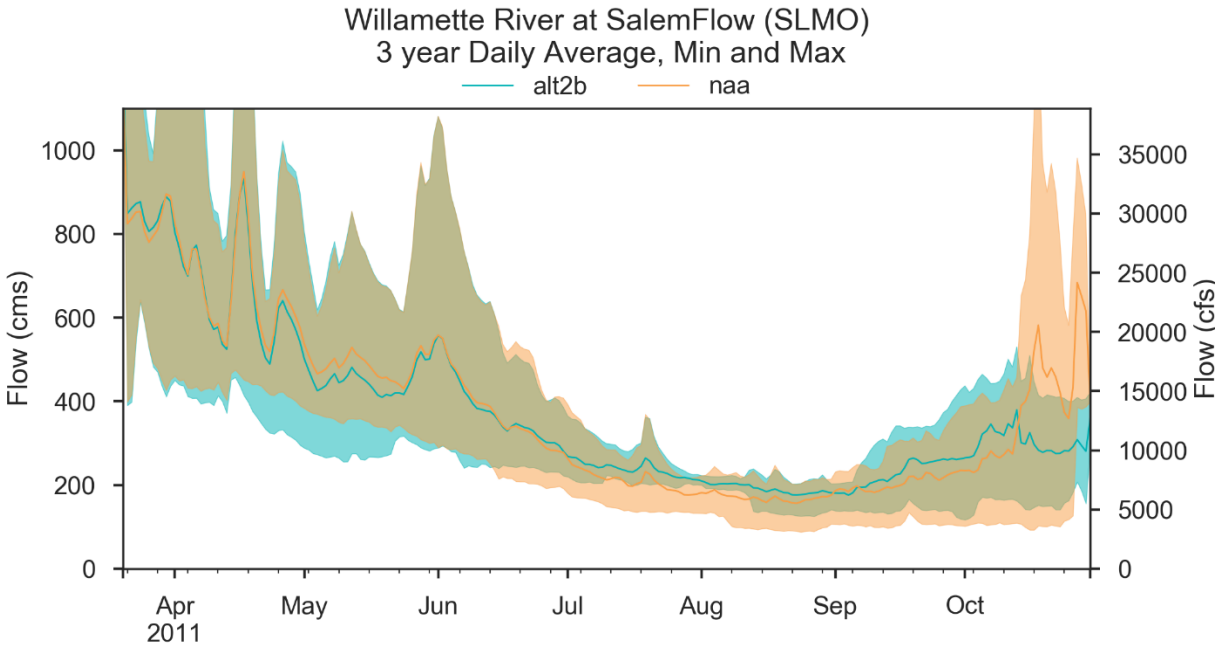


Figure 1-198. Streamflow Comparison of Daily Average, Min, and Max Willamette River at SLMO under NAA and Alternative 2b Conditions.

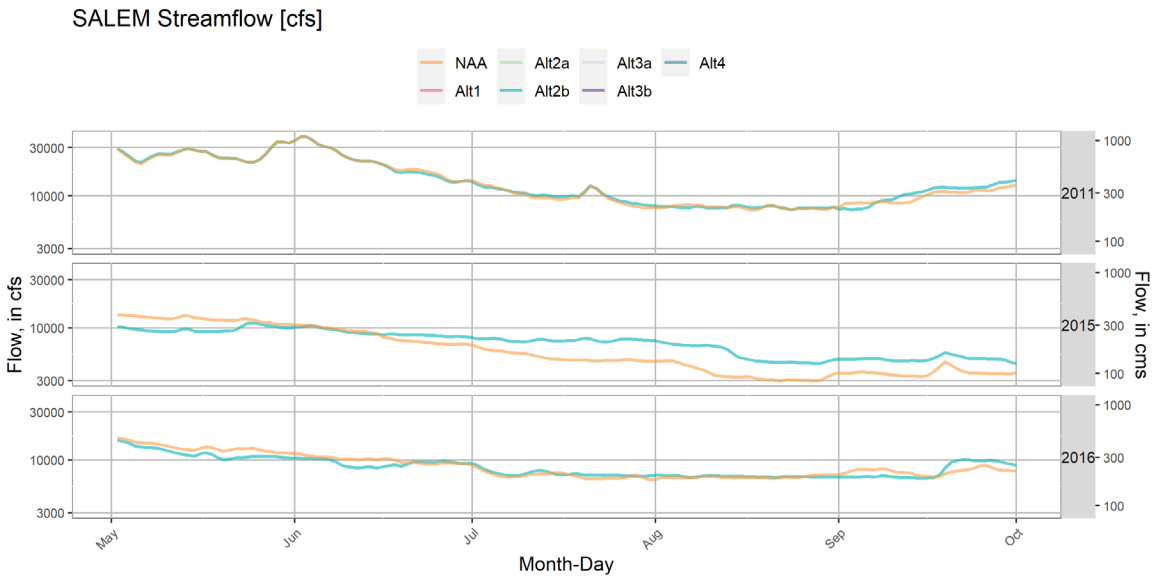


Figure 1-199. Streamflow Comparison Between Alternative 2b and NAA at Willamette River at SLMO.

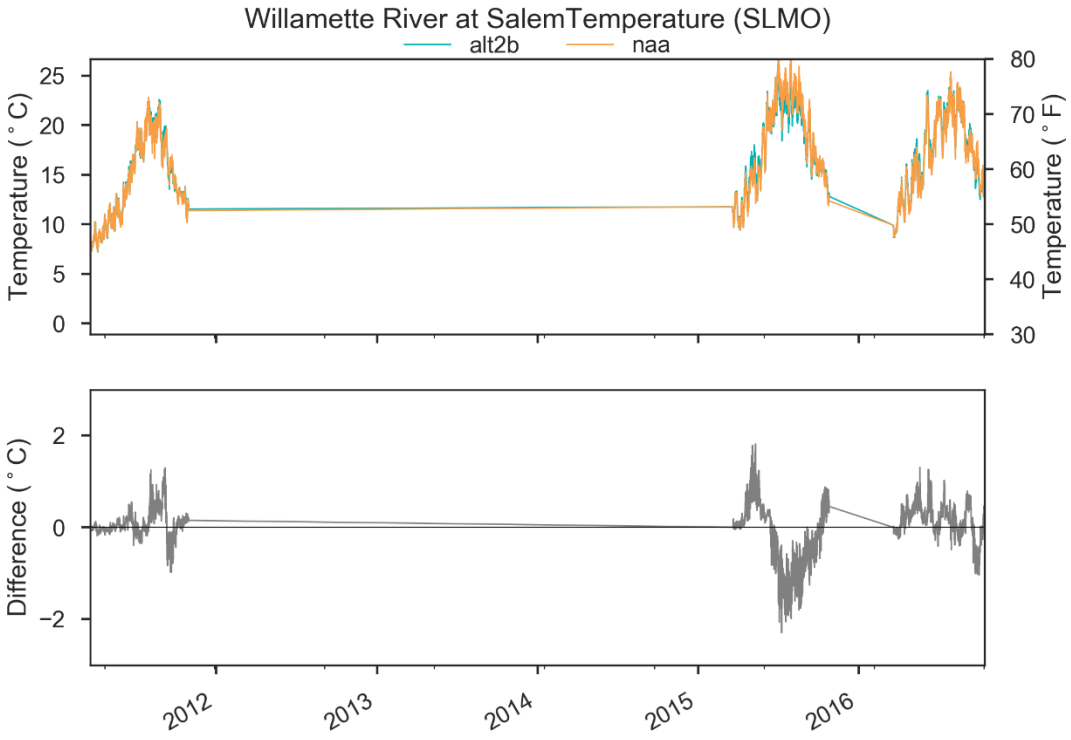


Figure 1-200. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 2b.

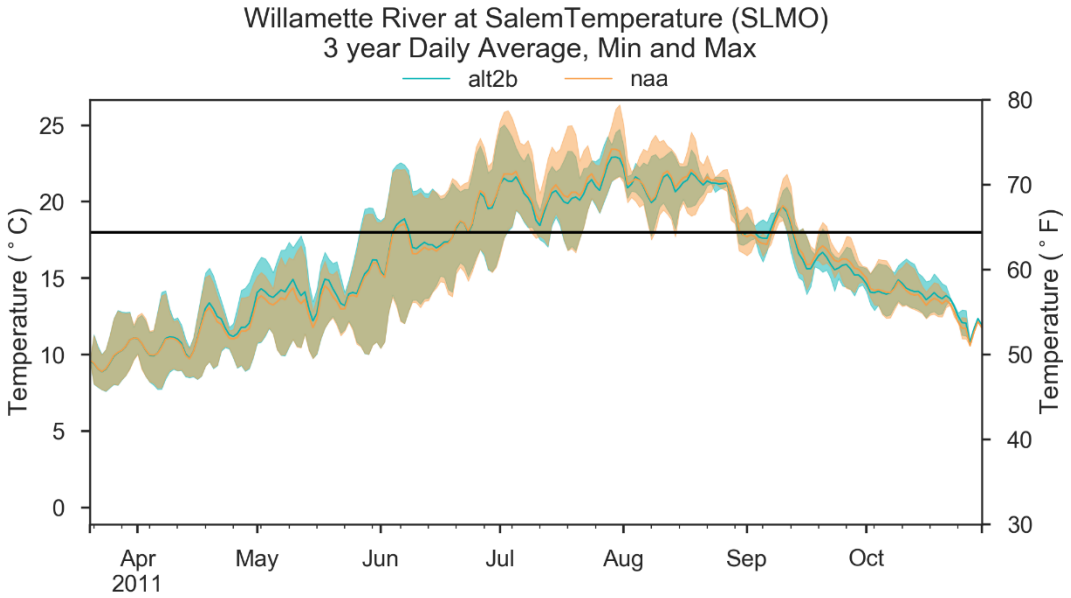


Figure 1-201. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b.

1.5.5 Alternative 3a – Operations-Focused Fish Passage

Alternative 3a measures that affected operations, lake storage, and water temperature included:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.
- Spring drawdown operations at Detroit, Lookout Point and Cougar (to the regulating outlet)
- Fall drawdown operations to lowest level possible given operational constraints at Blue River, Hills Creek, Green Peter, Detroit, Lookout Point and Cougar.
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.

1.5.5.1 North Santiam Dams

1.5.5.1.1 Detroit

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Detroit Lake decreased under Alternative 3a compared to NAA in 2011, 2015 and 2016 as the lake was drafted for the proposed fish passage operation through the UROs (Figure 1-202, Figure 1-203). The decreased storage coincided with reduced outflows during May-October (Figure 1-204).

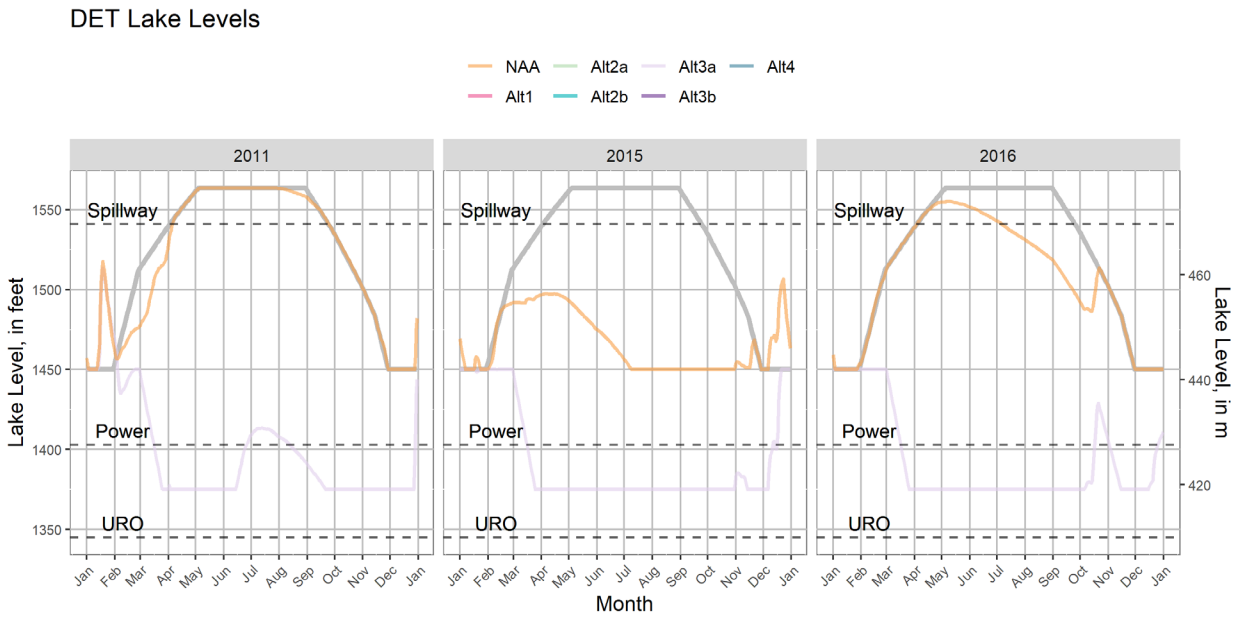


Figure 1-202. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA.

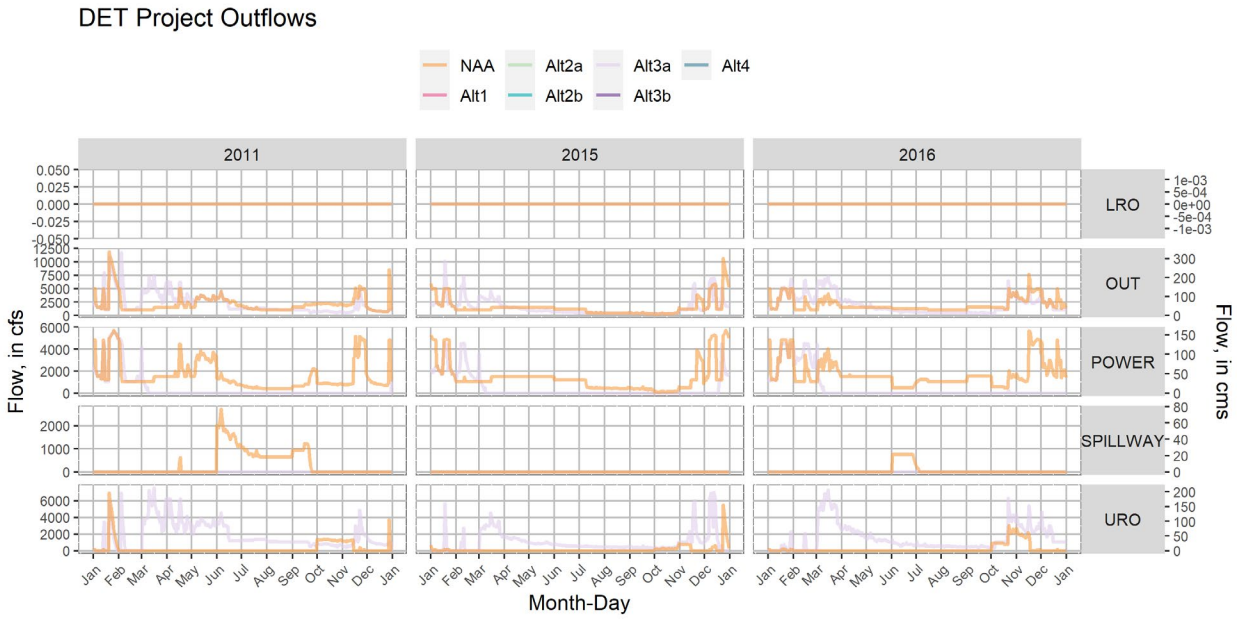


Figure 1-203. WV EIS HEC-ResSim Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 3a and NAA.

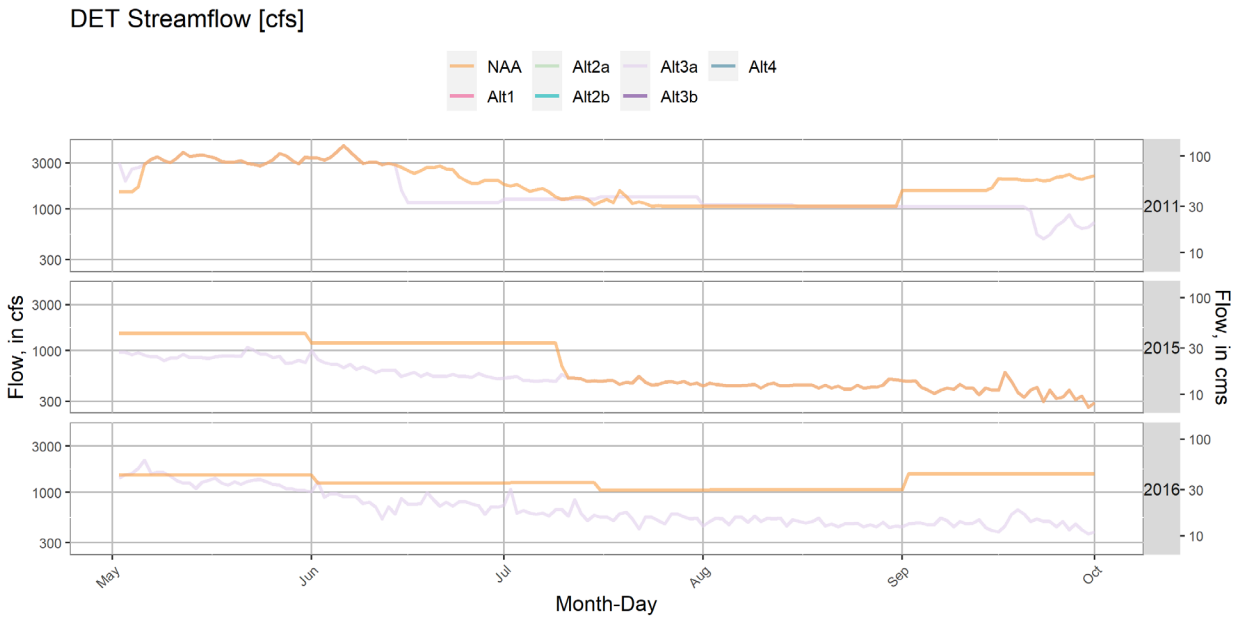


Figure 1-204. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 3a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-205, Figure 1-206, and Figure 1-207. Outflow temperatures from Detroit Dam in Alternative 3a were generally warmer than NAA May-September and cooler than NAA October-December as the lake surface area, volume, and residence time were decreased and releases were generally made through the UROs for fish passage operations (Figure 1-208, Figure 1-209).

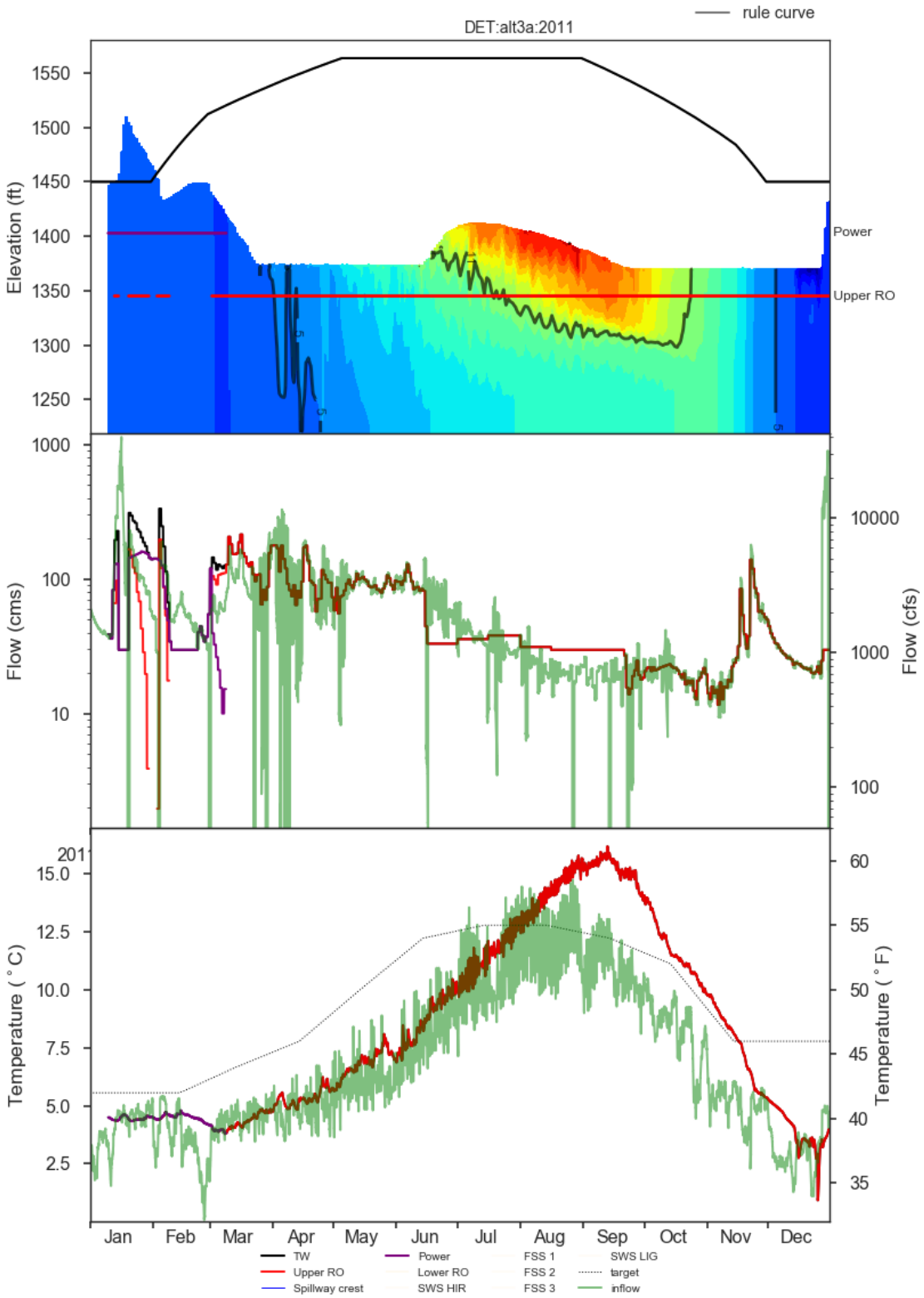


Figure 1-205. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3a in 2011.

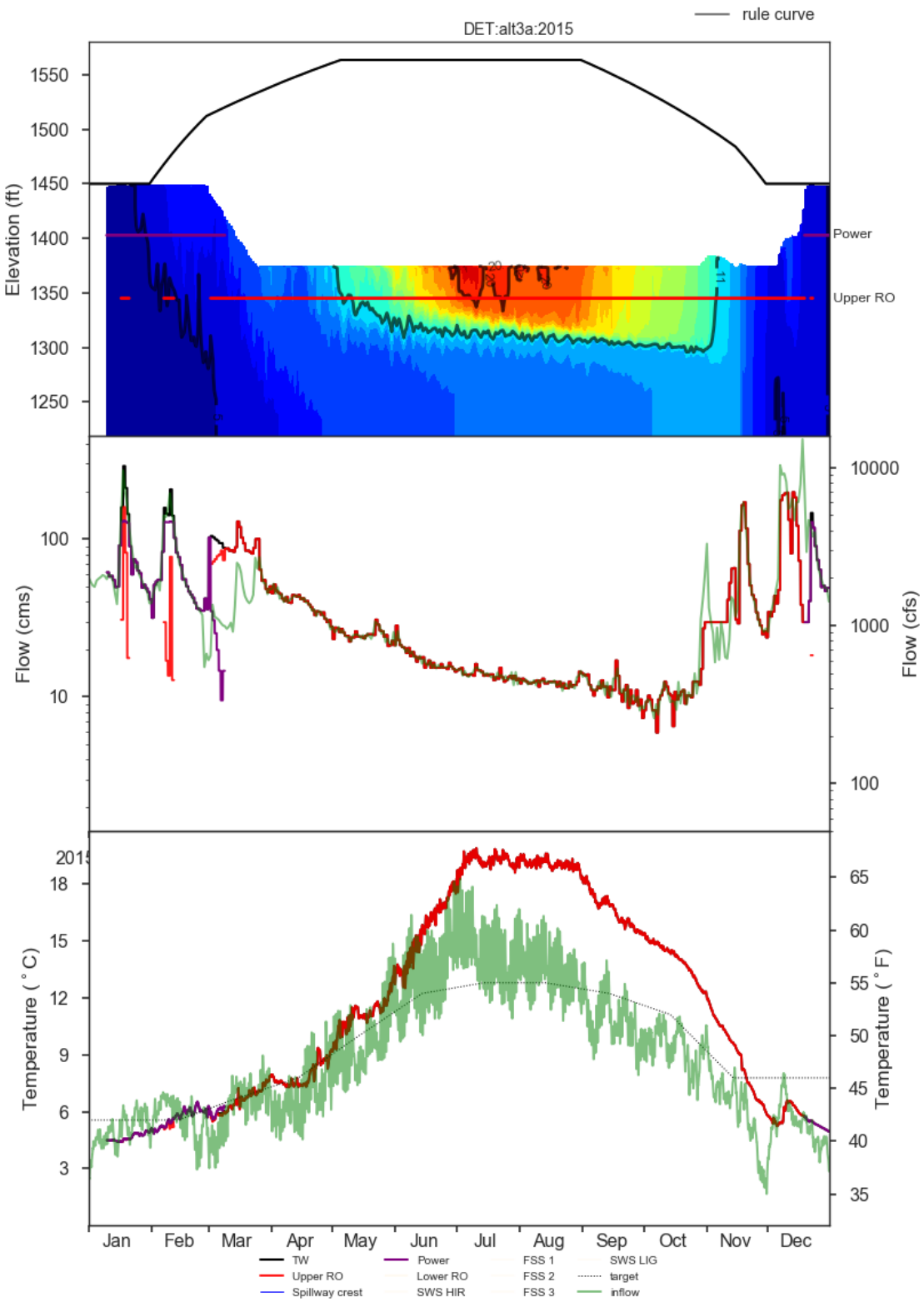


Figure 1-206. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3a in 2015.

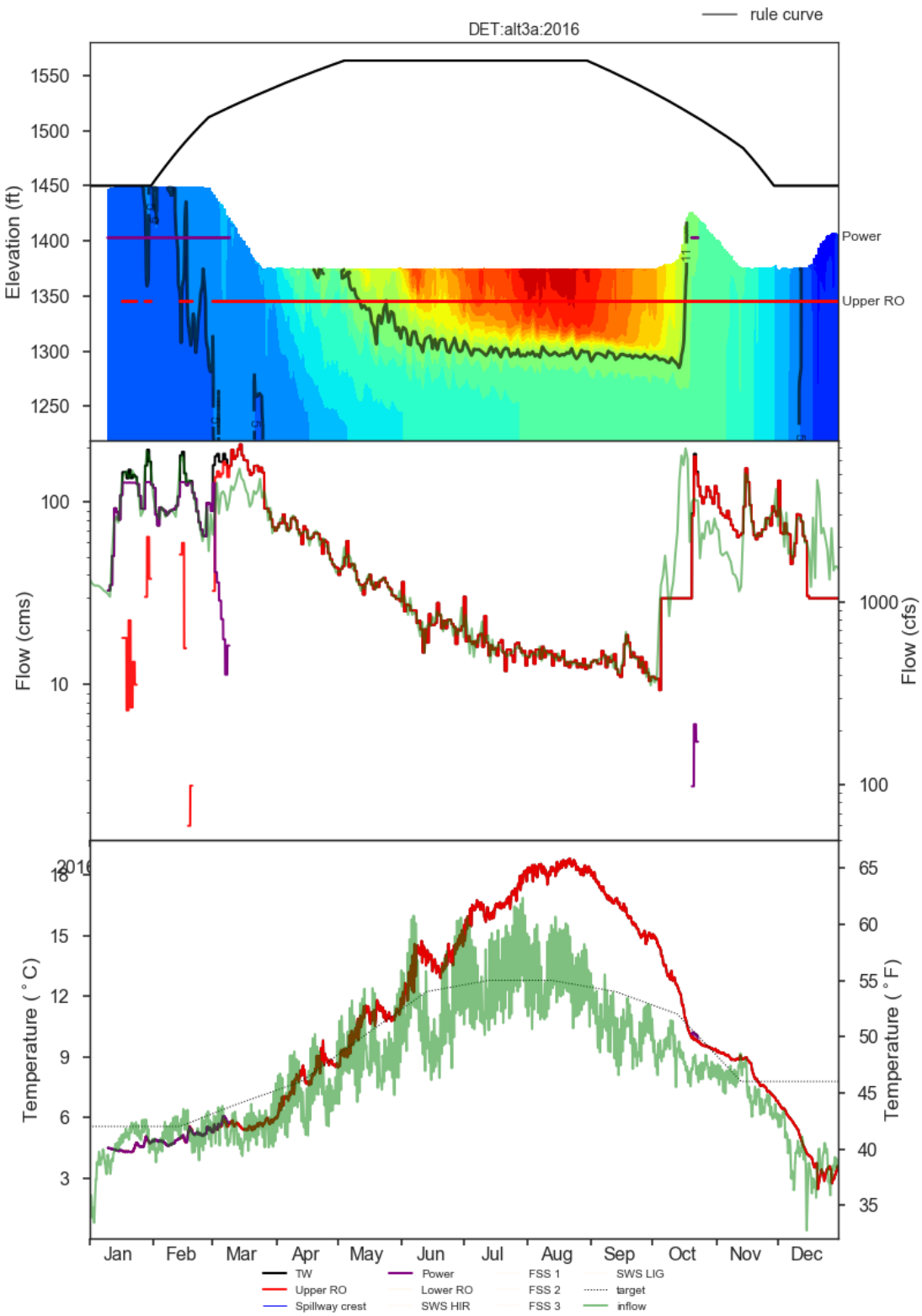


Figure 1-207. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3a in 2016.

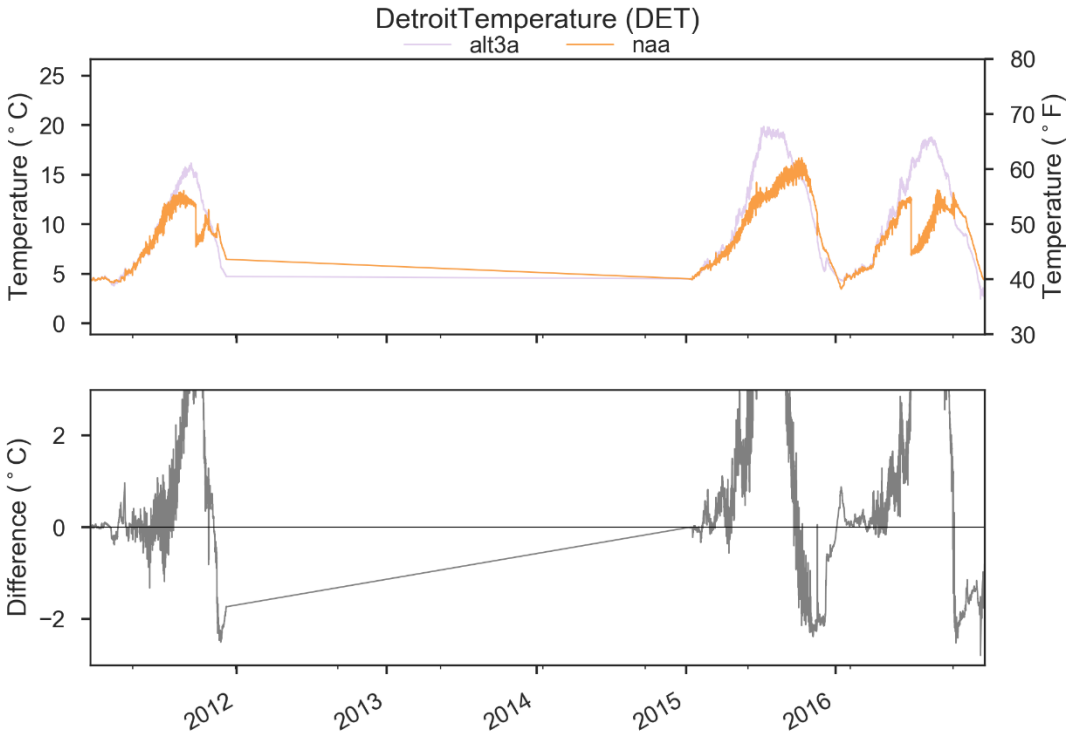


Figure 1-208. Comparison of DET Outflow Temperatures in NAA and Alternative 3a.

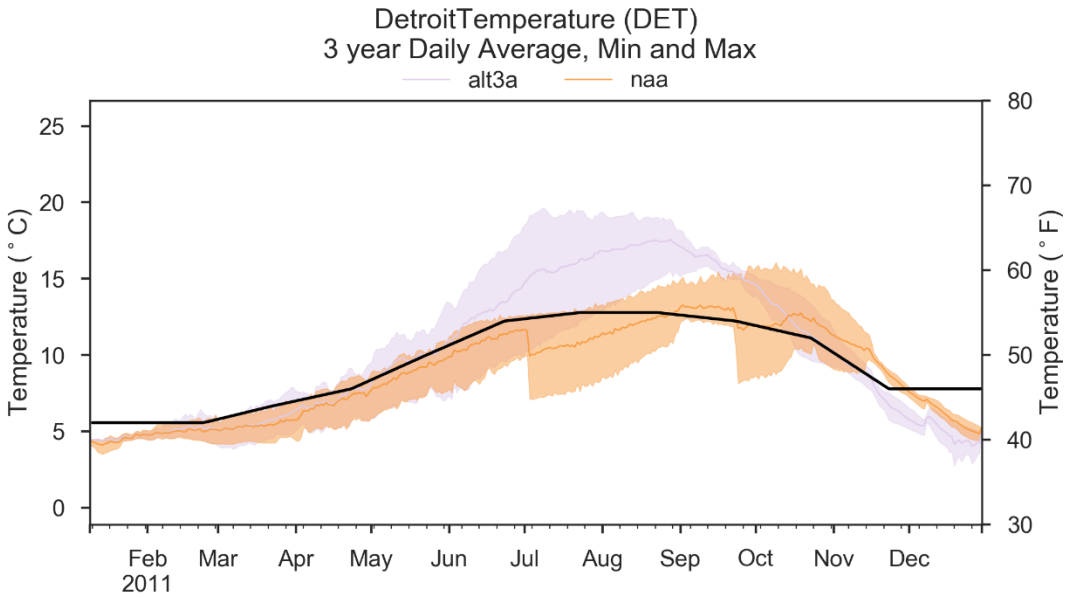


Figure 1-209. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target.

1.5.5.2 South Santiam Dams

1.5.5.2.1 Green Peter

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Green Peter were generally similar in Alternative 3a and NAA in 2011, 2015, and 2016 except for drawdown through the RO for fish passage during October-November (Figure 1-210, Figure 1-211, and Figure 1-212). Increased storage in July-October 2015 coincided with reduced outflows during spring and increased outflows. 2011 and 2016 operations were generally similar in Alternative 3a and NAA at Green Peter Lake January-June until increased outflows in July-October drafted the lake for fish passage operations through the ROs. The proposed operational temperature management through the spillway (during spring/summer) and RO (during autumn) in Alternative 3a led to increased outflow from these outlets and decreased power outflow compared to NAA (Figure 1-107).

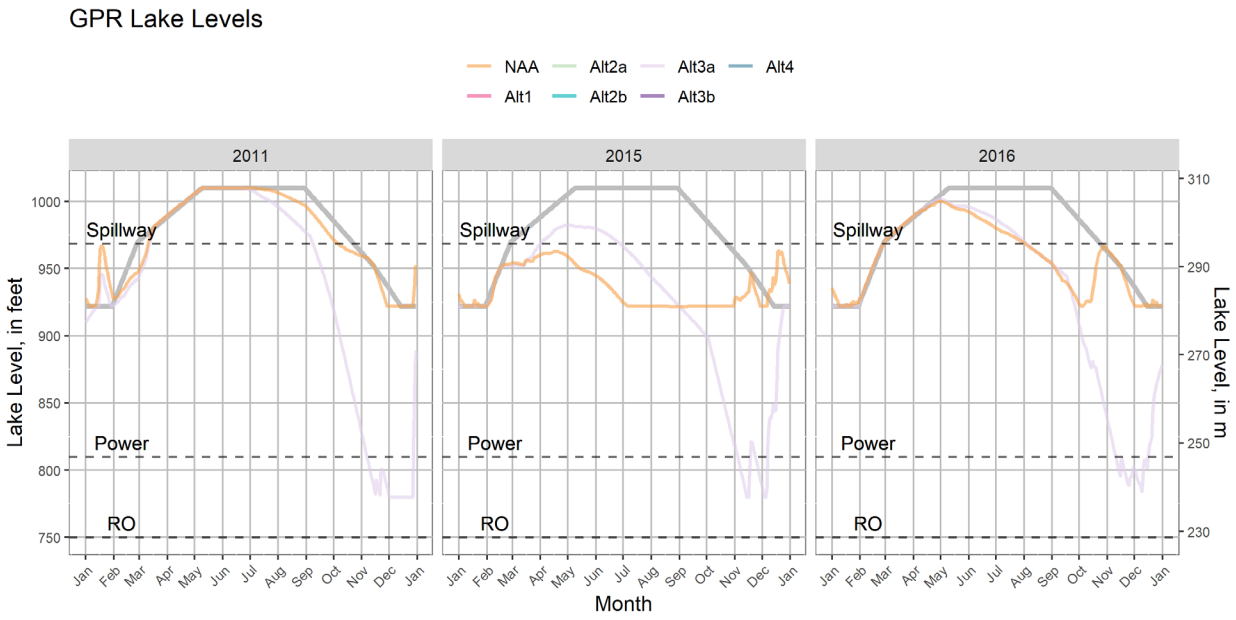


Figure 1-210. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA.

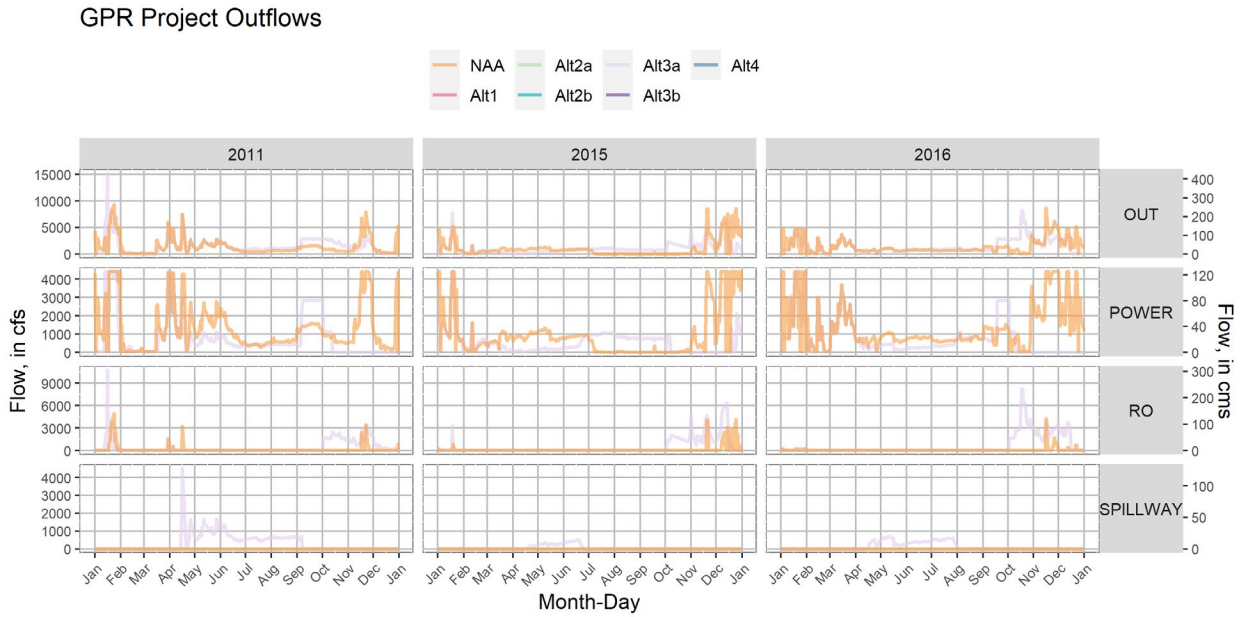


Figure 1-211. WV EIS HEC-ResSim Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 3a and NAA.

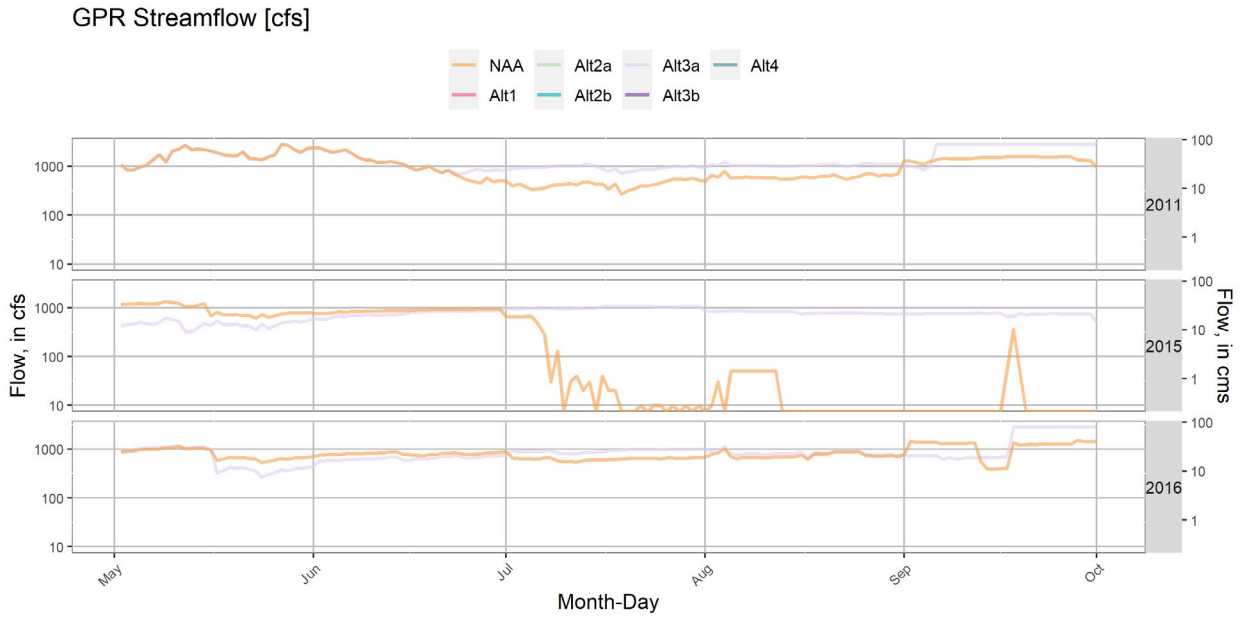


Figure 1-212. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-213, Figure 1-214, and Figure 1-215. Alternative 3a includes releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during

autumn to mixed with relatively deep power penstock releases to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and outlets were submerged. Spillway access was limited in some years (2015 especially), which led to an abrupt drop in tailwater temperature when spillway access ended in mid-summer of those years. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam (Figure 1-216, Figure 1-217). Generally, the autumn fish passage operation (drawdown to the RO) resulted in cooler autumn temperatures (November-December) compared to NAA (Figure 1-217).

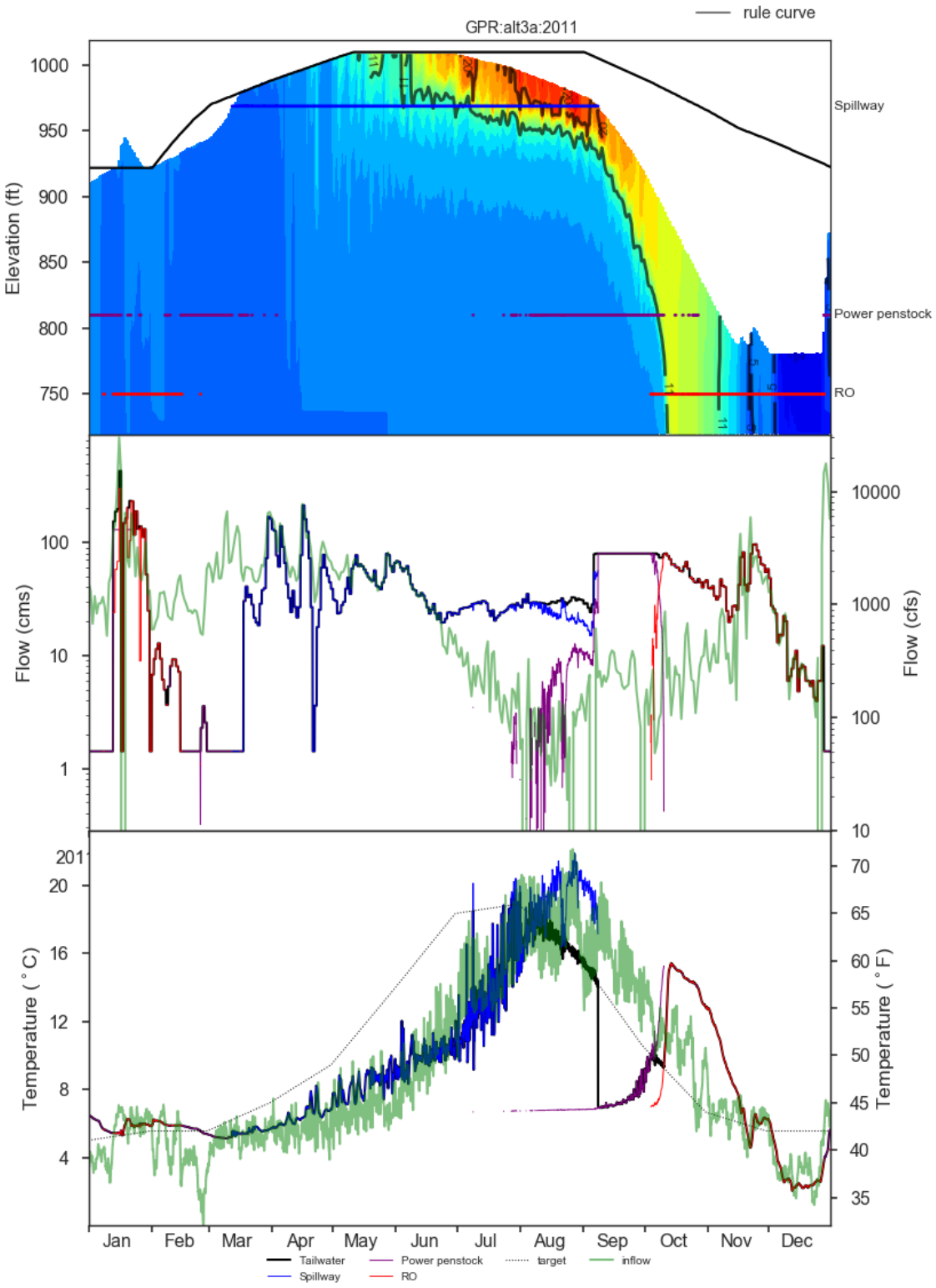


Figure 1-213. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3a in 2011.

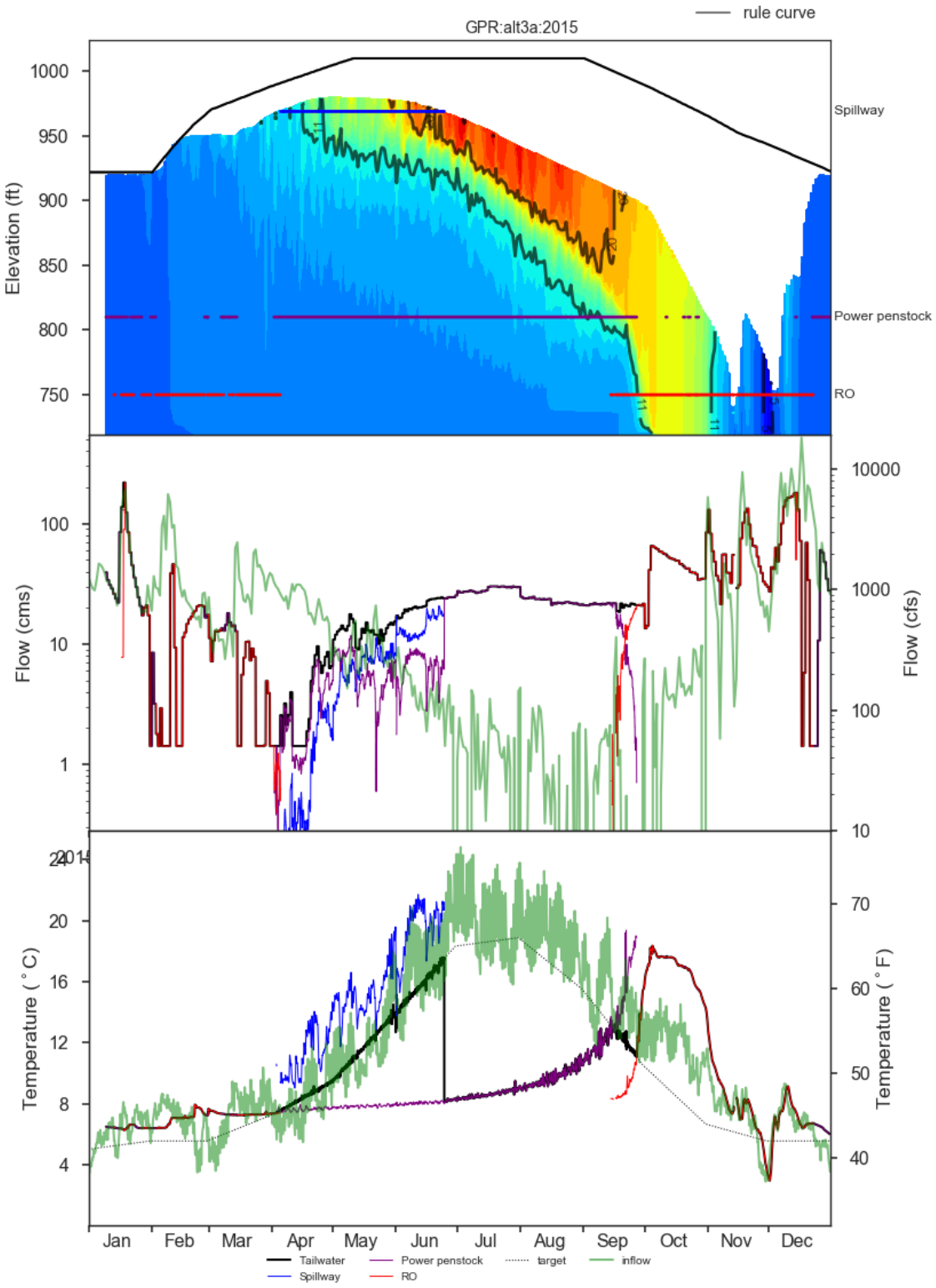


Figure 1-214. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3a in 2015.

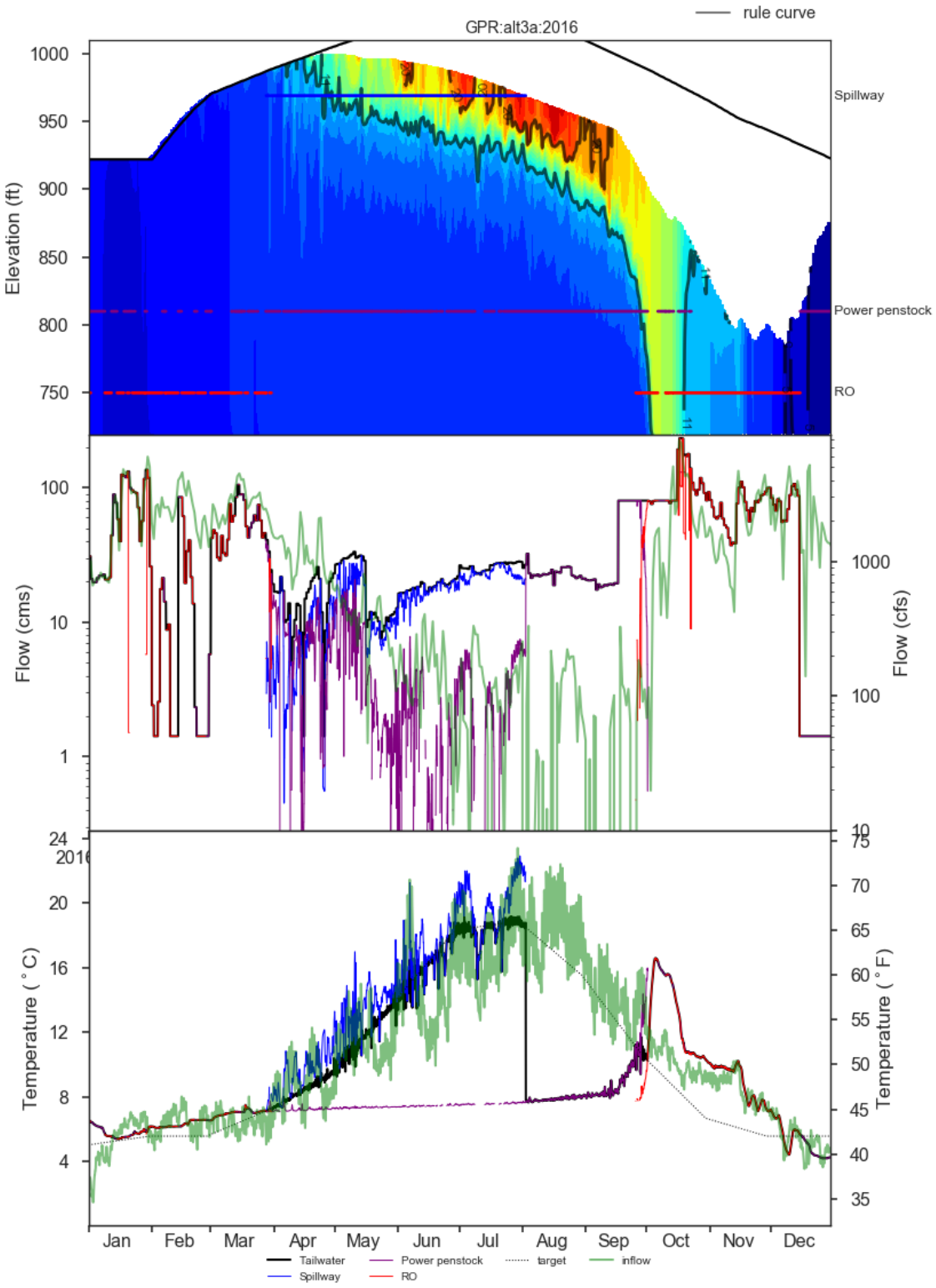


Figure 1-215. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3a in 2016.

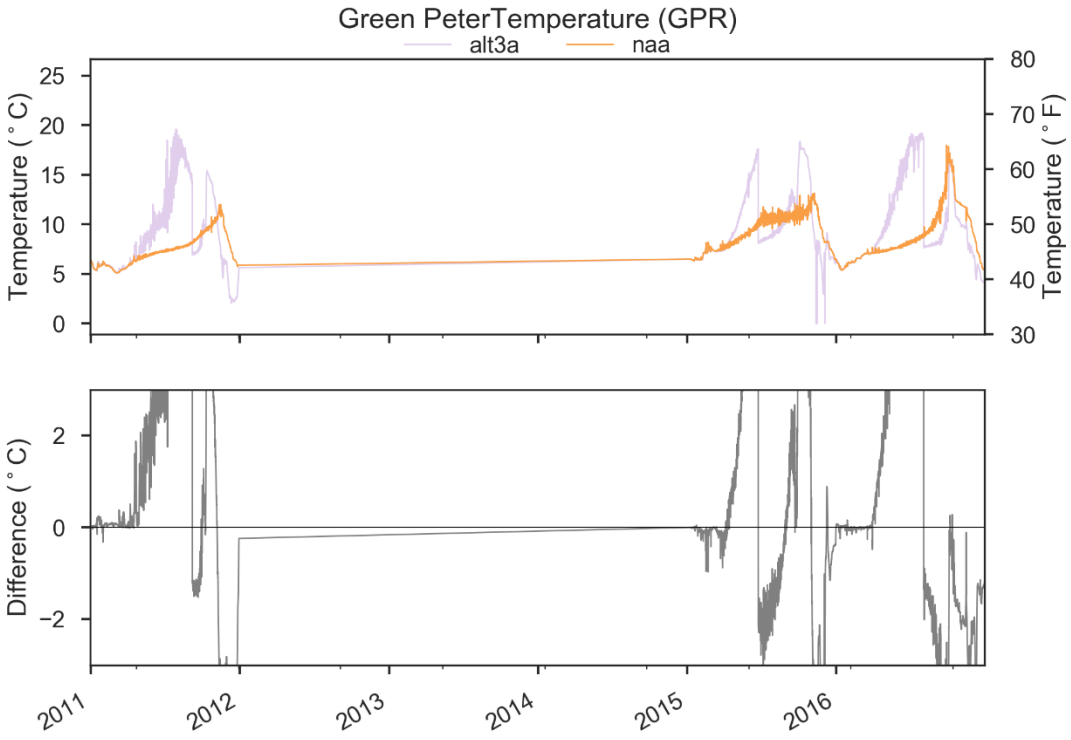


Figure 1-216. Comparison of GPR Outflow Temperatures in NAA and Alternative 3a.

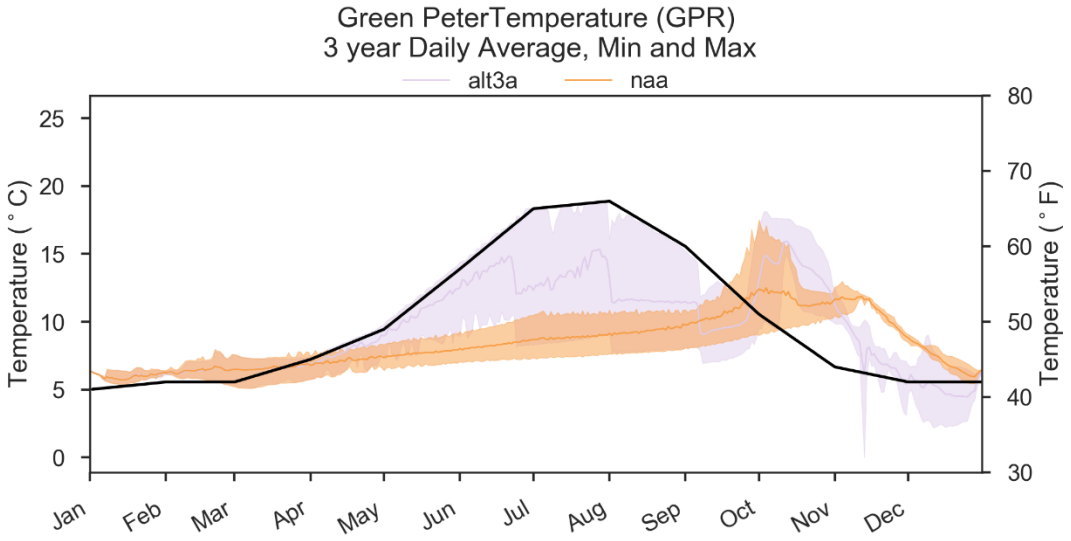


Figure 1-217. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target.

1.5.5.2.2 Foster

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Foster were generally similar in Alternative 3a compared to NAA in 2011 and 2016 but increased in 2015 in Alternative 3a compared to NAA (Figure 1-218, Figure 1-219, and Figure 1-220). Total outflow from Foster Dam increased July-September in 2015 due to upstream GPR operations, coinciding with greater storage at FOS in Alternative 3a compared to NAA during that time.

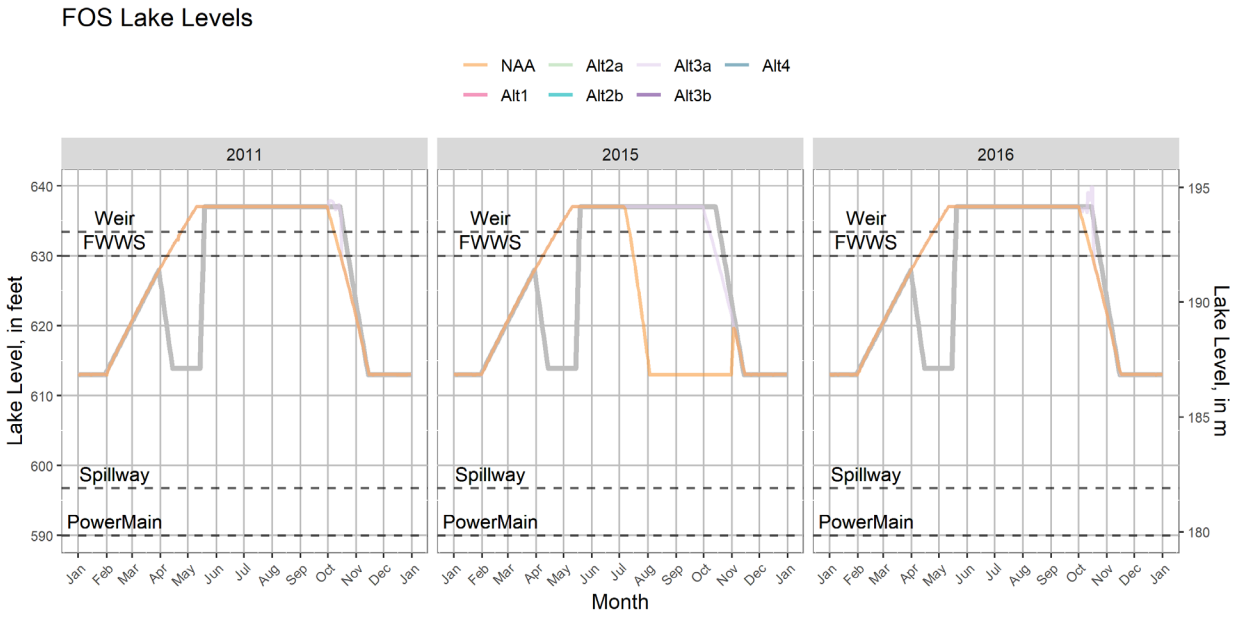


Figure 1-218. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA.

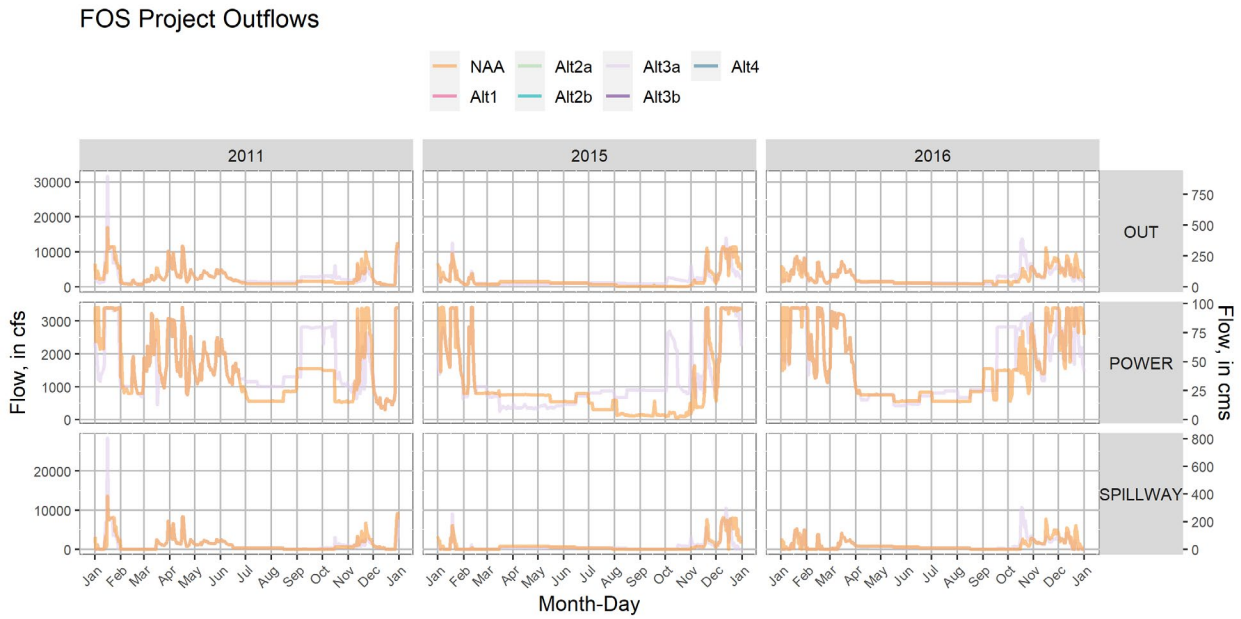


Figure 1-219. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3a and NAA.

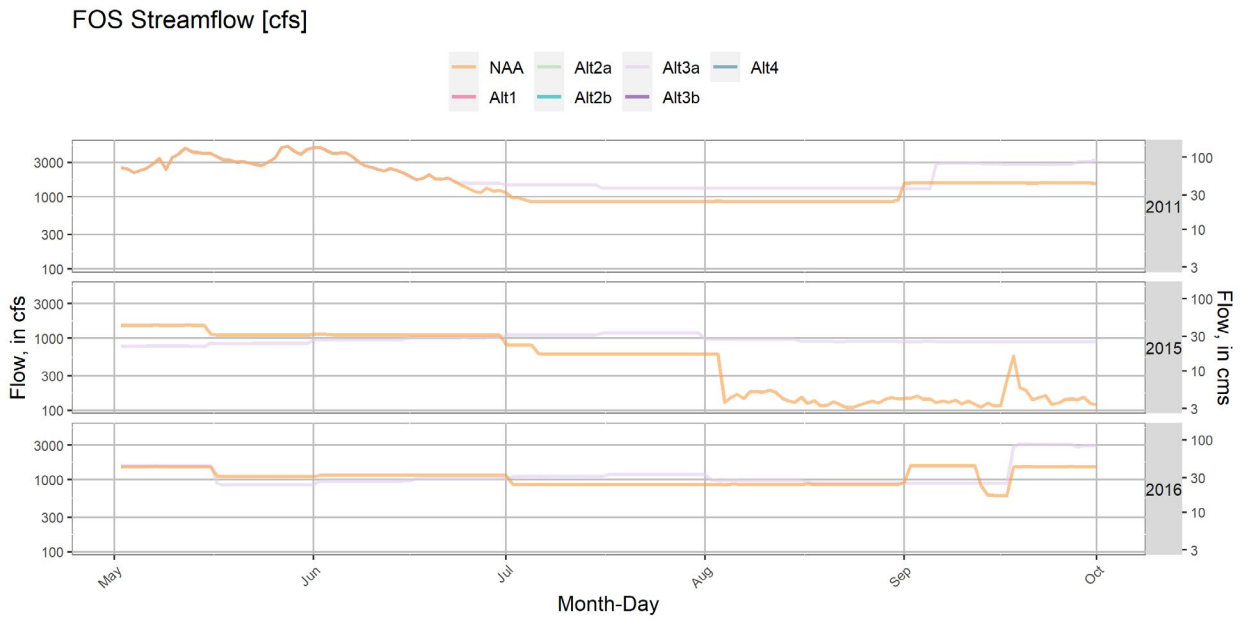


Figure 1-220. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 3a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-221, Figure 1-222, and Figure 1-223. Foster Lake temperature was affected by Green Peter Dam release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the

temperature pattern (Sullivan and Rounds, 2021). Relatively warmer spillway releases from Green Peter upstream resulted in warmer tailwater temperature in spring and summer compared to NAA (Figure 1-224, Figure 1-225). Generally, the autumn fish passage operation (drawdown to the RO at Green Peter) resulted in cooler autumn temperatures (November-December) compared to NAA downstream of Foster Dam.

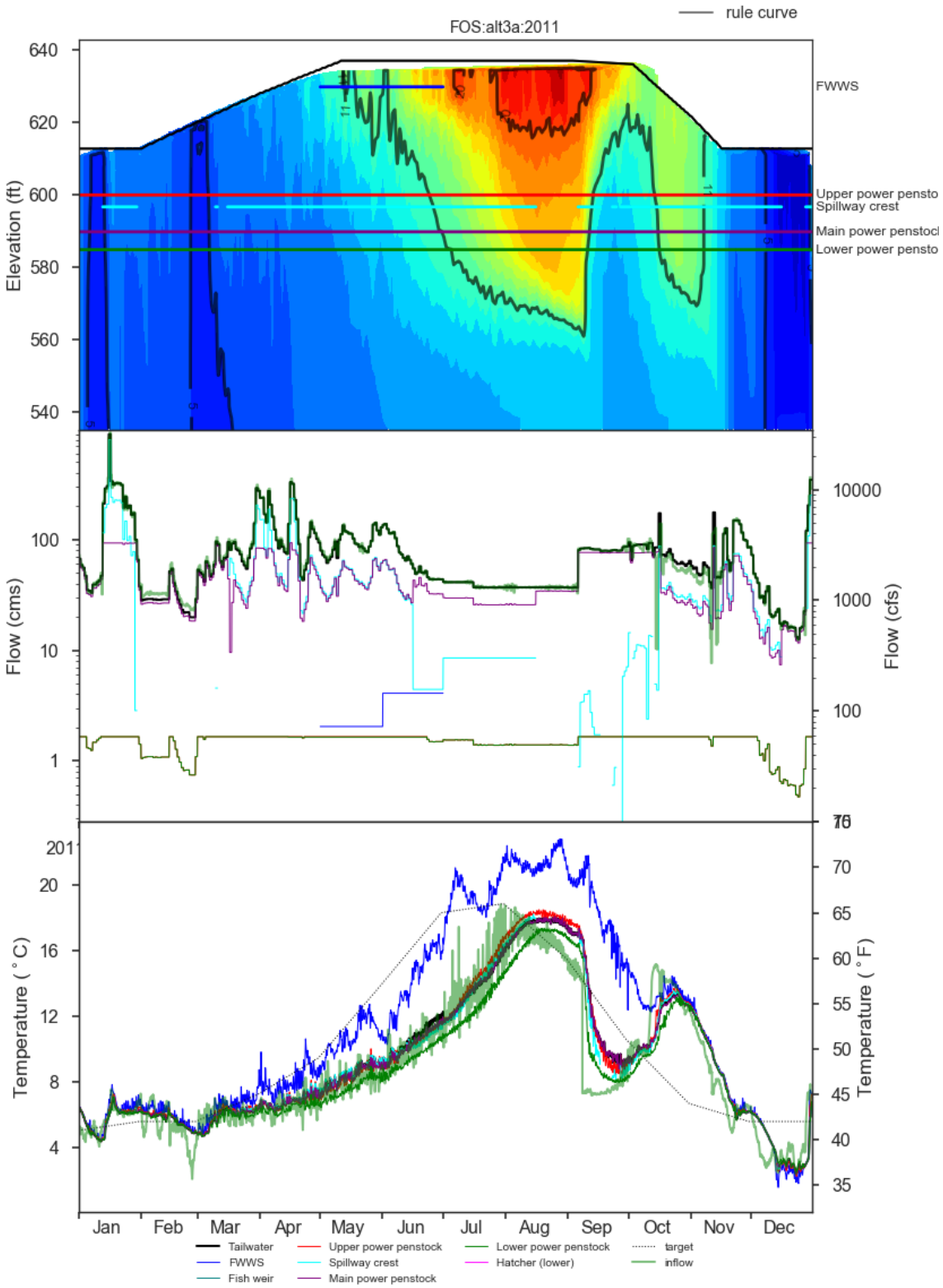


Figure 1-221. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3a in 2011.

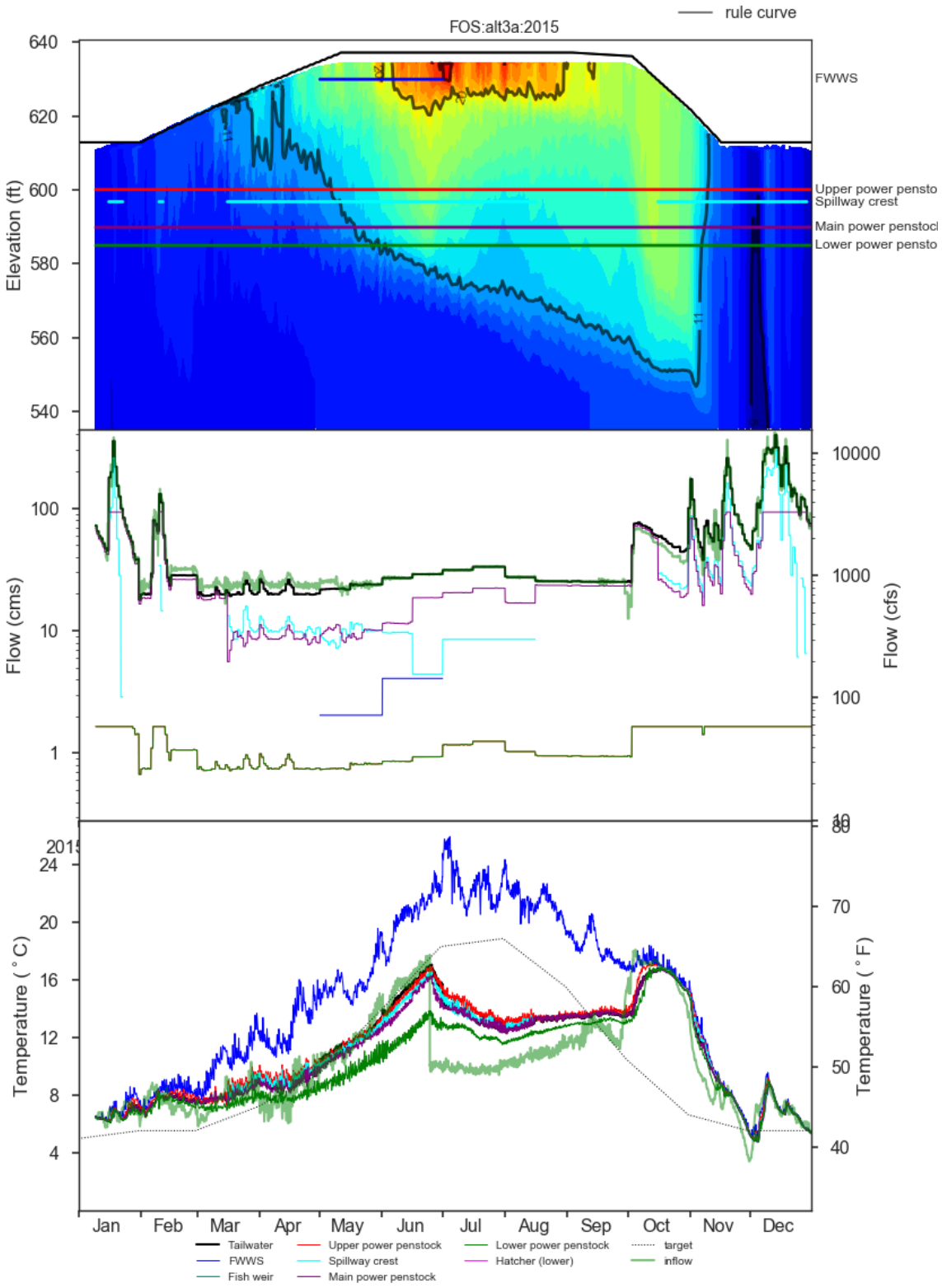


Figure 1-222. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3a in 2015.

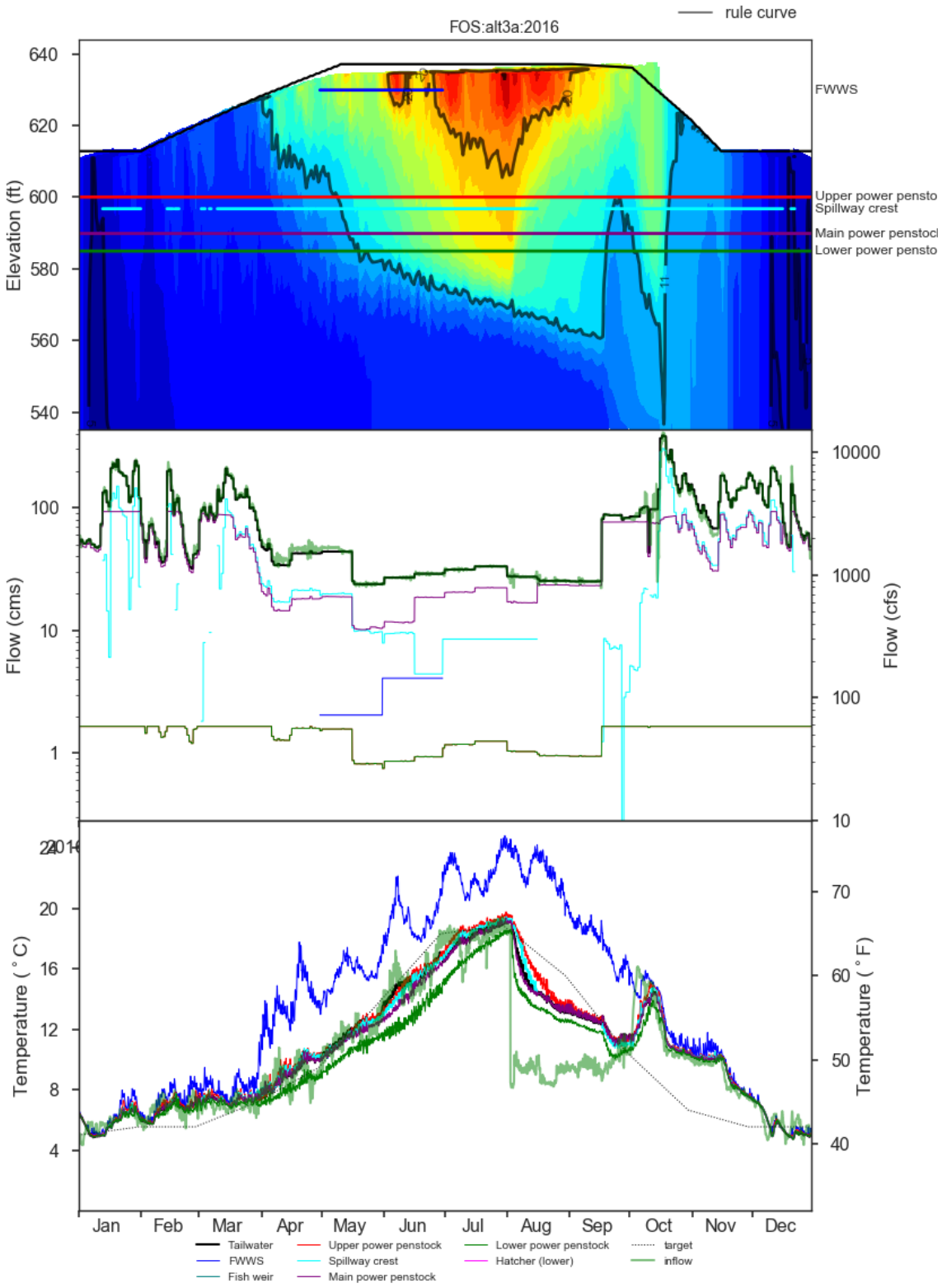


Figure 1-223. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3a in 2016.

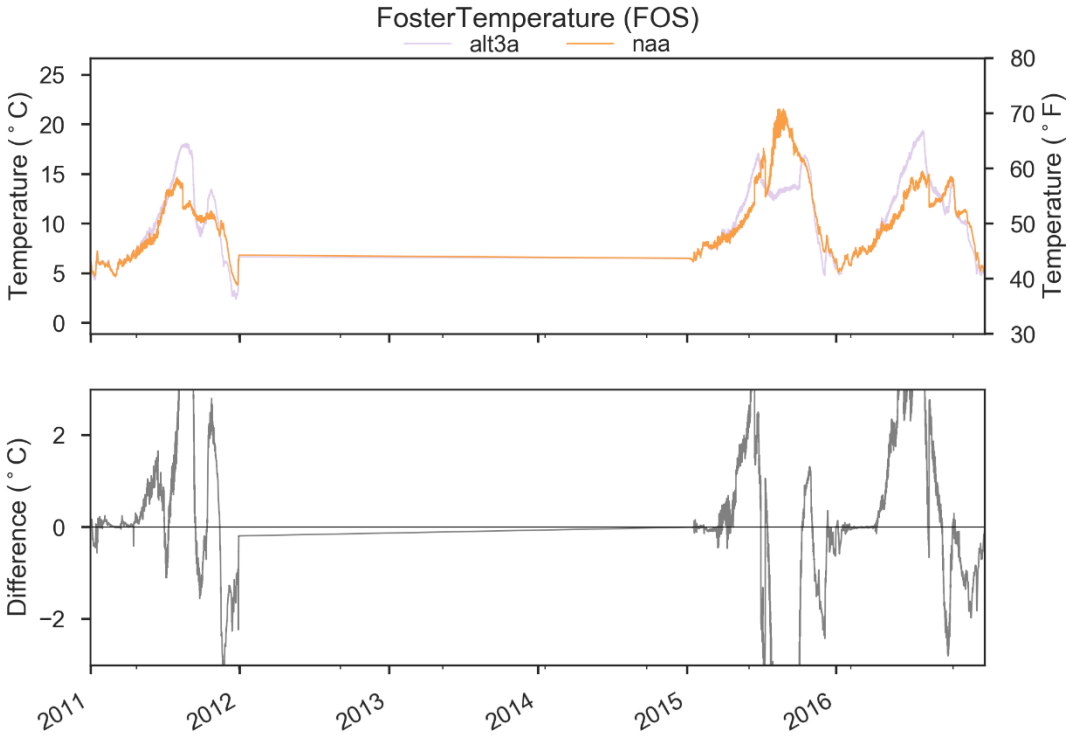


Figure 1-224. Comparison of FOS outflow temperatures in NAA and Alternative 3a.

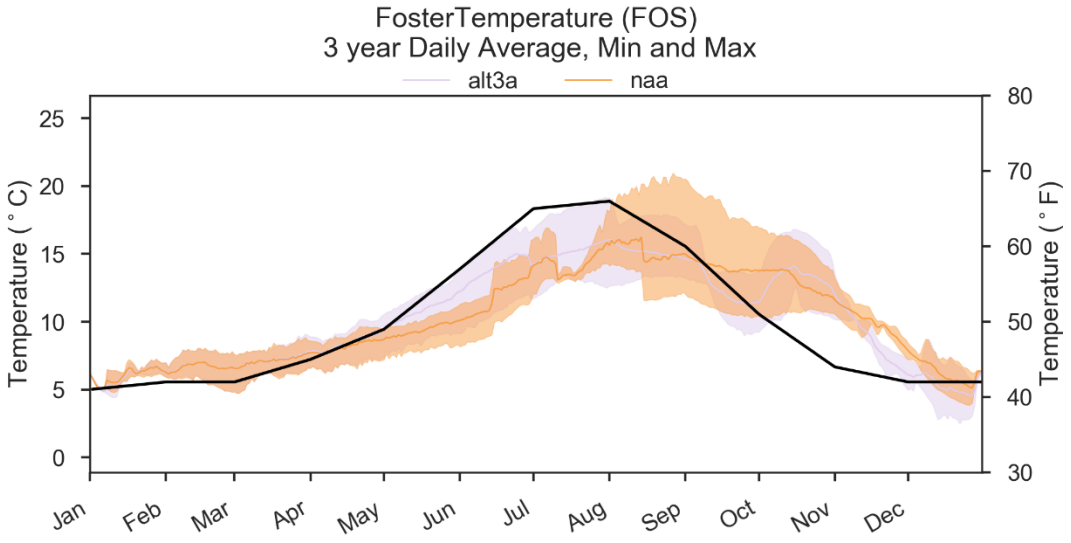


Figure 1-225. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target.

1.5.5.3 McKenzie Dams

1.5.5.3.1 Cougar

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Cougar Lake decreased in Alternative 3a compared to NAA in 2011, 2015, and 2016 to allow for proposed fish passage operations through the diversion tunnel (Figure 1-226, Figure 1-227, and Figure 1-228). Decreased storage coincided with reduced outflows during spring and summer (Figure 1-227). Outflows were primarily routed through the RO in Alternative 3a.

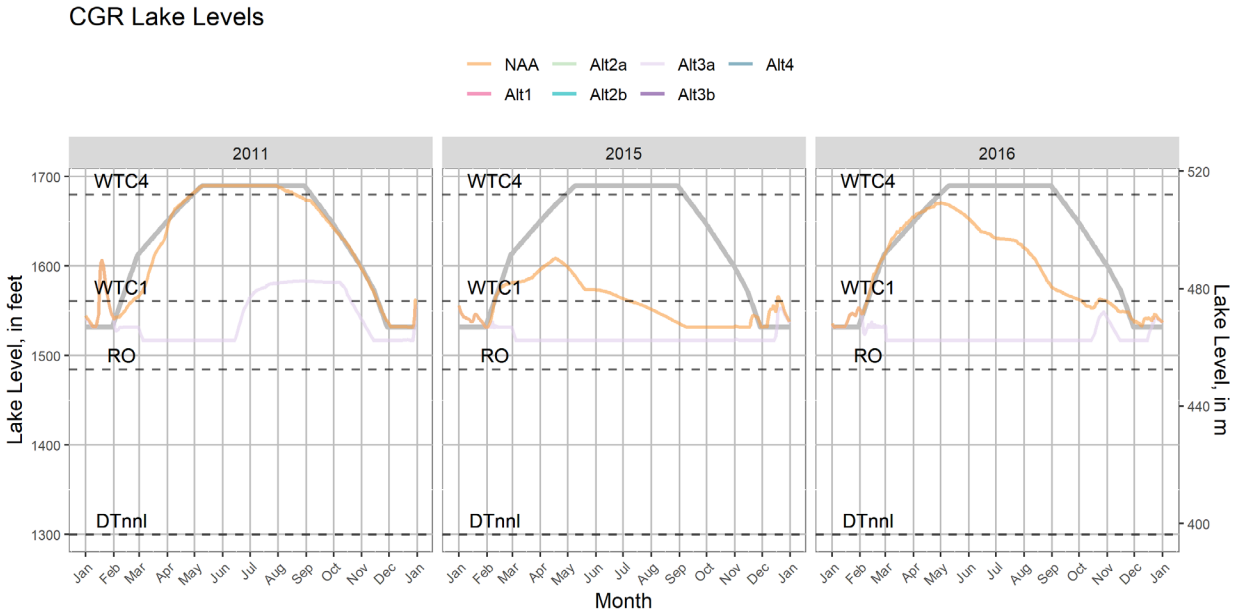


Figure 1-226. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA.

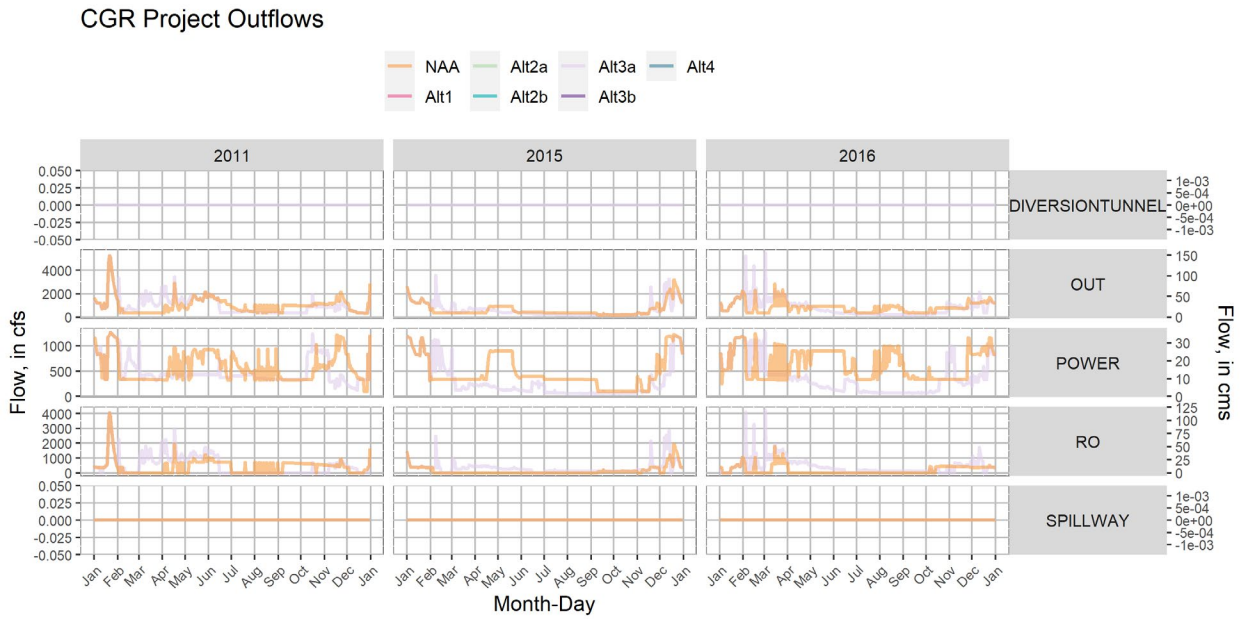


Figure 1-227. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3a and NAA.

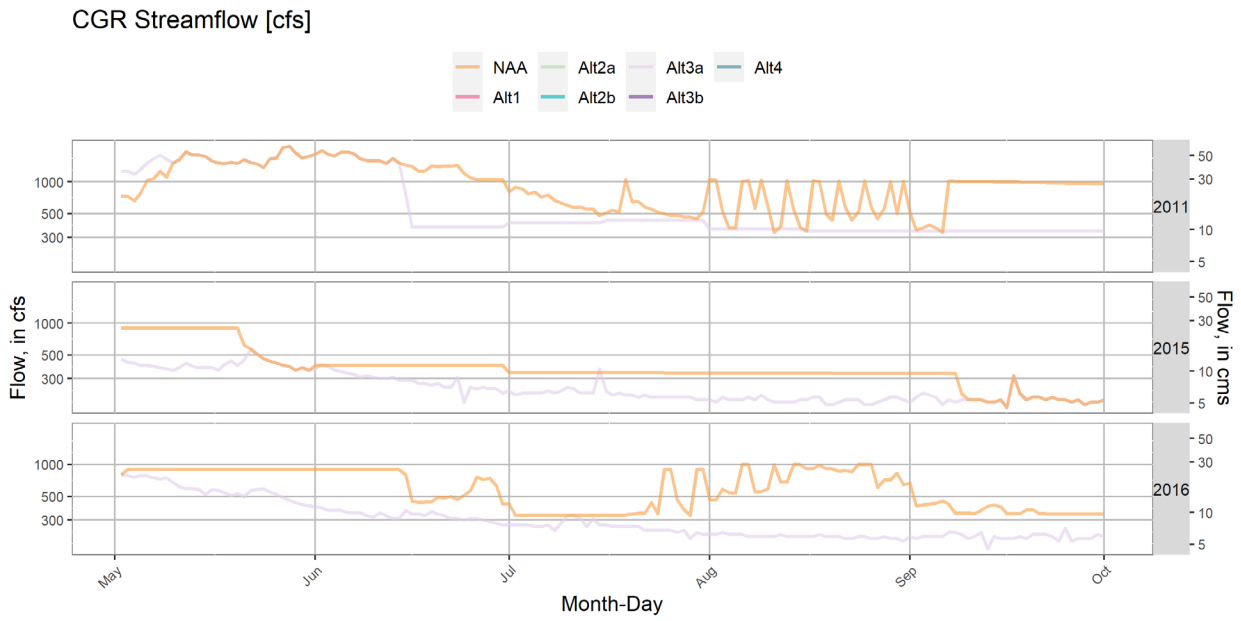


Figure 1-228. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Cougar Lake are shown in Figure 1-229, Figure 1-230, and Figure 1-231. Outflow temperatures from Cougar Dam in Alternative 3a were cooler than NAA June-August and warmer than NAA September-November. Downstream release temperatures were sensitive to the depth of the thermocline throughout the year in Alternative 3a as the proposed fish operation routed all releases through the RO (Figure 1-232, Figure 1-233).

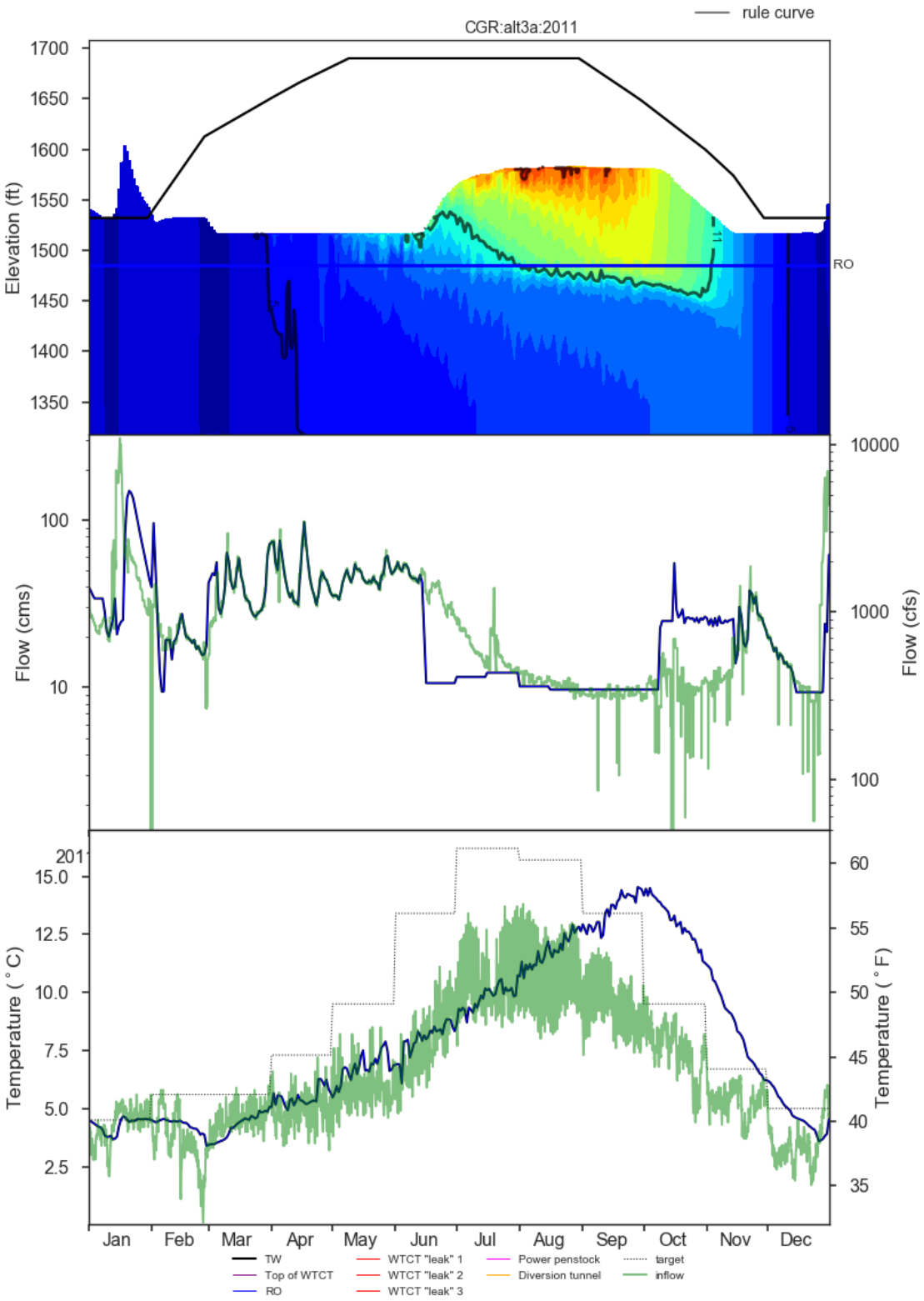


Figure 1-229. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3a in 2011.

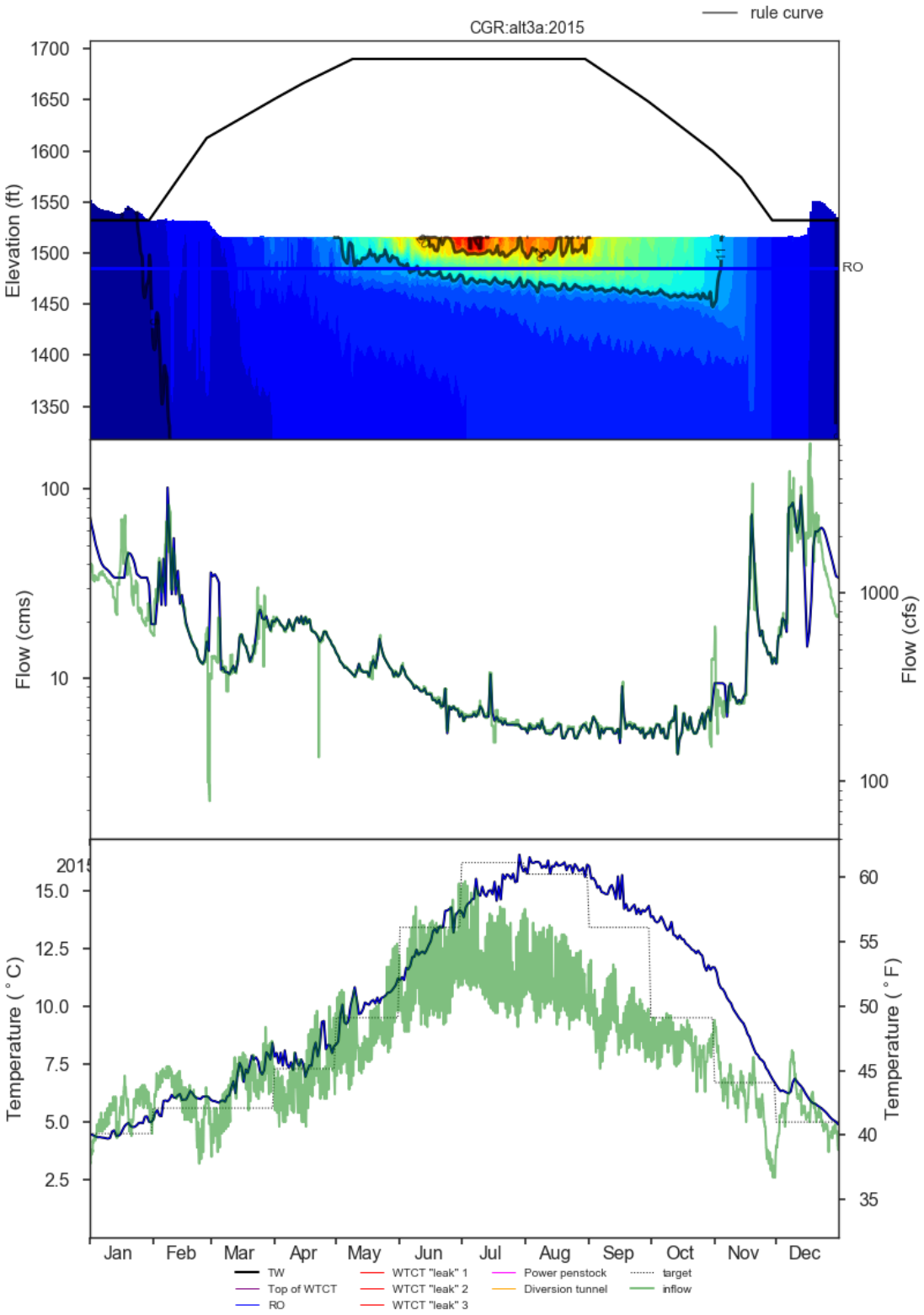


Figure 1-230. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3a in 2015.

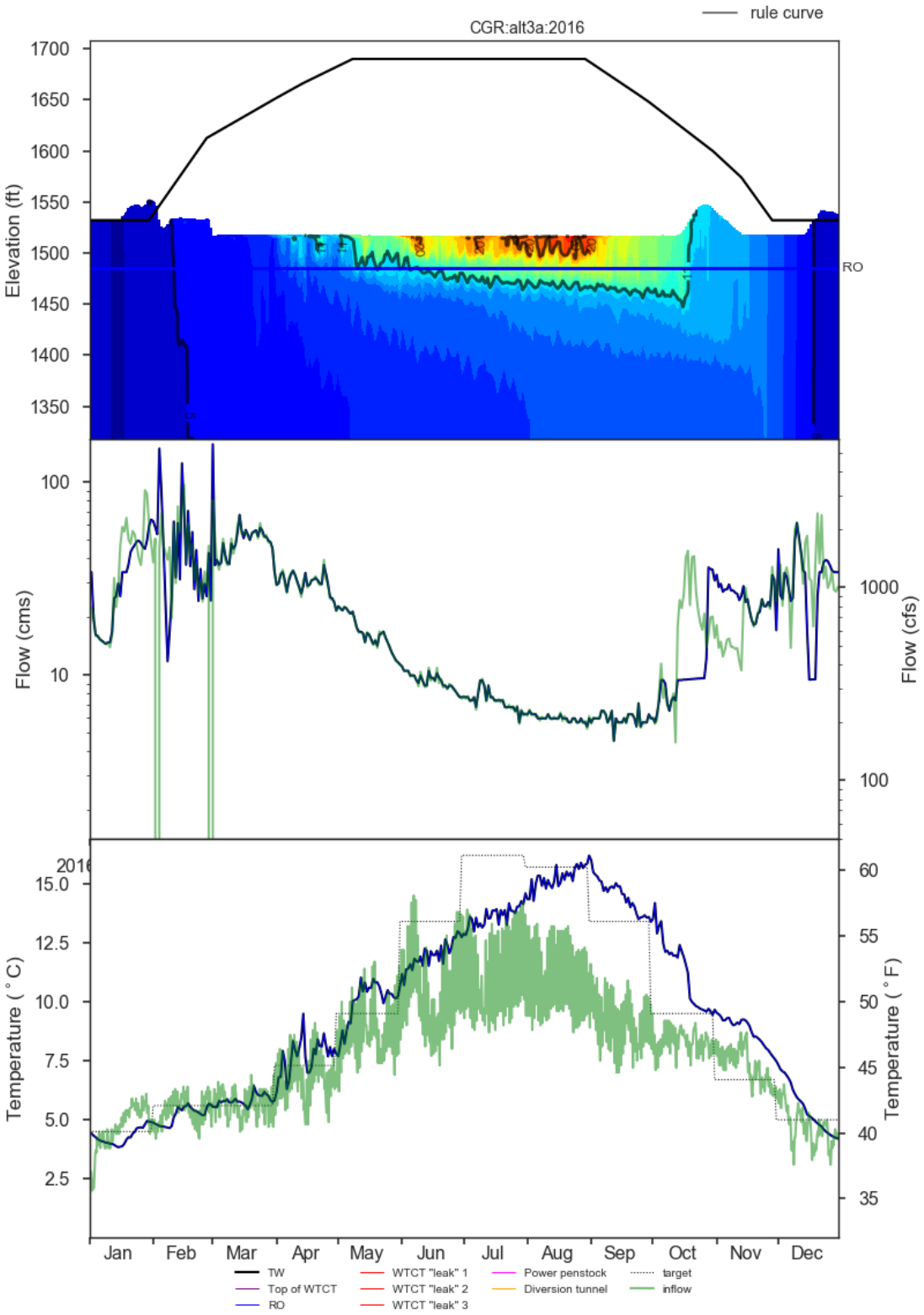


Figure 1-231. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3a in 2016.

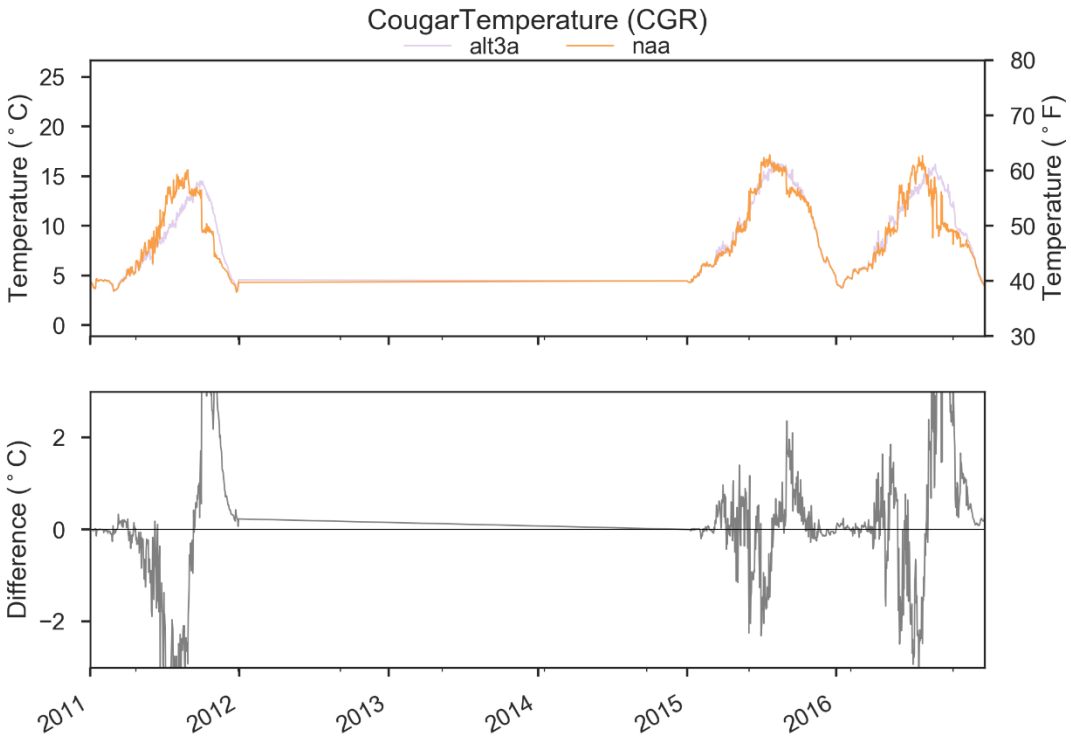


Figure 1-232. Comparison of CGR Outflow Temperatures in NAA and Alternative 3a.

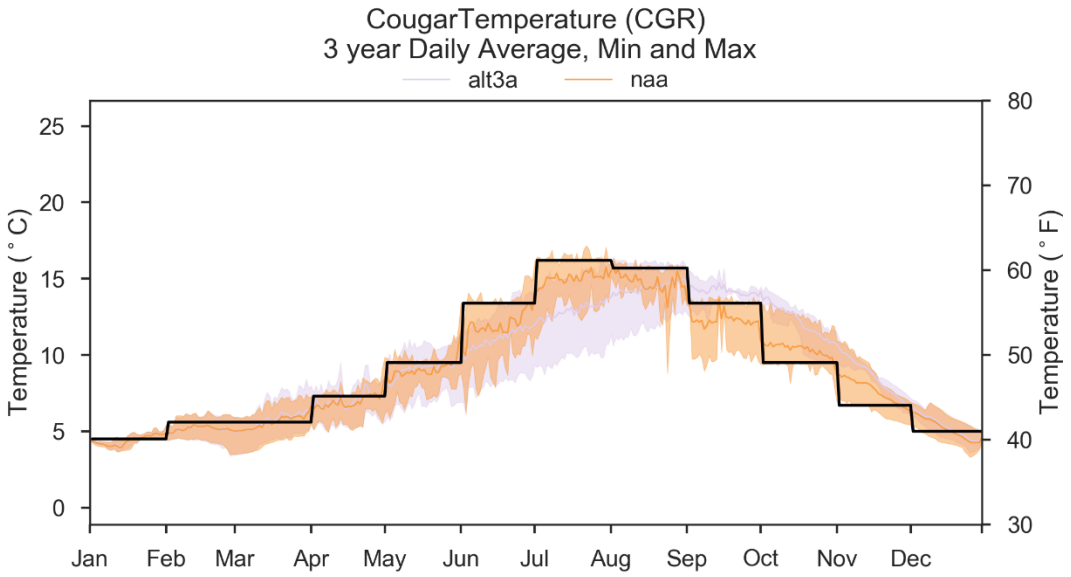


Figure 1-233. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target.

1.5.5.4 Middle Fork Willamette Dams

1.5.5.4.1 Hills Creek

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Hills Creek Lake generally increased under Alternative 3a compared to NAA from the spring to early summer and decreased from the late summer to winter. (Figure 1-234, Figure 1-235, and Figure 1-236). Outflow was routed through the power penstocks and emergency spillway (assumed to be structurally modified to allow for small non-emergency flow without causing dam safety issues) at Hills Creek in Alternative 3a (Figure 1-235).

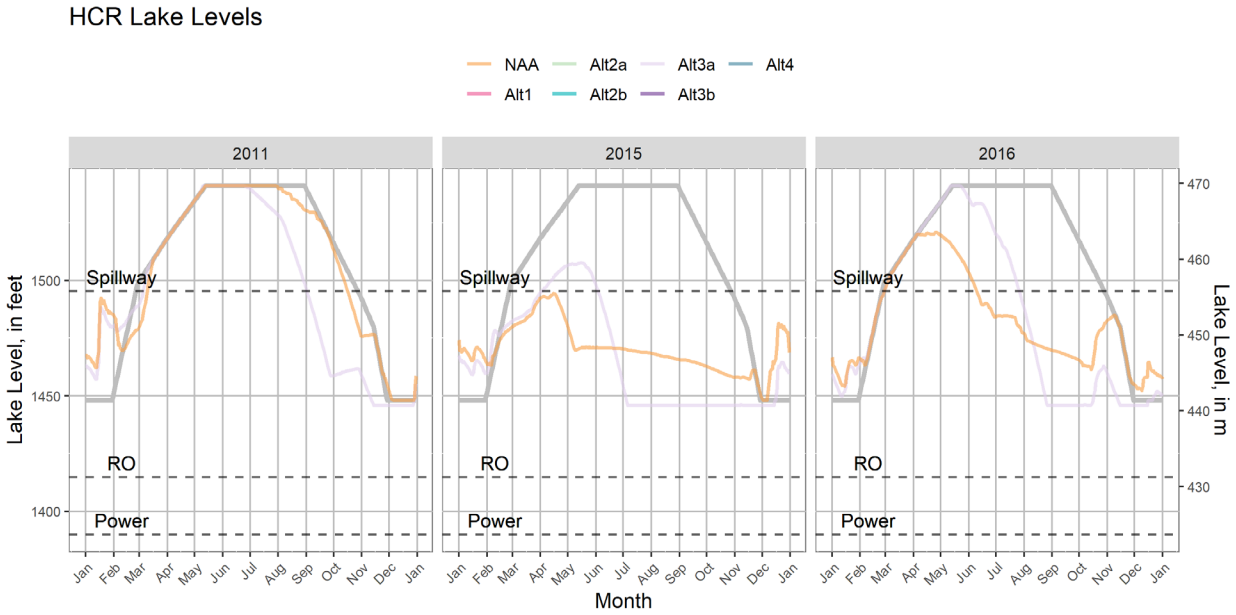


Figure 1-234. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA.

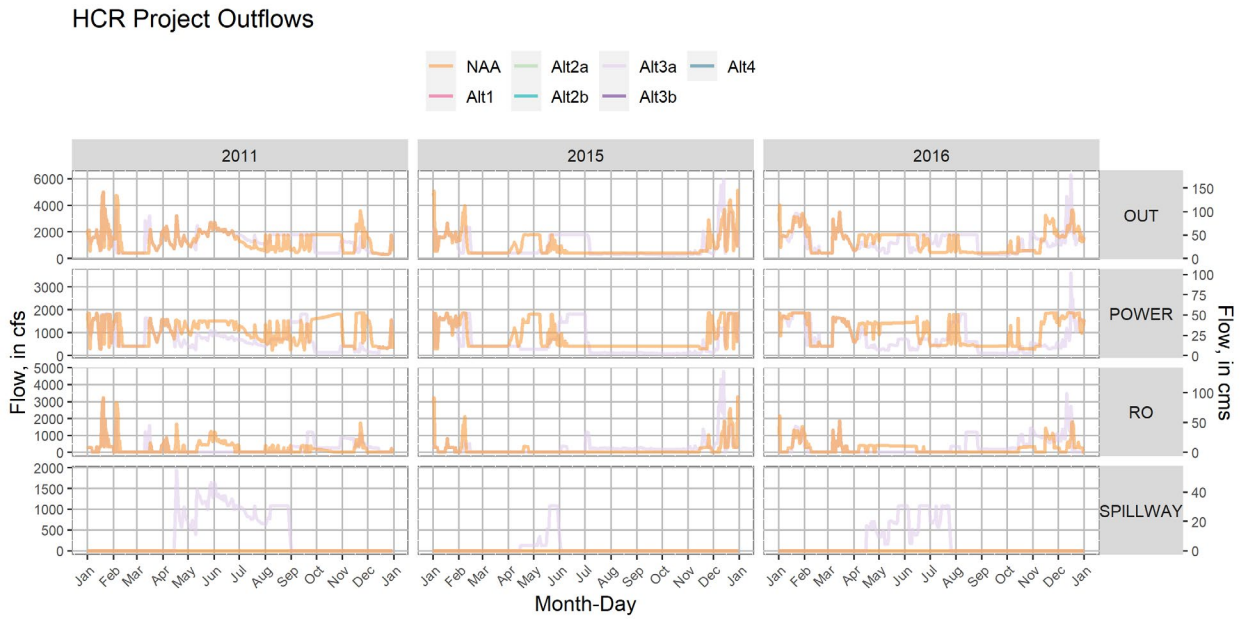


Figure 1-235. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3a and NAA.

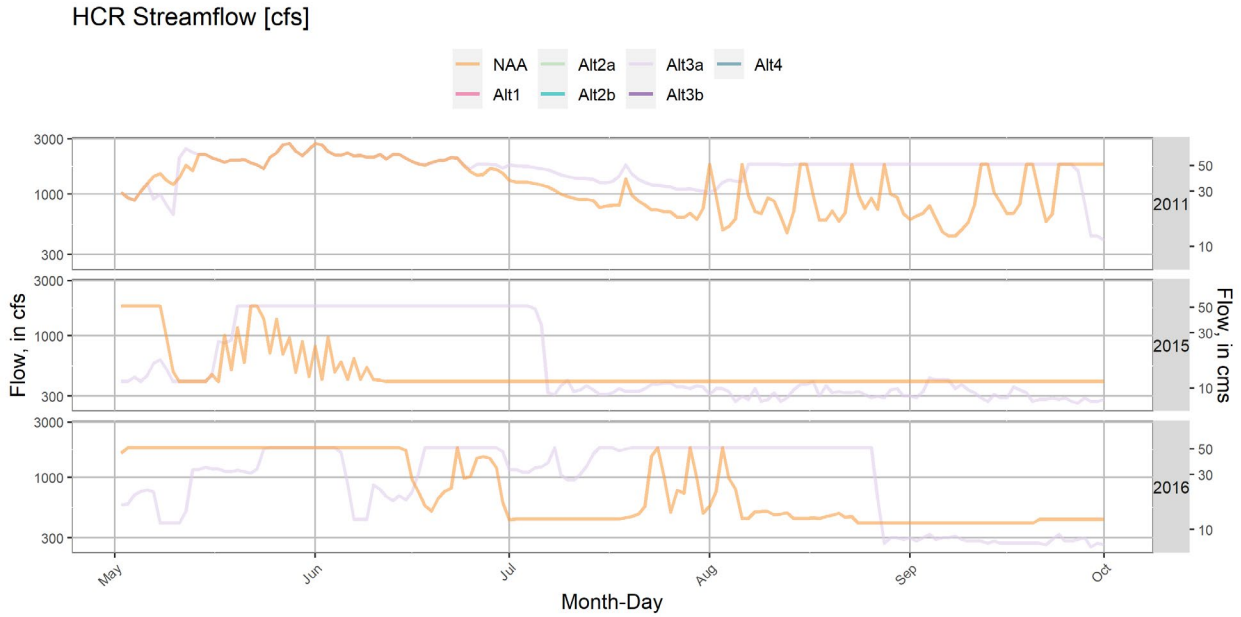


Figure 1-236. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 3a at Hills Creek Lake are shown in Figure 1-237, Figure 1-238, and Figure 1-239. Hills Creek tailwater temperatures were generally warmer in Alternative 3a compared to NAA in May-July and cooler than NAA September – December (Figure 1-240, Figure 1-241) because of the proposed spillway operations (and spillway modifications).

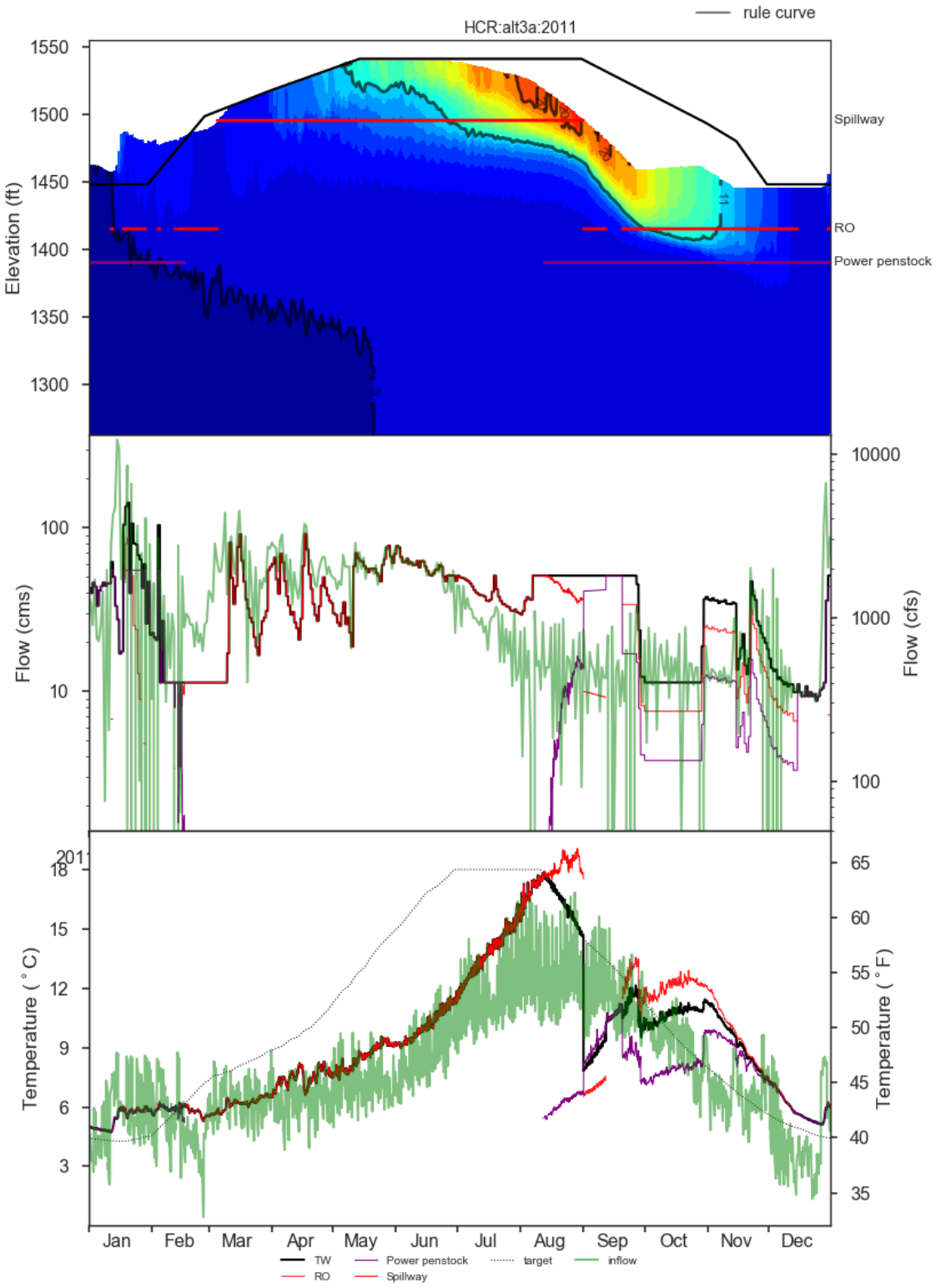


Figure 1-237. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3a in 2011.

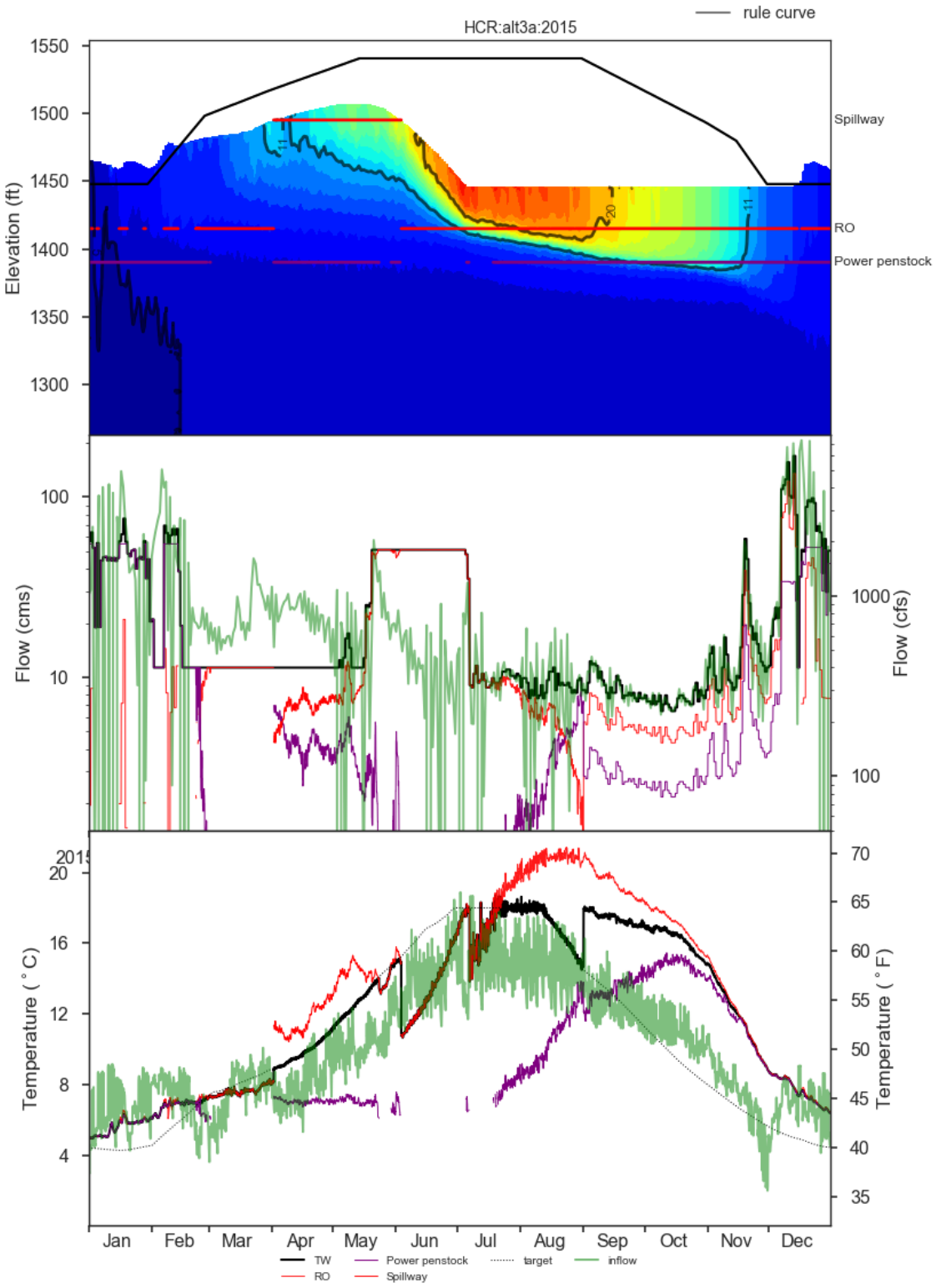


Figure 1-238. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3a in 2015.

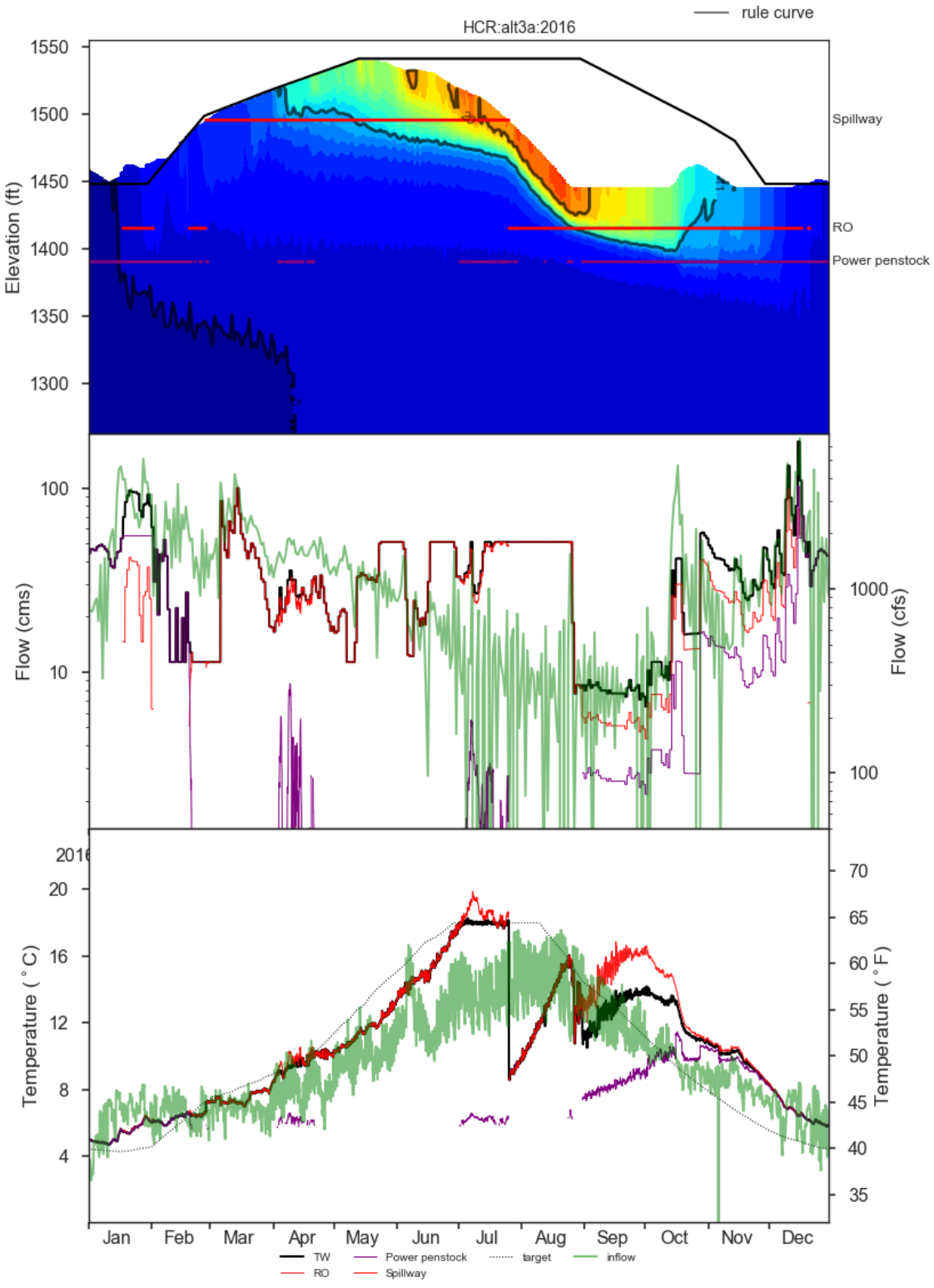


Figure 1-239. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3a in 2016.

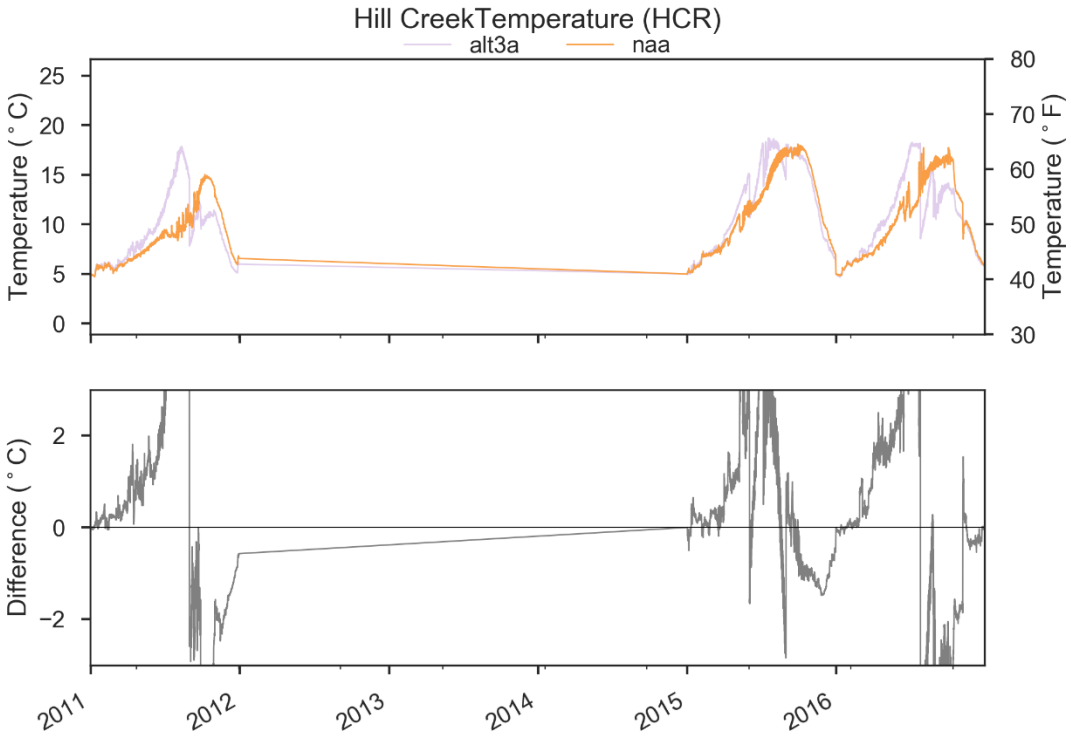


Figure 1-240. Comparison of HCR Outflow Temperatures in NAA and Alternative 3a.

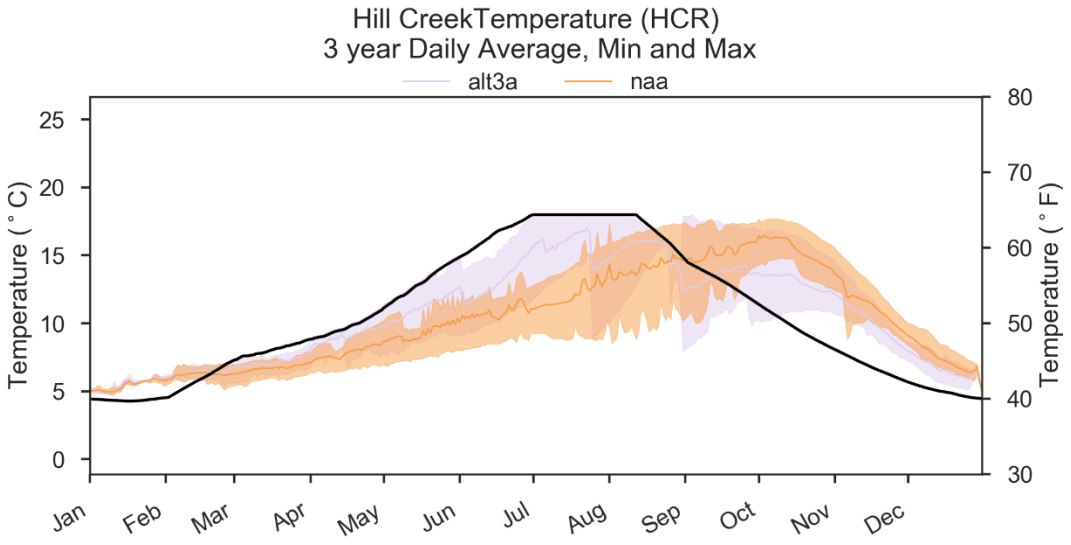


Figure 1-241. Comparison of HCR 3-year Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target.

1.5.5.4.2 Lookout Point

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Lookout Point decreased in Alternative 3a compared to NAA in 2011, 2015 and 2016 as the lake was drafted for the proposed fish passage operation through the ROs (Figure 1-242, Figure 1-243, and Figure 1-244). The decreased storage generally coincided with reduced outflows during May-October comparing Alternative 3a to NAA (Figure 1-244).

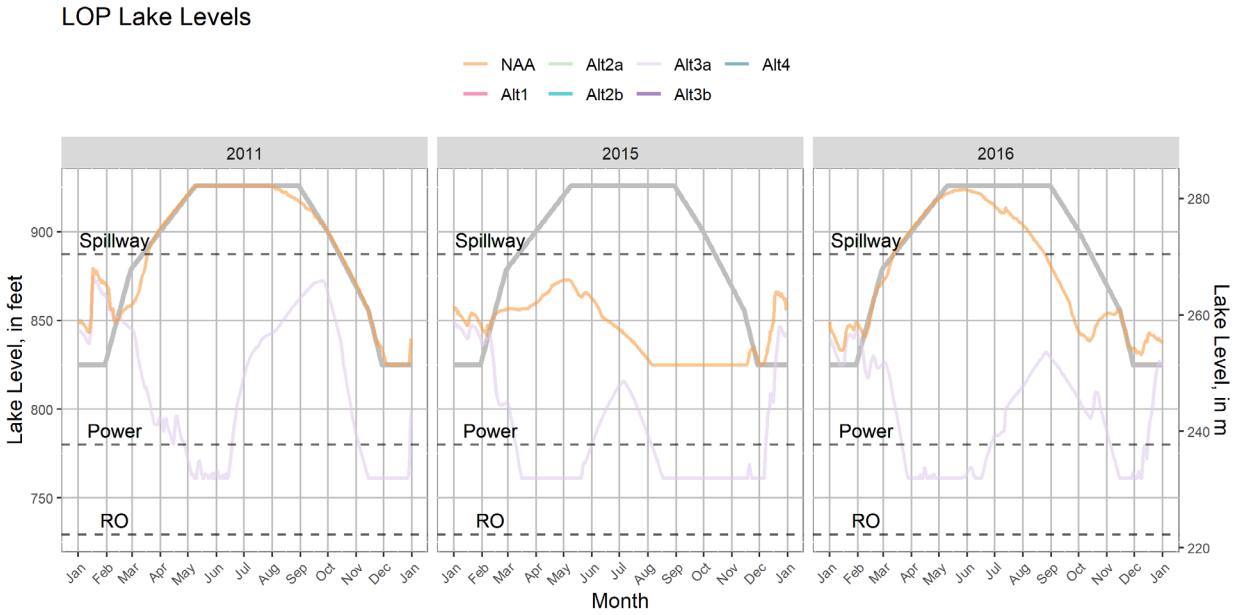


Figure 1-242. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA.

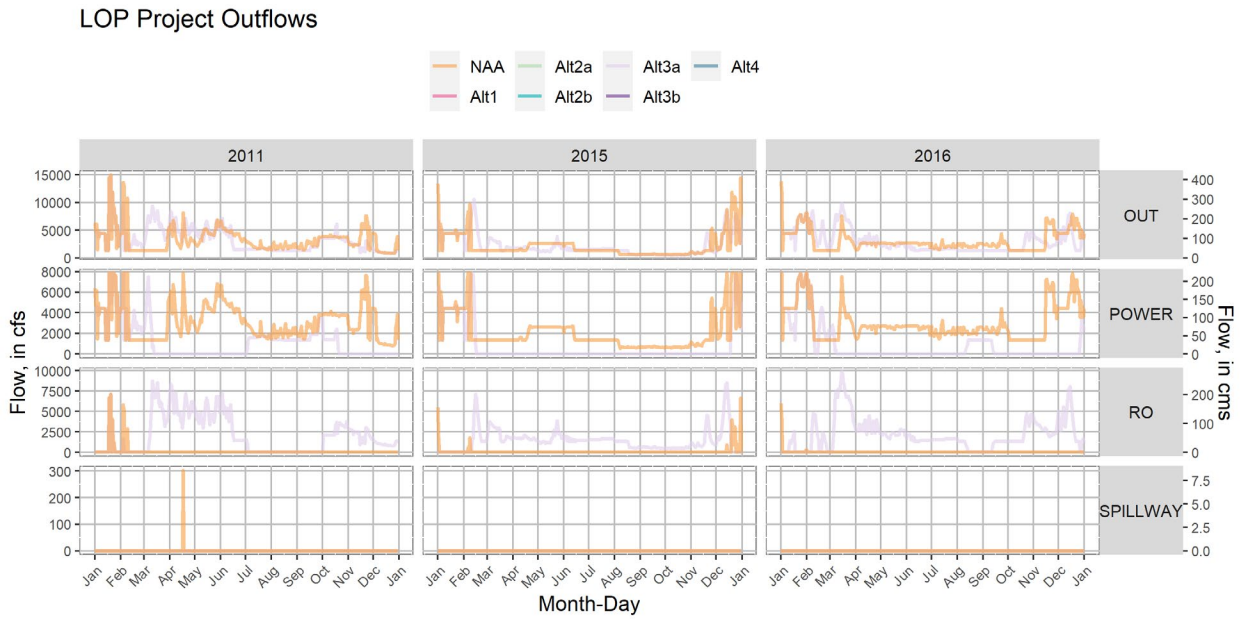


Figure 1-243. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3a and NAA.

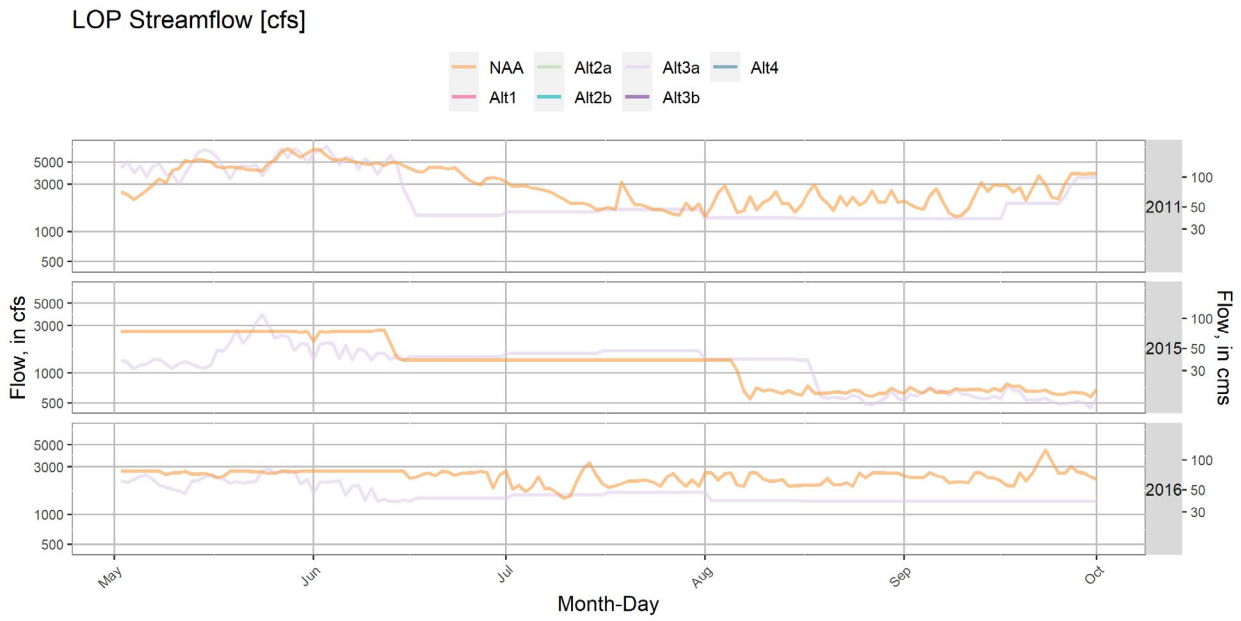


Figure 1-244. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Lookout Point Lake are shown in Figure 1-245, Figure 1-246, and Figure 1-247. Outflow temperatures from Lookout Point Dam in Alternative 3a were generally warmer than NAA May-September and cooler than NAA October-December in 2011, 2015, and 2016 as the lake surface area, volume, and residence time was decreased and releases were primarily made through the ROs for fish passage operations (Figure 1-248, Figure 1-249).

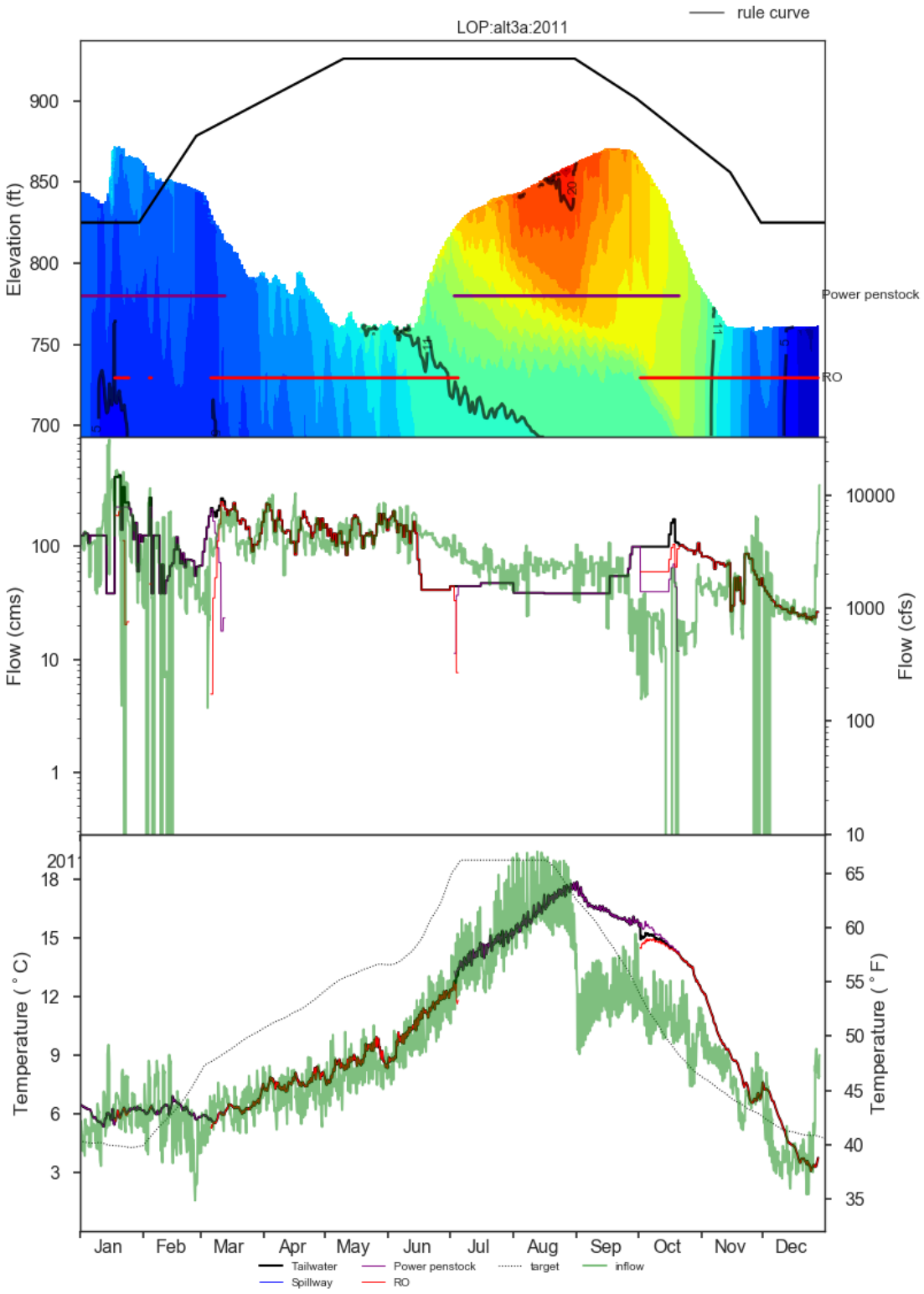


Figure 1-245. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3a in 2011.

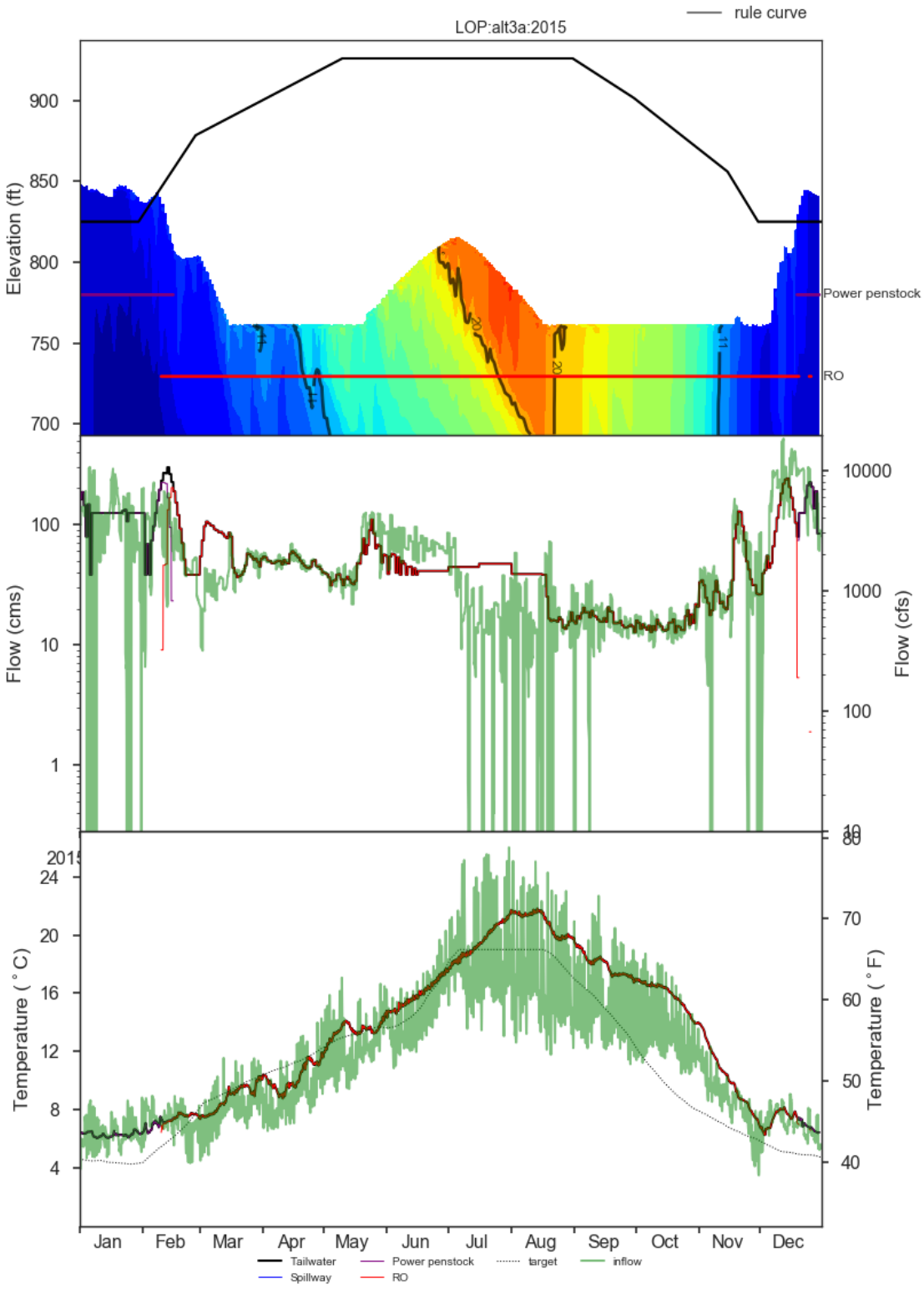


Figure 1-246. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3a in 2015.

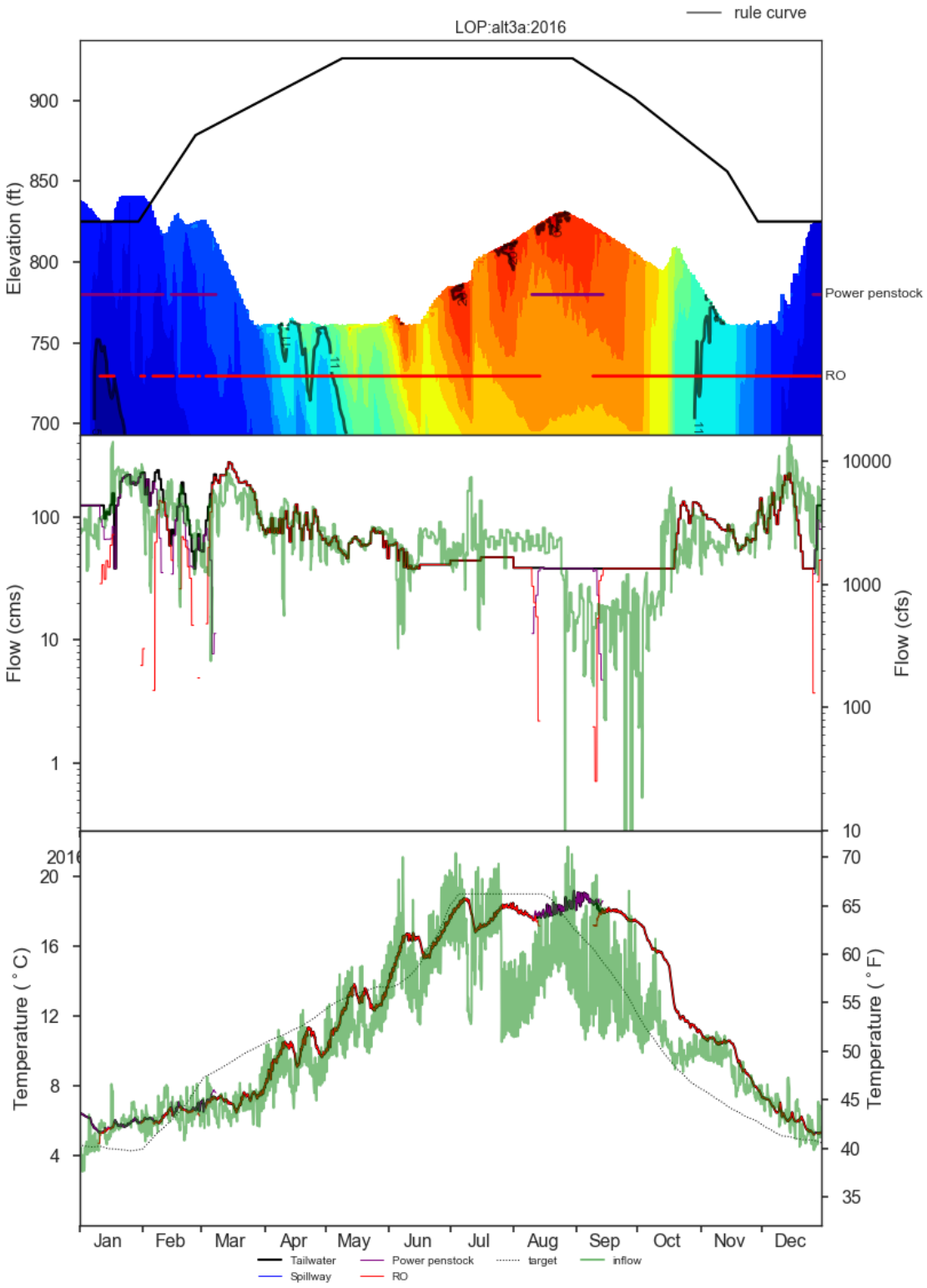


Figure 1-247. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3a in 2016.

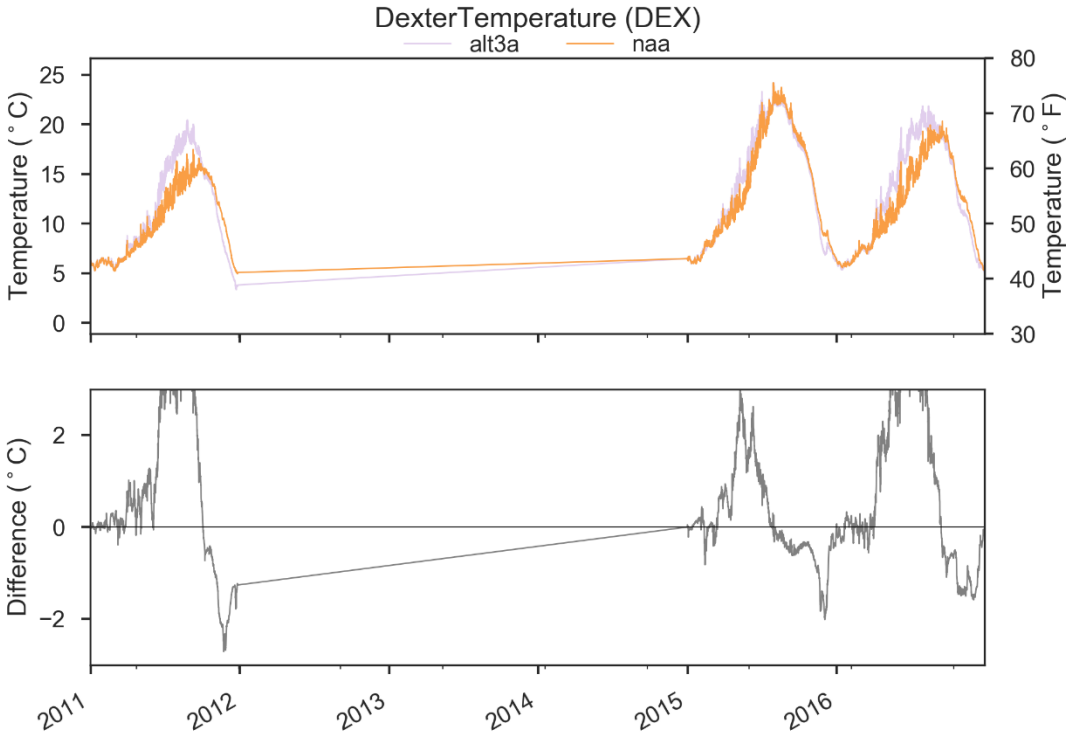


Figure 1-248. Comparison of DEX Outflow Temperatures in NAA and Alternative 3a.

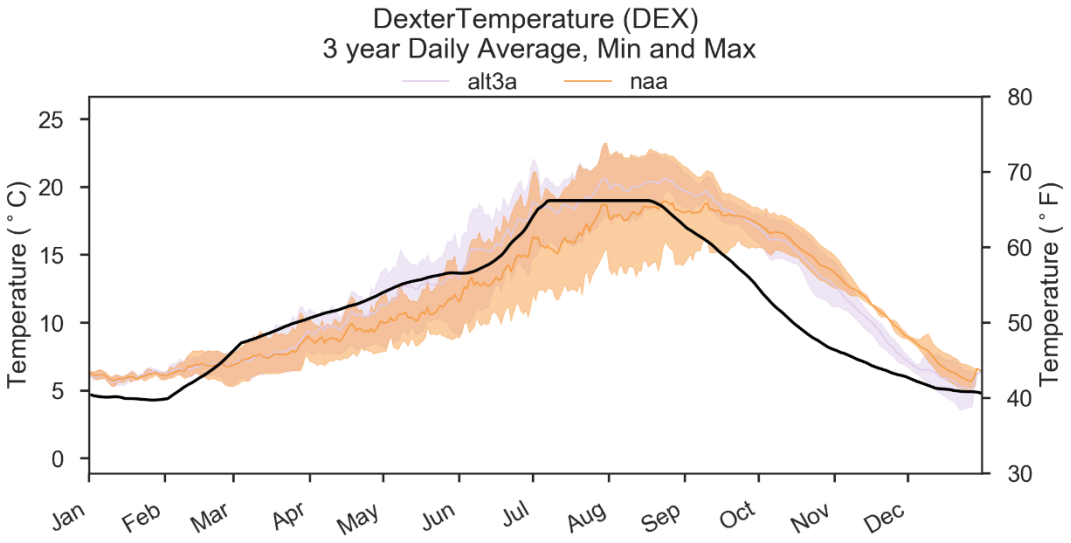


Figure 1-249. Comparison of DEX 3-year Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target.

1.5.5.5 Mainstem Willamette River

Streamflow under Alternative 3a was generally lower than NAA (Figure 1-250). The exception to this result was in 2015, where flow differences were generally lower April to mid-June and higher from mid-June to mid-September compared to NAA, likely due to Measure 30 rules that increase dam outflows in advance of heat wave events (Figure 1-251). These flow changes resulted in warmer water temperatures from April until mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (Figure 1-252, Figure 1-253). Water temperatures at Salem were also affected by upstream dam operations, which likely contributed to warmer temperatures when comparing Alternative 3a to NAA. Overall water temperature differences between Alternative 3a and NAA were less than 2 degrees Celsius.

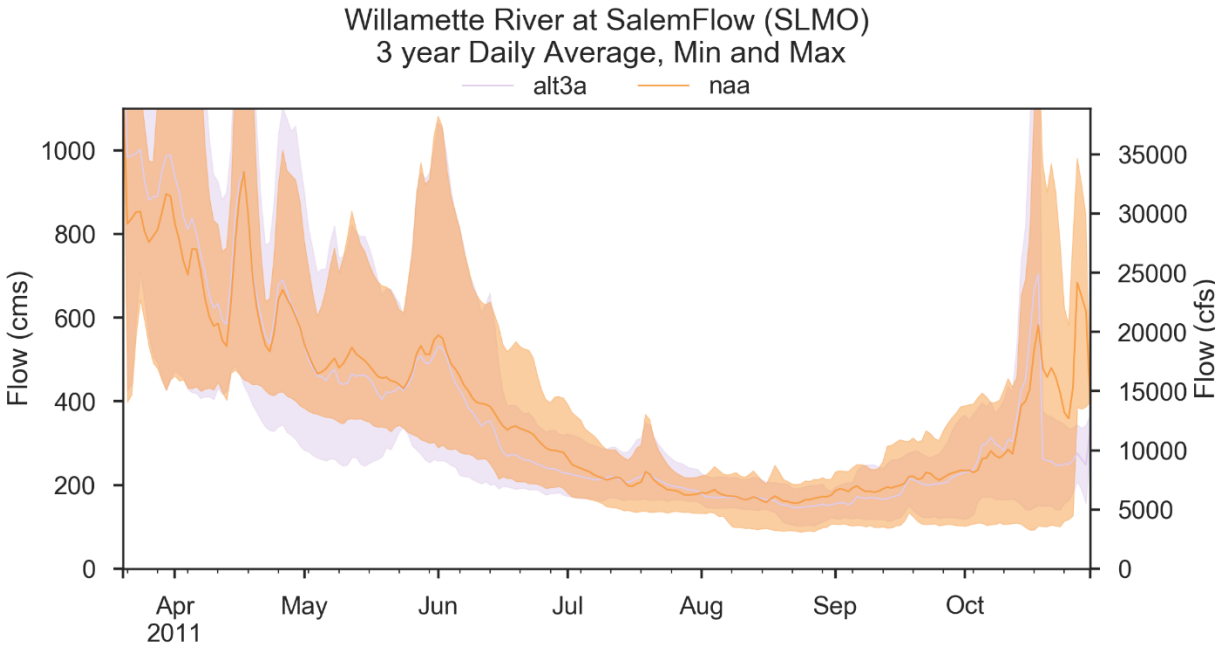


Figure 1-250. Streamflow Comparison of Average, Min, Max Willamette River at SLMO under NAA and Alternative 3a Conditions.

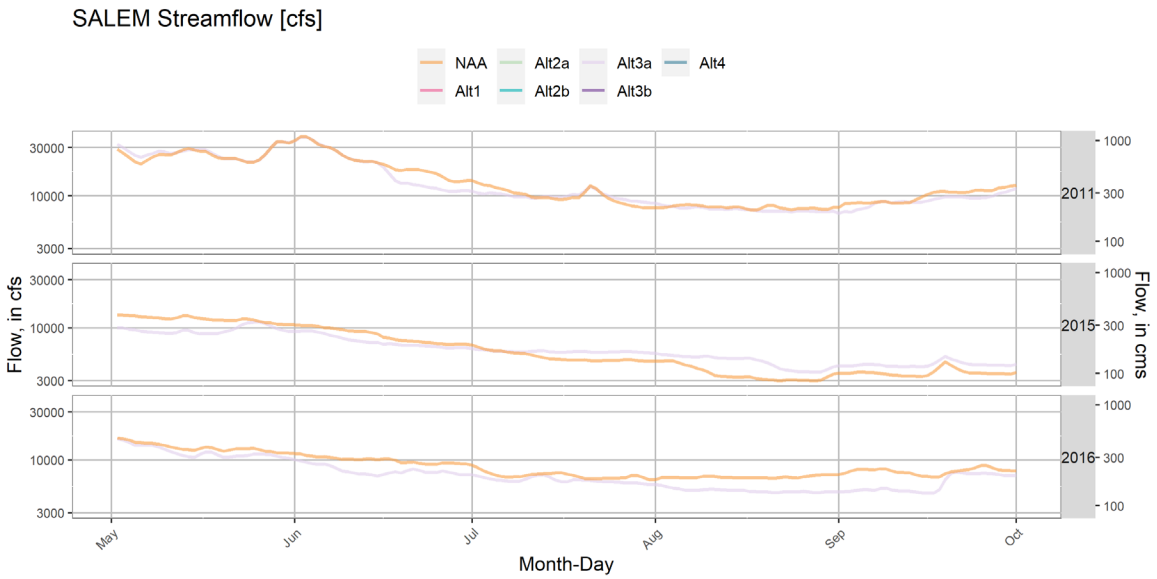


Figure 1-251. Streamflow Comparison Between Alternative 3a and NAA at Willamette River at SLMO.

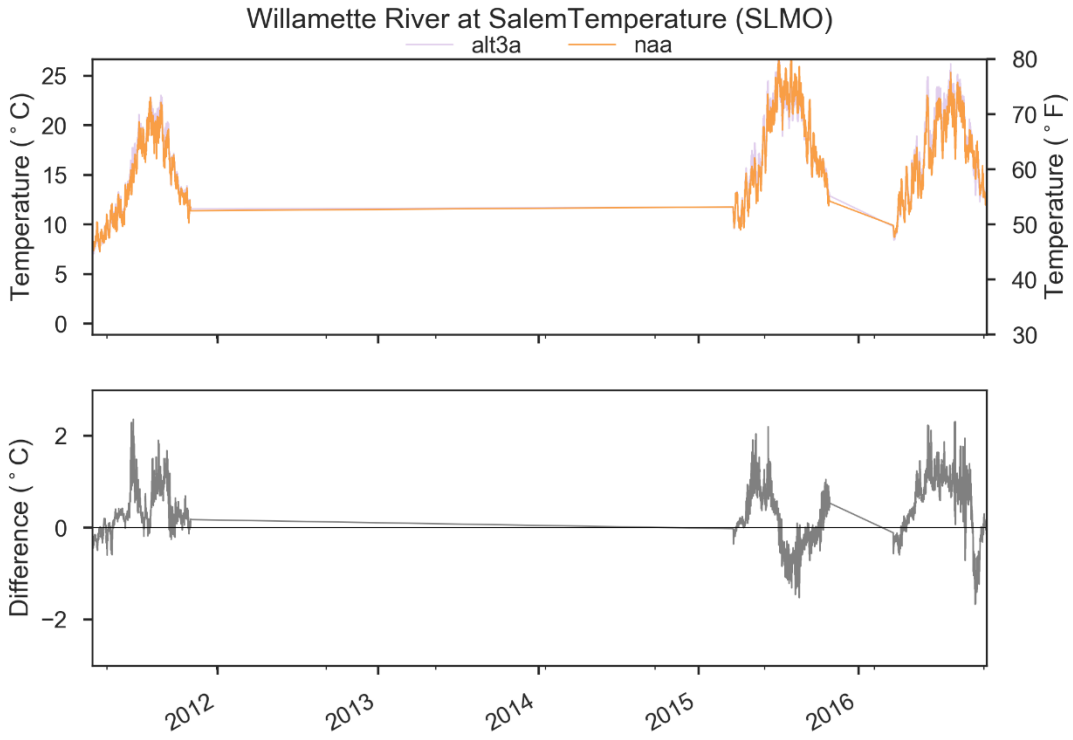


Figure 1-252. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 3a.

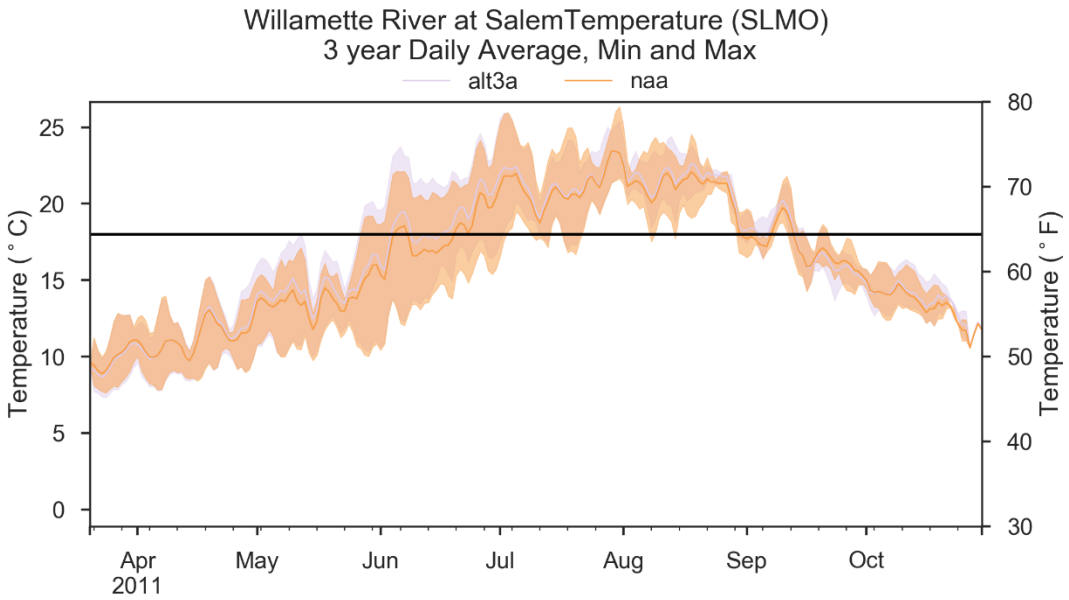


Figure 1-253. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a.

1.5.6 Alternative 3b – Operations-Focused Fish Passage Alternative (using diversion tunnel at COU)

Alternative 3b measures that affected operations, lake storage, and water temperature included:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.
- Spring drawdown operations at Hills Creek, Green Peter, and Cougar (to the diversion tunnel)
- Fall drawdown operations to lowest level possible given operational constraints at Blue River, Hills Creek, Green Peter, Detroit, Lookout Point and Cougar.
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.

1.5.6.1 North Santiam Dams

1.5.6.1.1 Detroit

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Detroit were generally similar in Alternative 3b and NAA in 2011, 2015, and 2016 aside from October-November during drawdown to the UROs for fish passage (Figure 1-254, Figure 1-255, and Figure 1-256). Some increased storage in 2015 coincided with reduced outflows during spring and increased outflows in July-October. 2011 and 2016 operations were generally similar in Alternative 3b and NAA at Detroit Lake January-June but followed increased outflows in July-October to draft the lake for fish passage operations through the UROs in autumn. The proposed temperature management and fish passage operation through the spillway (during spring/summer) and URO (during autumn) in Alternative 3b led to increased outflow from these outlets and decreased power outflow compared to NAA (Figure 1-255).

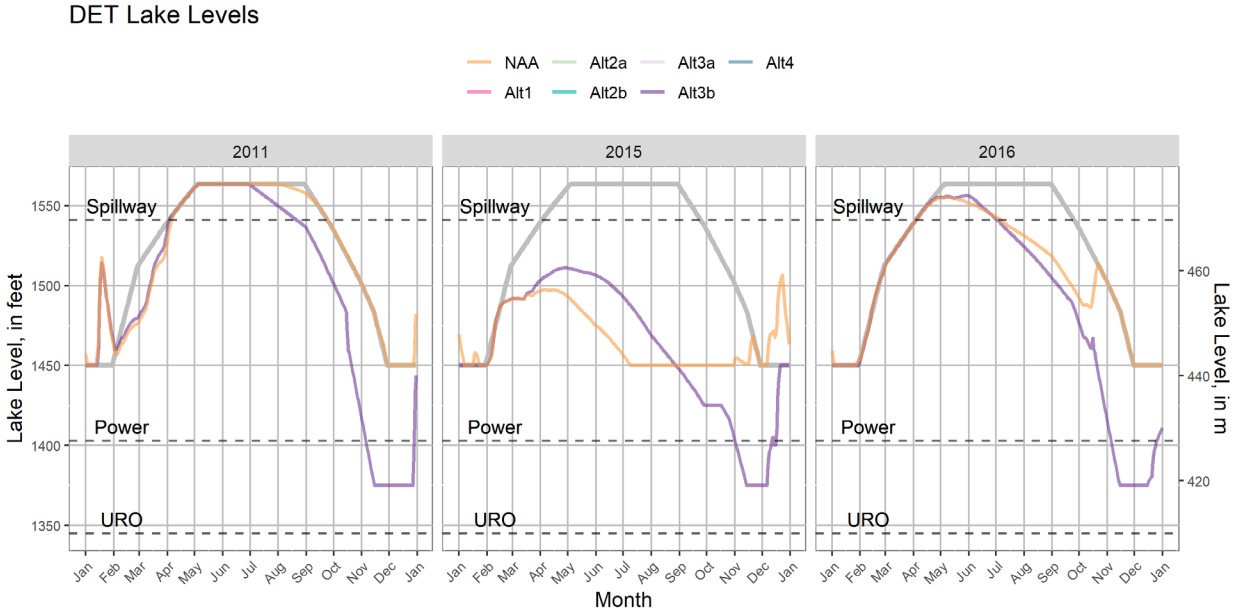


Figure 1-254. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA.

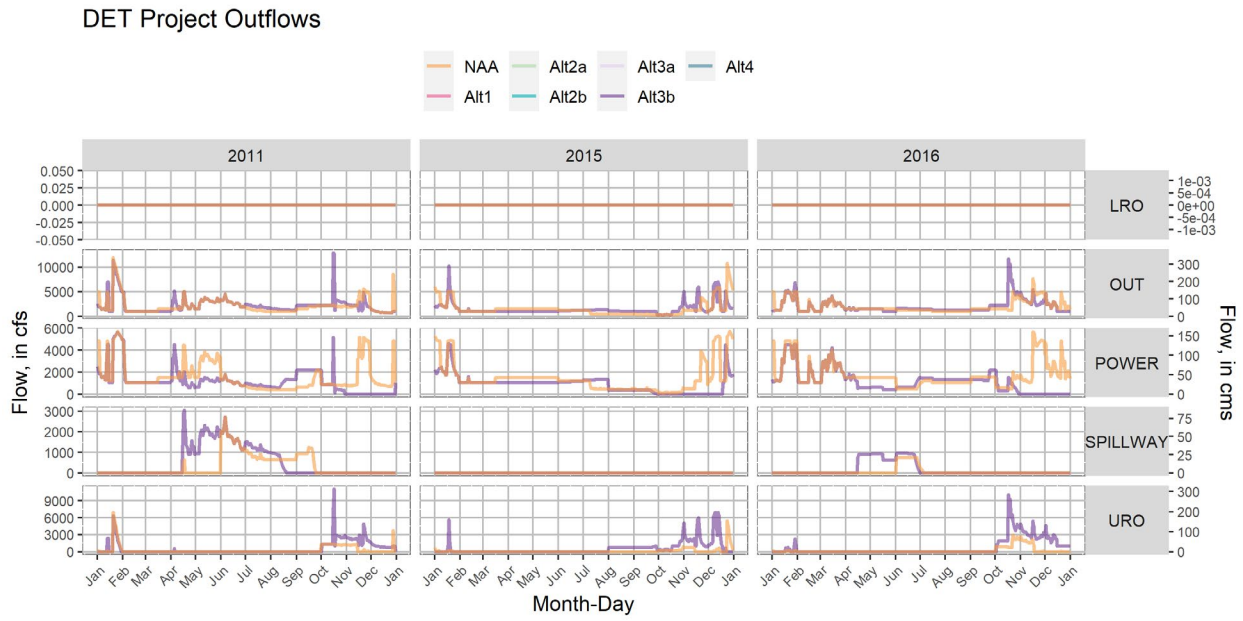


Figure 1-255. WV EIS HEC-ResSim Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 3b and NAA.

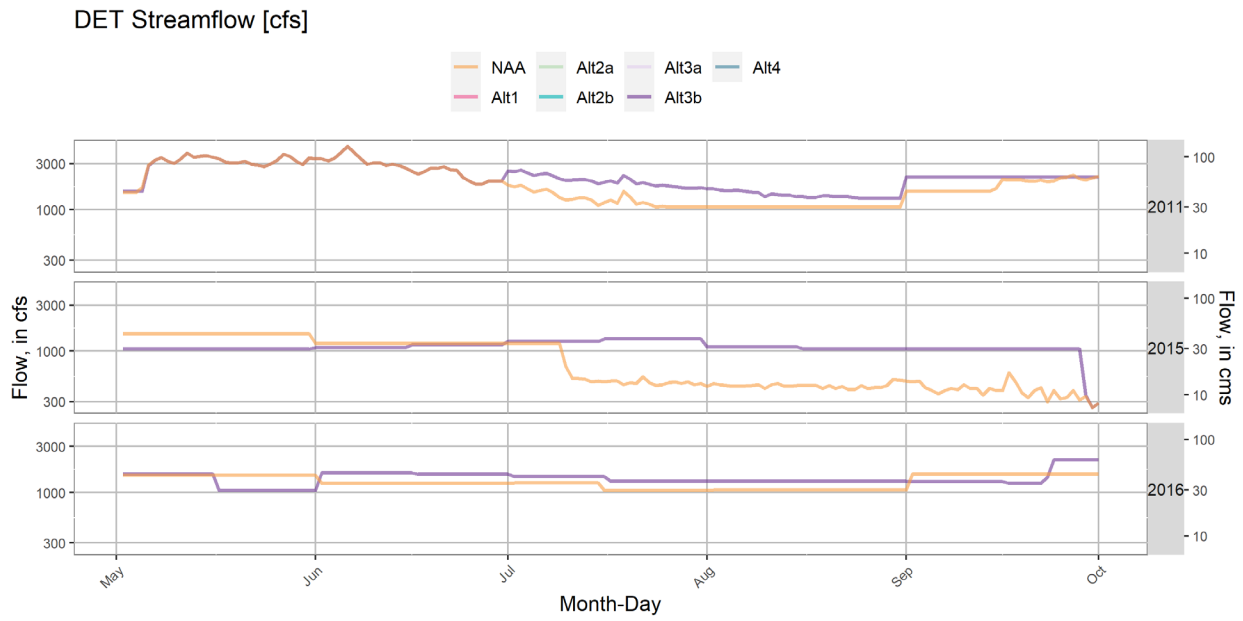


Figure 1-256. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 Under Alternative 3b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-257, Figure 1-258, and Figure 1-259. Alternative 3b included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during

autumn to mix non-power releases with relatively deep power penstock releases to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and outlets were submerged. Spillway access was not available in 2015 and was limited in 2016 and 2011, which led to an abrupt drop in tailwater temperature when spillway access ended in mid-summer. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam (Figure 1-260, Figure 1-261). Lower RO (LRO) outlets were used in Alternative 3b as the CE-QUAL-W2 attempted to blend deeper, cooler water to meet the relatively cool temperature target; typically during late-September through mid-October. Generally, the autumn fish passage operation (drawdown to about the URO level) resulted in cooler autumn temperatures (November-December) compared to NAA (Figure 1-261).

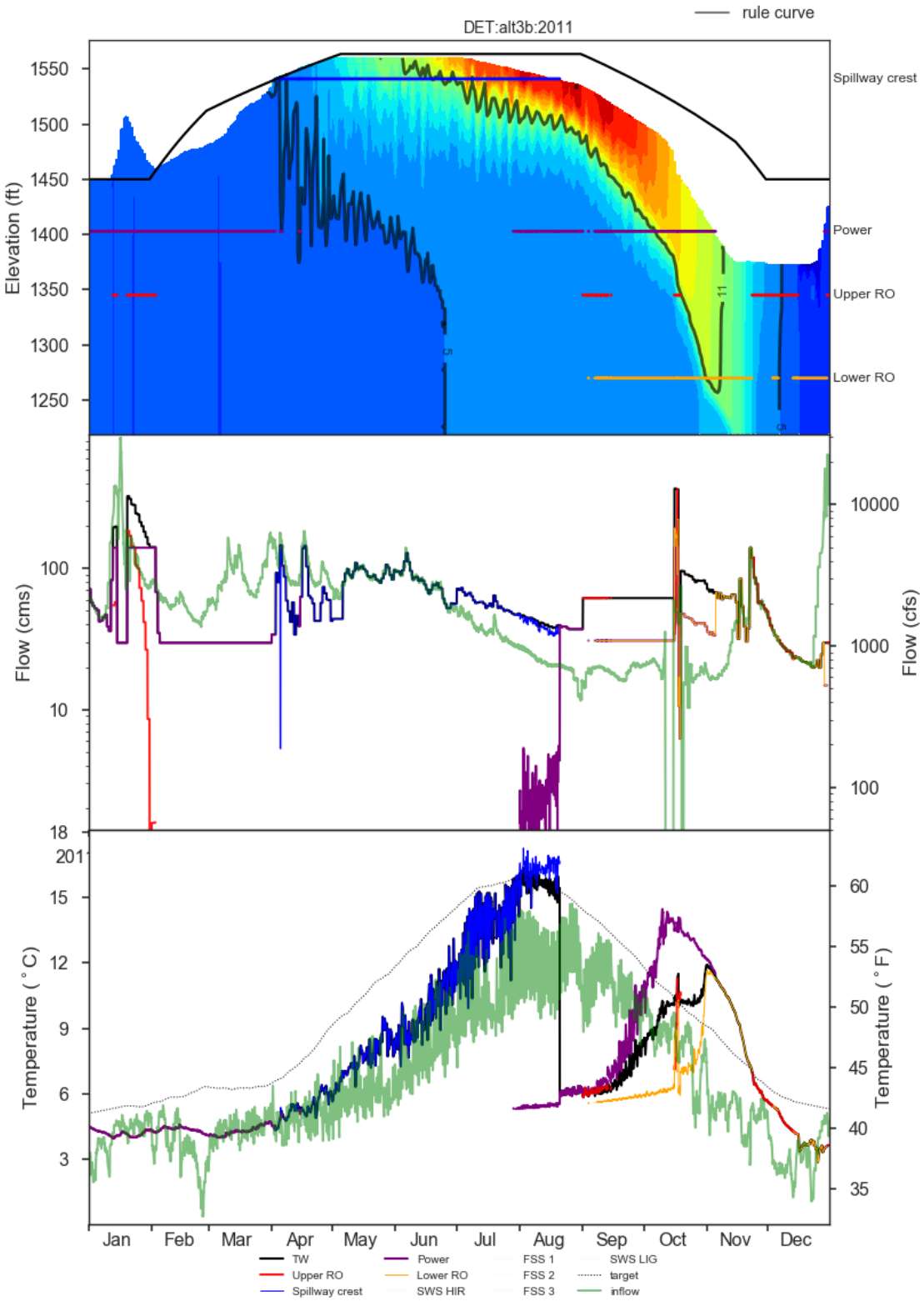


Figure 1-257. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3b in 2011.

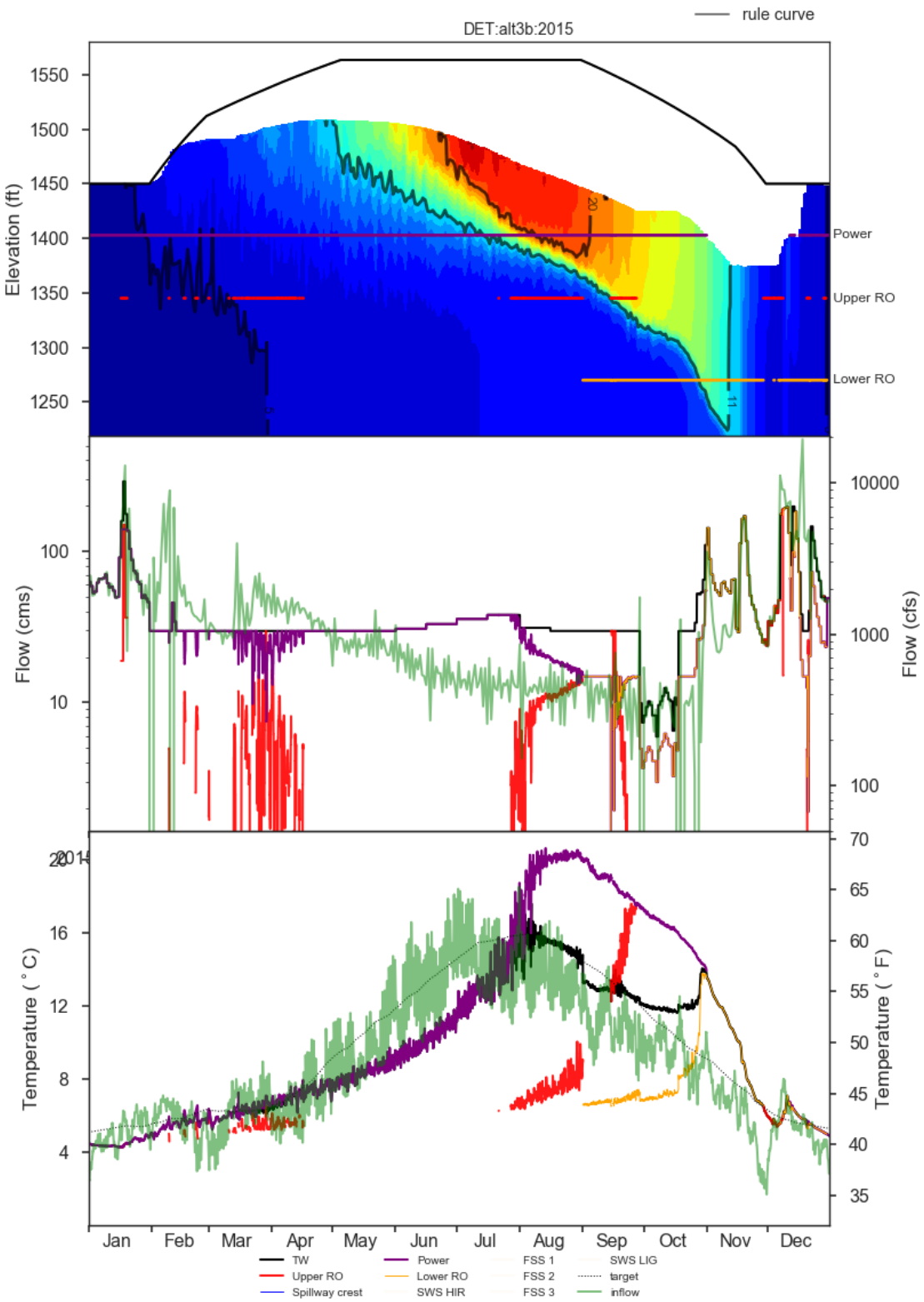


Figure 1-258. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3b in 2015.

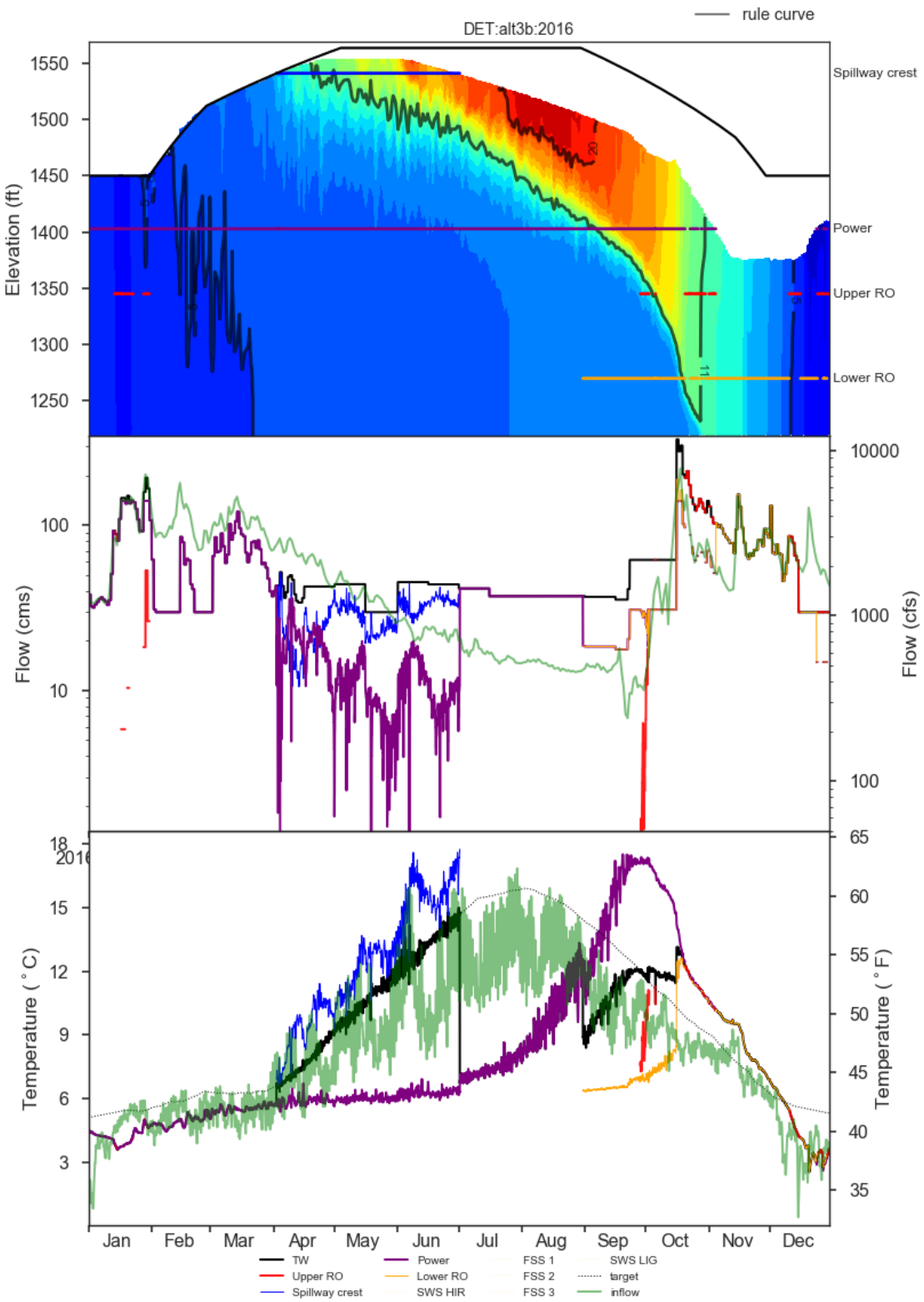


Figure 1-259. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3b in 2016.

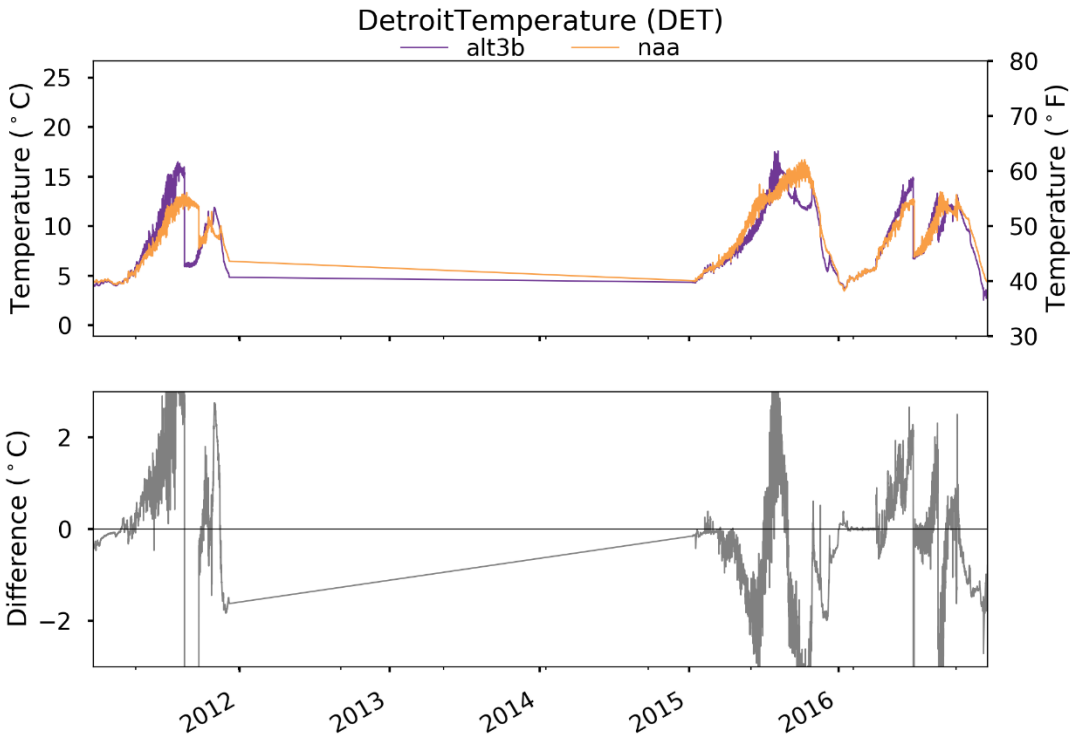


Figure 1-260. Comparison of DET outflow temperatures in NAA and Alternative 3b.

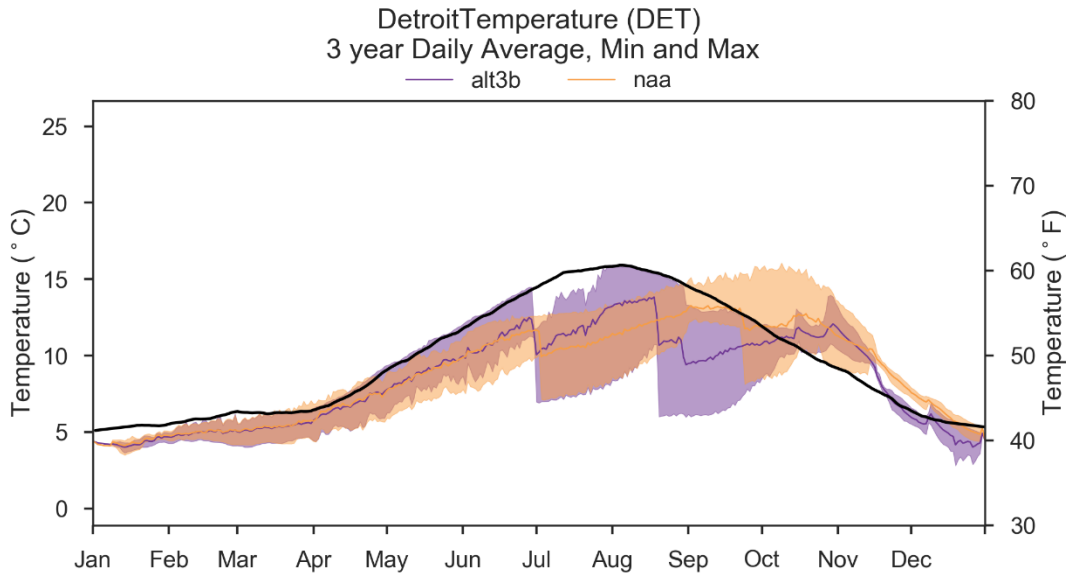


Figure 1-261. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target.

1.5.6.2 South Santiam Dams

1.5.6.2.1 Green Peter

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Green Peter Lake decreased in Alternative 3b compared to NAA in 2011, 2015 and 2016 as the lake was drafted for the proposed fish passage operation through the Ros (Figure 1-262, Figure 1-263, Figure 1-264). The decreased storage coincided with reduced outflows during May-October comparing Alternative 3b to NAA (Figure 1-264).

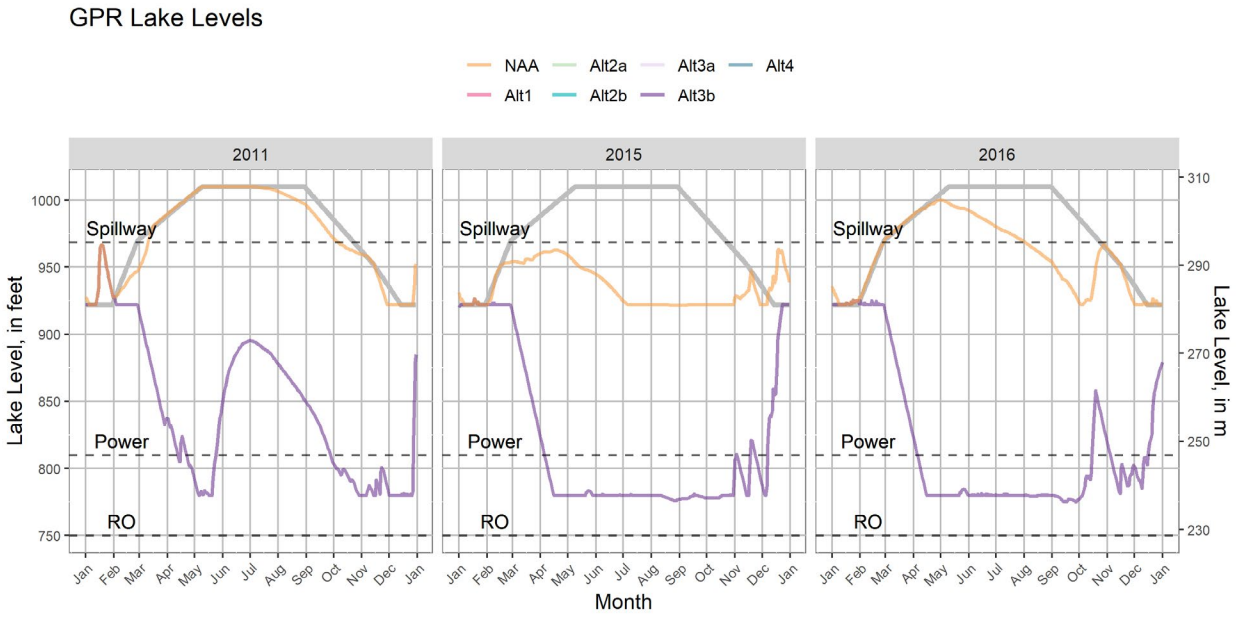


Figure 1-262. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA.

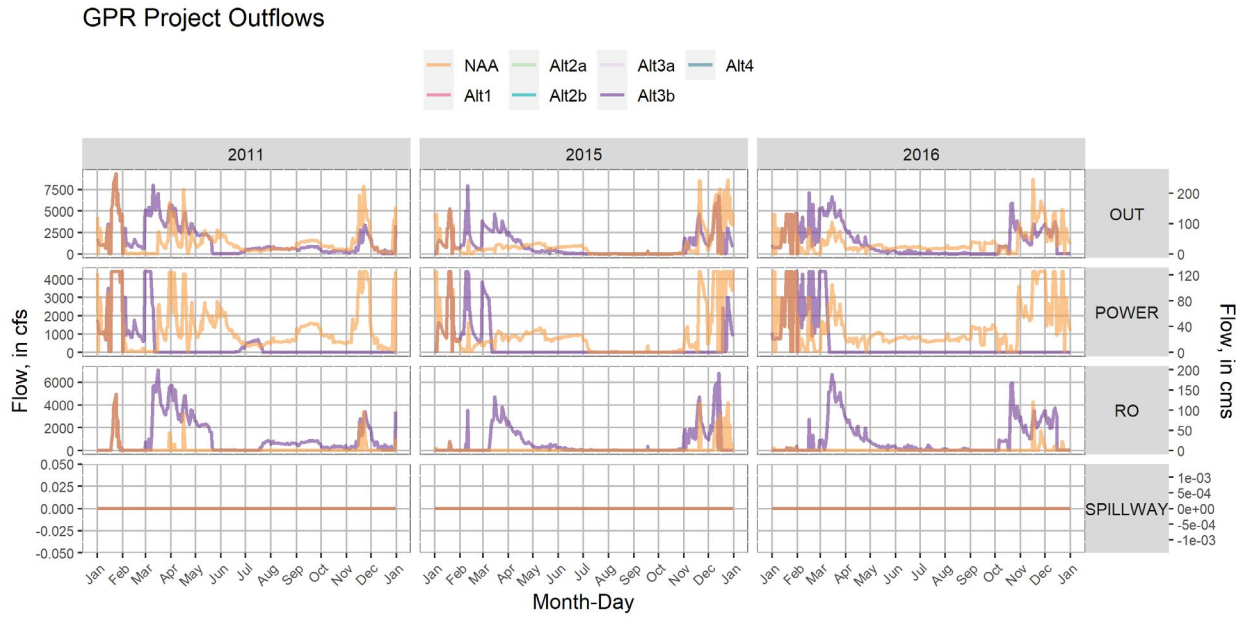


Figure 1-263. WV EIS HEC-ResSim Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA.

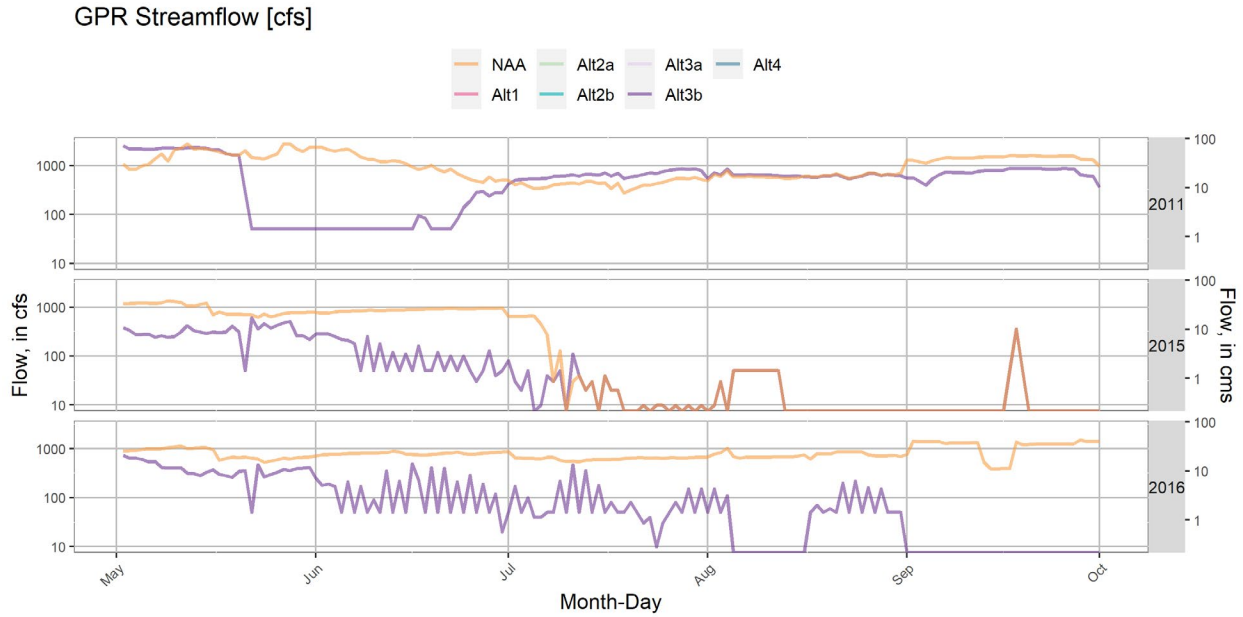


Figure 1-264. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Alternative 3b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-265, Figure 1-266, and Figure 1-267. Outflow temperatures from Green Peter Dam in Alternative 3b were generally warmer

than NAA May-September and cooler than NAA October-December in 2011, 2015, and 2016 as the lake surface area, volume, and residence time decreased and releases were generally through the Ros for fish passage operations (Figure 1-268, Figure 1-269).

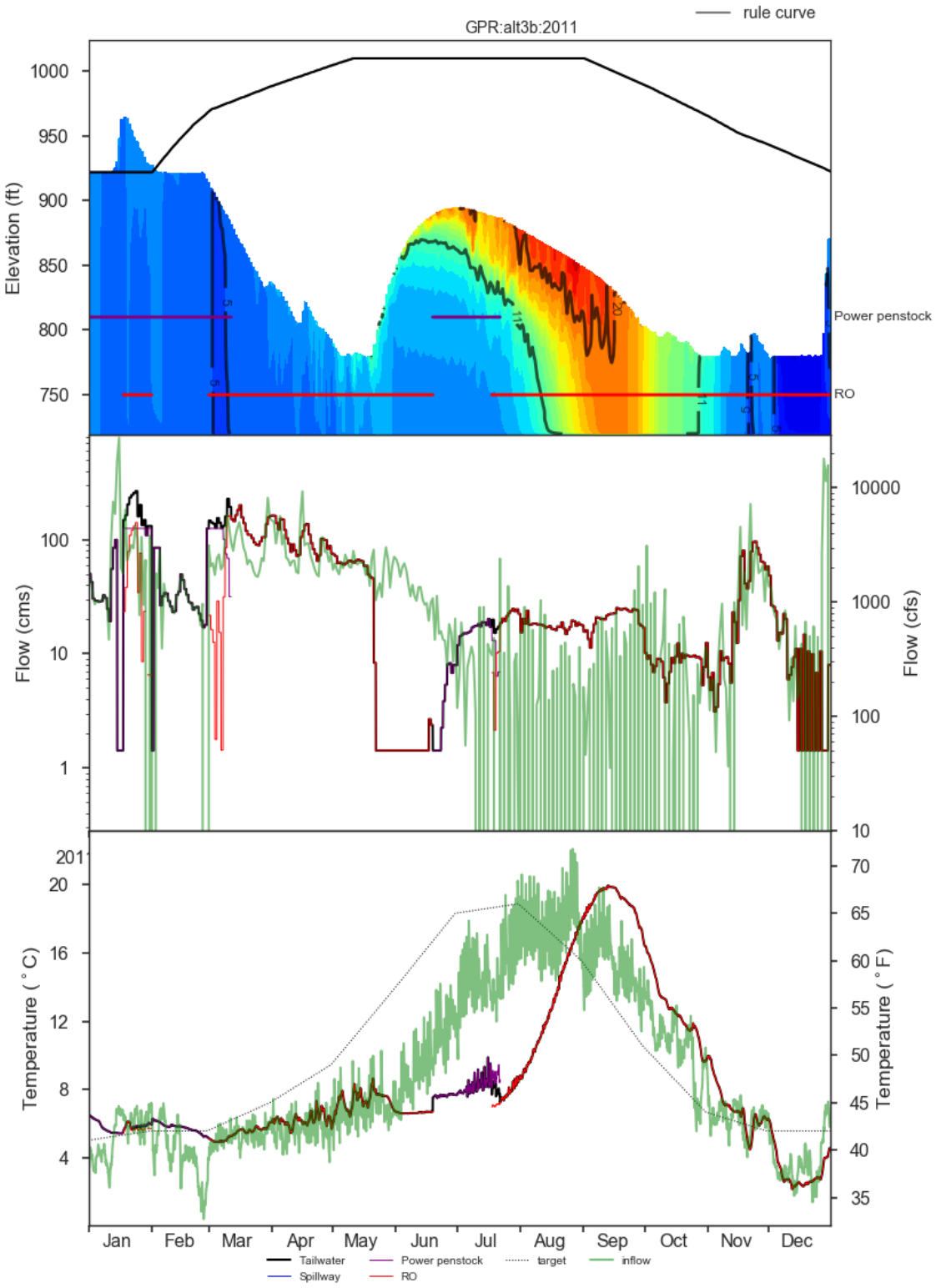


Figure 1-265. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3b in 2011.

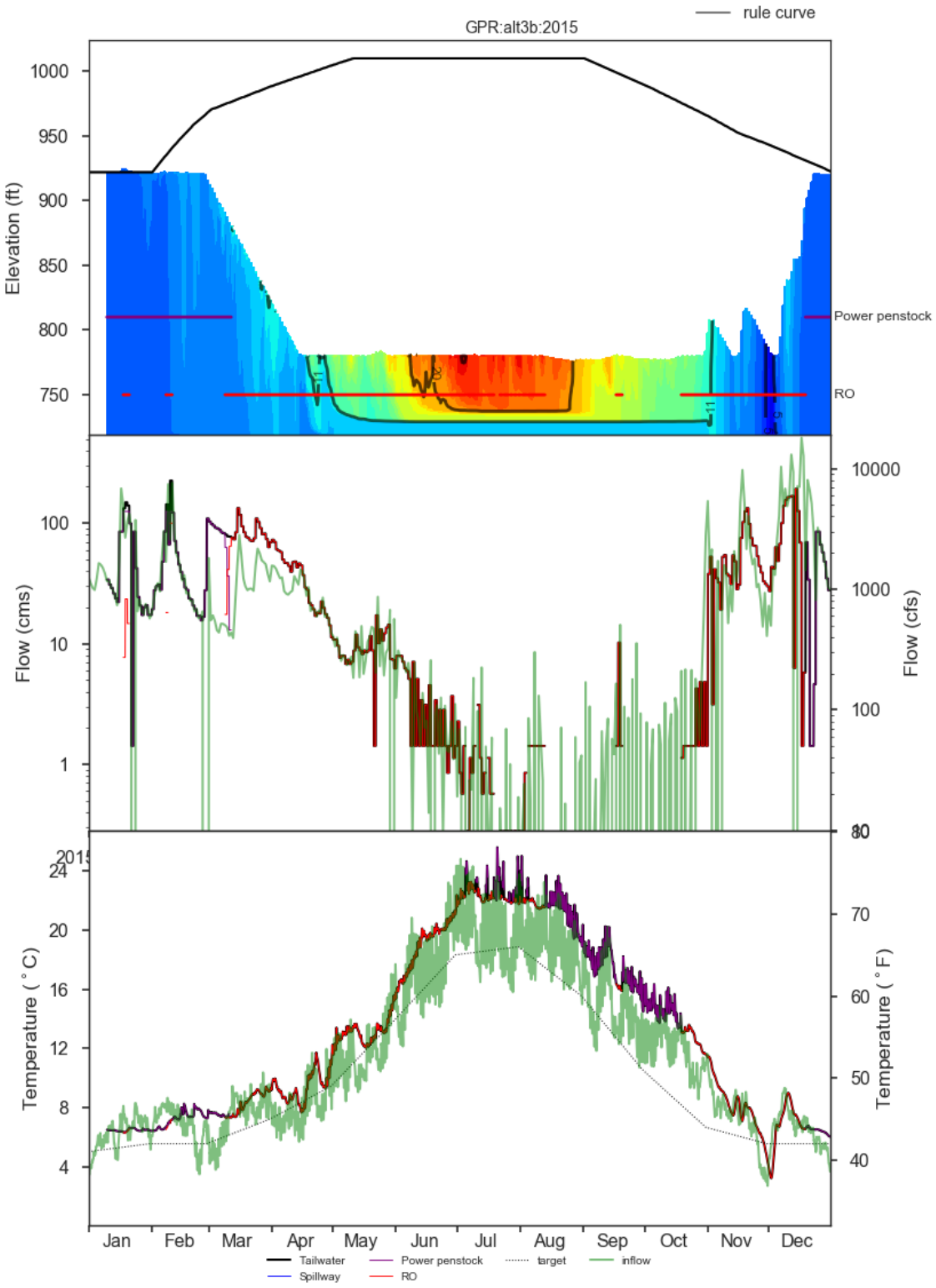


Figure 1-266. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3b in 2015.

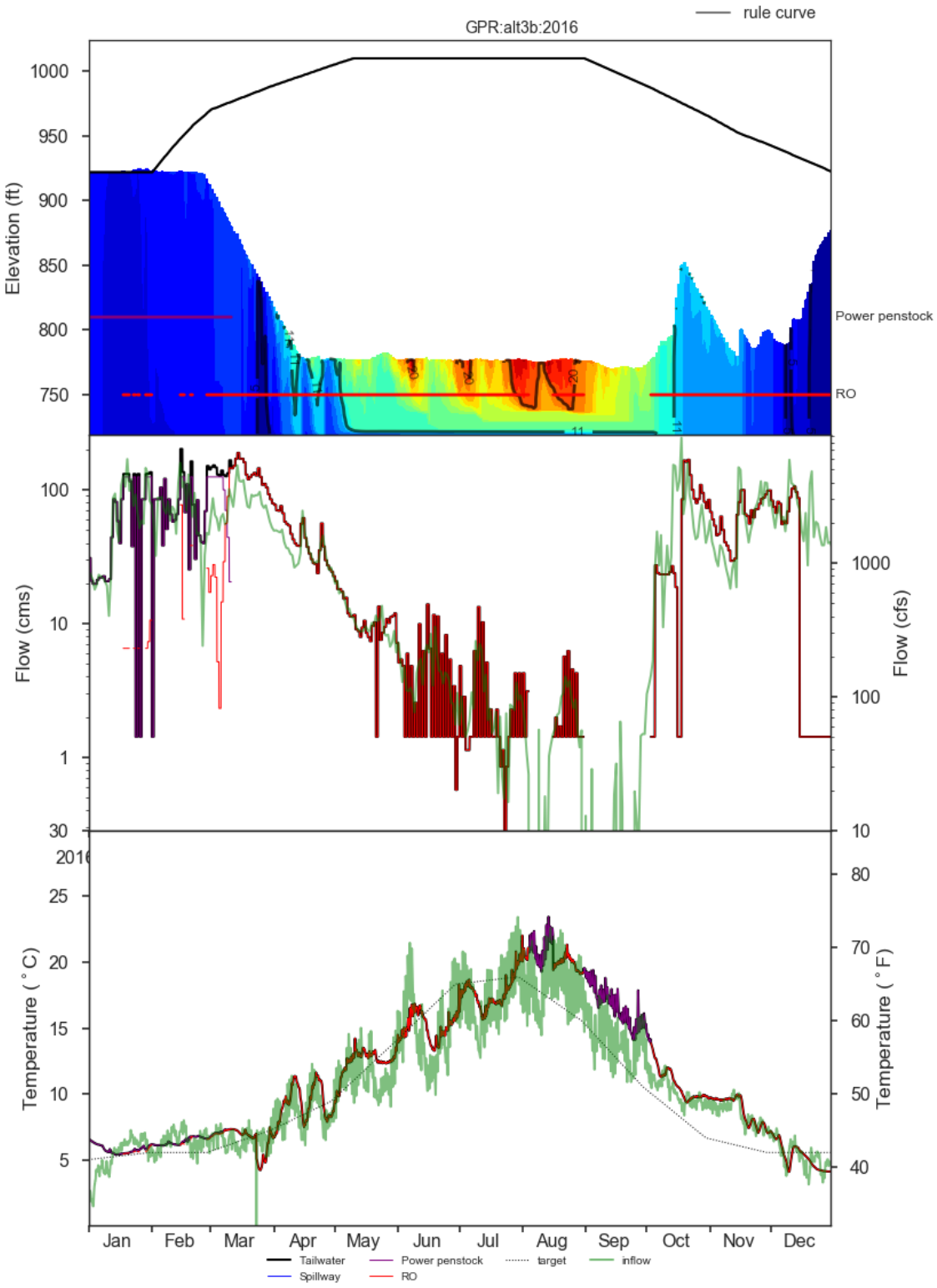


Figure 1-267. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3b in 2016.

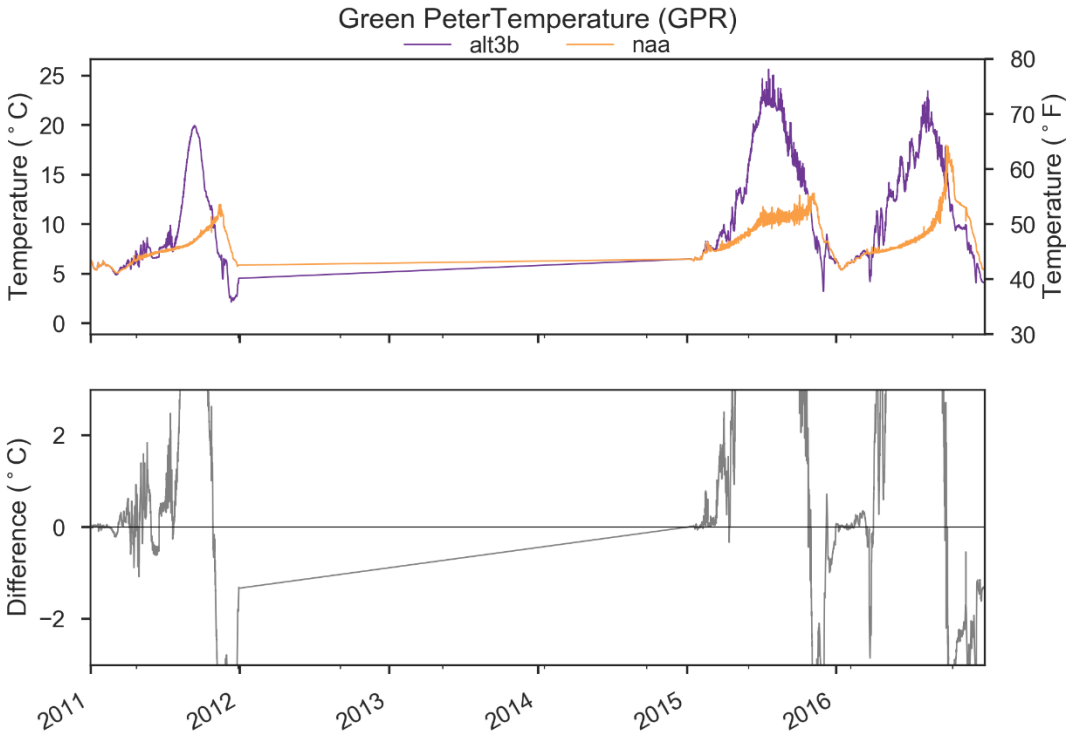


Figure 1-268. Comparison of GPR Outflow Temperatures in NAA and Alternative 3b.

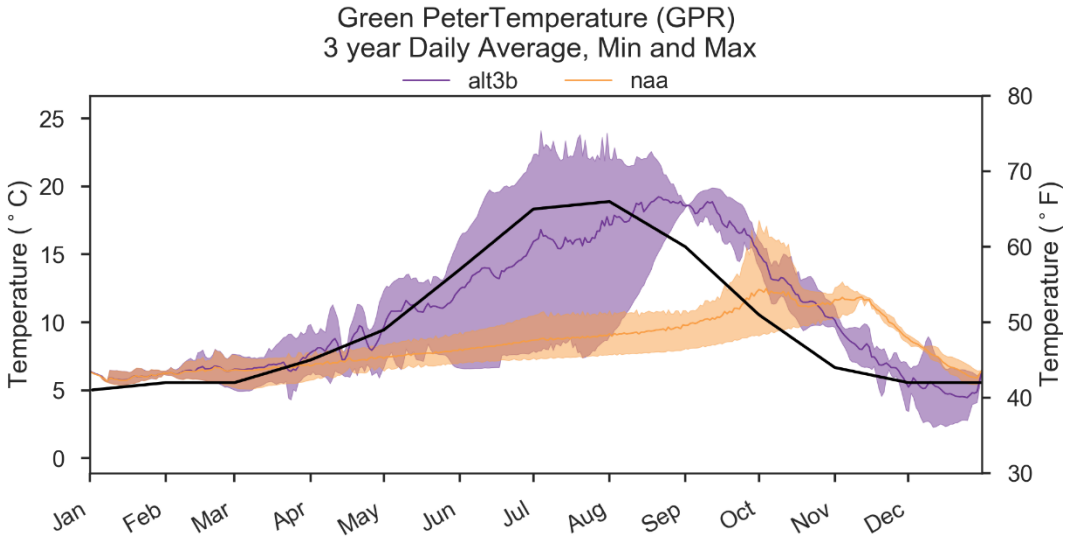


Figure 1-269. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target.

1.5.6.2.2 Foster

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Foster were generally lower in Alternative 3b compared to NAA in 2015 and 2016 but similar to NAA in 2011 (Figure 1-218, Figure 1-219, and Figure 1-220). Upstream flows from Green Peter were reduced in Alternative 3b, which resulted in early drafting of Foster Lake as HEC-ResSim rules attempted to meet downstream flow targets. Total outflow from Foster Dam generally decreased May-October in Alternative 3b compared to NAA.

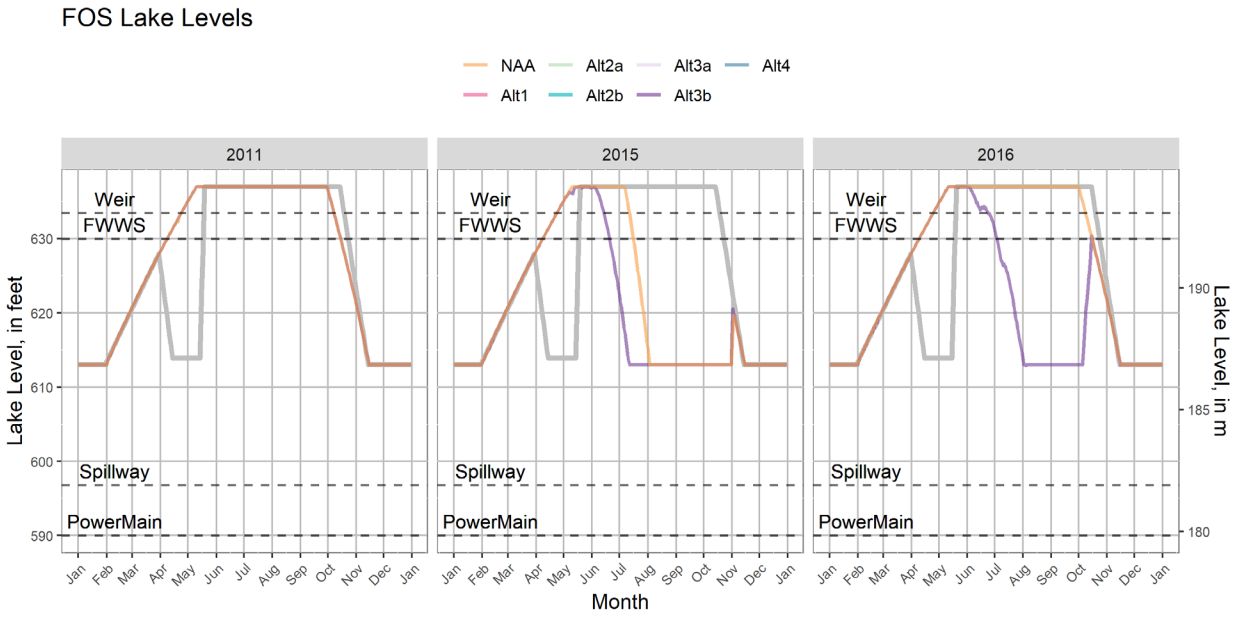


Figure 1-270. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA.

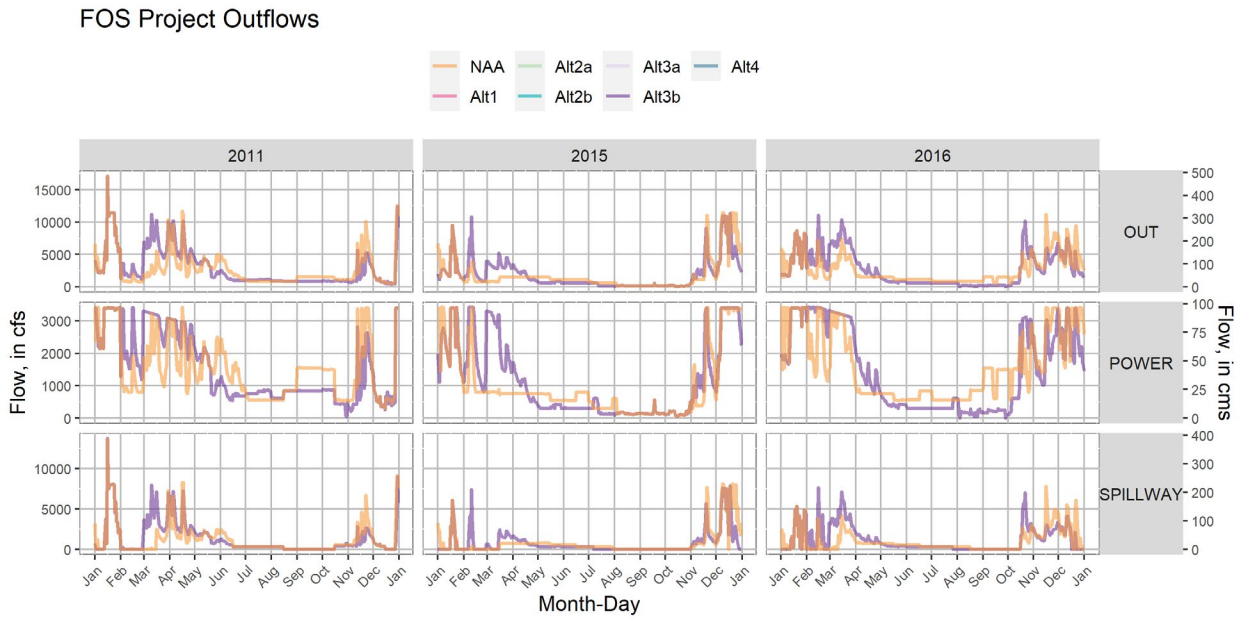


Figure 1-271. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA.

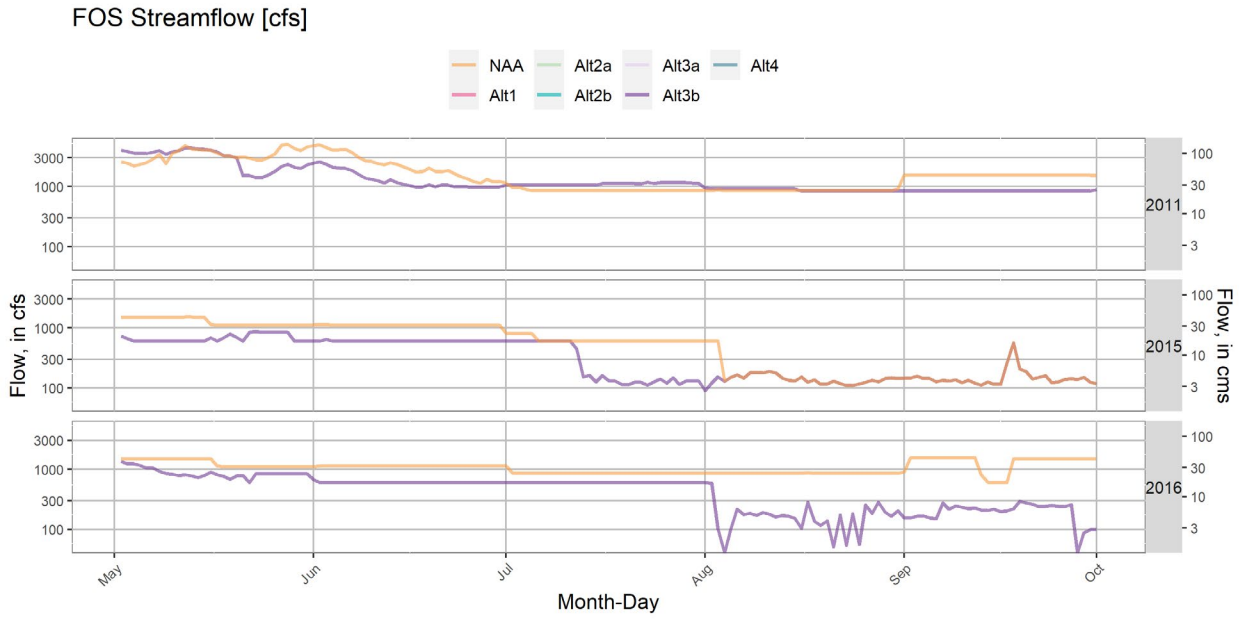


Figure 1-272. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-270, Figure 1-271, and Figure 1-272. Foster Lake temperature was affected by Green Peter Dam operations release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in

the temperature pattern (Sullivan and Rounds, 2021). Relatively warmer spillway releases from Green Peter upstream resulted in warmer tailwater temperature in May-October comparing Alternative 3b to NAA (Figure 1-273, Figure 1-274). Generally, the extended drawdown to the RO at Green Peter upstream resulted in warmer tailwater temperature in May-October and cooler autumn temperatures (November-December) compared to NAA downstream of Foster Dam.

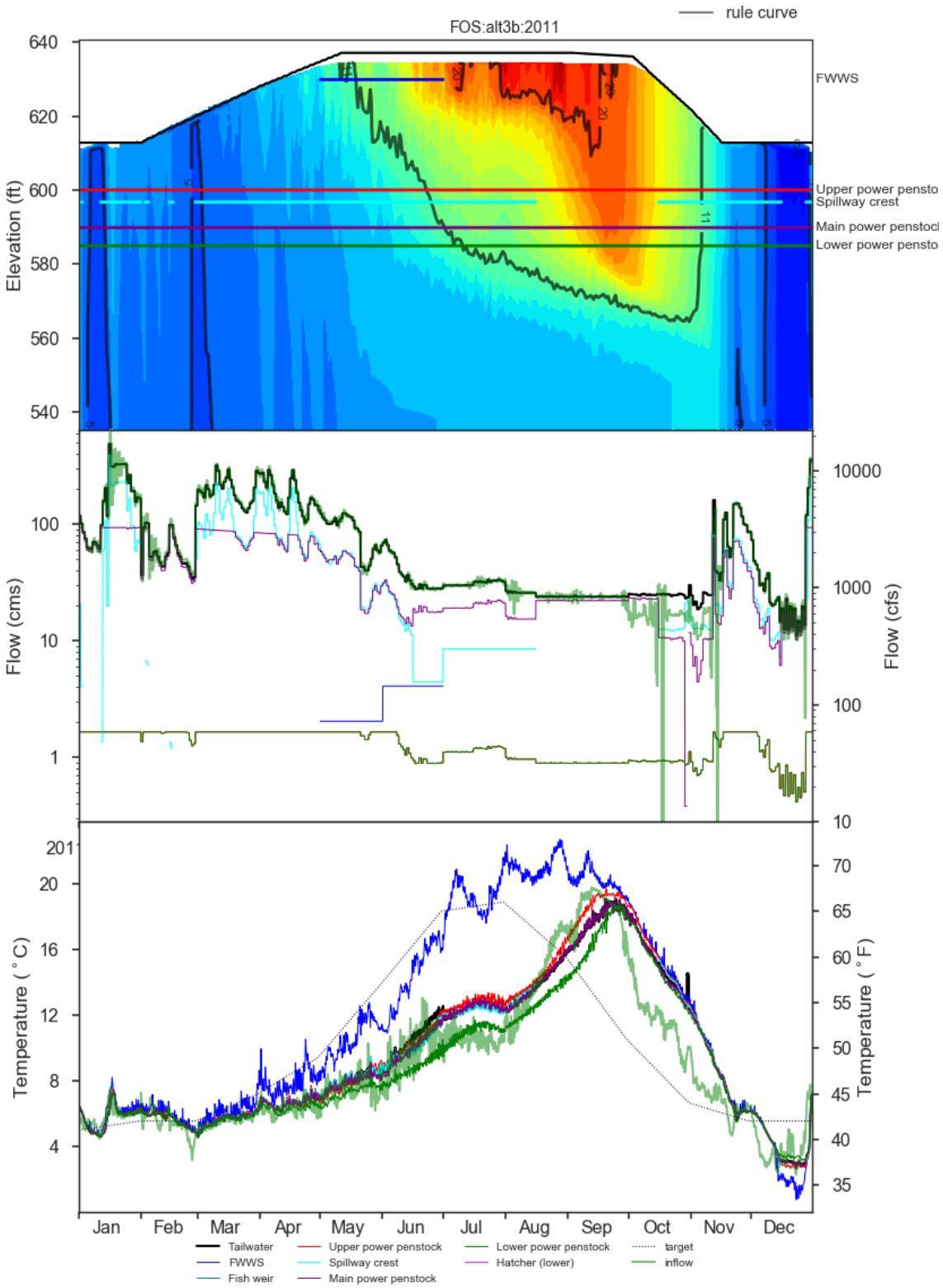


Figure 1-273. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3b in 2011.

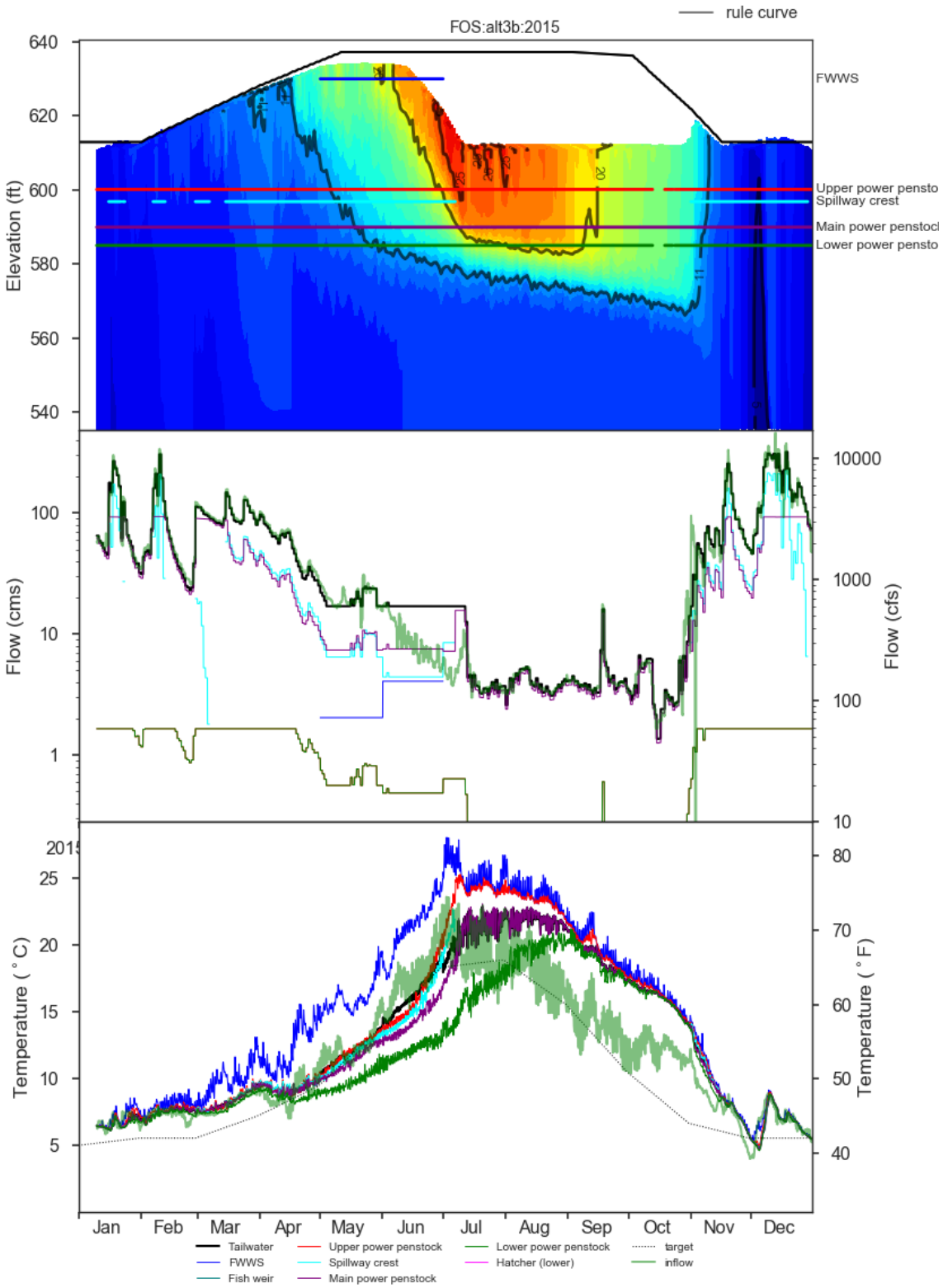


Figure 1-274. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3b in 2015.

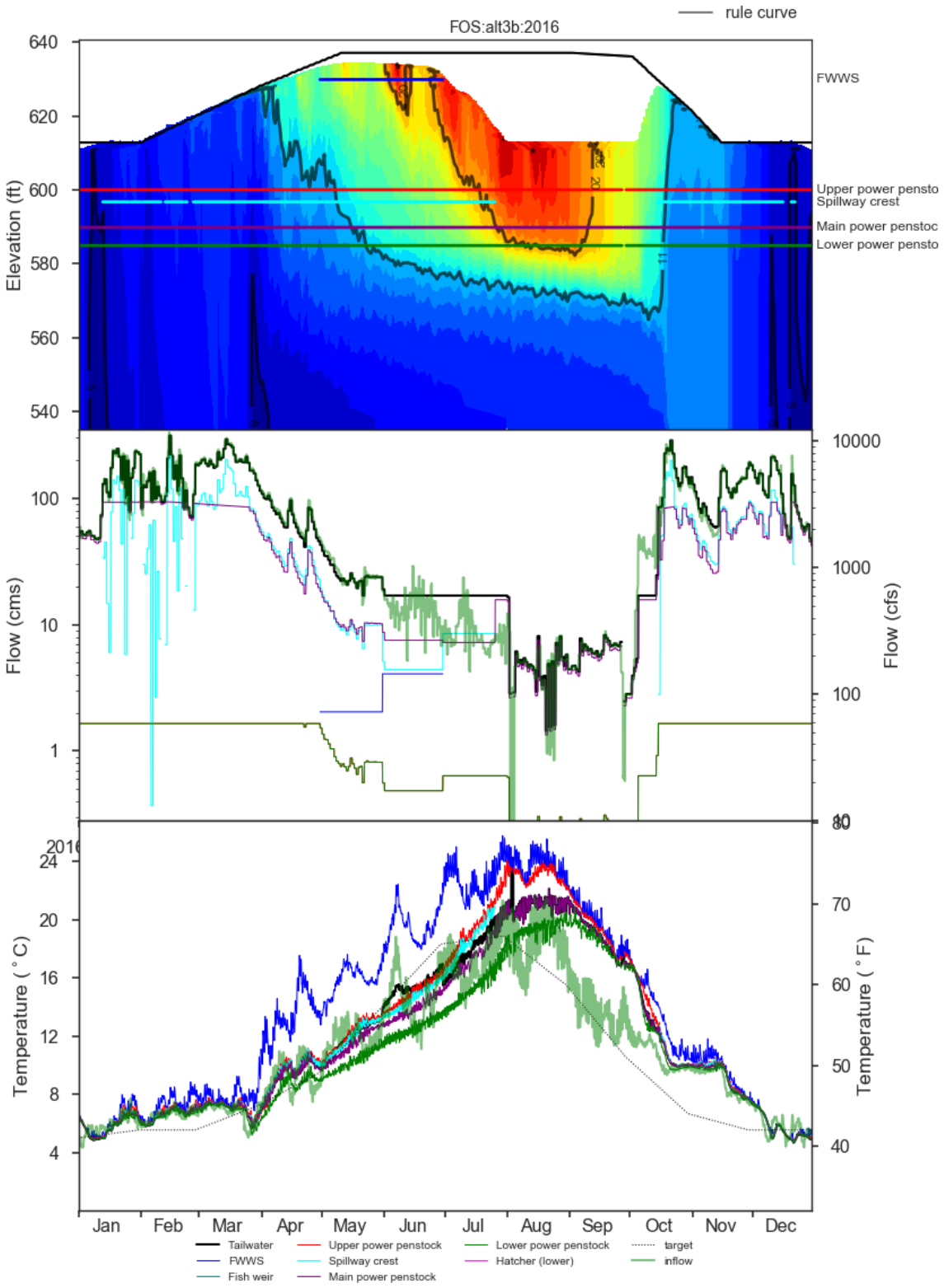


Figure 1-275. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3b in 2016.

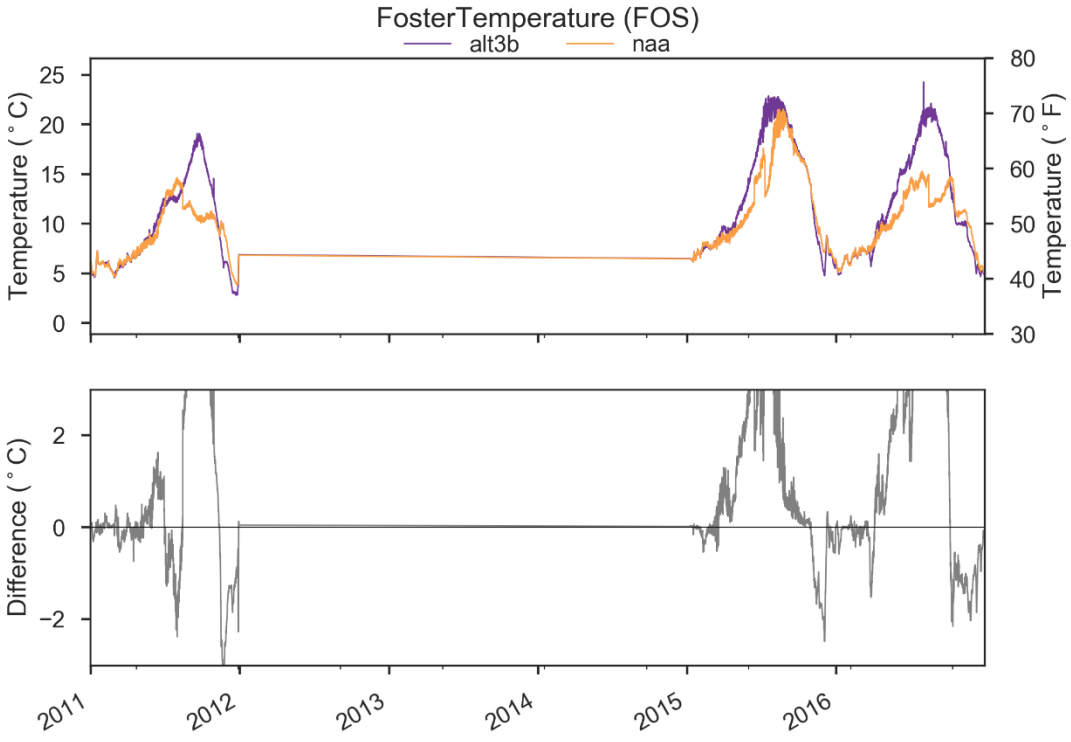


Figure 1-276. Comparison of FOS outflow temperatures in NAA and Alternative 3b.

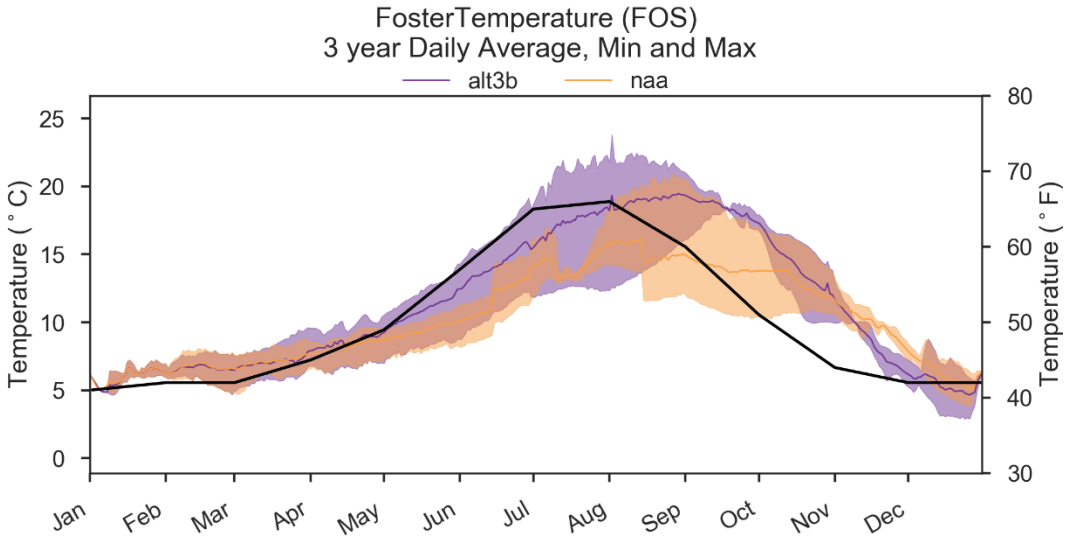


Figure 1-277. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target.

1.5.6.3 McKenzie Dams

1.5.6.3.1 Cougar

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Cougar Lake decreased significantly under Alternative 3b compared to NAA in 2011, 2015, and 2016 to allow for proposed fish passage operations through the diversion tunnel (Figure 1-278, Figure 1-279, Figure 1-280). The decreased storage coincided with reduced outflows during spring and summer (Figure 1-279). Outflows were primarily routed through the diversion tunnel in Alternative 2b, except when the lake refilled to about 30 feet above the RO intake (e.g., 2011).

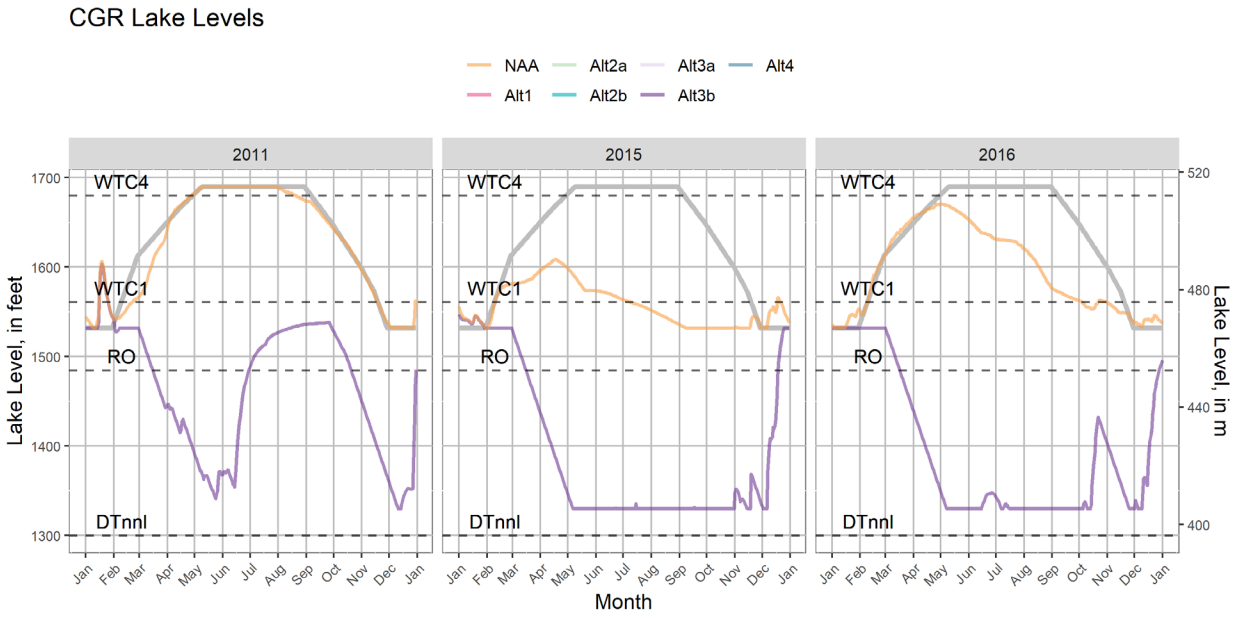


Figure 1-278. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA.

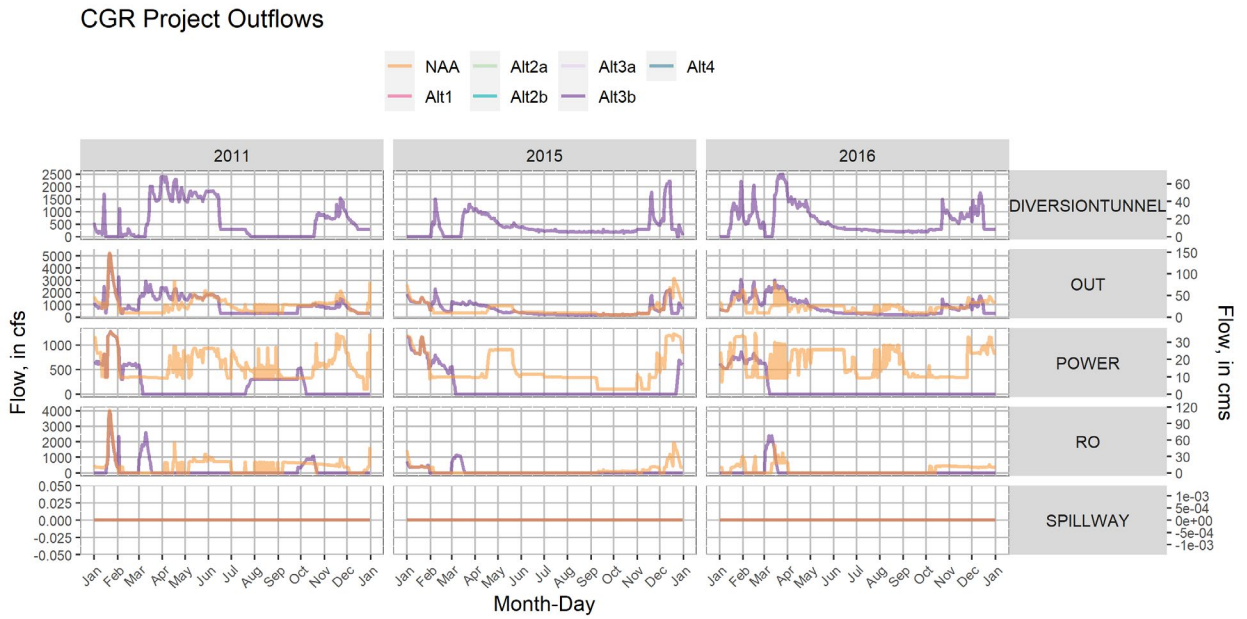


Figure 1-279. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA.

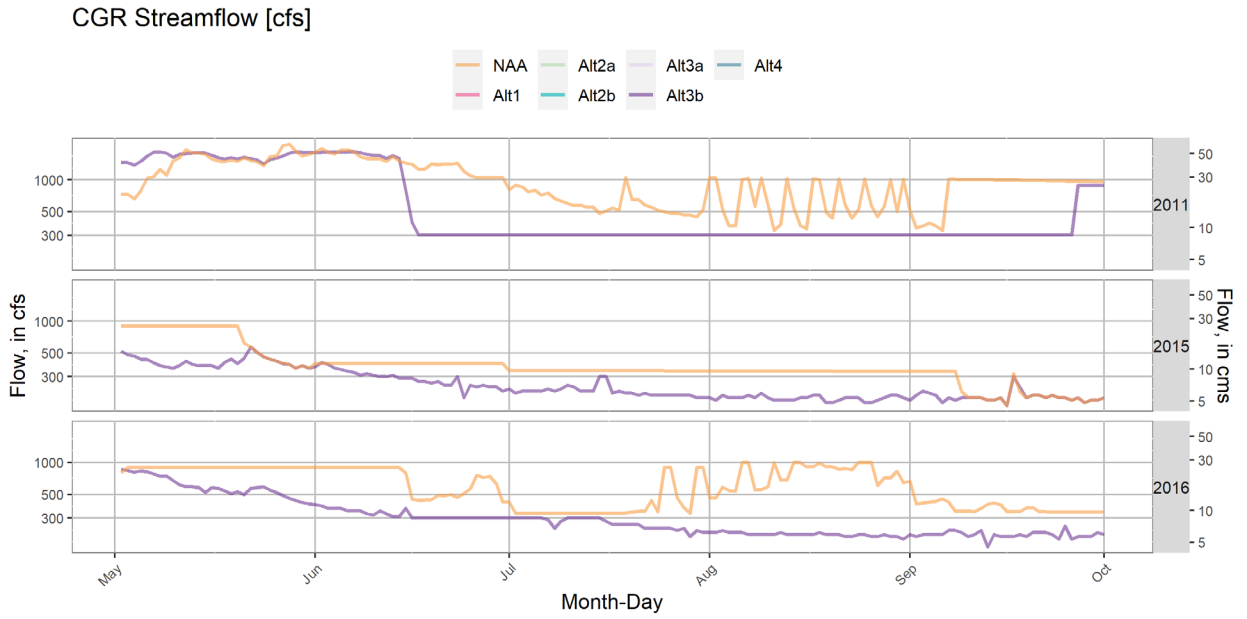


Figure 1-280. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 3b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 3b at Cougar Lake are shown in Figure 1-281, Figure 1-282, and Figure 1-283. Outflow temperatures from Cougar Dam in Alternative 3b were cooler than NAA year-round in 2011, 2015, and 2016 as the lake surface area, volume, and residence time decreased (Figure 1-284, Figure 1-285).

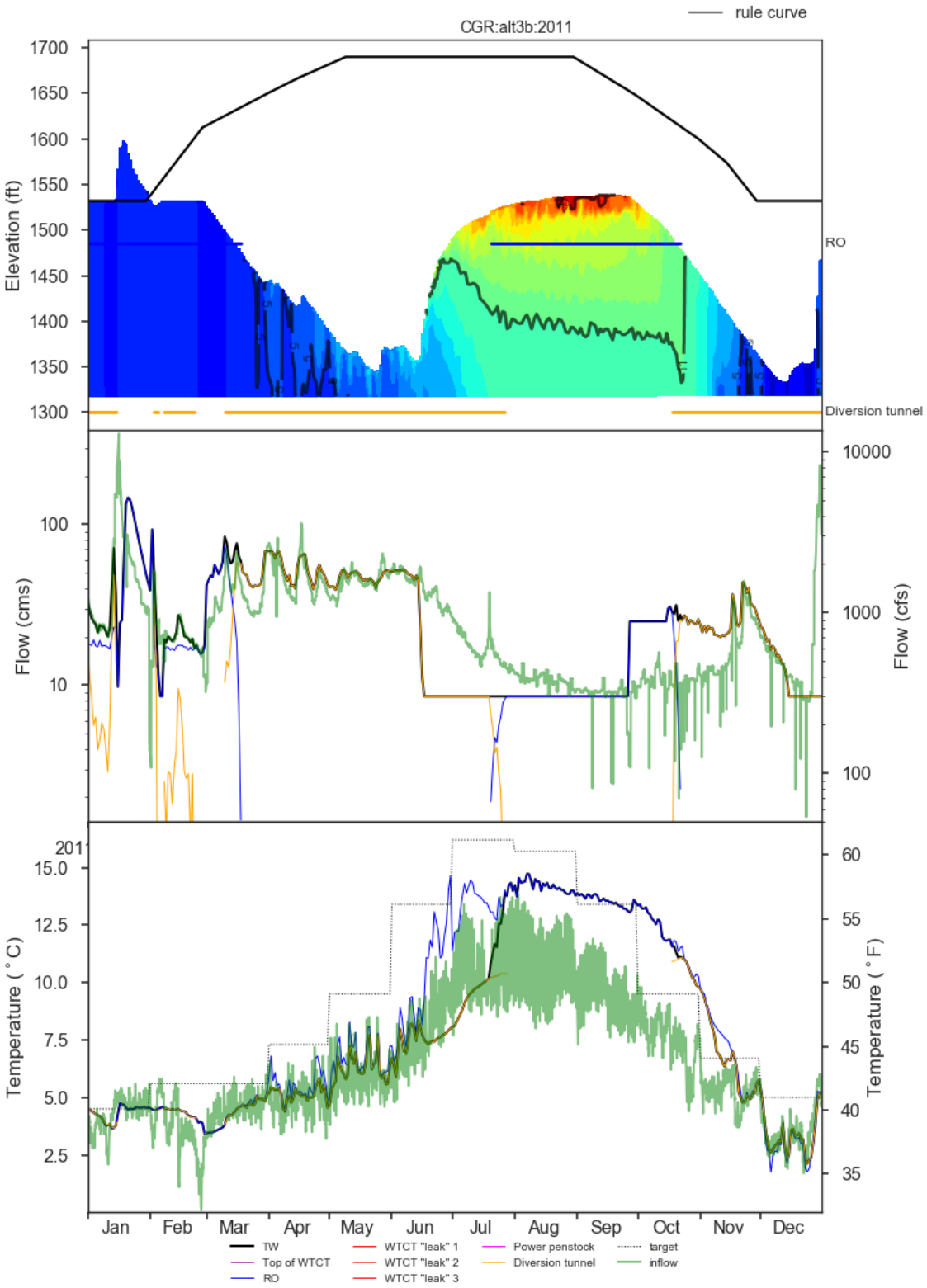


Figure 1-281. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3b in 2011.

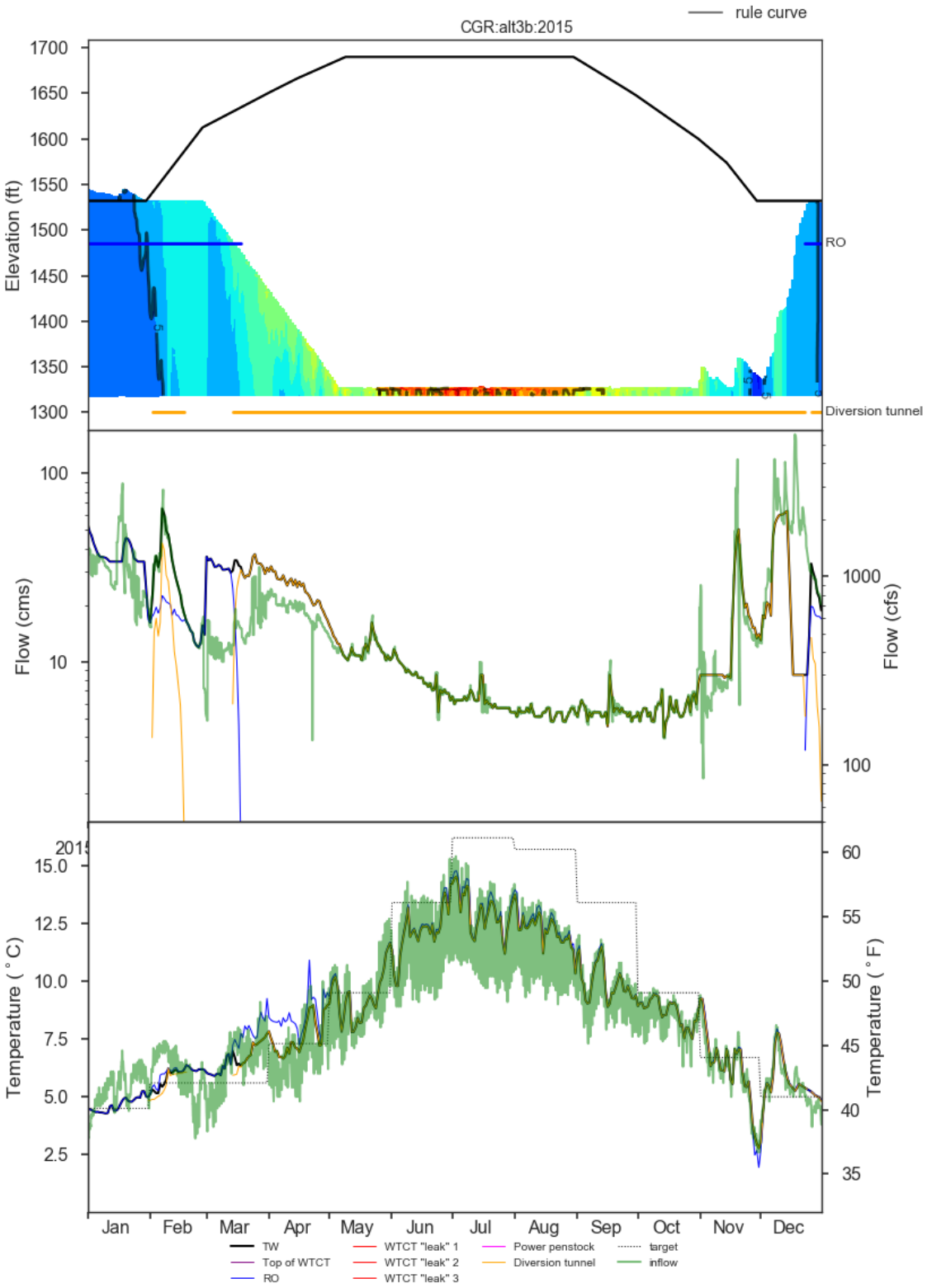


Figure 1-282. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3b in 2015.

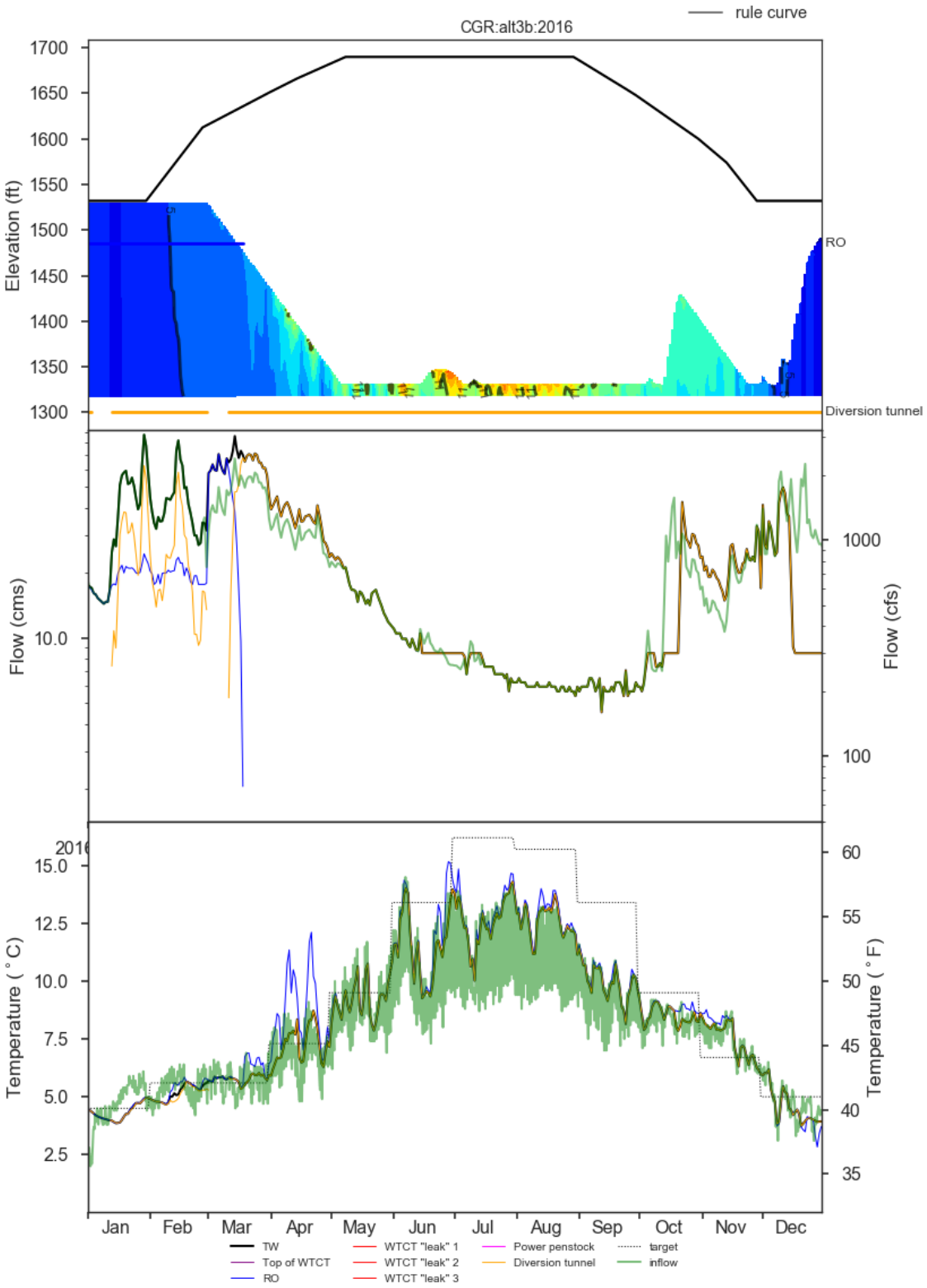


Figure 1-283. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3b in 2016.

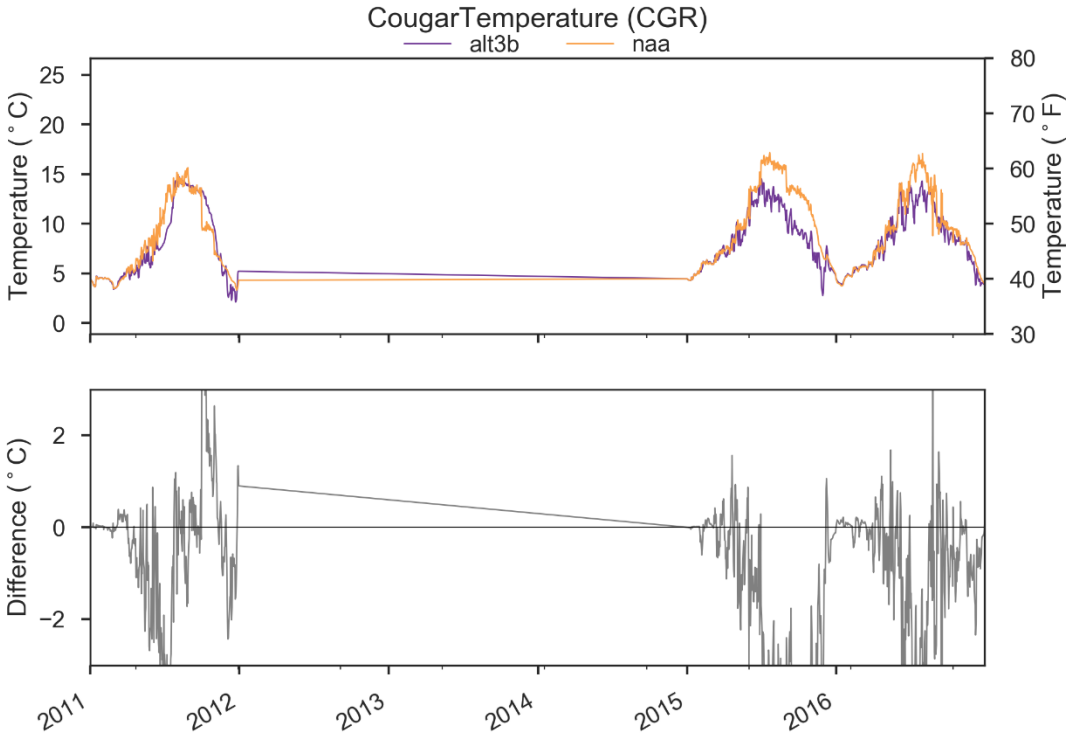


Figure 1-284. Comparison of CGR Outflow Temperatures in NAA and Alternative 1.

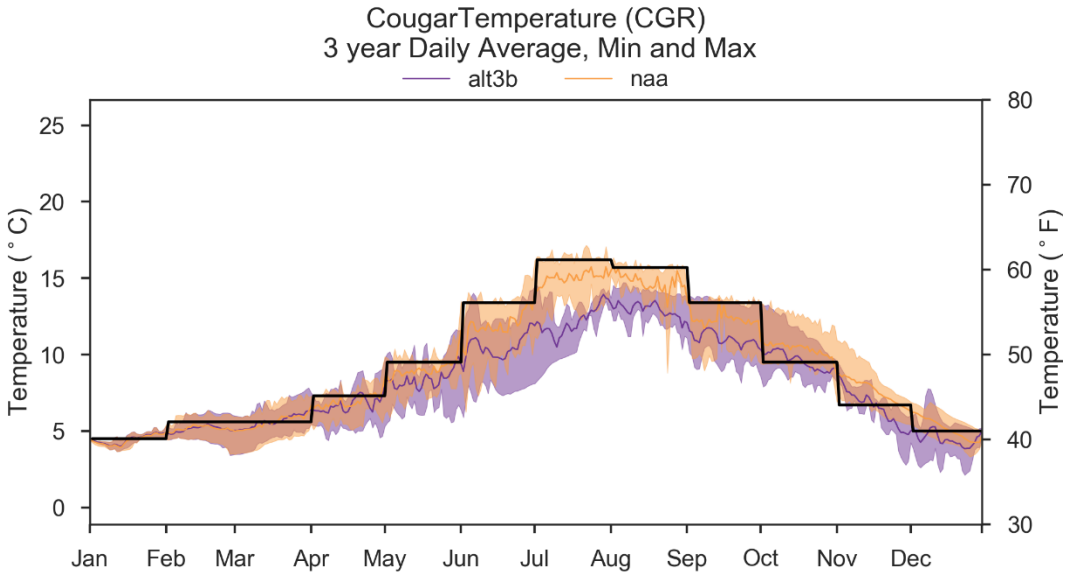


Figure 1-285. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target.

1.5.6.4 Middle Fork Willamette Dams

1.5.6.4.1 Hills Creek

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Hills Creek Lake generally decreased under Alternative 3b compared to NAA in 2015 and 2016 aside from August-November in 2015 when multiple measures were utilized related to fish passage and downstream flow targets (Figure 1-286, Figure 1-287, and Figure 1-288). The decreased storage generally coincided with reduced outflows comparing Alternative 3b to NAA (Figure 1-288).

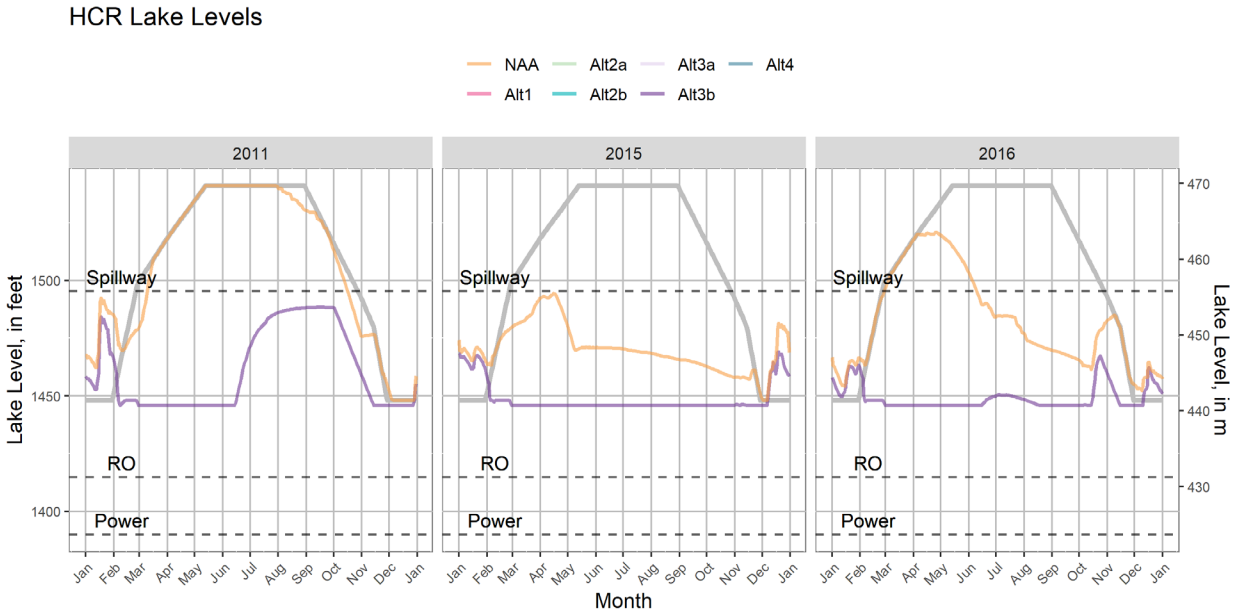


Figure 1-286. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA.

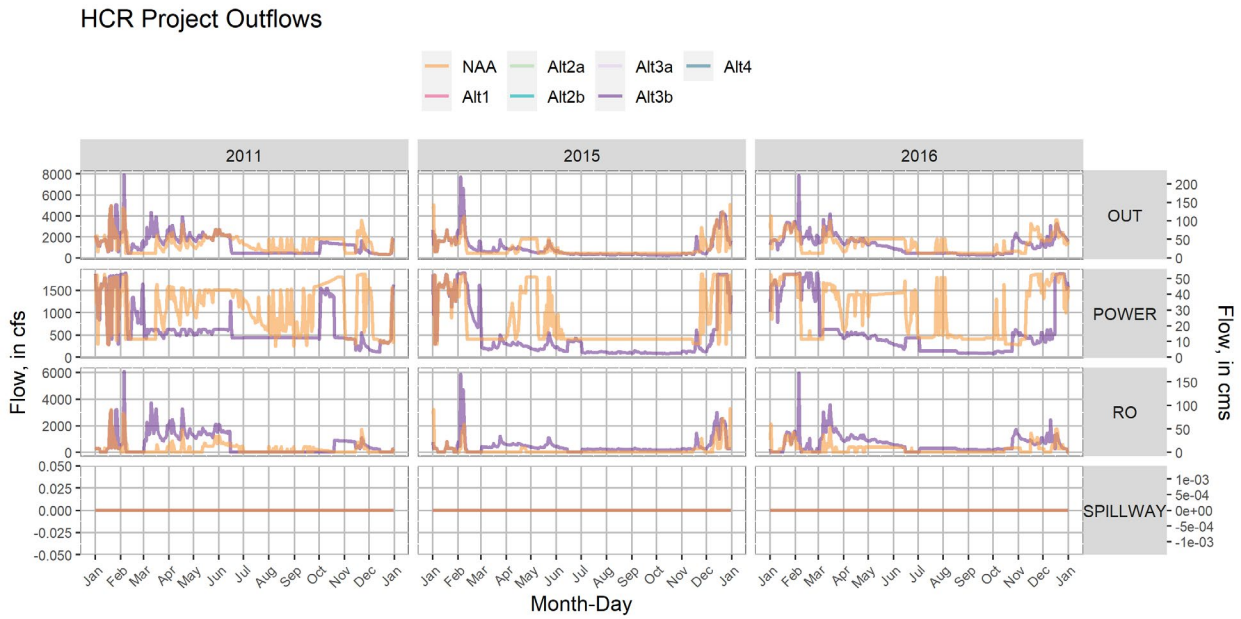


Figure 1-287. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA.

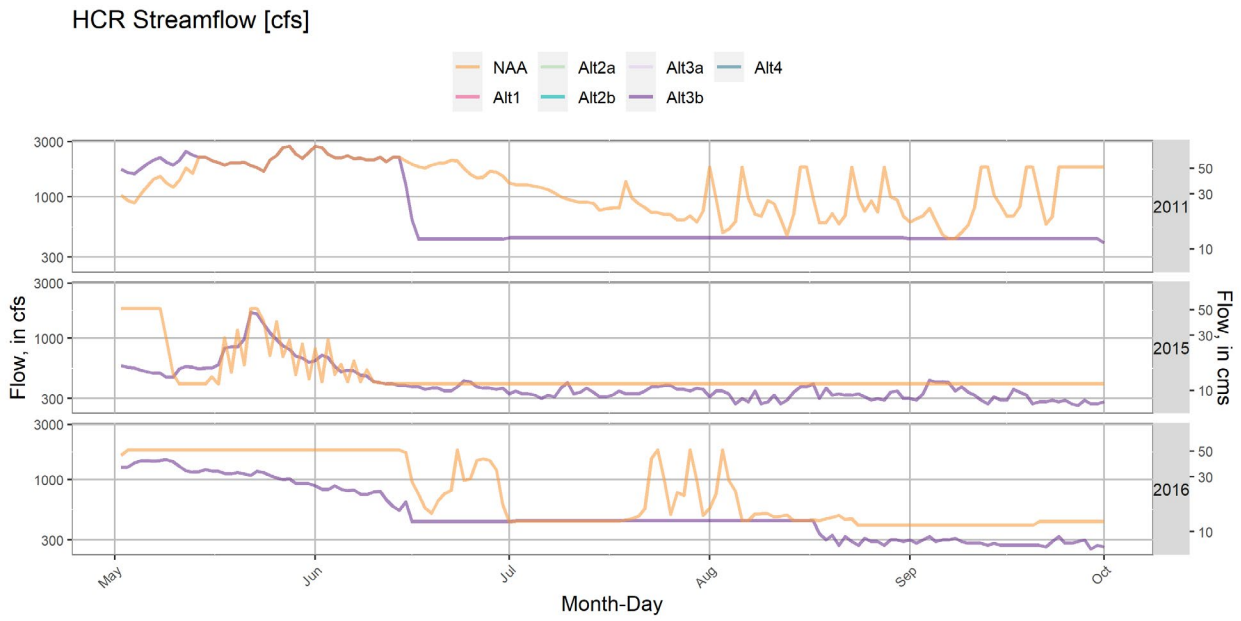


Figure 1-288. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 under Alternative 3b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 3b at Hills Creek Lake are shown in Figure 1-289, Figure 1-290, and Figure 1-291. Hills Creek tailwater temperatures were generally warmer in

Alternative 3b compared to NAA in April-October and similar to NAA November-December (Figure 1-292, Figure 1-293) as a result of the proposed drawdown operations.

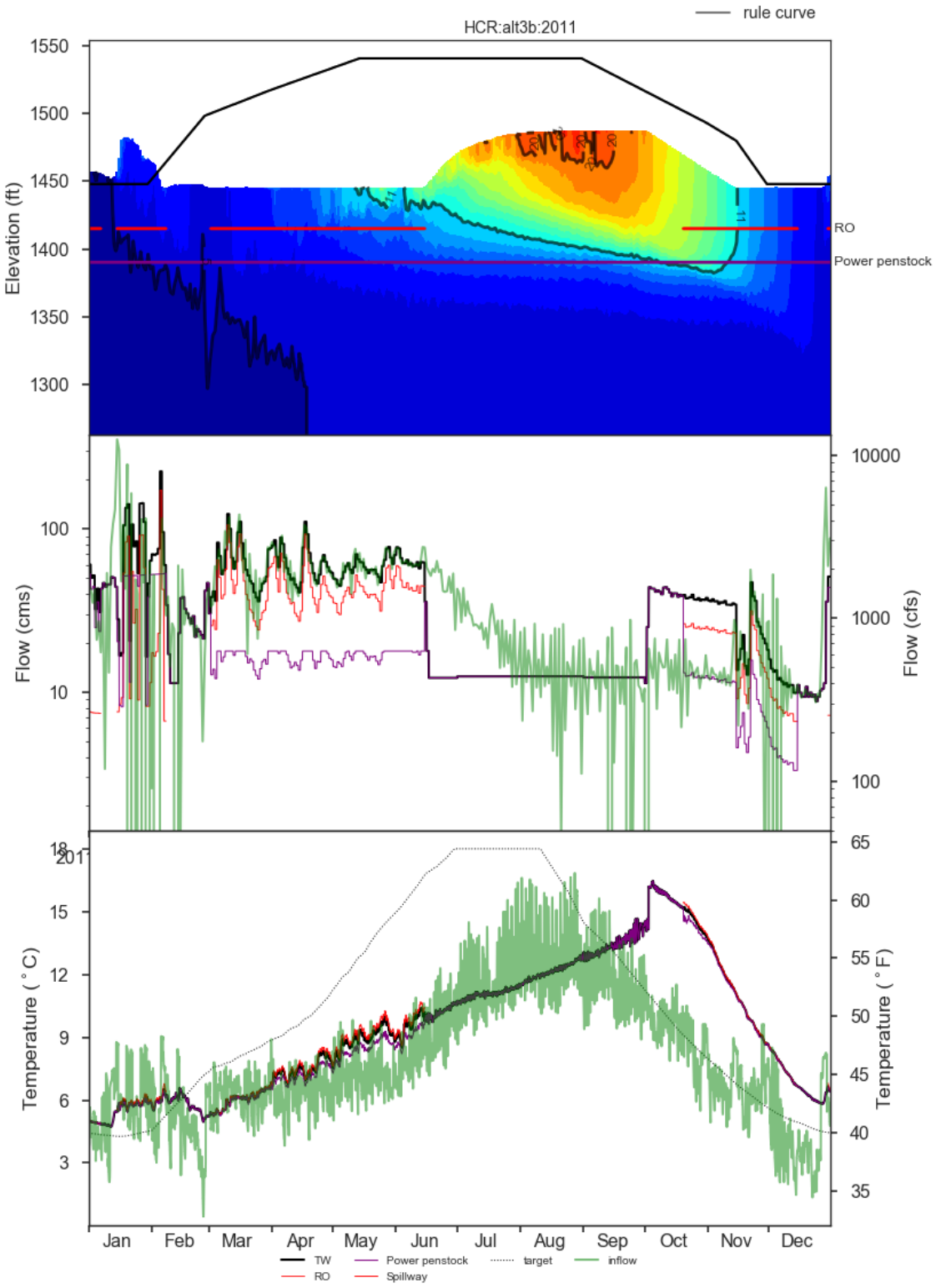


Figure 1-289. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3b in 2011.

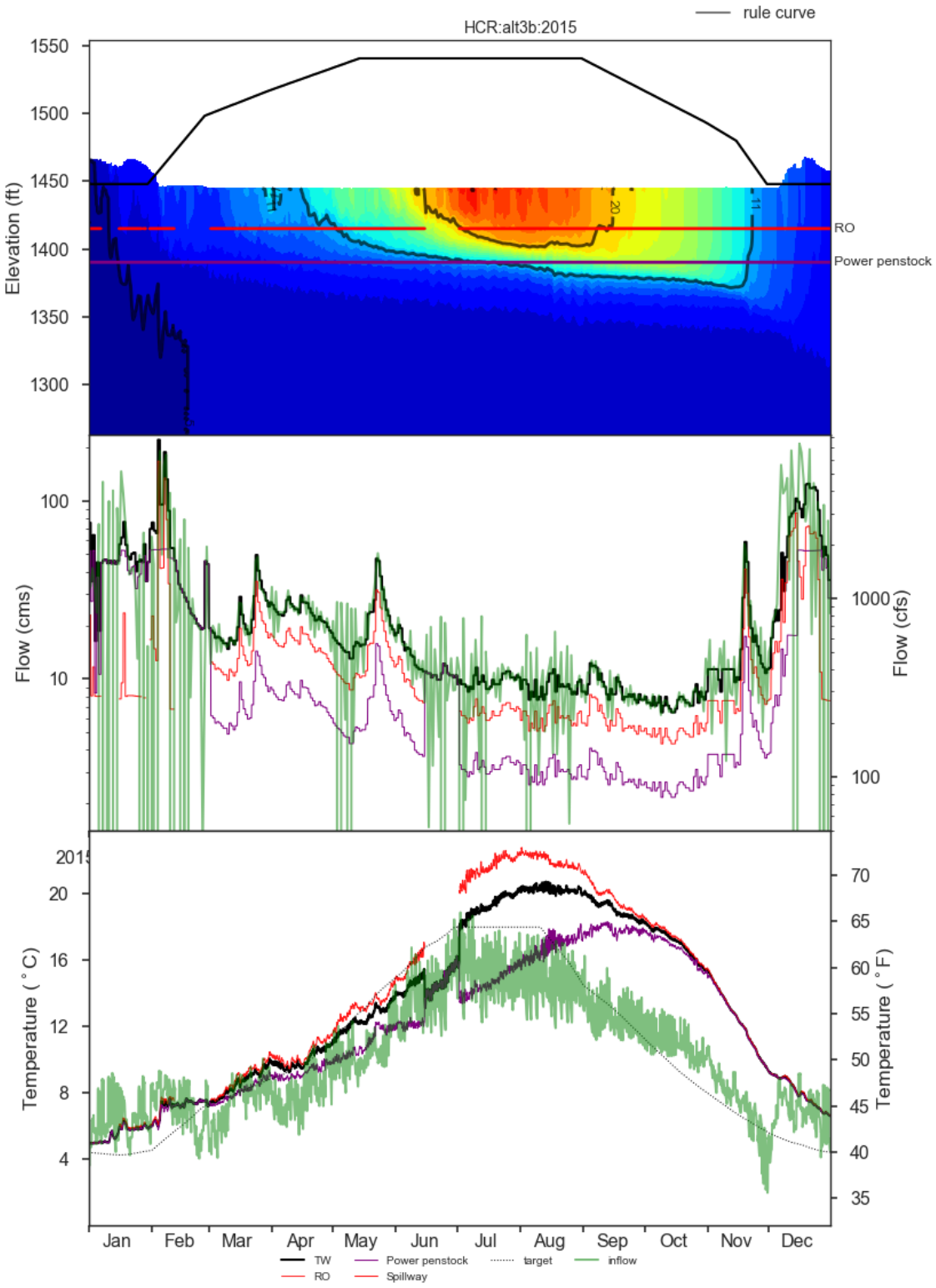


Figure 1-290. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3b in 2015.

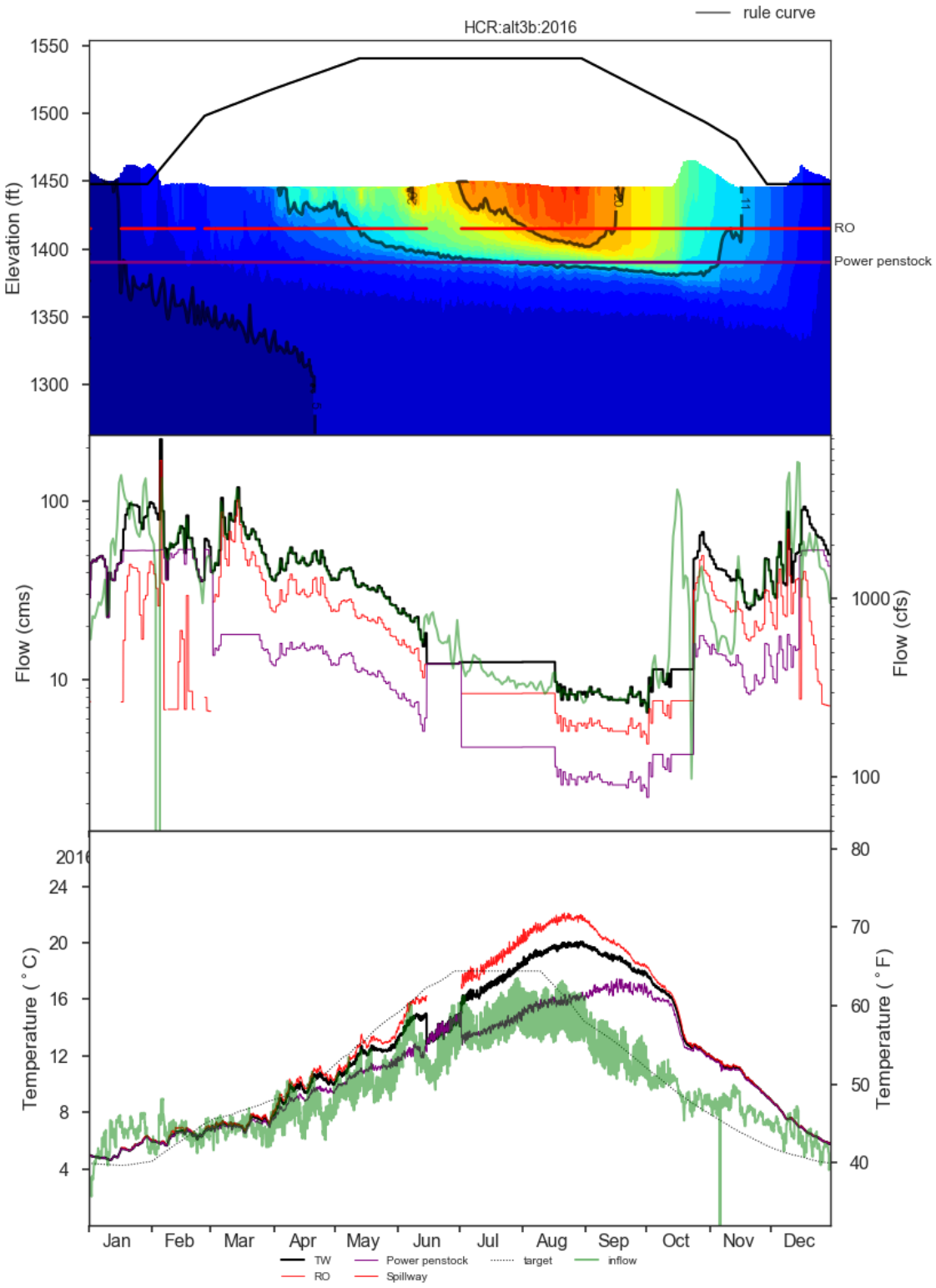


Figure 1-291. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3b in 2016.

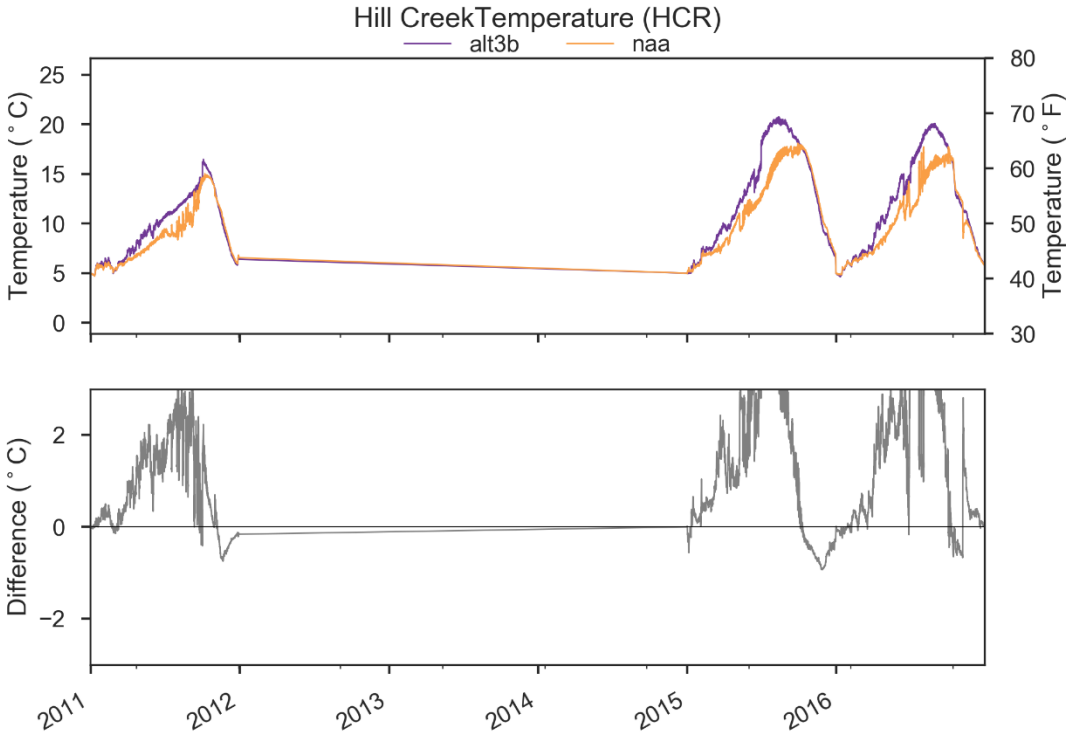


Figure 1-292. Comparison of HCR Outflow Temperatures in NAA and Alternative 3b.

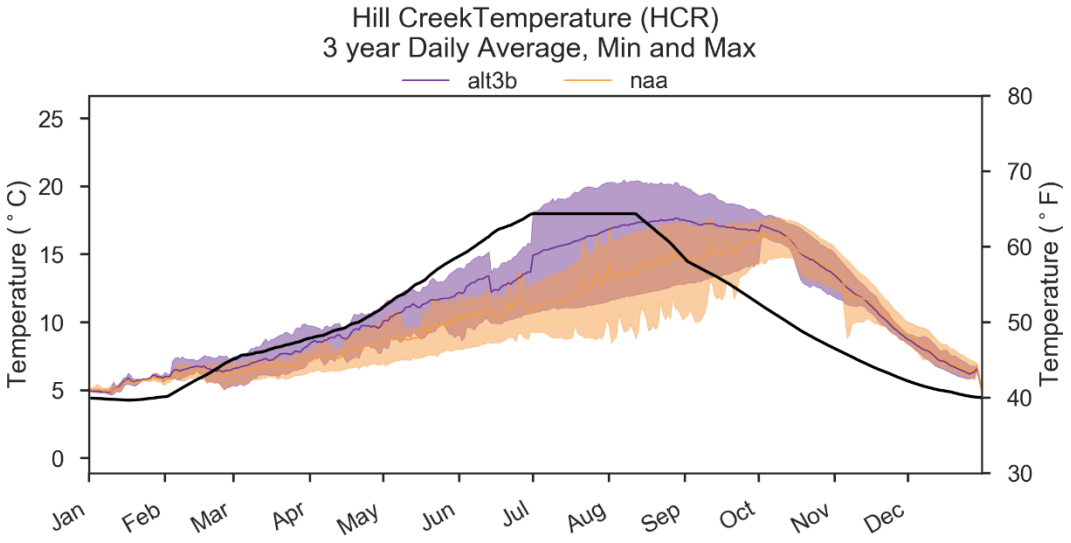


Figure 1-293. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target.

1.5.6.4.2 Lookout Point

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Lookout Point were generally similar in Alternative 3b and NAA in 2011, 2015, and 2016 aside from October-November, during drawdown to the Ros for fish passage (Figure 1-294, Figure 1-295, Figure 1-296). Some increased storage in 2015 coincided with reduced outflows during spring… 2011 and 2016 operations were generally similar in Alternative 3b and NAA at Lookout Point Lake in January-June followed by increased outflows in July-October to draft the lake for fish passage operations through the Ros in autumn. The proposed temperature management and fish passage operation through the spillway (during spring/summer) and RO (during autumn) in Alternative 3b led to increased outflow from these outlets and decreased power outflow compared to NAA (Figure 1-295).

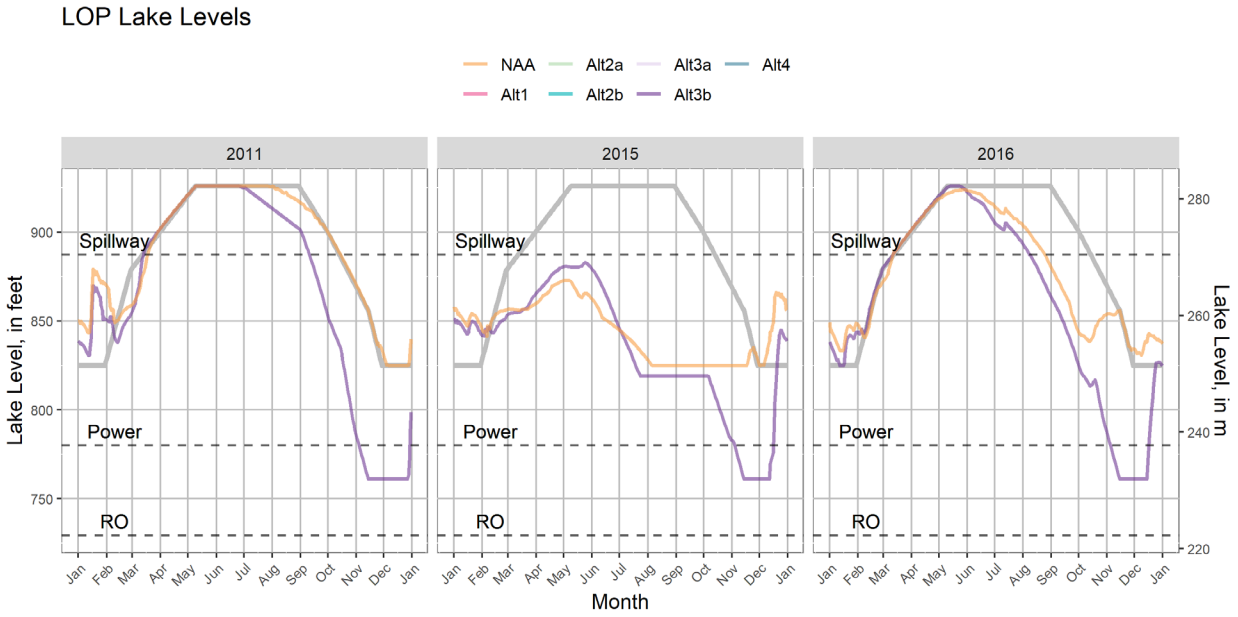


Figure 1-294. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA.

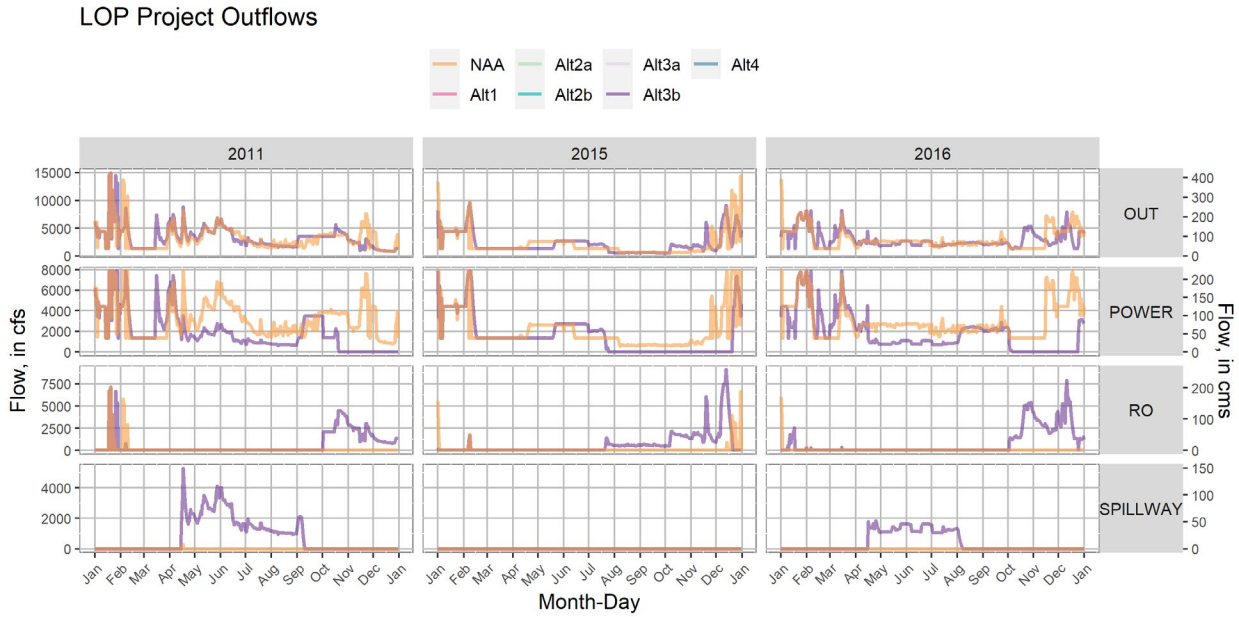


Figure 1-295. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA.

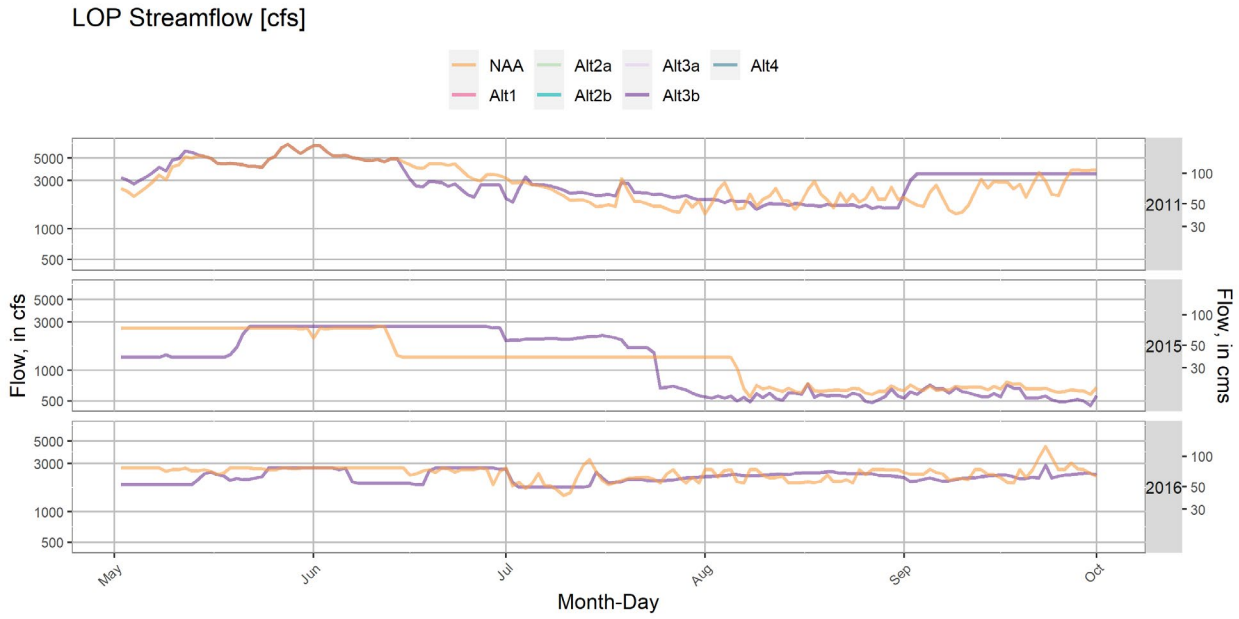


Figure 1-296. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Lookout Point Lake are shown in Figure 1-297, Figure 1-298, and Figure 1-299. Alternative 3b included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets

during autumn to mix releases from these non-power releases with relatively deep power penstock releases to meet the downstream temperature target.

Alternative 3b tailwater release temperatures from LOP-DEX generally matched the temperature target (warmer than NAA during summer) when sufficient warm or cool water was available and outlets were submerged. LOP spillway access was not available in 2015 and was limited in 2016 which led to an abrupt drop in tailwater temperature when spillway access ended in mid-summer (Figure 1-300, Figure 1-301). Generally, the autumn fish passage operation at LOP (drawdown to about the RO level) resulted in cooler temperatures September-December compared to NAA (Figure 1-301), but tailwater temperature was highly variable across the three years simulated.

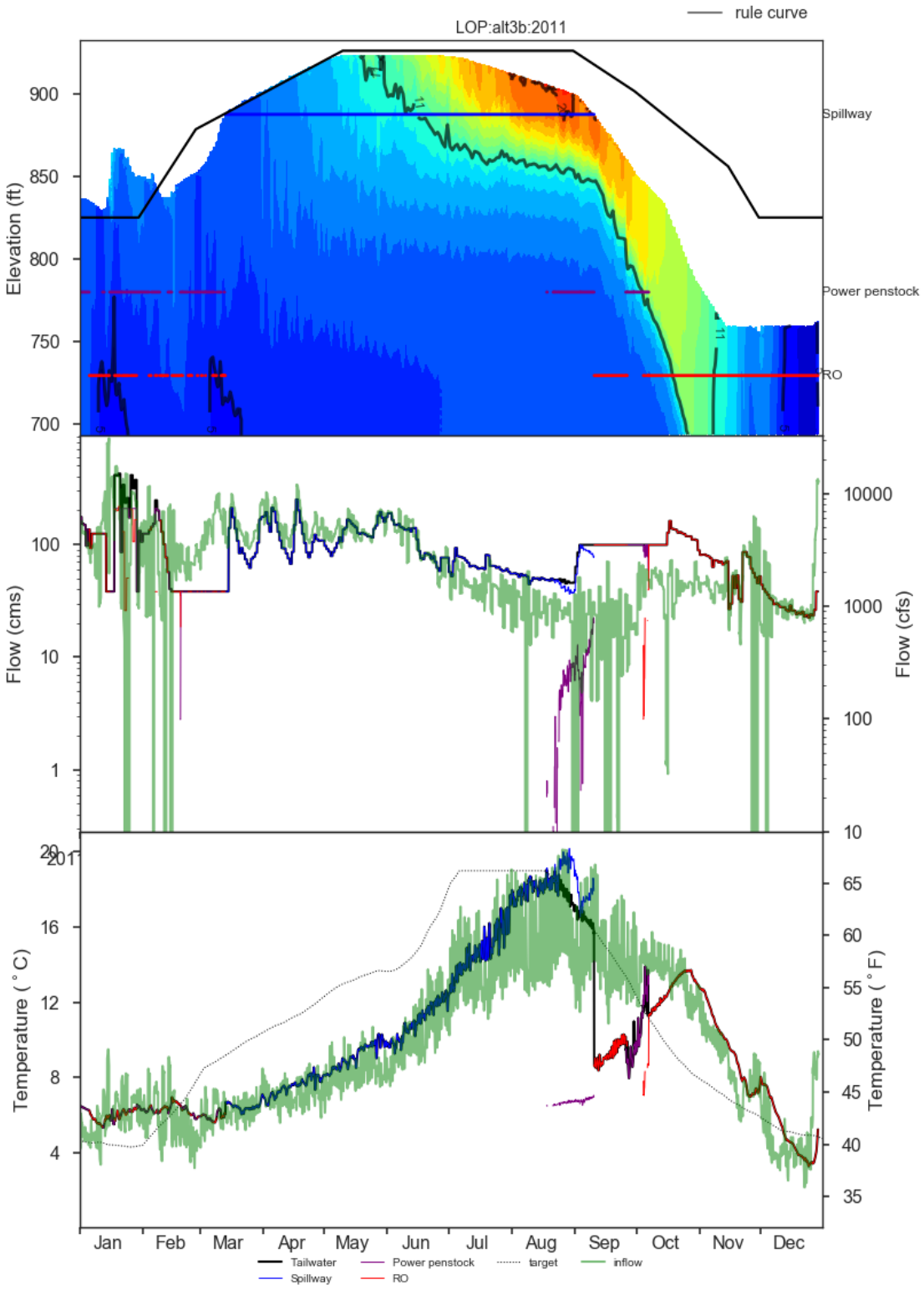


Figure 1-297. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3b in 2011.

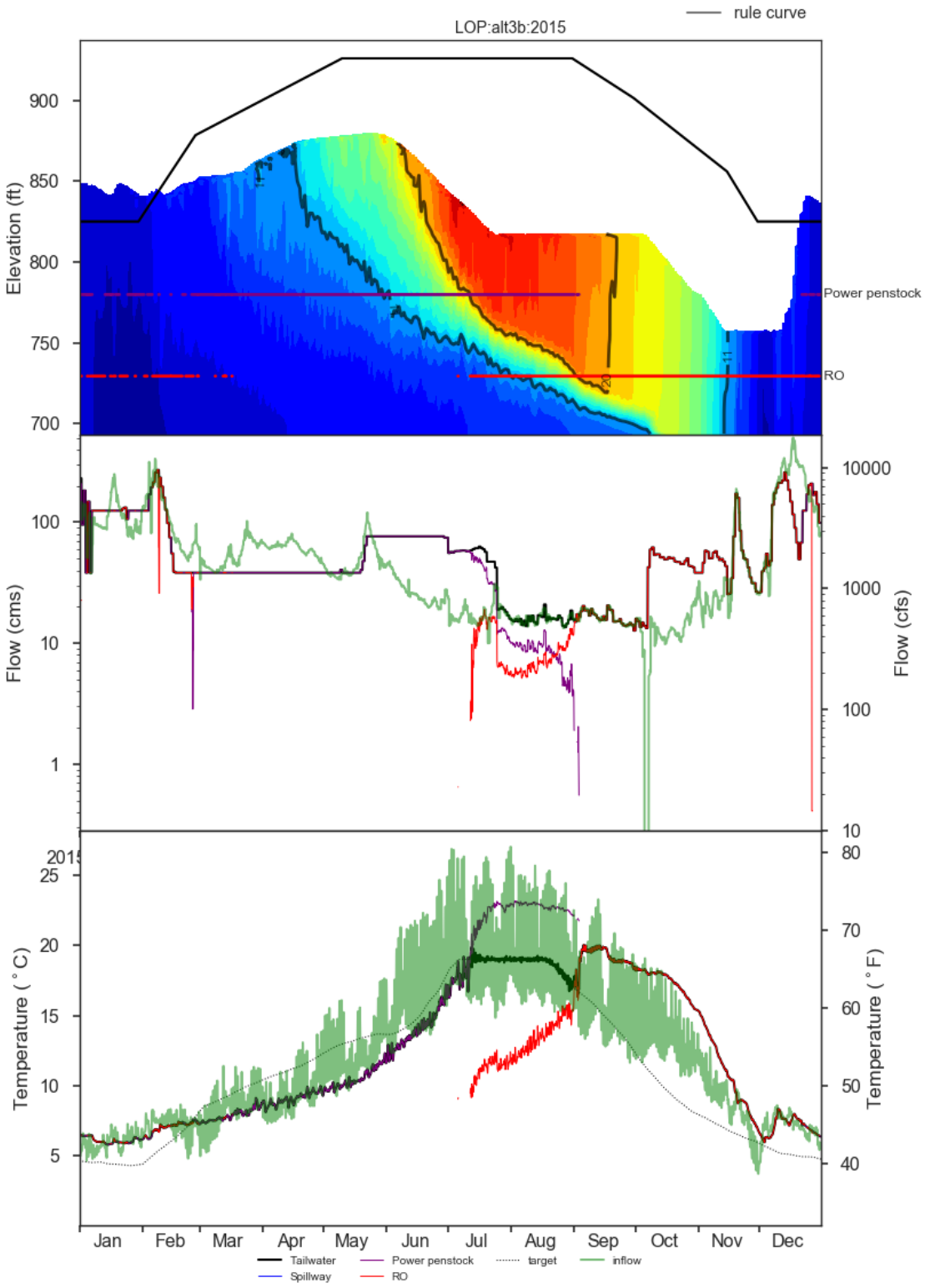


Figure 1-298. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3b in 2015.

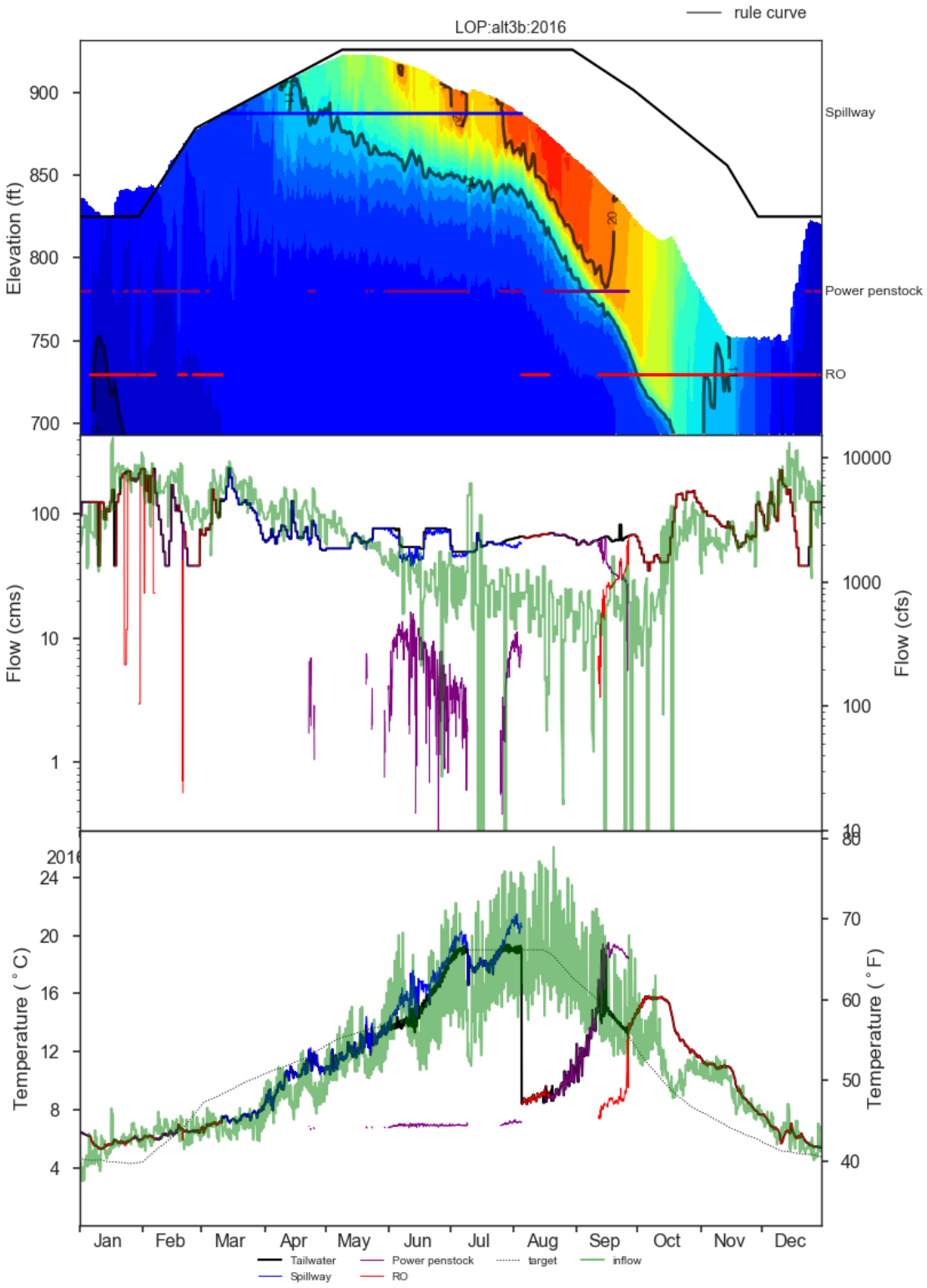


Figure 1-299. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3b in 2016.

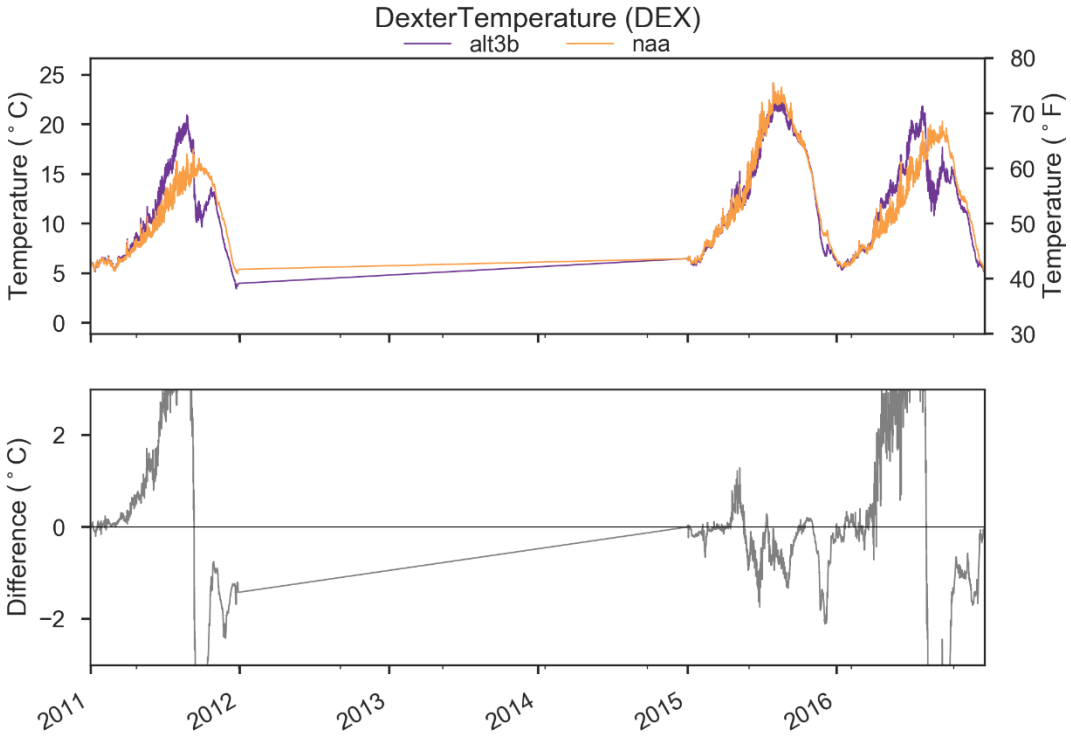


Figure 1-300. Comparison of DEX Outflow Temperatures in NAA and Alternative 3b.

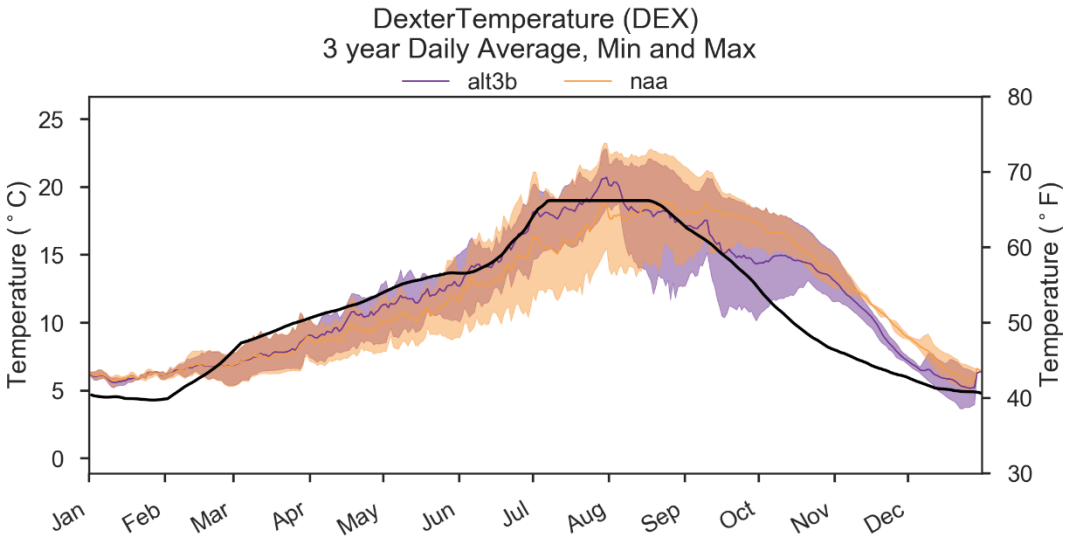


Figure 1-301. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target.

1.5.6.5 Mainstem Willamette River

Streamflow under Alternative 3b was generally lower than NAA (Figure 1-302) except in 2015, when flows were higher from mid-June to October, due to Measure 30 rules that increase dam outflows in advance of heat wave events (Figure 1-303). These flow changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to October compared with NAA in 2015 (Figure 1-304, Figure 1-305). Water temperatures at Salem were also affected by upstream dam operations, which likely contributed to warmer temperatures when comparing Alternative 3b to NAA. Overall water temperature differences between Alternative 3b and NAA were less than 2 degrees Celsius.

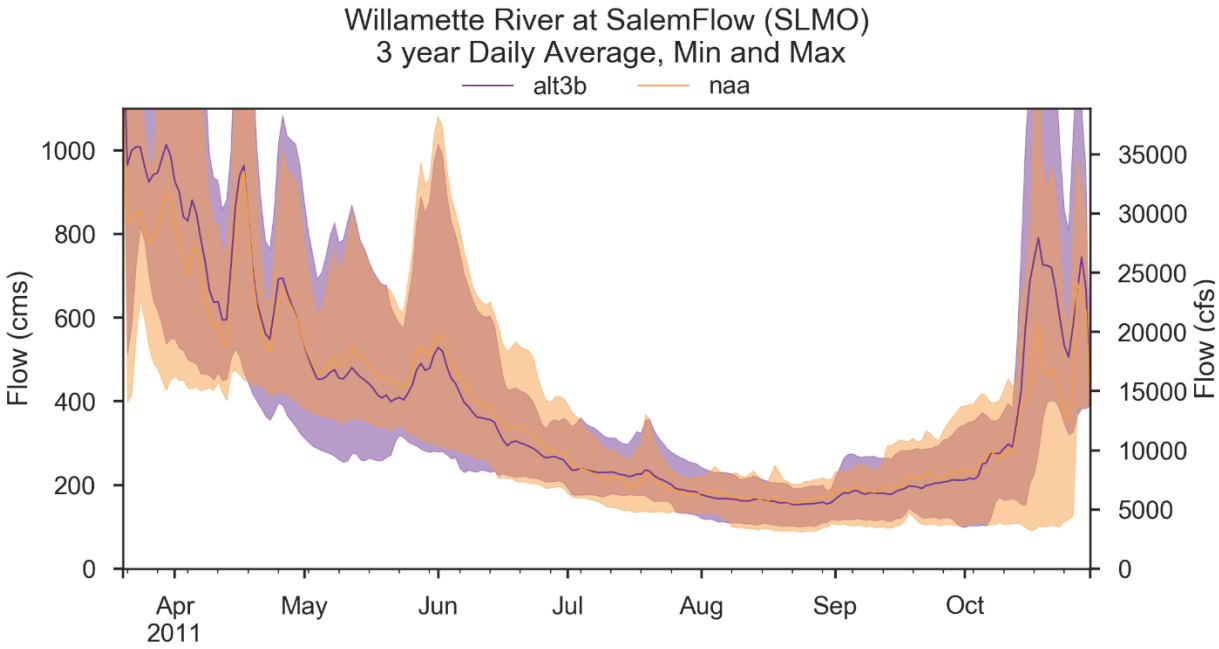


Figure 1-302. Streamflow Comparison of Average, Min, and Max Willamette River at SLMO under NAA and Alternative 3b Conditions.

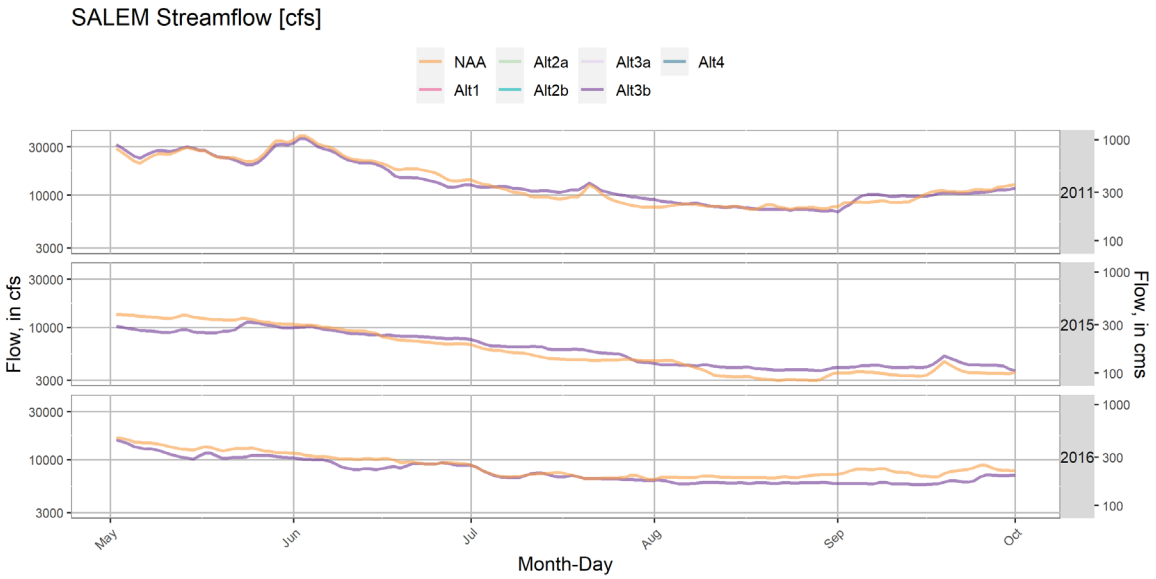


Figure 1-303. Streamflow Comparison Between Alternative 3b and NAA at Willamette River at SLMO.

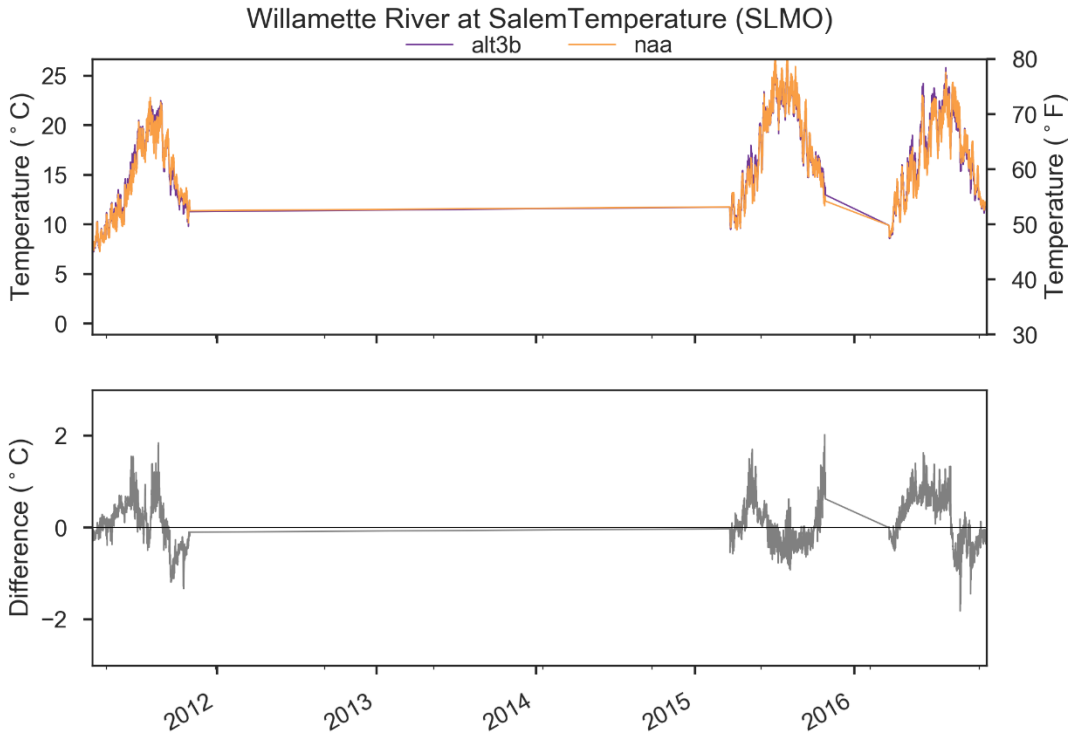


Figure 1-304. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 3b.

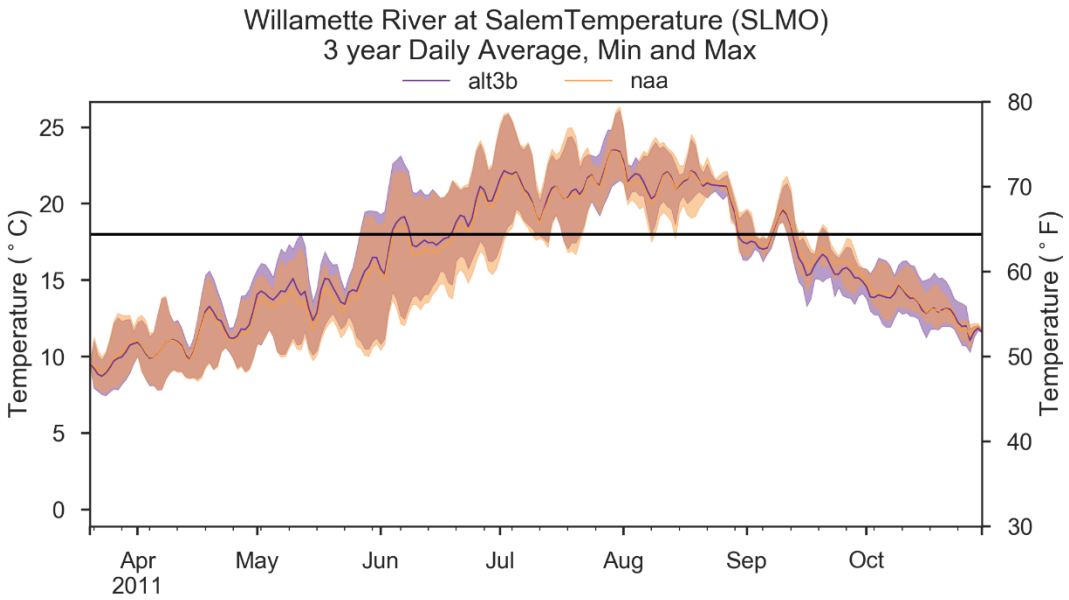


Figure 1-305. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b.

1.5.7 Alternative 4 – Structures-Based Fish Passage Alternative

Alternative 4 measures that affected operations, lake storage, and water temperature included:

- Structural improvements for water temperature (water temperature control towers or selective water withdrawal structures) at Detroit, Hills Creek, and Lookout Point dams.
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.
- Use of spillway for surface spill in spring and summer and RO during fall at Green Peter.
- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.

1.5.7.1 North Santiam Dams

1.5.7.1.1 Detroit

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Detroit Lake generally increased under Alternative 4 compared to NAA in 2015 and 2016 aside from September-November in 2015 when the power pool was utilized

for downstream flow augmentation (Figure 1-306, Figure 1-308). The increased storage coincided with reduced outflows during spring and increased outflows in summer during 2015 and 2016.Total outflow in 2011 was generally similar in Alternative 4 and NAA at Detroit Lake. The proposed SWS and FSS in Alternative 4 allowed all outflow within powerhouse capacity (assumed at 4600 cfs) to be routed from a floating outlet through the Power outlets for temperature management, rather than the Spillway or URO flow used in NAA for temperature management (Figure 1-307).

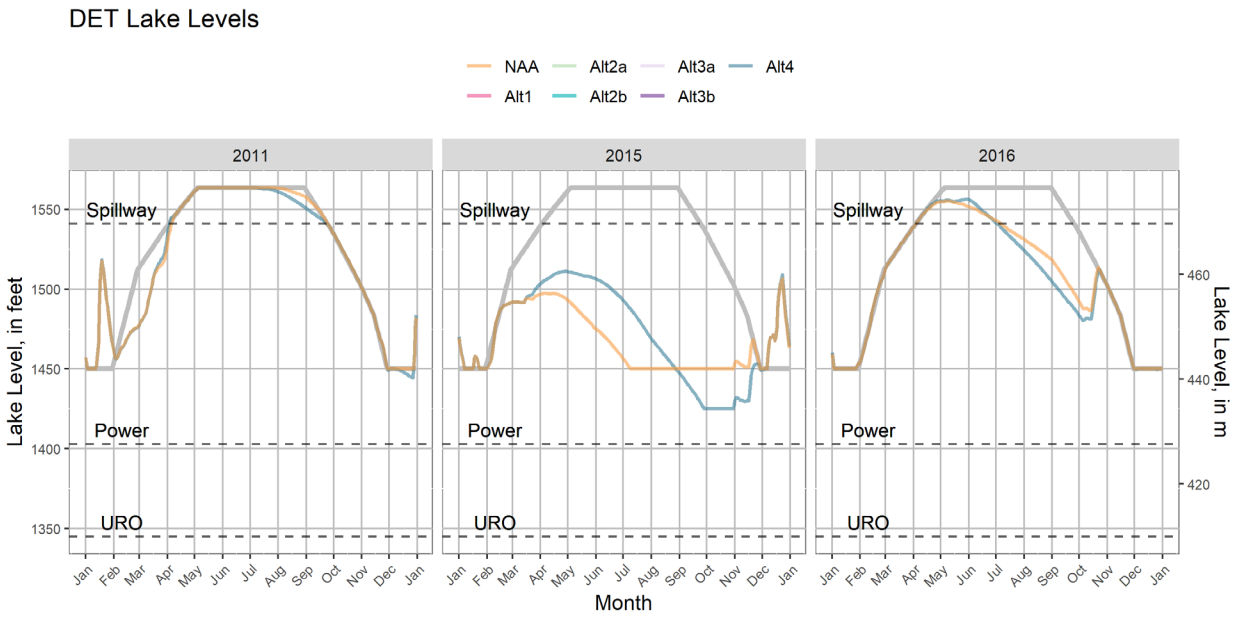


Figure 1-306. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 4 and NAA.

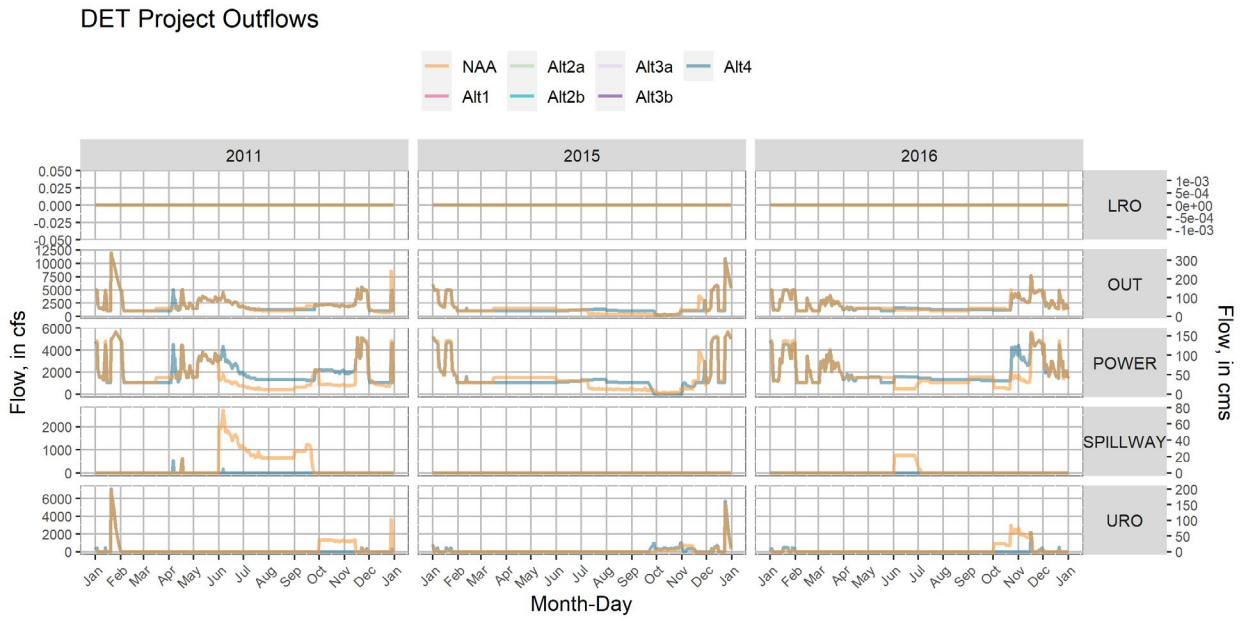


Figure 1-307. WV EIS HEC-ResSim Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA.

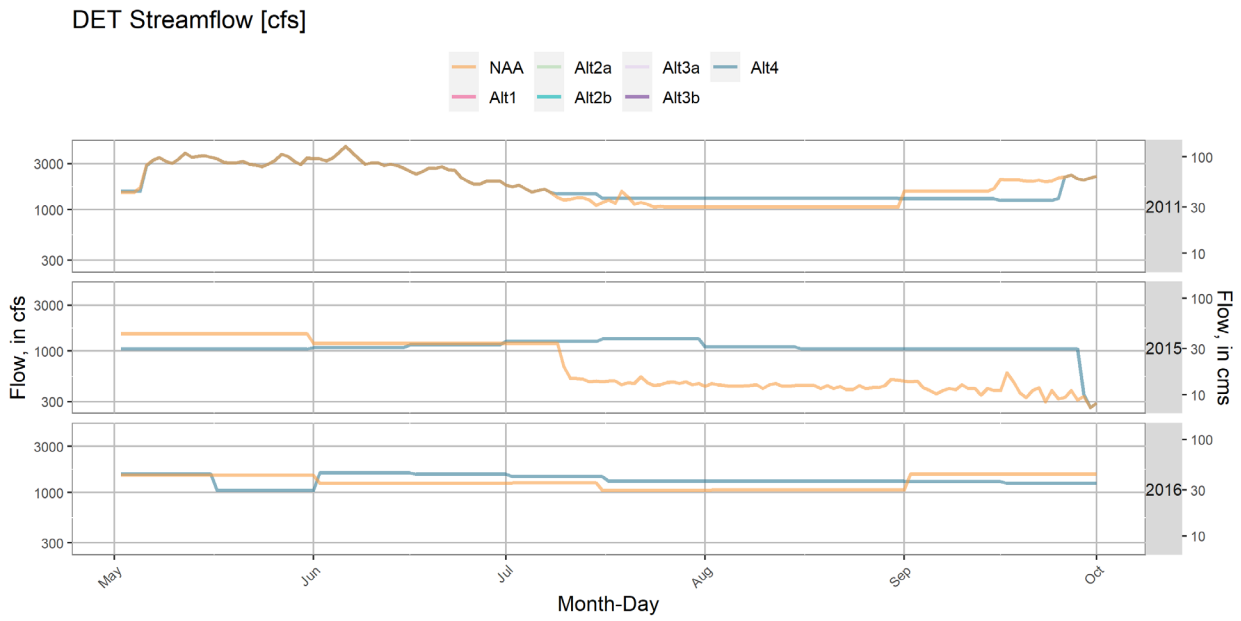


Figure 1-308. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-309, Figure 1-310, and Figure 1-311 . Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the Upper RO. Tailwater release temperatures

generally matched the temperature target when sufficient warm or cool water was available. Generally, the proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn (Figure 1-312, Figure 1-313).

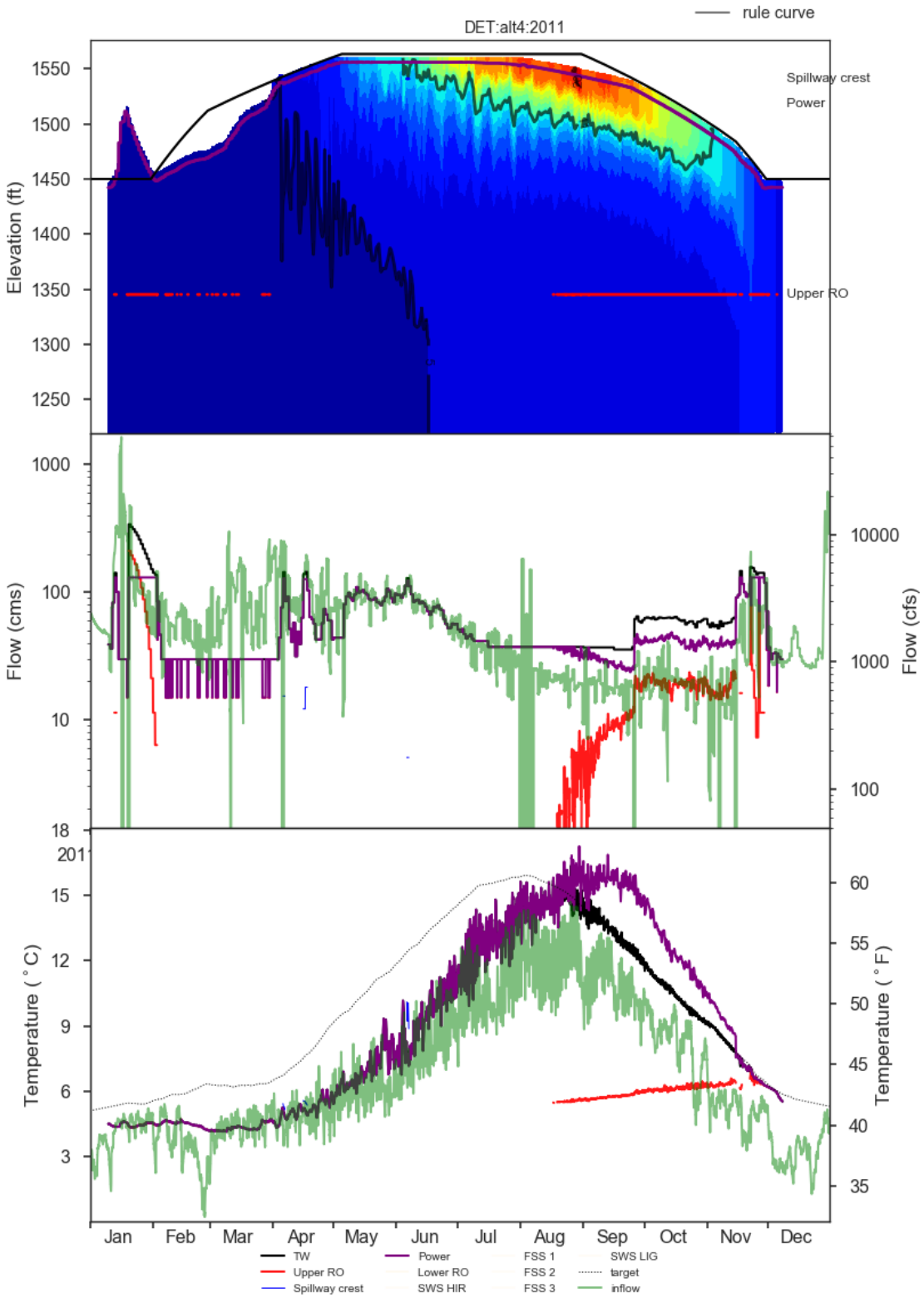


Figure 1-309. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 4 in 2011.

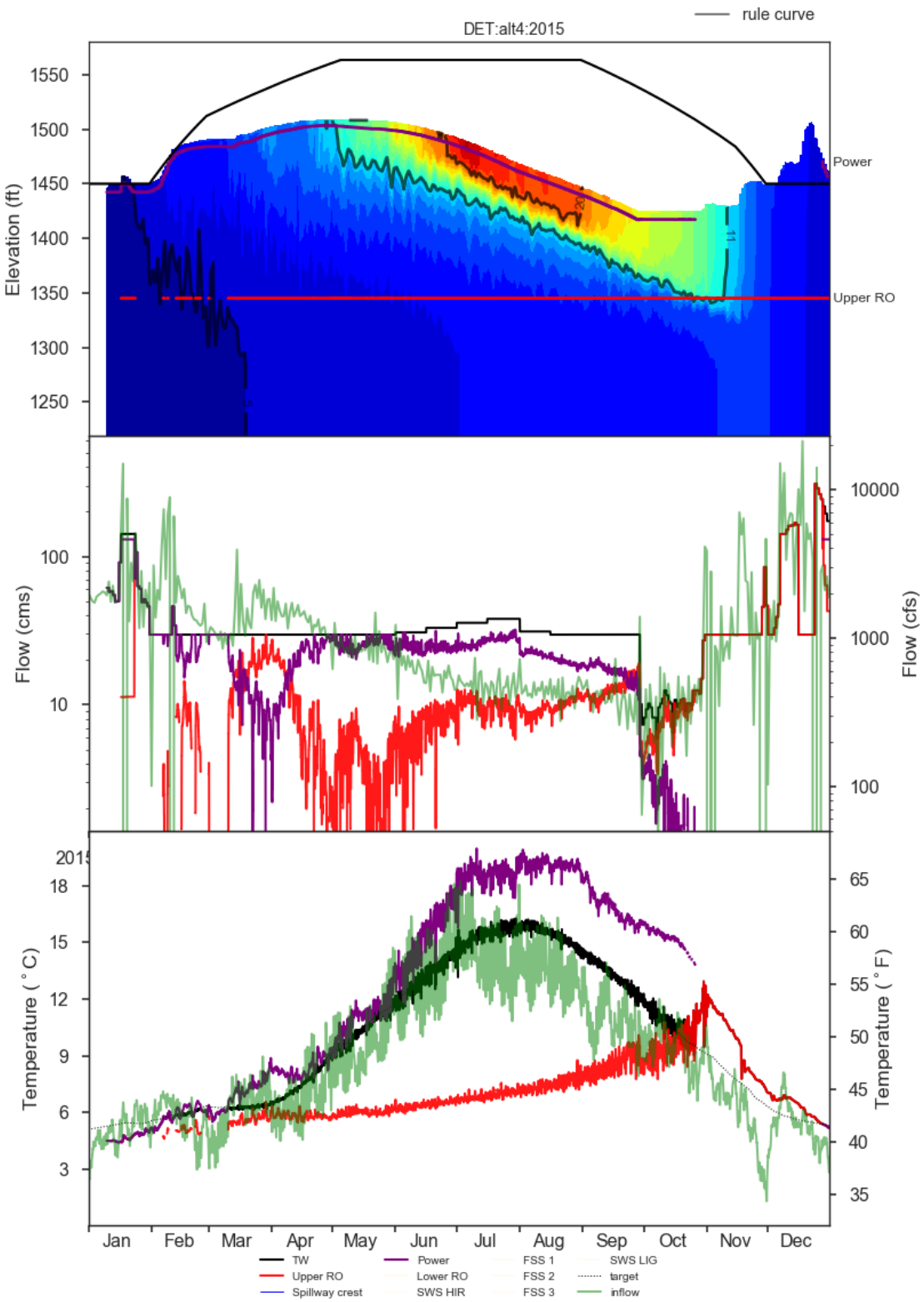


Figure 1-310. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 4 in 2015.

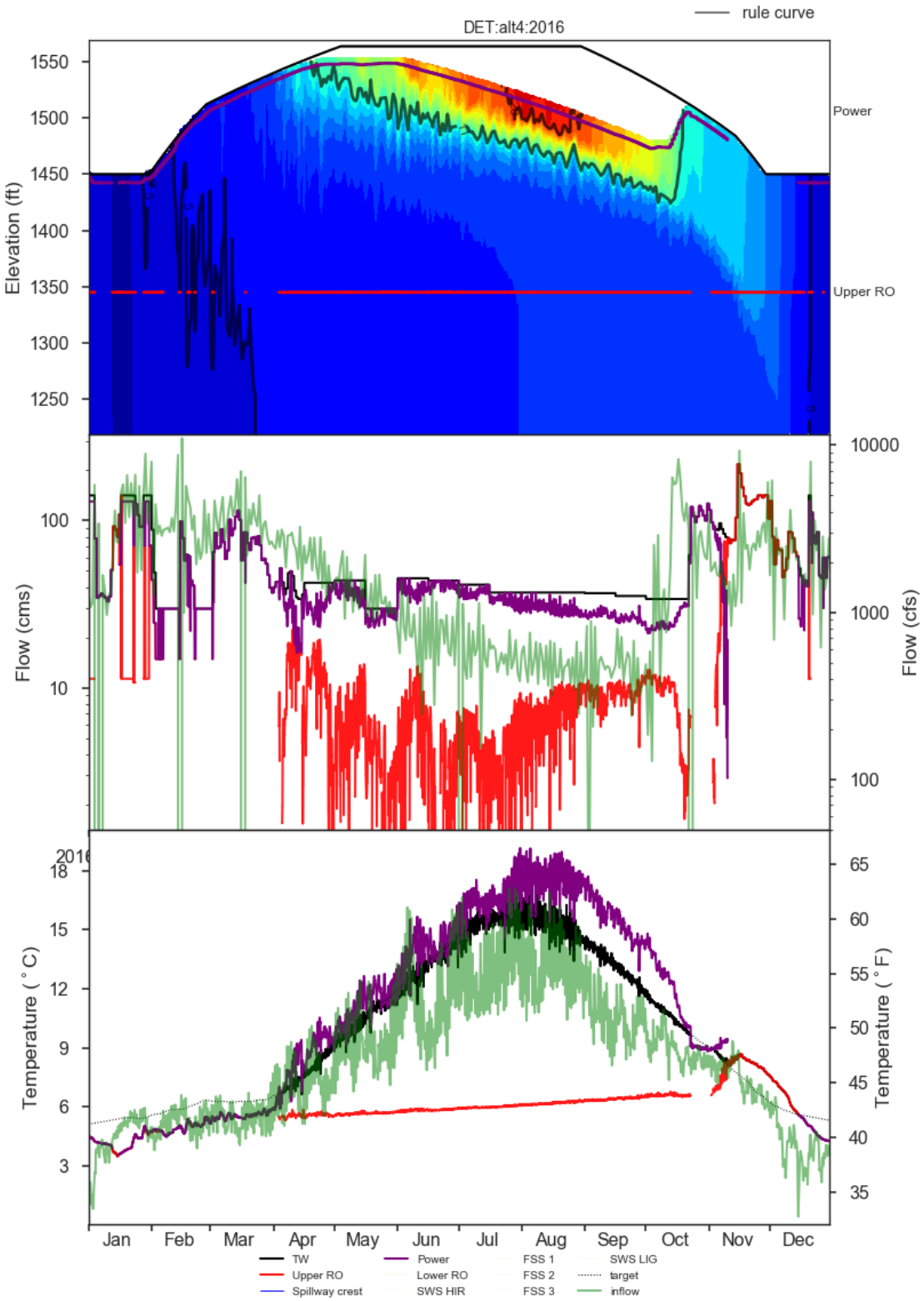


Figure 1-311. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 4 in 2016.

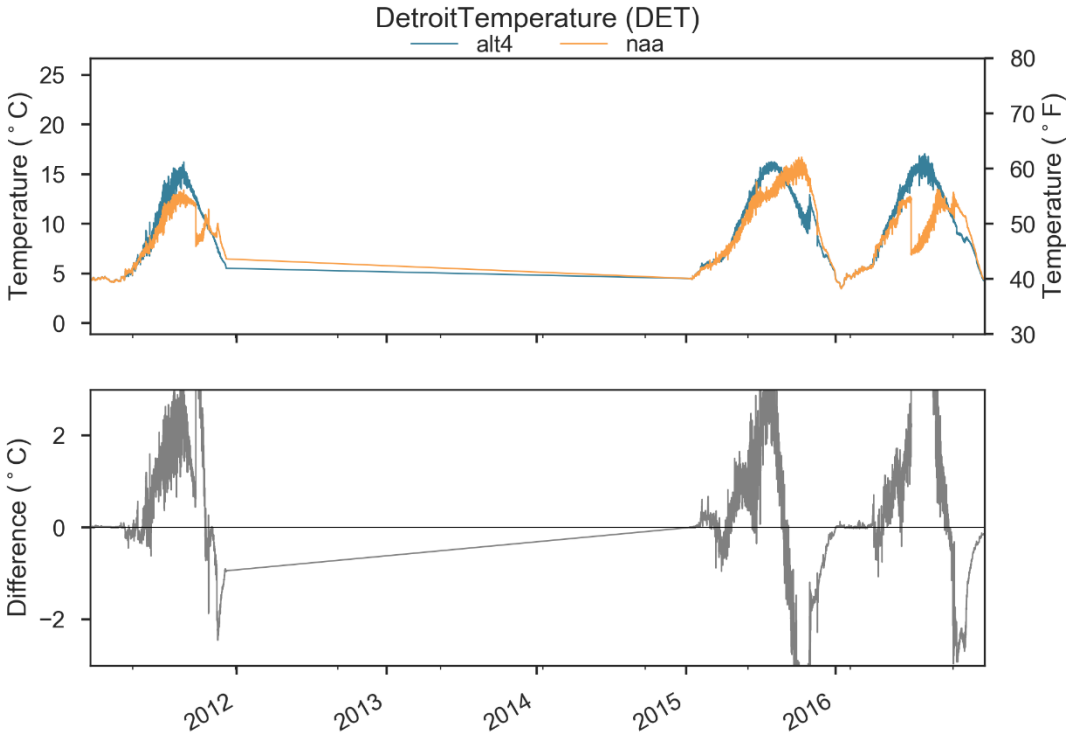


Figure 1-312. Comparison of DET outflow temperatures in NAA and Alternative 4.

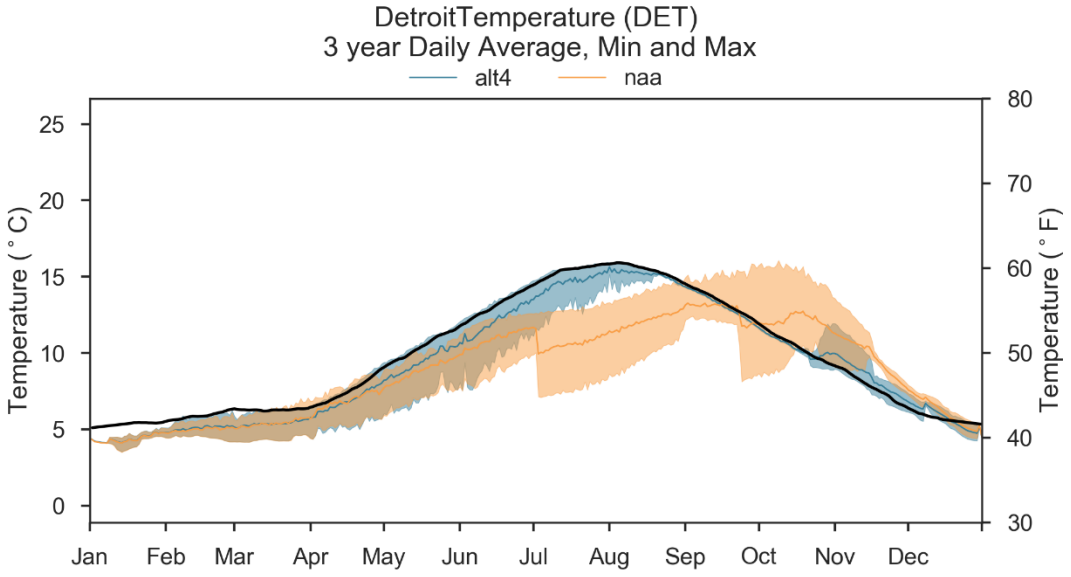


Figure 1-313 Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target.

1.5.7.2 South Santiam Dams

1.5.7.2.1 Green Peter

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Green Peter generally similar under Alternative 4 compared to NAA in 2016, decreased in 2011, and increased in 2015 aside from October-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-314, Figure 1-316). The increased storage coincided with reduced outflows during spring and increased outflows in July-October during 2015. 2011 and 2016 operations were generally similar in Alternative 4 and NAA at Green Peter Lake. The proposed temperature management operation through the spillway (during spring/summer) and RO (during autumn) in Alternative 4 led to increased outflow from these outlets compared to NAA (Figure 1-315).

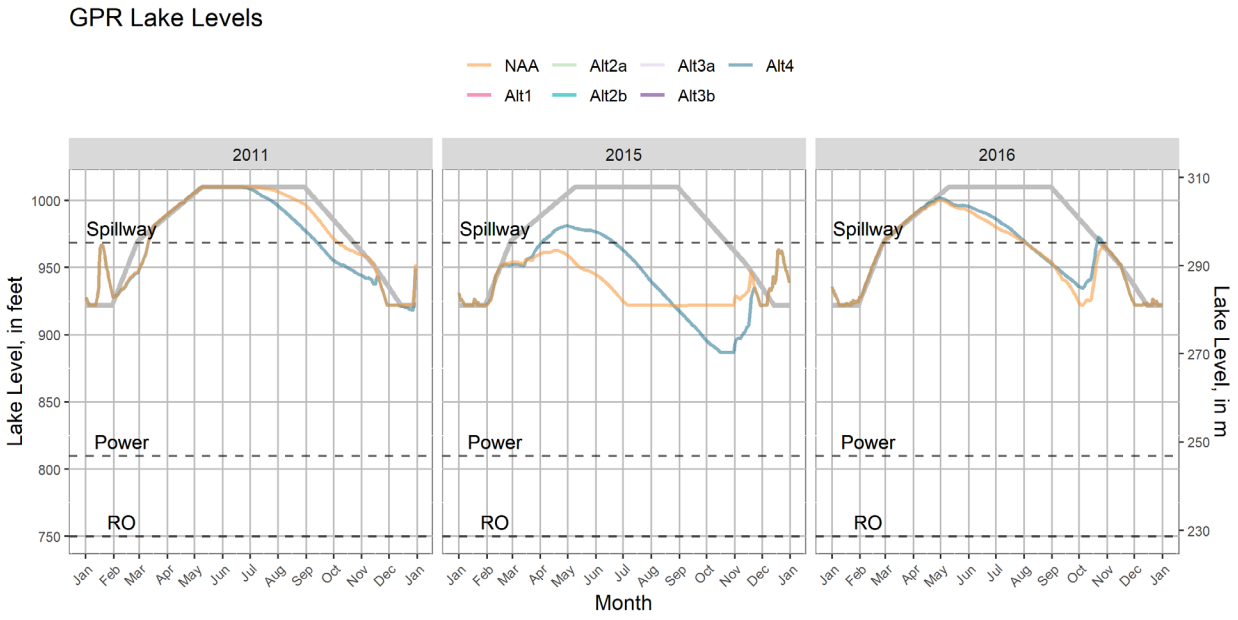


Figure 1-314. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 under Alternative 4 and NAA.

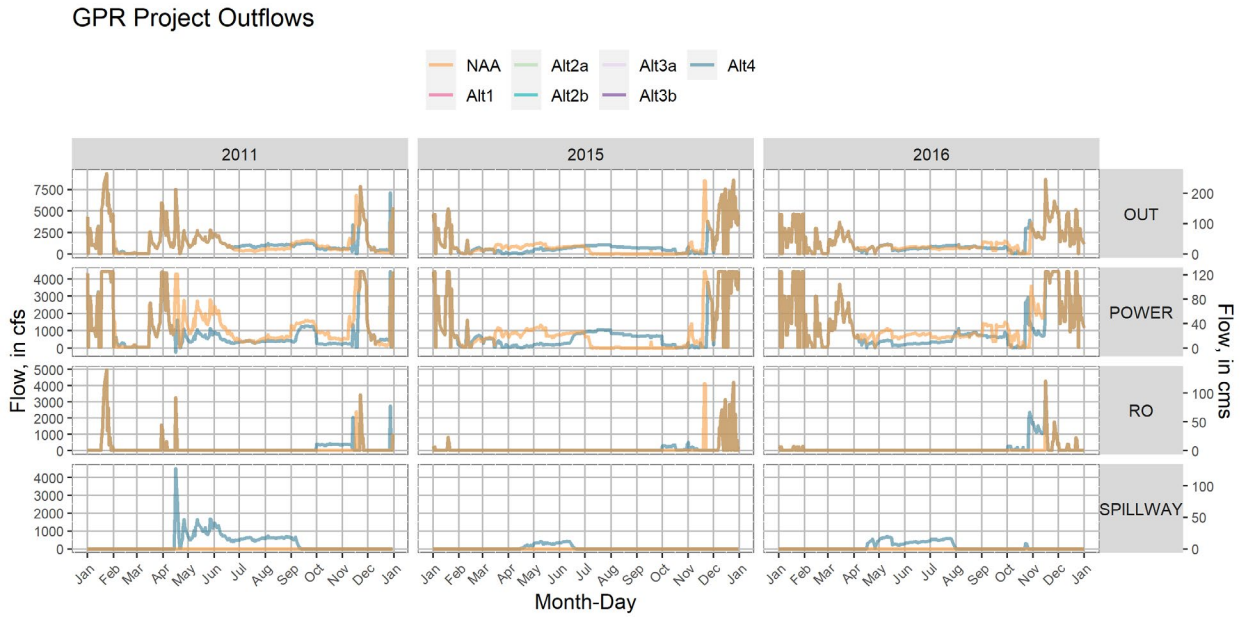


Figure 1-315. WV EIS HEC-ResSim Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA.

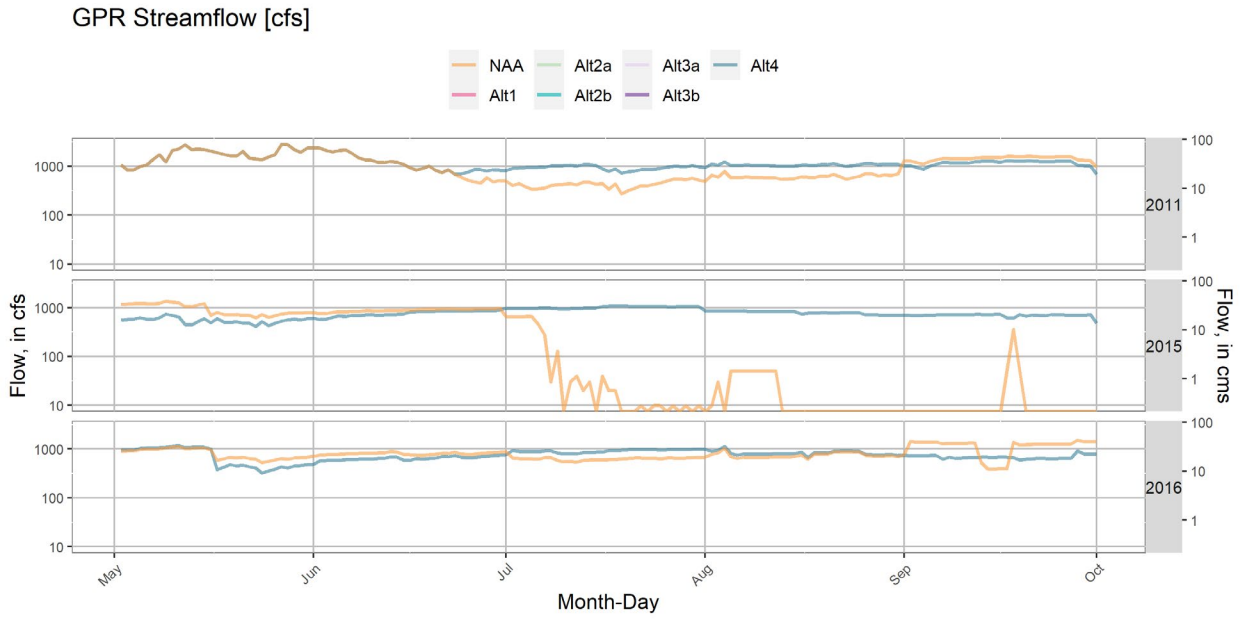


Figure 1-316. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-317, Figure 1-318, and Figure 1-319. Alternative 4 included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during

autumn to mix with relatively deep power penstock releases in to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and those outlets were submerged. However, spillway access was limited in all 3 years, leading to an abrupt drop in tailwater temperature when spillway access ended in mid-summer. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam (Figure 1-320, Figure 1-321).

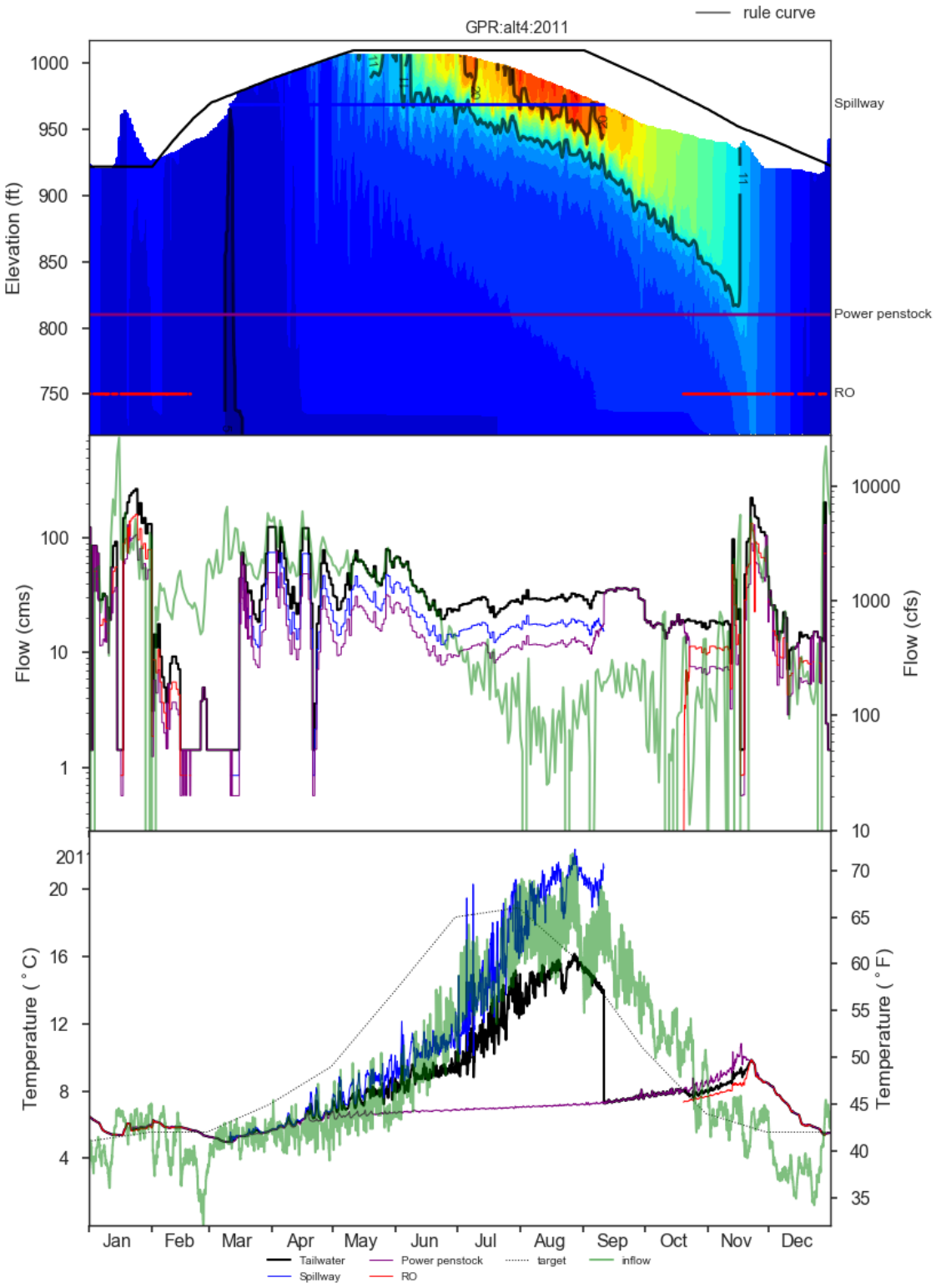


Figure 1-317. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 4 in 2011.

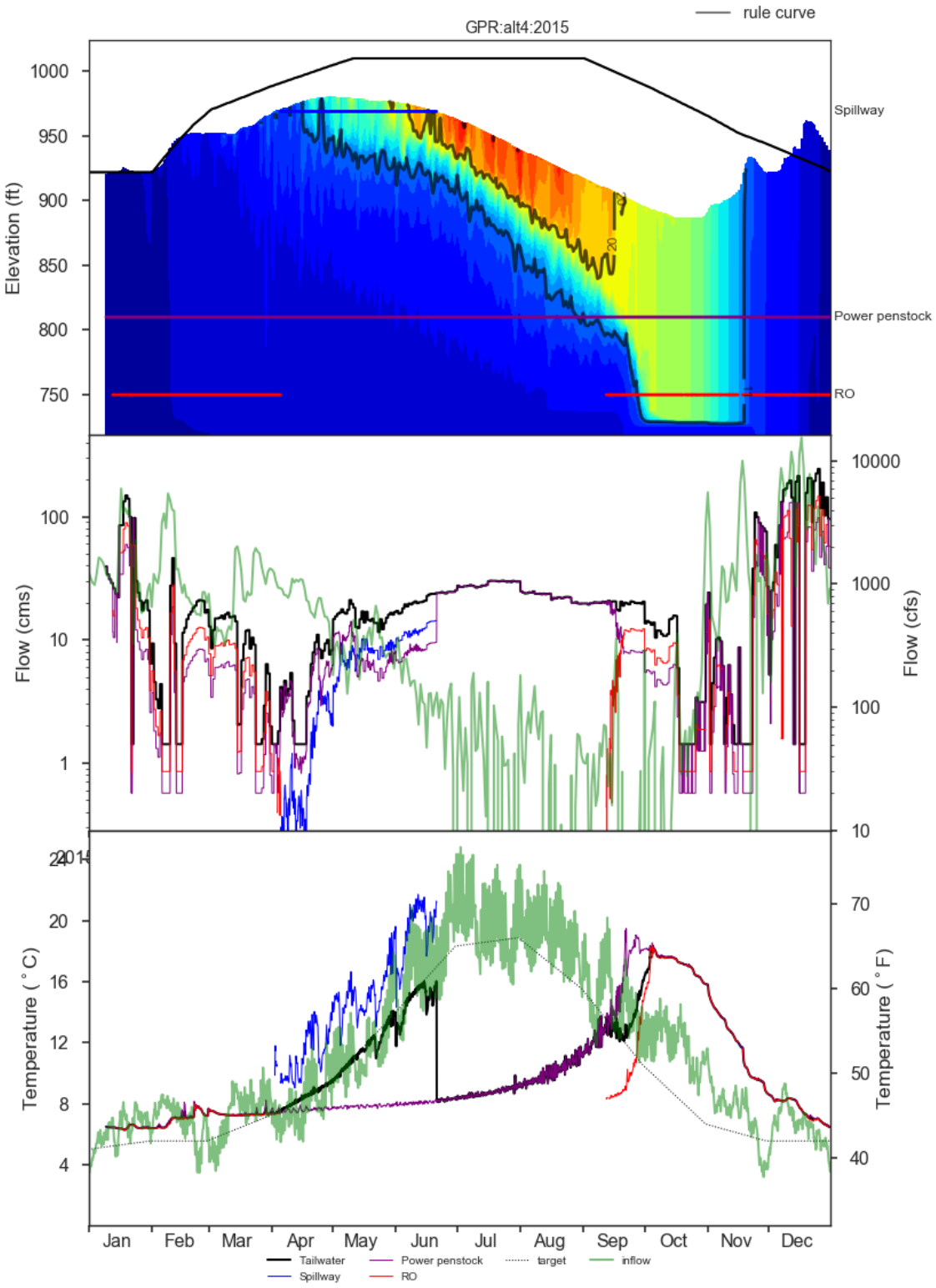


Figure 1-318. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 4 in 2015.

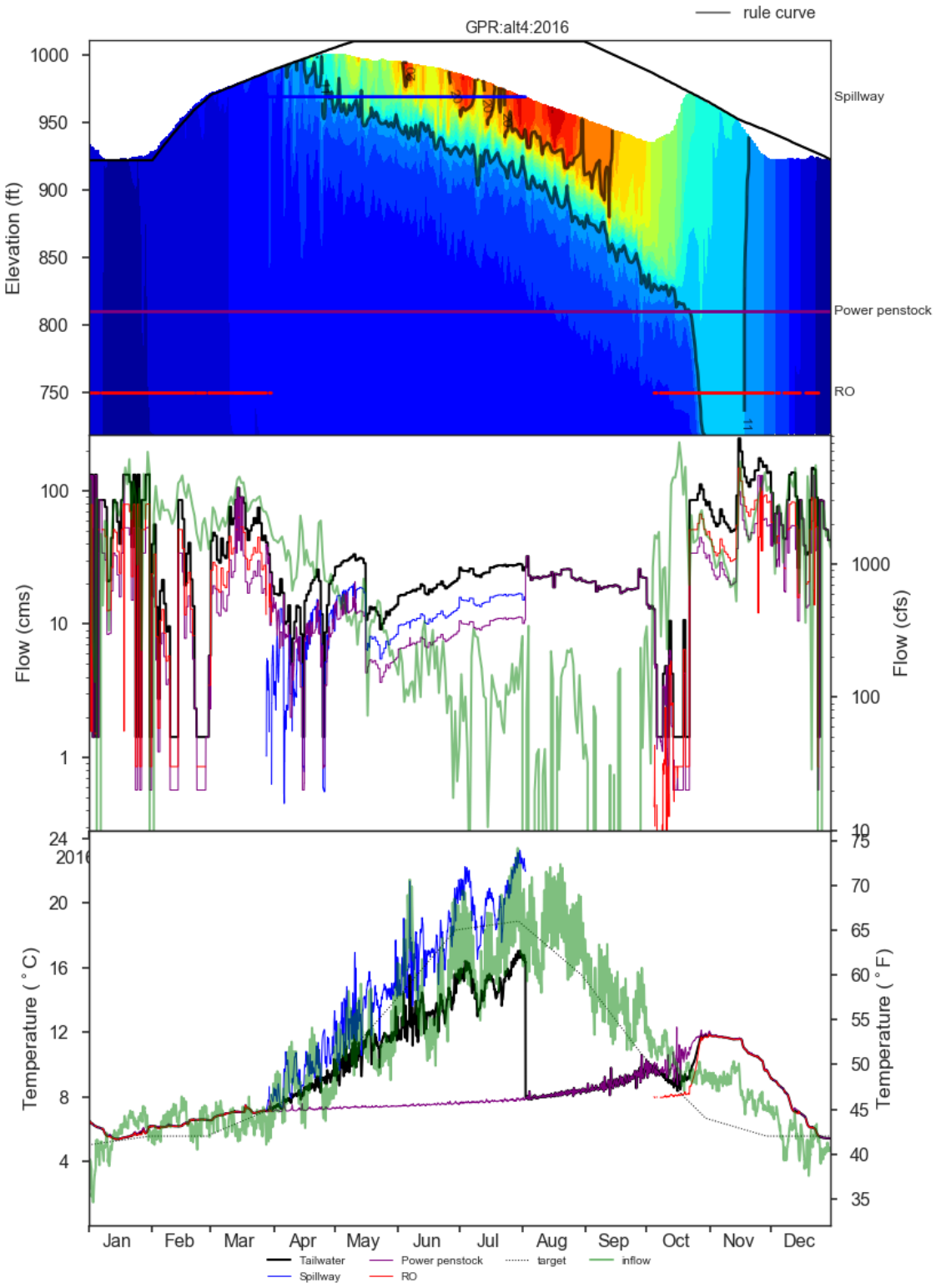


Figure 1-319. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 4 in 2016.

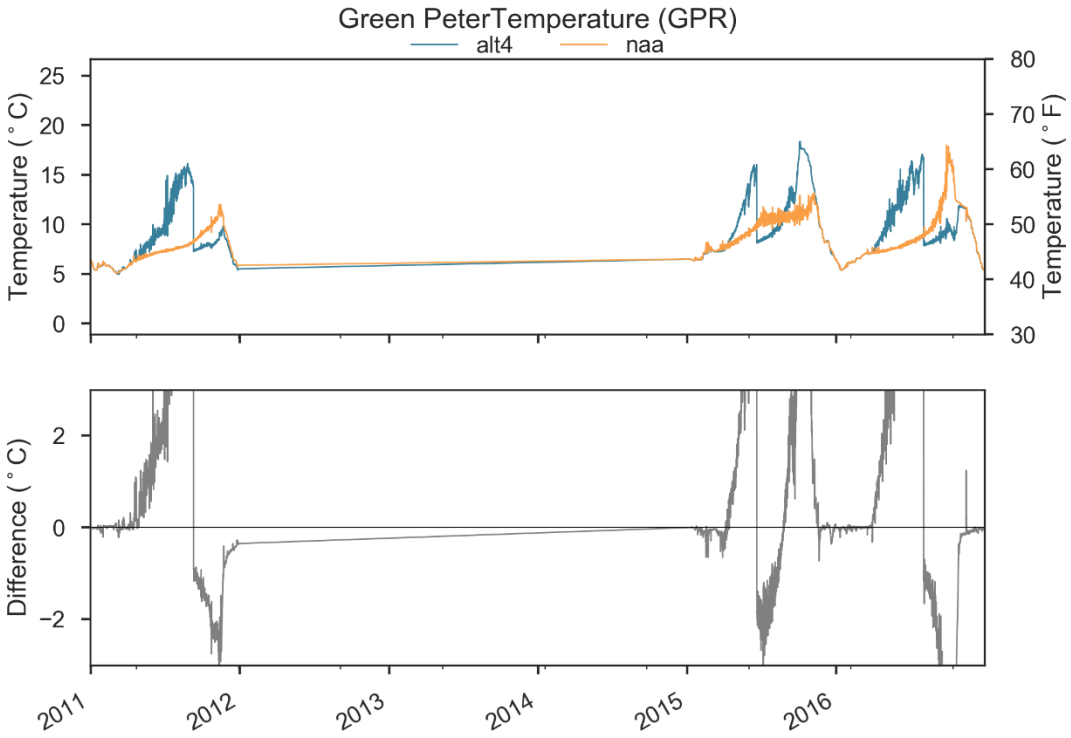


Figure 1-320. Comparison of GPR Outflow Temperatures in NAA and Alternative 4.

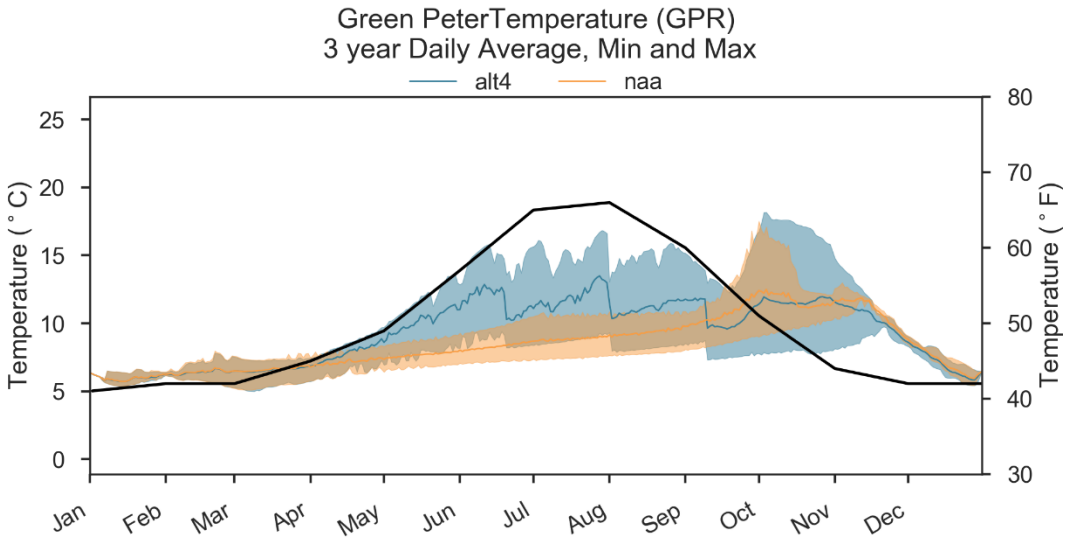


Figure 1-321. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target.

1.5.7.2.2 Foster

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Foster were generally similar in 2011 and 2016 but increased in 2015 under Alternative 4 compared to NAA (Figure 1-322, Figure 1-324). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam. The proposed modifications to the fish weir and FWWS in Alternative 4 resulted in lower outflow routed through the Power outlets for temperature management, especially during spring and summer, compared to NAA (Figure 1-323).

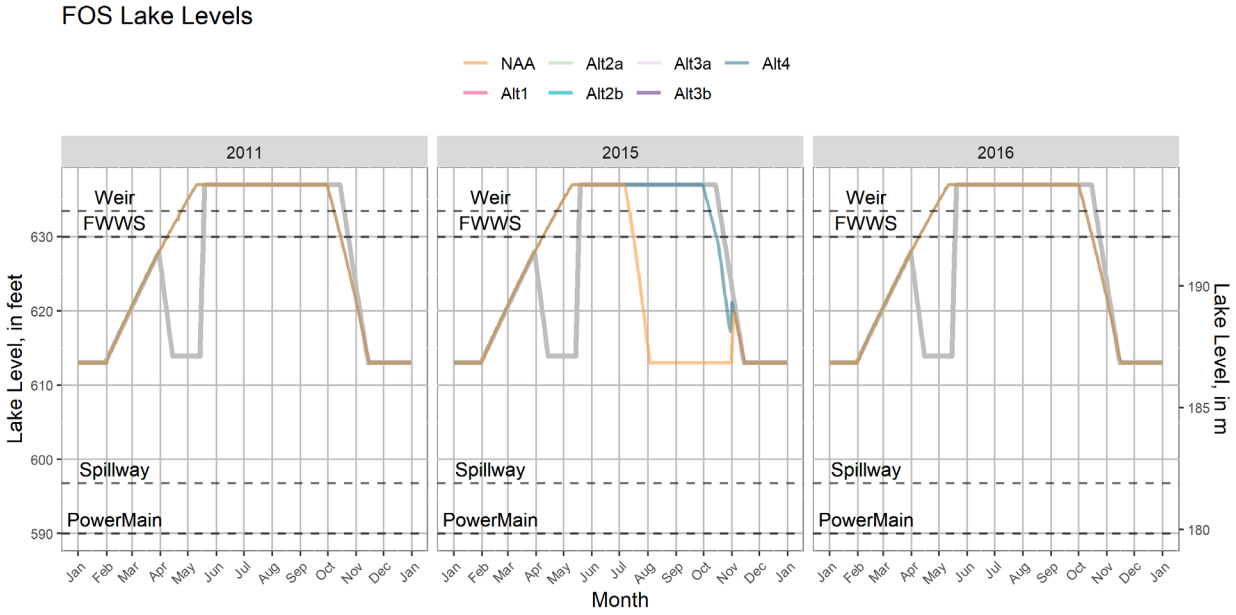


Figure 1-322. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 4 and NAA.

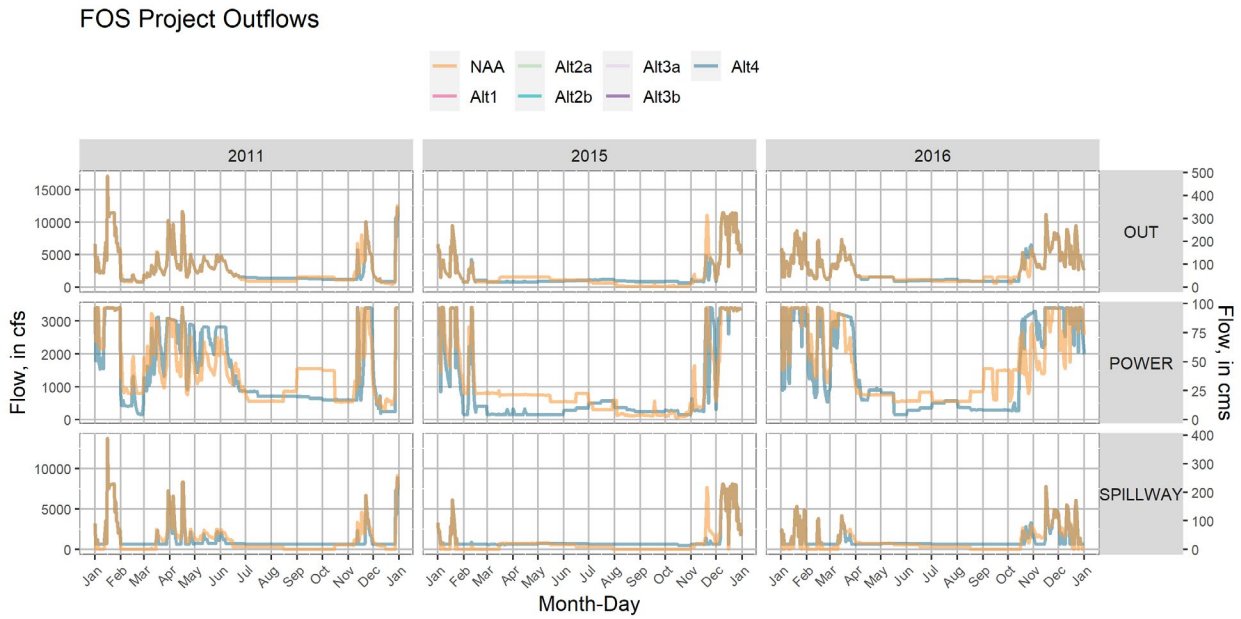


Figure 1-323. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA.

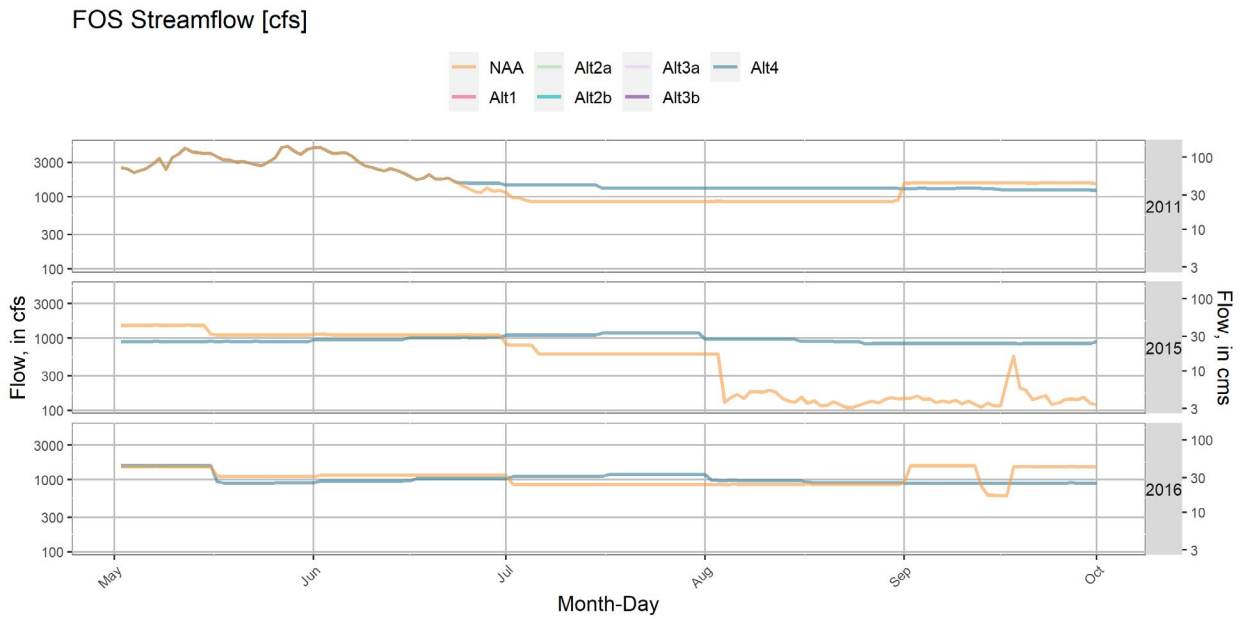


Figure 1-324. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-325, Figure 1-326, and Figure 1-327. Foster Lake temperature was affected by Green Peter Dam operations release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in

the temperature pattern (Sullivan and Rounds, 2021). Outflows from the proposed fish weir and FWWS resulted in warmer tailwater temperature in spring and summer compared to NAA and similar temperatures to NAA in autumn (Figure 1-328, Figure 1-329).

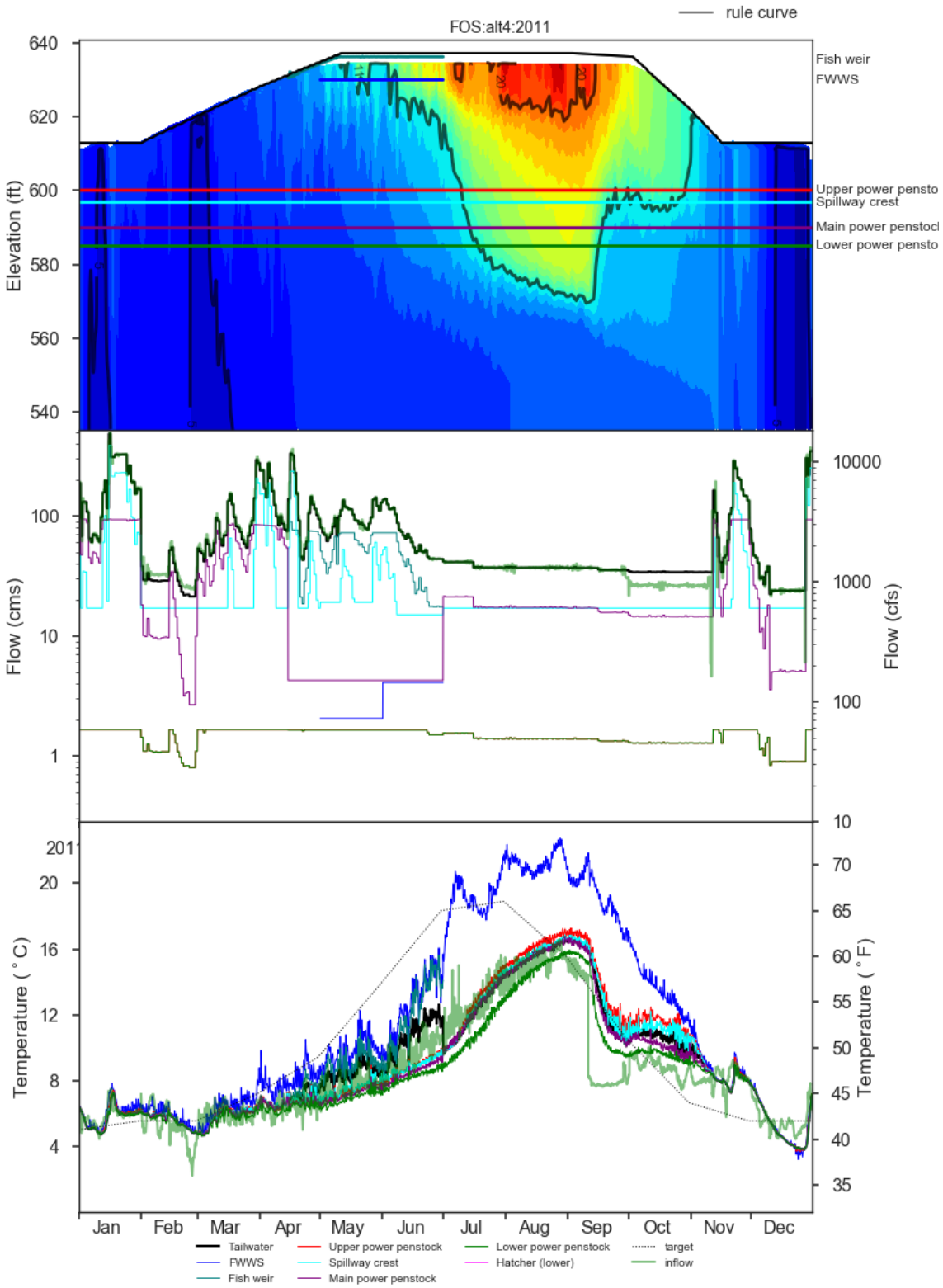


Figure 1-325. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 4 in 2011.

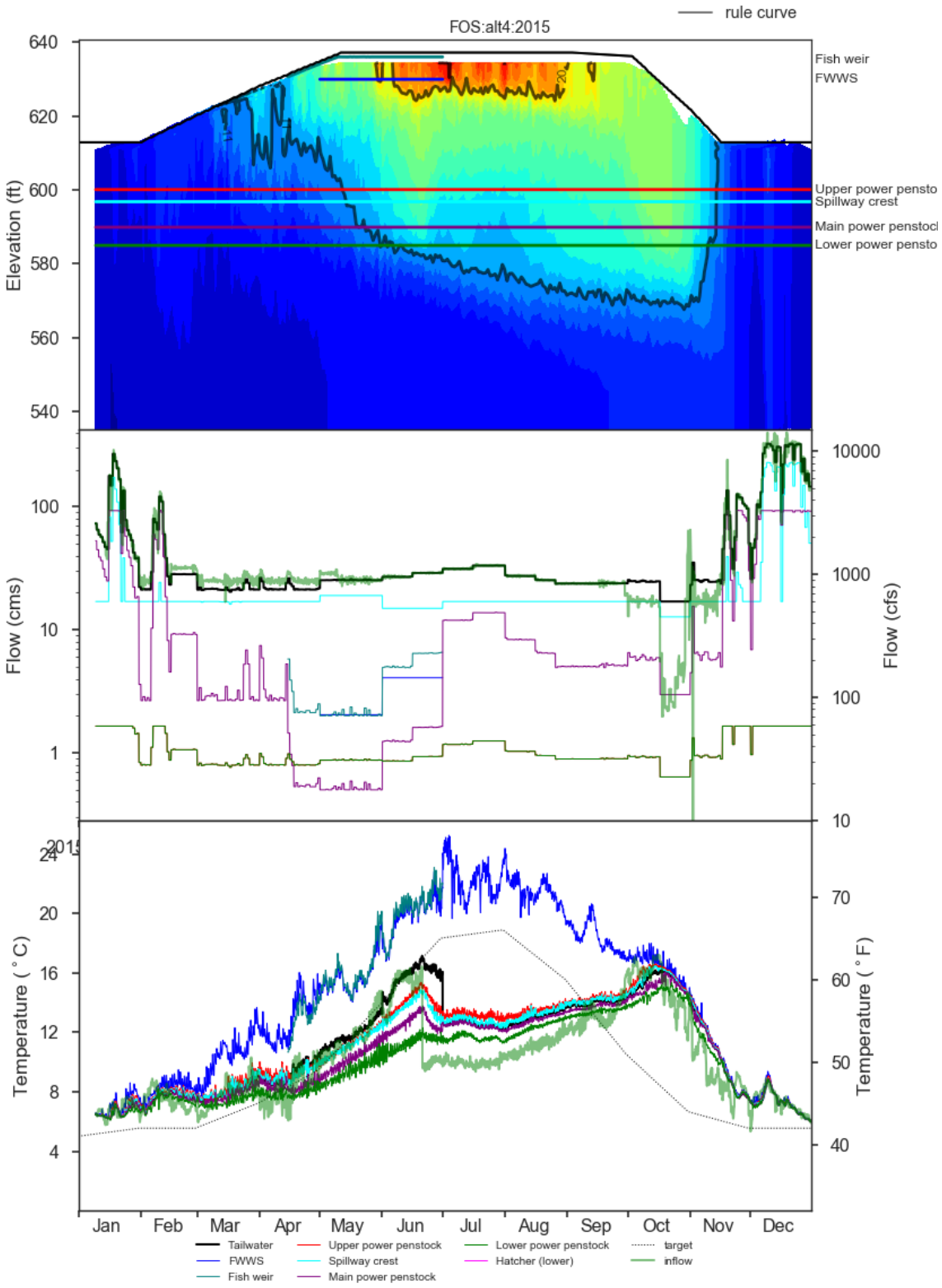


Figure 1-326. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 4 in 2015.

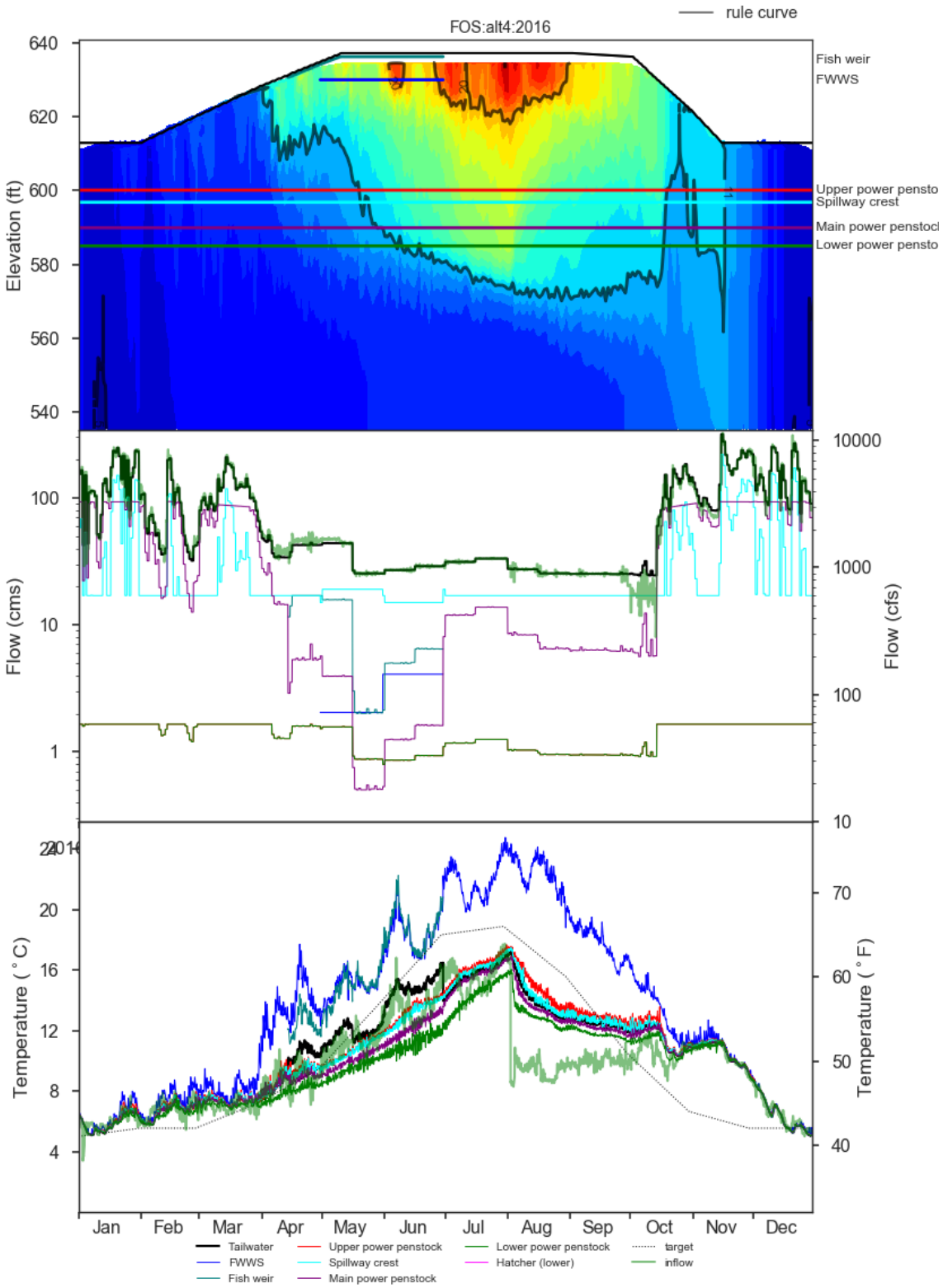


Figure 1-327. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 4 in 2016.

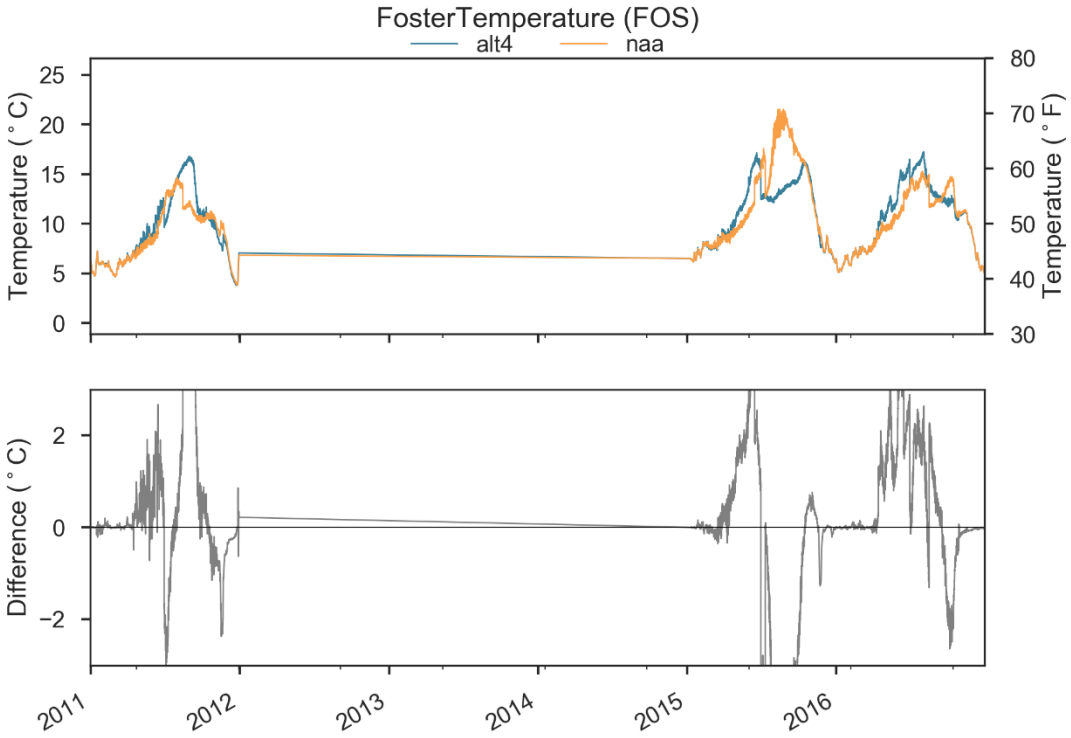


Figure 1-328. Comparison of FOS outflow temperatures in NAA and Alternative 4.

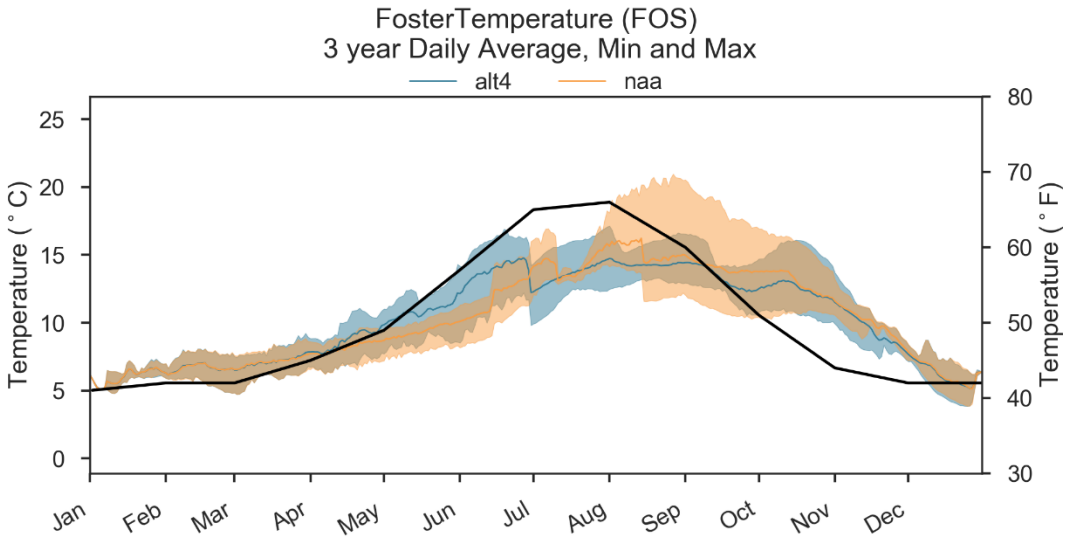


Figure 1-329 Comparison of FOS 3-year daily Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target.

1.5.7.3 McKenzie Dams

1.5.7.3.1 Cougar

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Cougar Lake increased under Alternative 4 compared to NAA in 2015 and 2016 aside from September-November in 2015 where the power pool was utilized for downstream flow augmentation when available (Figure 1-330 and Figure 1-332). The increased storage coincided with reduced outflows during spring and increased outflows in summer (while the lake was above minimum lake elevation rules set in HEC-ResSim) during 2015 and 2016 (Figure 1-331). 2011 operations were generally similar in Alternative 1 and NAA at Cougar Lake.

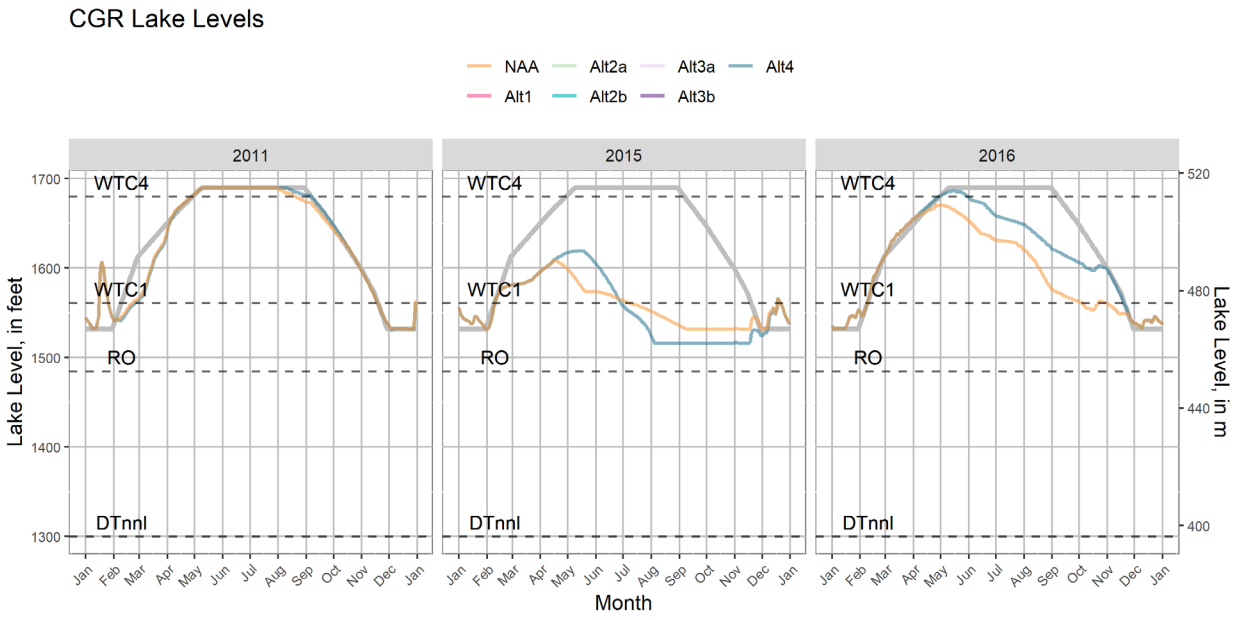


Figure 1-330. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 4 and NAA.

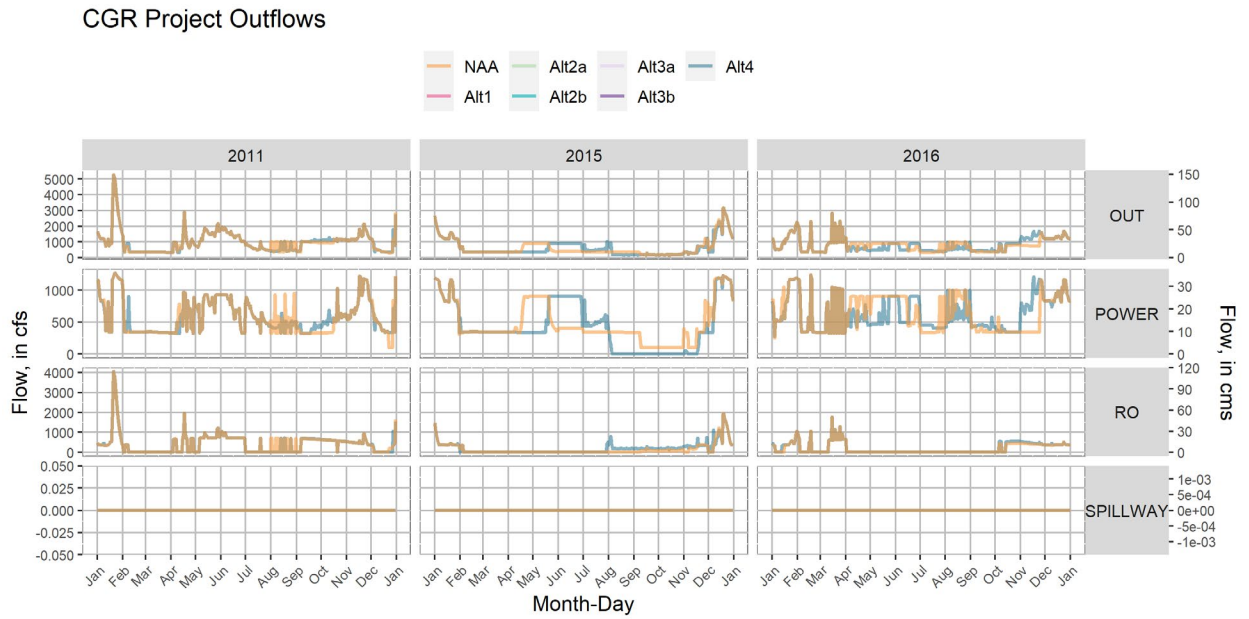


Figure 1-331. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA.

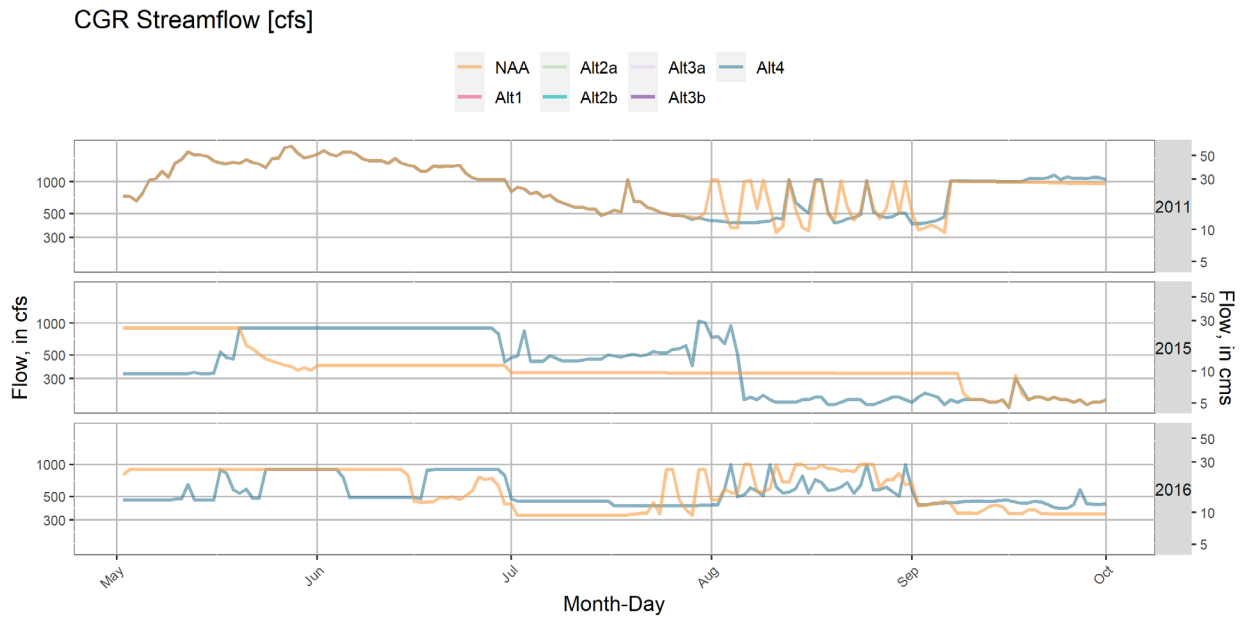


Figure 1-332. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Cougar Lake are shown in Figure 1-333, Figure 1-334, and Figure 1-335. Outflows from the existing temperature tower and proposed FSS resulted in similar tailwater temperature in Alternative 4 compared to NAA (Figure 1-336 and Figure 1-337) aside

from minor differences in each calendar year scenario that were likely linked to differences in lake levels and the shift in timing of when the lake was drafted below the bottom usable elevation of the WTCT. The addition of a FSS structure in Alternative 4 is not expected to have a large effect on the ability of the existing WTCT functionality with respect to temperature management (USACE, 2019a).

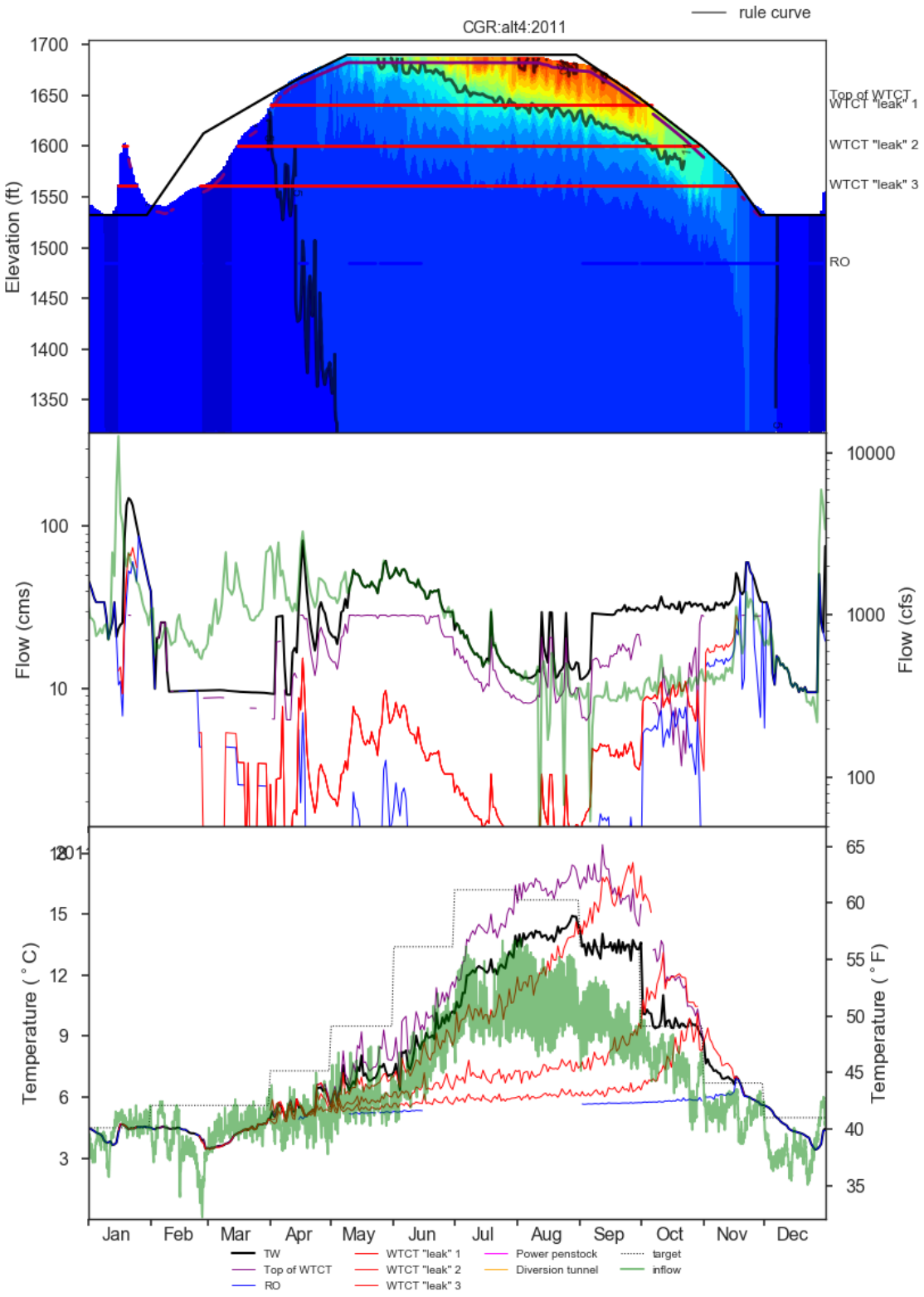


Figure 1-333. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 4 in 2011.

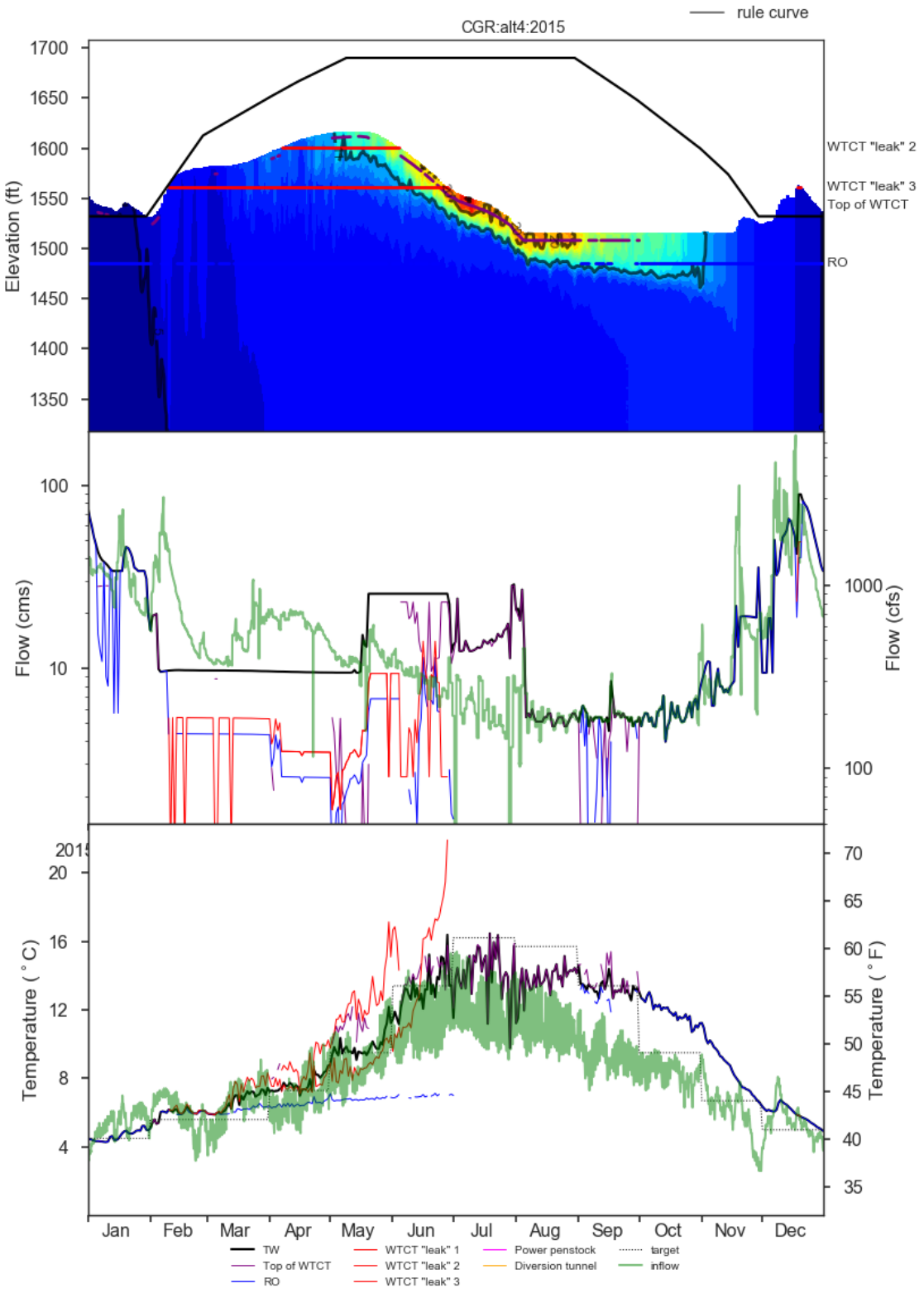


Figure 1-334. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 4 in 2015.

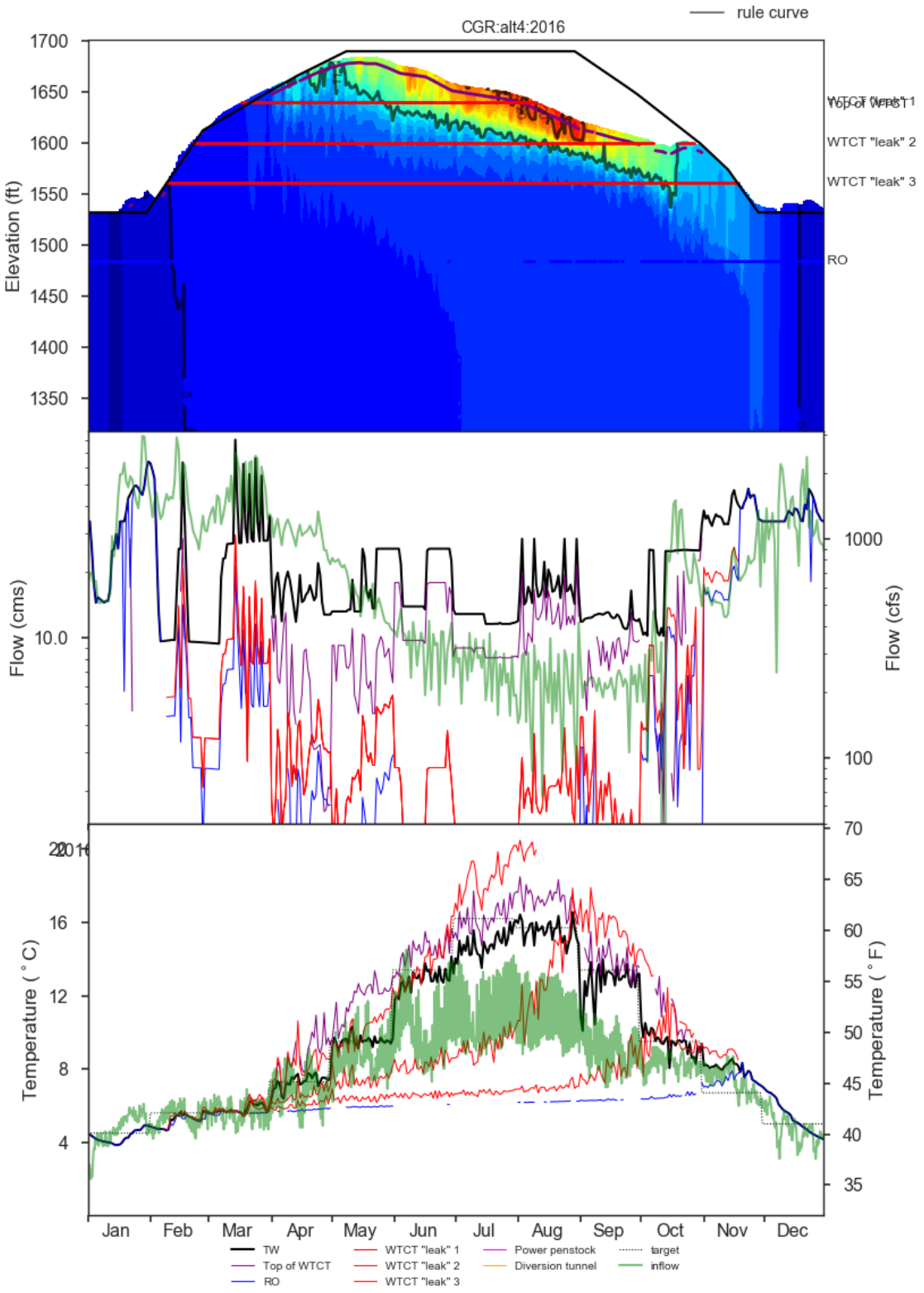


Figure 1-335. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 4 in 2016.

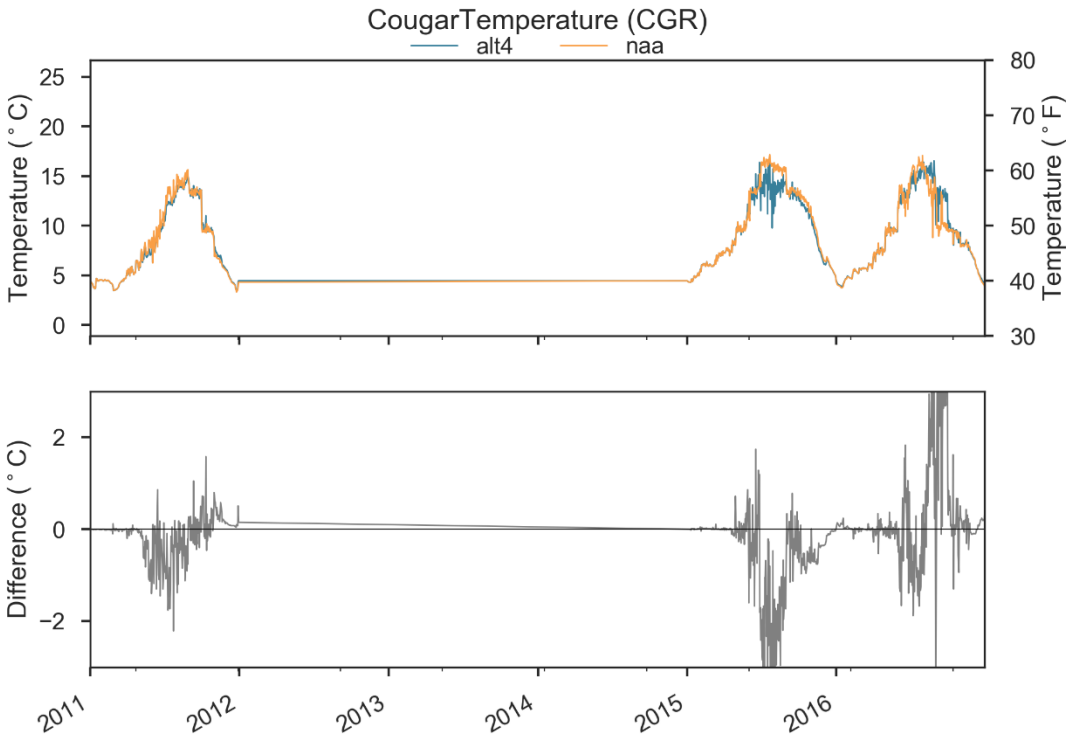


Figure 1-336. Comparison of CGR Outflow Temperatures in NAA and Alternative 4.

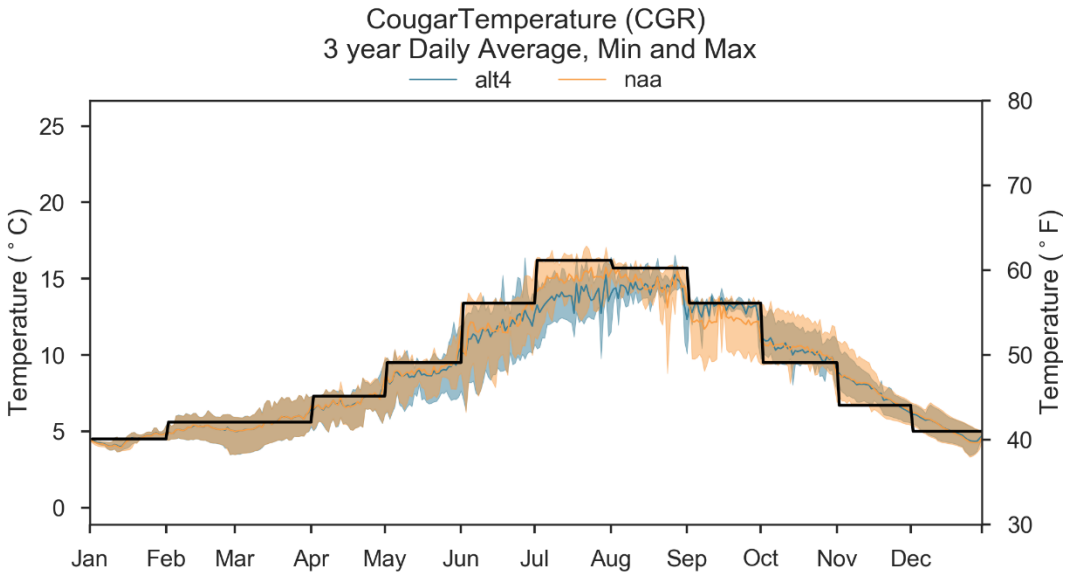


Figure 1-337. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target.

1.5.7.4 Middle Fork Willamette Dams

1.5.7.4.1 Hills Creek

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Hills Creek Lake generally increased under Alternative 4 compared to NAA in 2015 and 2016 aside from August-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-338, Figure 1-340). The increased storage coincided with reduced outflows during spring and increased outflows in June-July during 2015 and July-October in 2016 (Figure 1-339). 2011 operations were similar in Alternative 4 and NAA at Hills Creek Lake.

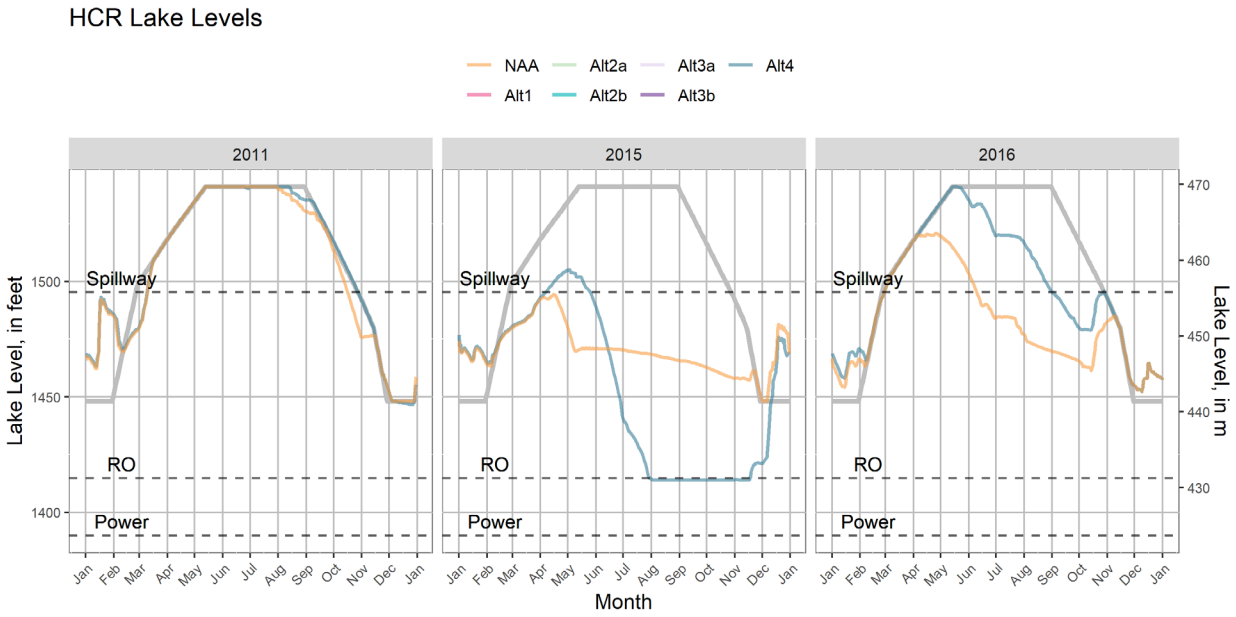


Figure 1-338. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 4 and NAA.

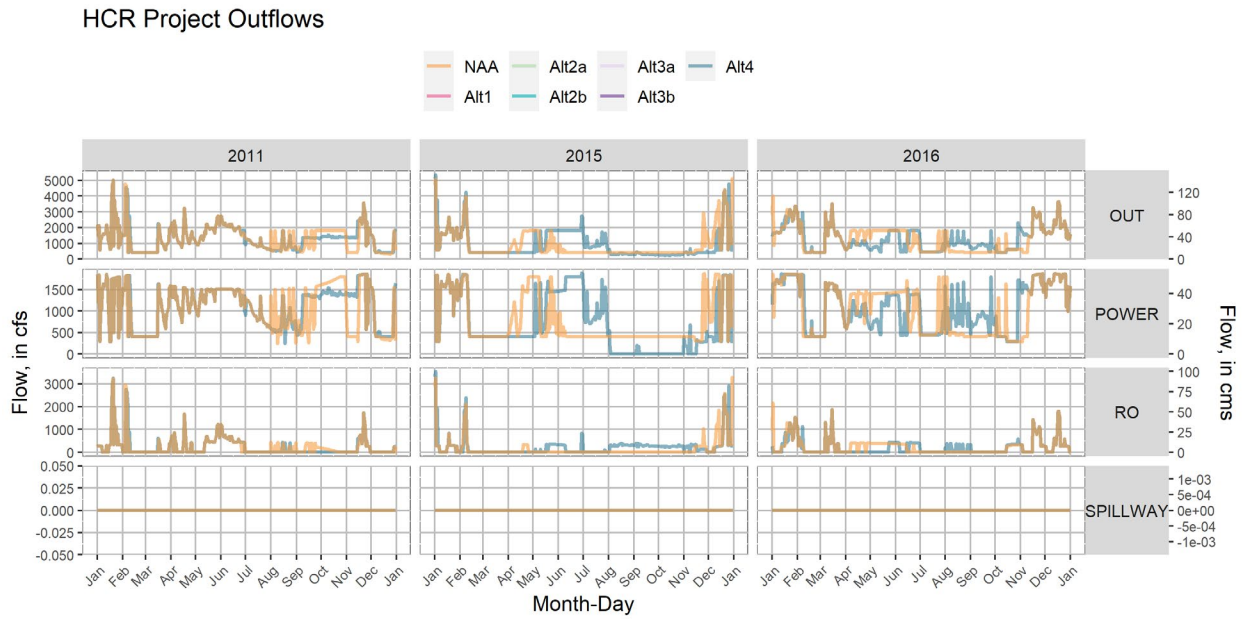


Figure 1-339. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA.

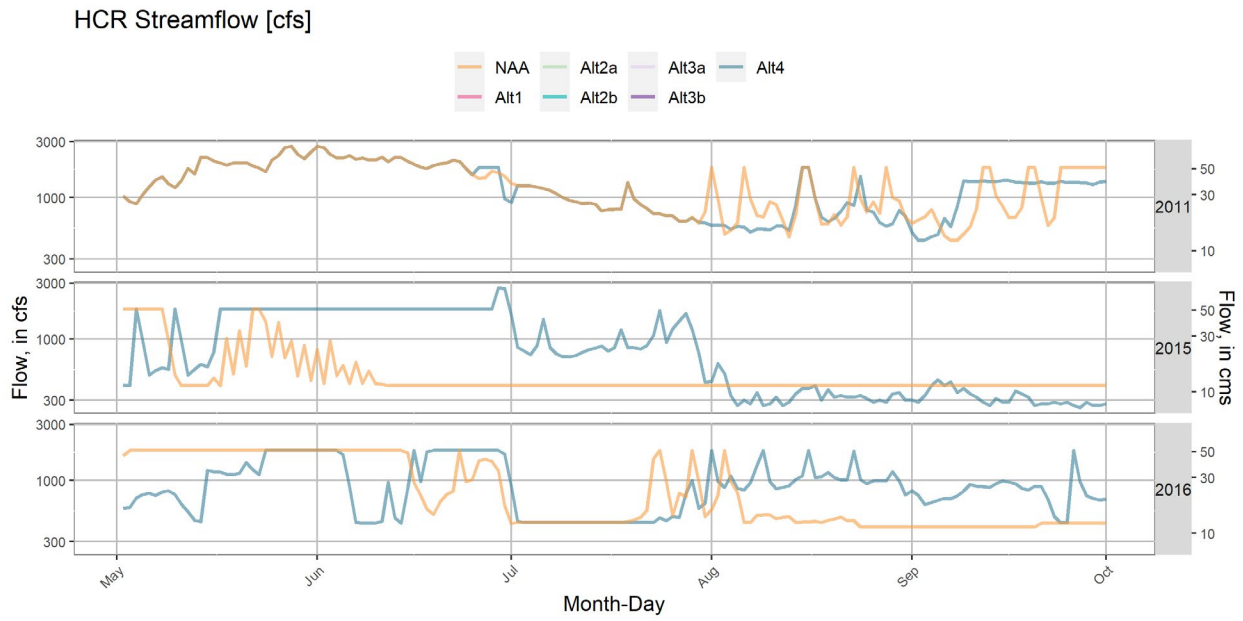


Figure 1-340. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 4 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 4 at Hills Creek Lake are shown in Figure 1-341, Figure 1-342, and Figure 1-343. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the RO. Tailwater release

temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, these proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn in 2011, 2015, and 2016 (Figure 1-344, Figure 1-345).

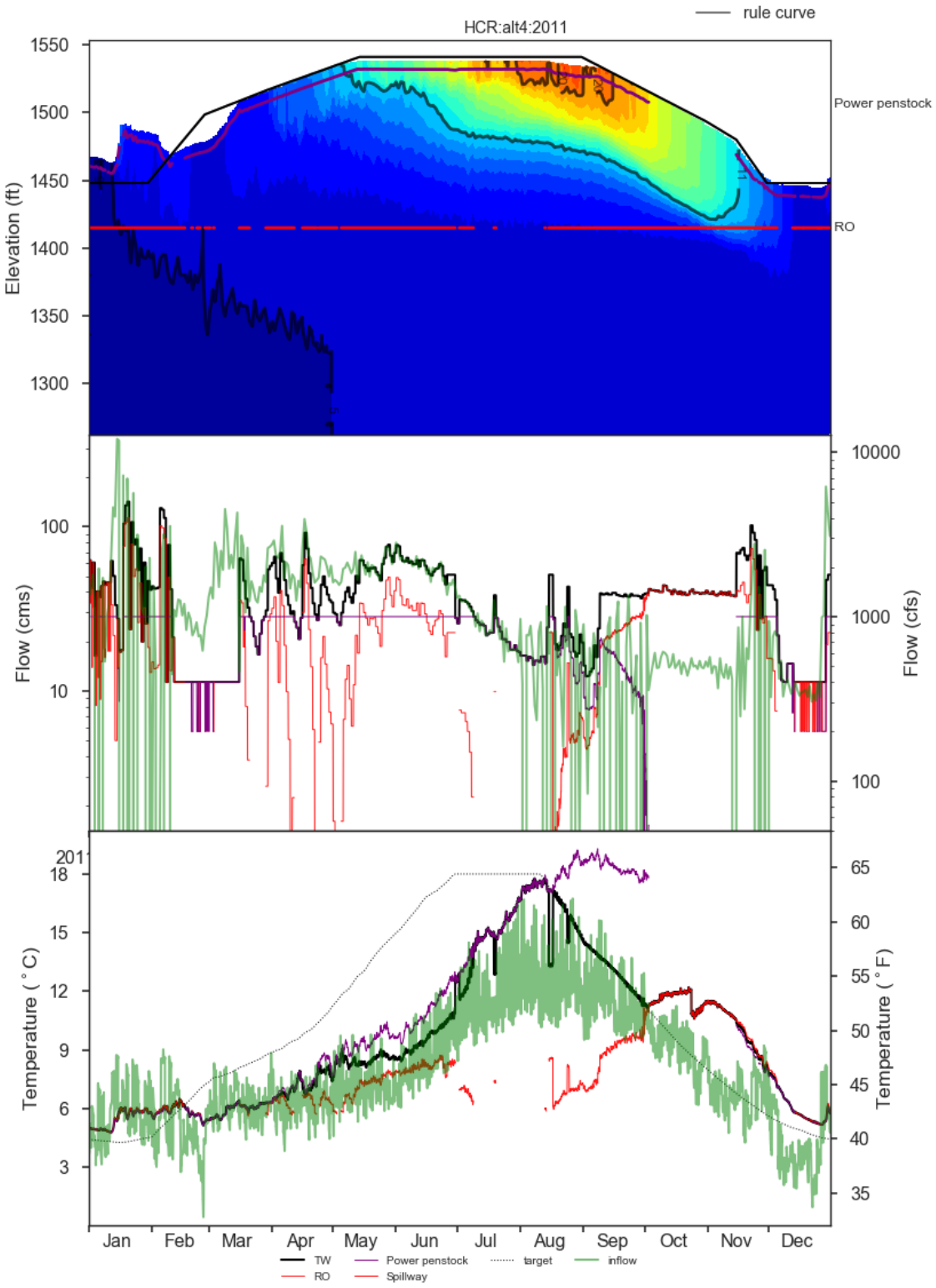


Figure 1-341. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 4 in 2011.

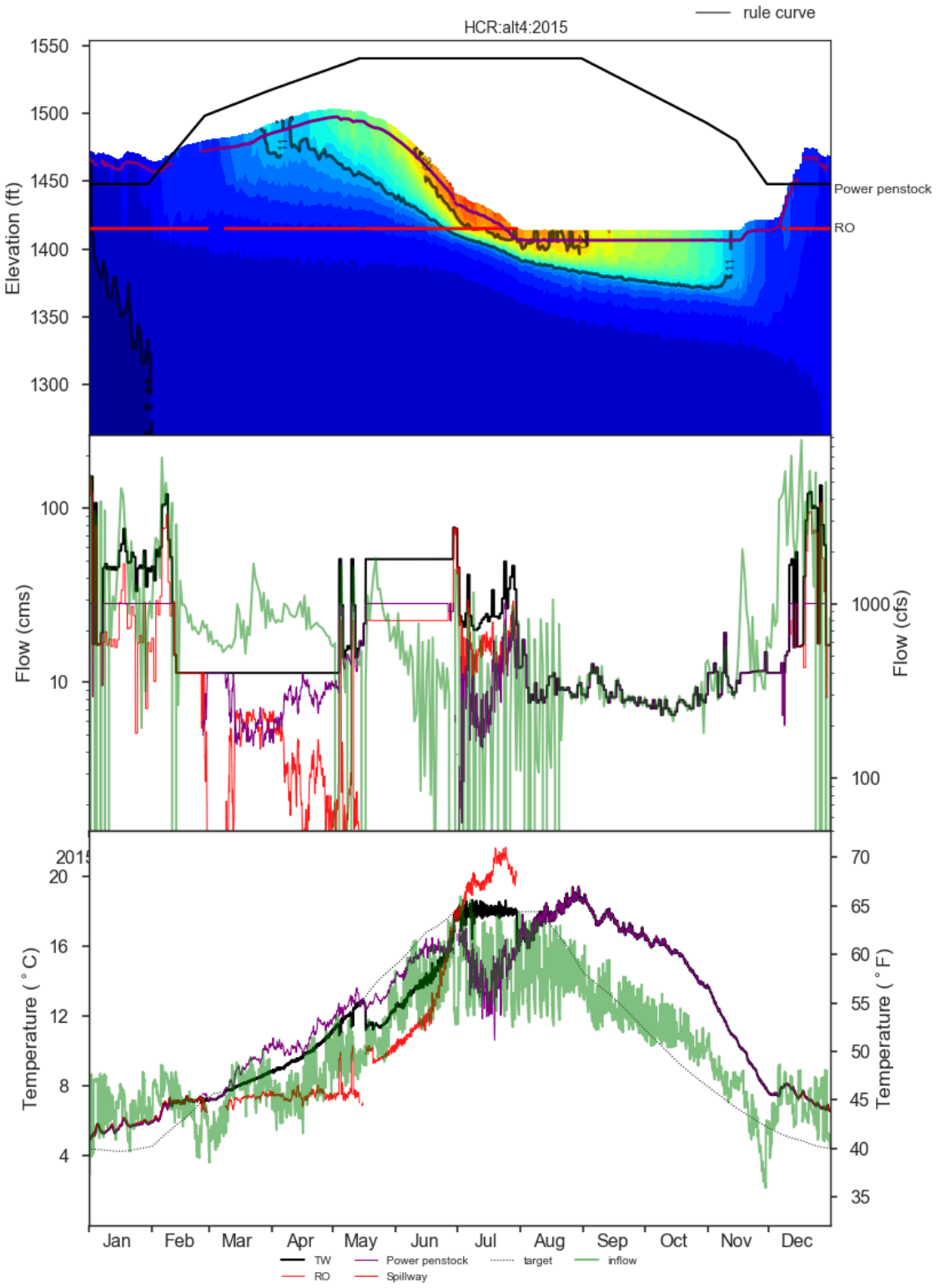


Figure 1-342. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 4 in 2015.

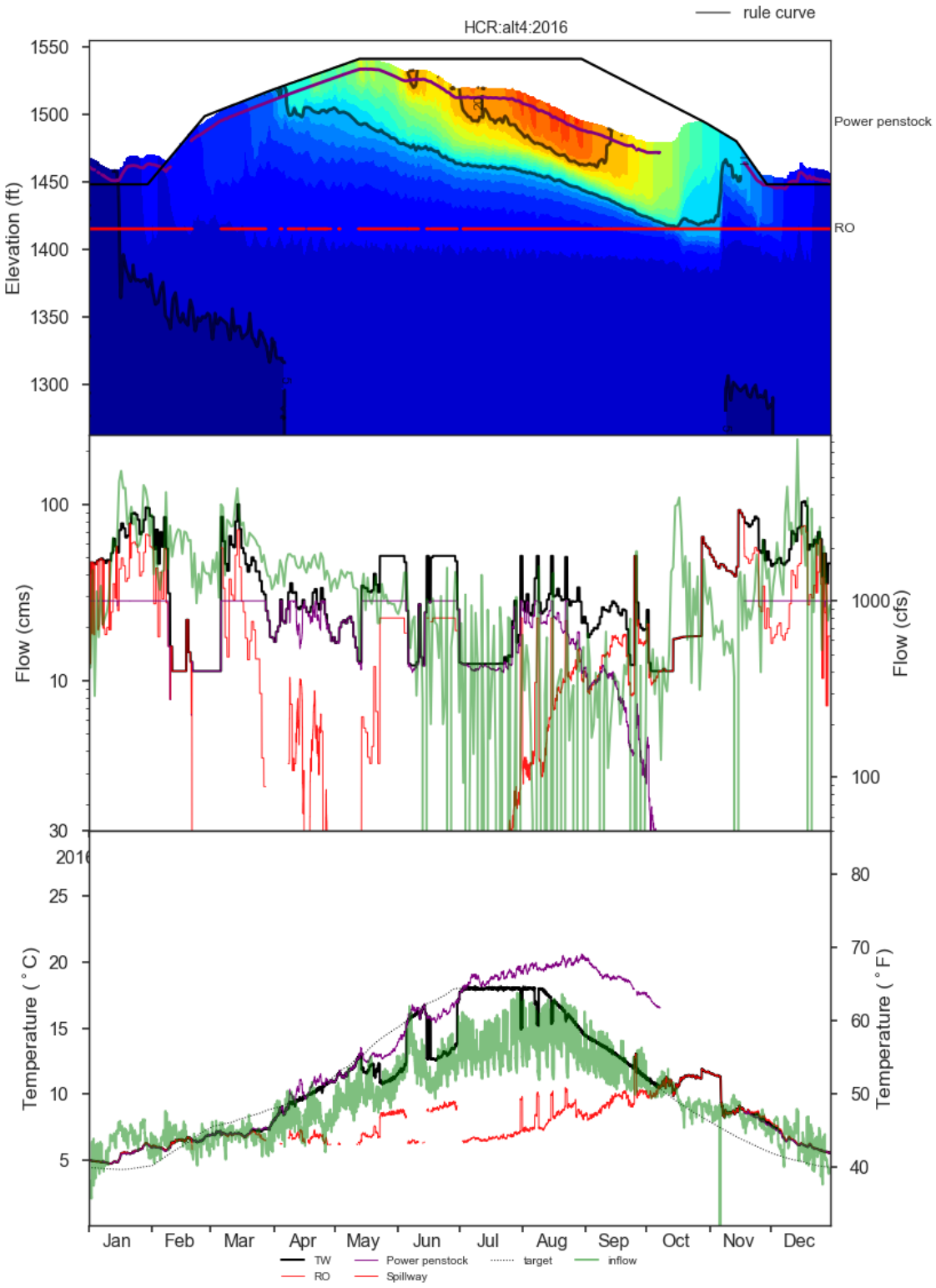


Figure 1-343. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 4 in 2016.

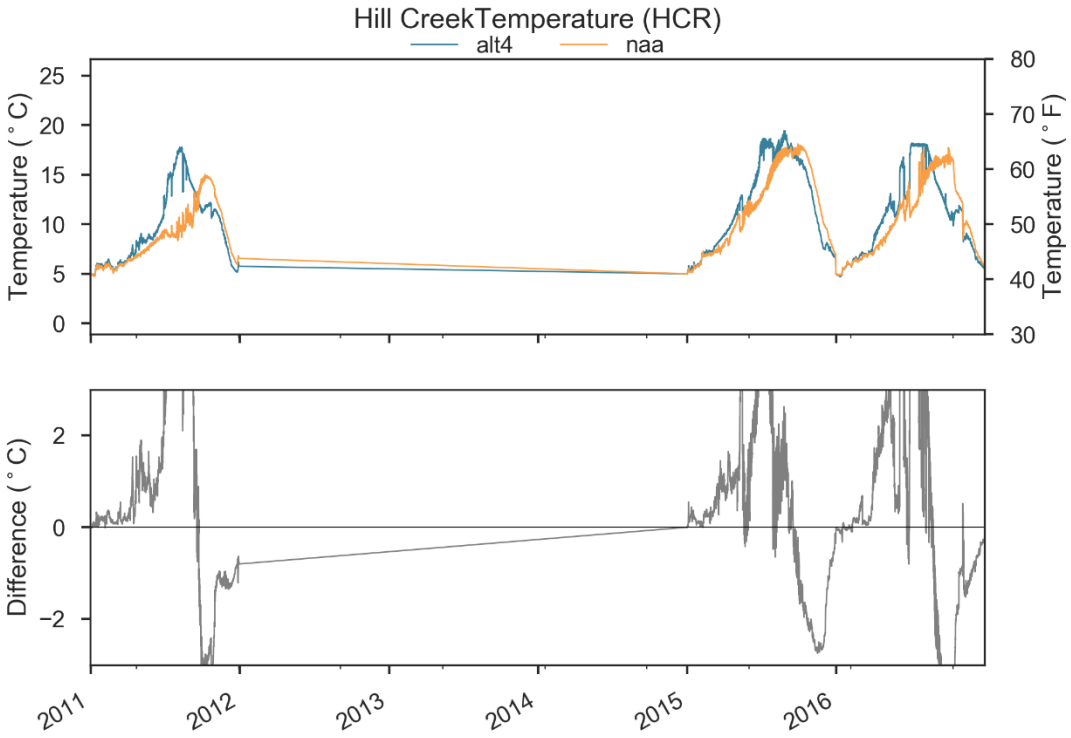


Figure 1-344. Comparison of HCR outflow temperatures in NAA and Alternative 4.

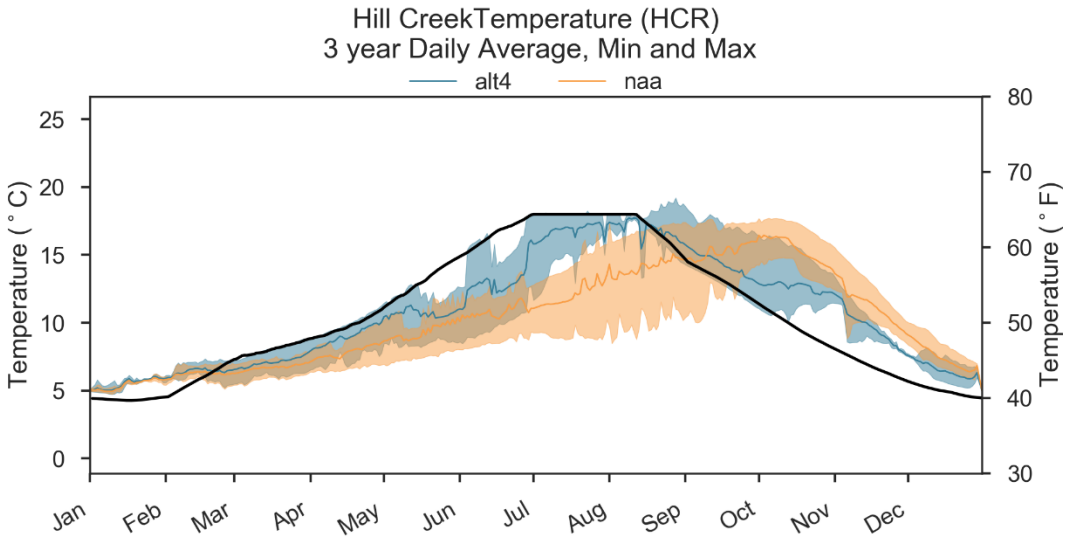


Figure 1-345. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target.

1.5.7.4.2 Lookout Point

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Lookout Point Lake in Alternative 4 were generally similar to NAA in 2011, 2015, and 2016 (Figure 1-346, Figure 1-348) aside from minor differences in timing of refill and release rates that were associated with upstream HCR operations. The proposed SWS and FSS in Alternative 4 allowed all outflow within powerhouse capacity (assumed at 6000 cfs) to be routed from a floating outlet through the Power outlets for temperature management (Figure 1-347).

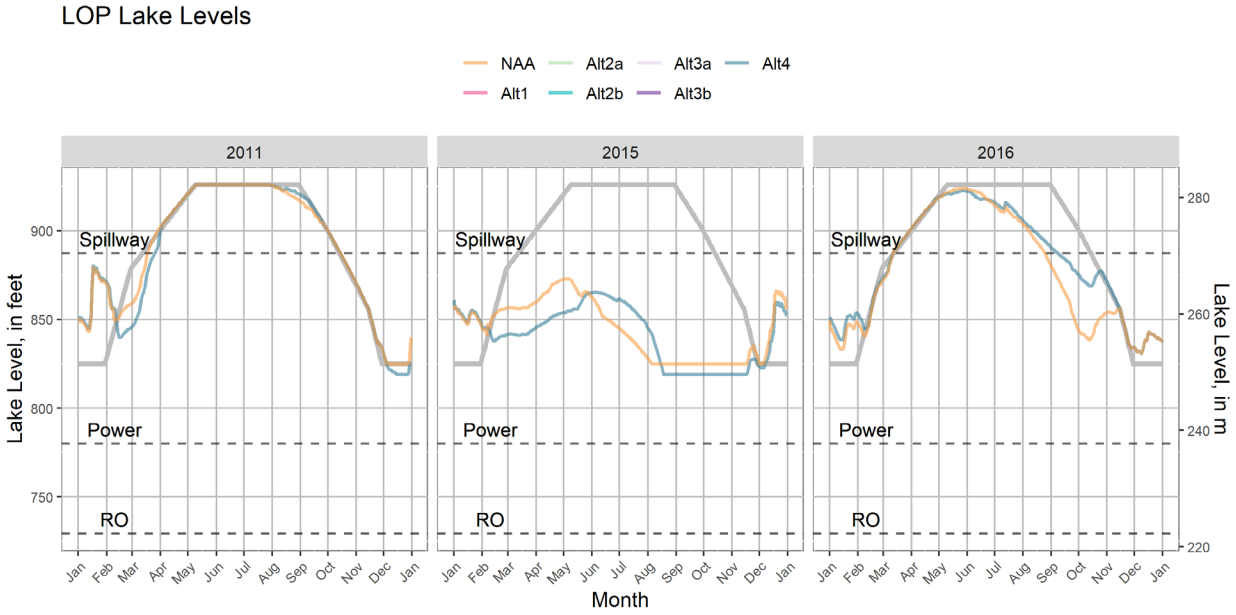


Figure 1-346. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 4 and NAA.

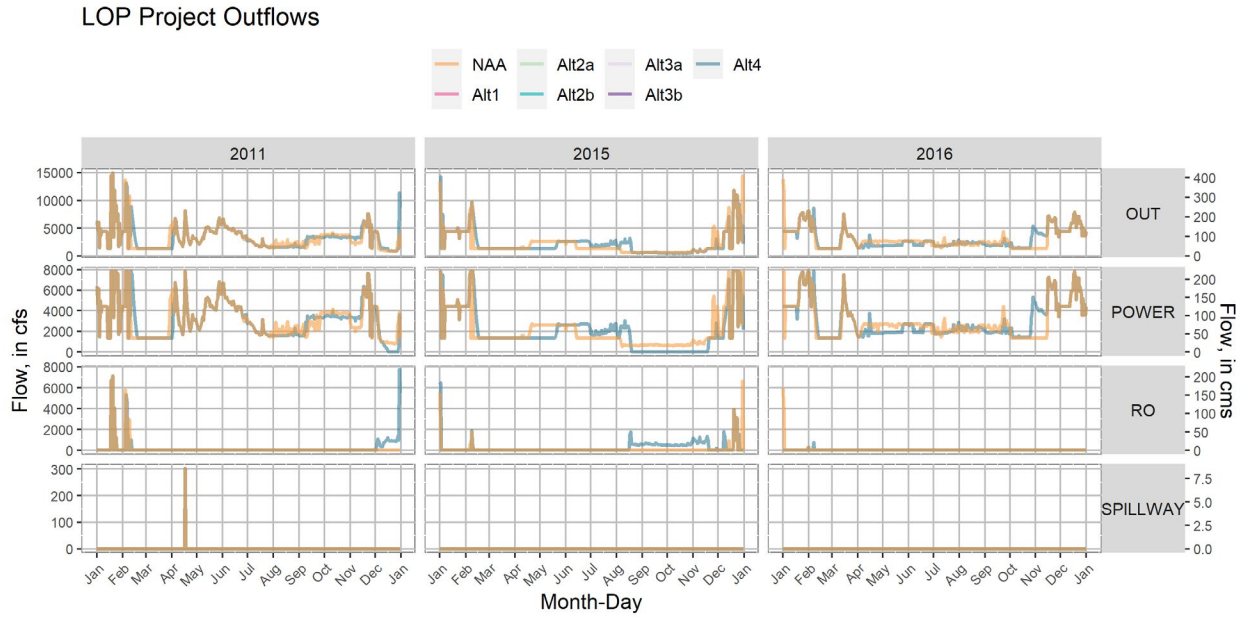


Figure 1-347. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA.

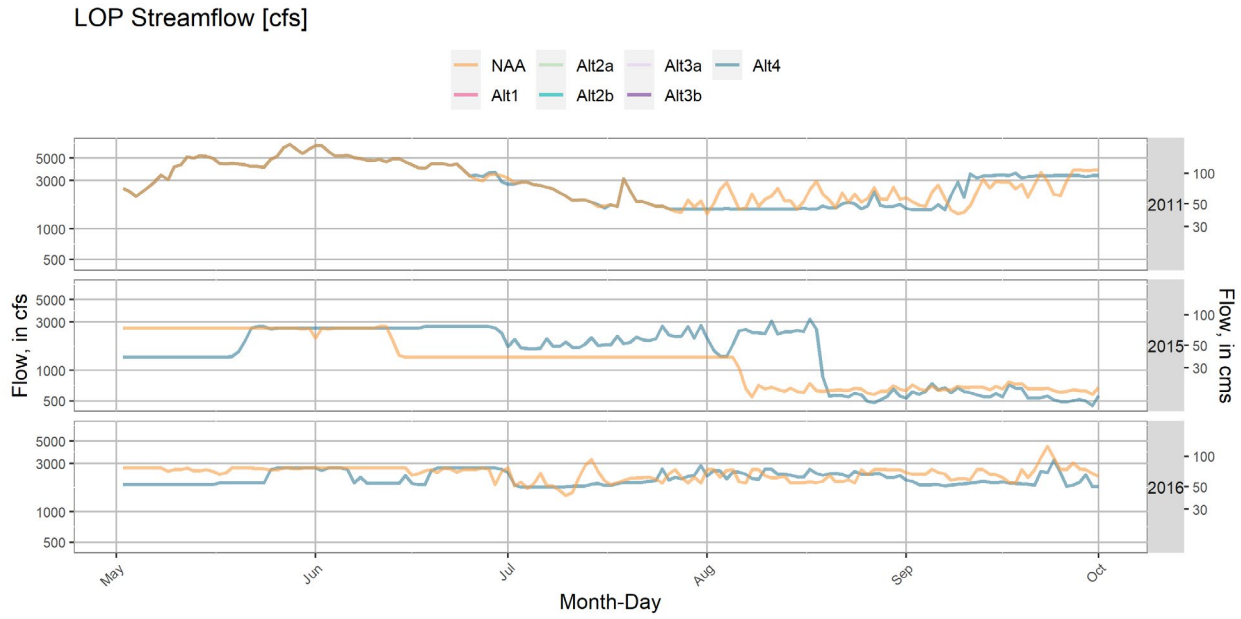


Figure 1-348. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Lookout Point Lake in Alternative 4 are shown in Figure 1-349, Figure 1-350, and Figure 1-351. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the RO. Tailwater release

temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, these proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn in 2011, 2015, and 2016 (Figure 1-352, Figure 1-353) as measured below Dexter Dam.

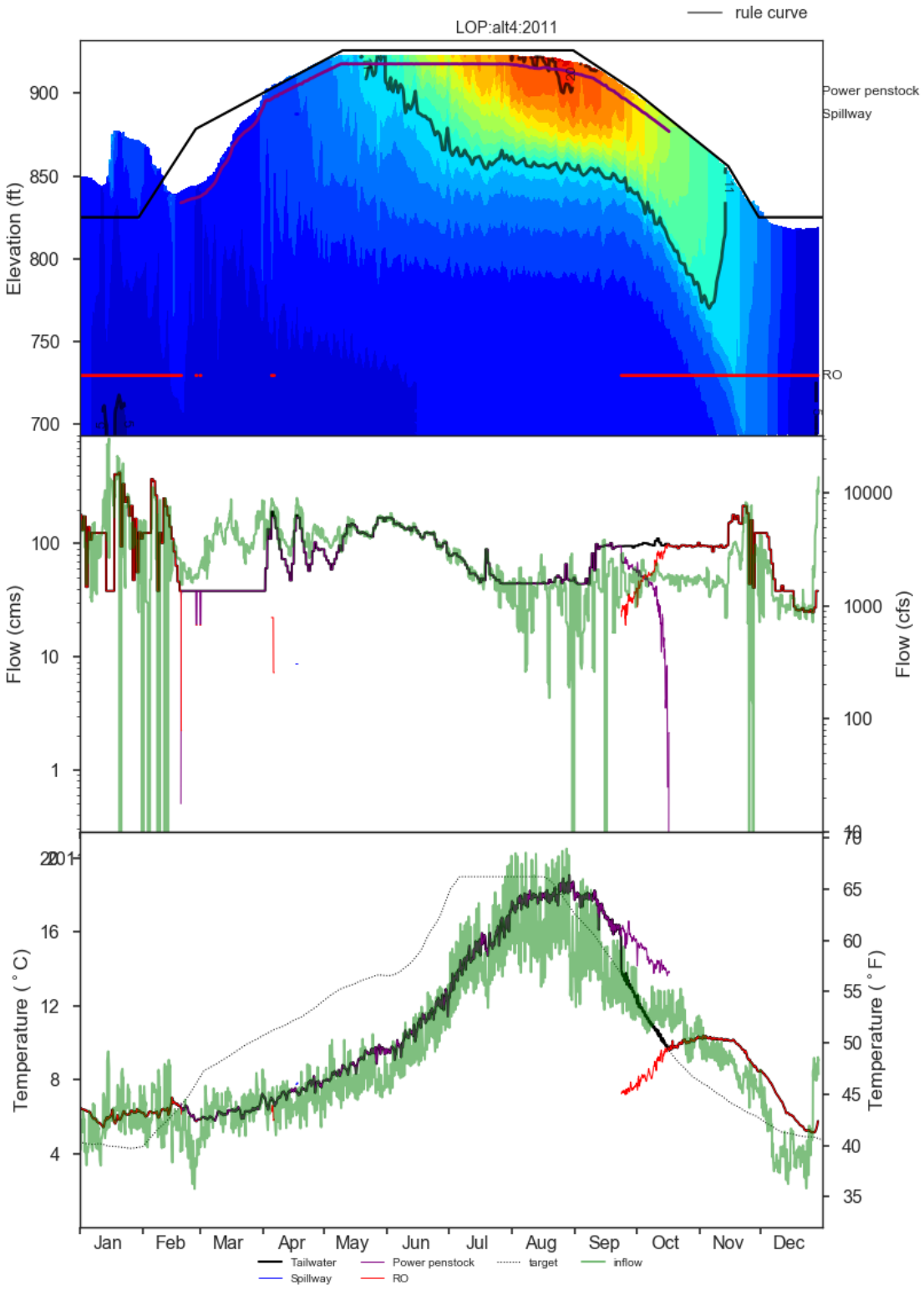


Figure 1-349. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 4 in 2011.

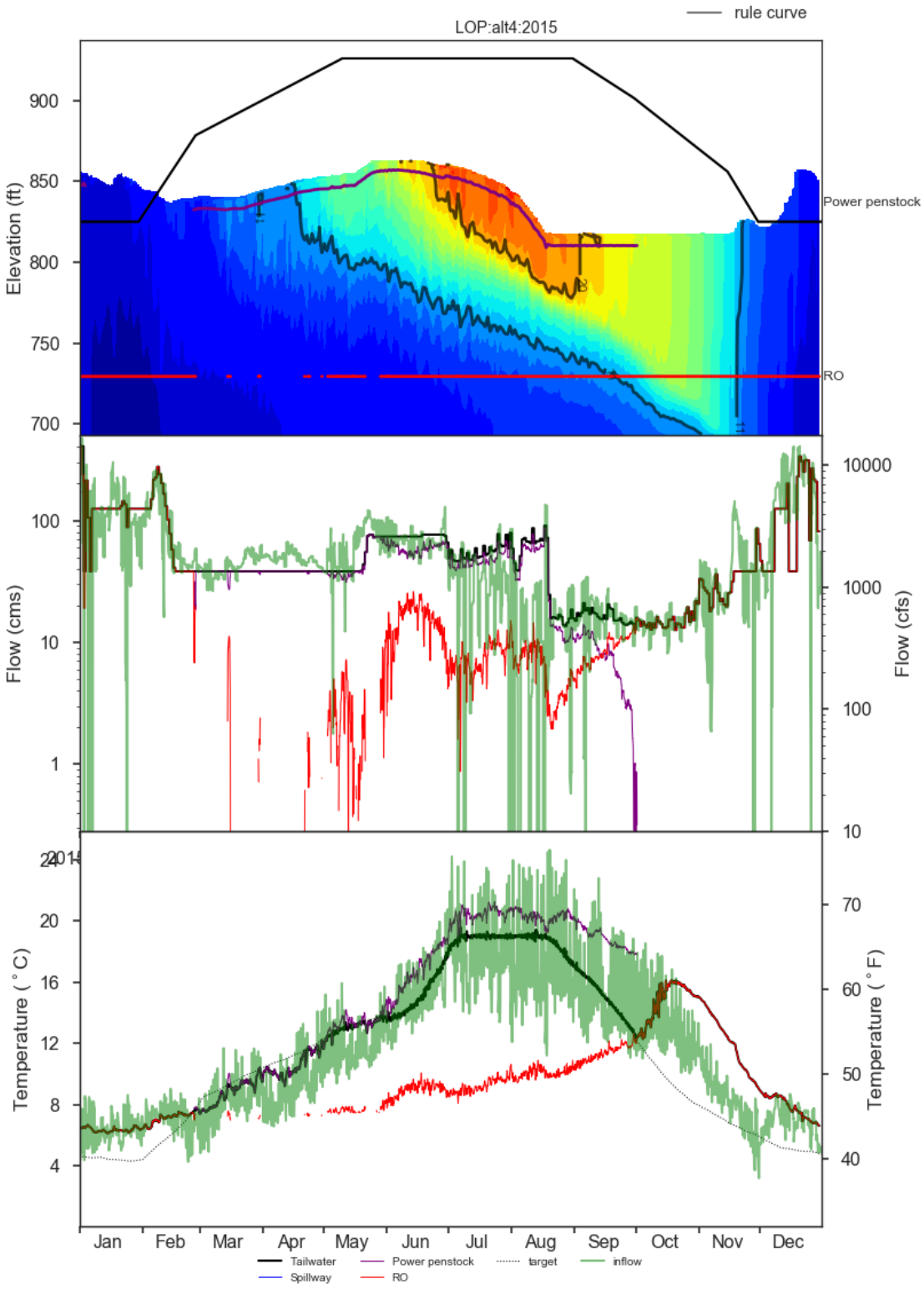


Figure 1-350. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 4 in 2015.

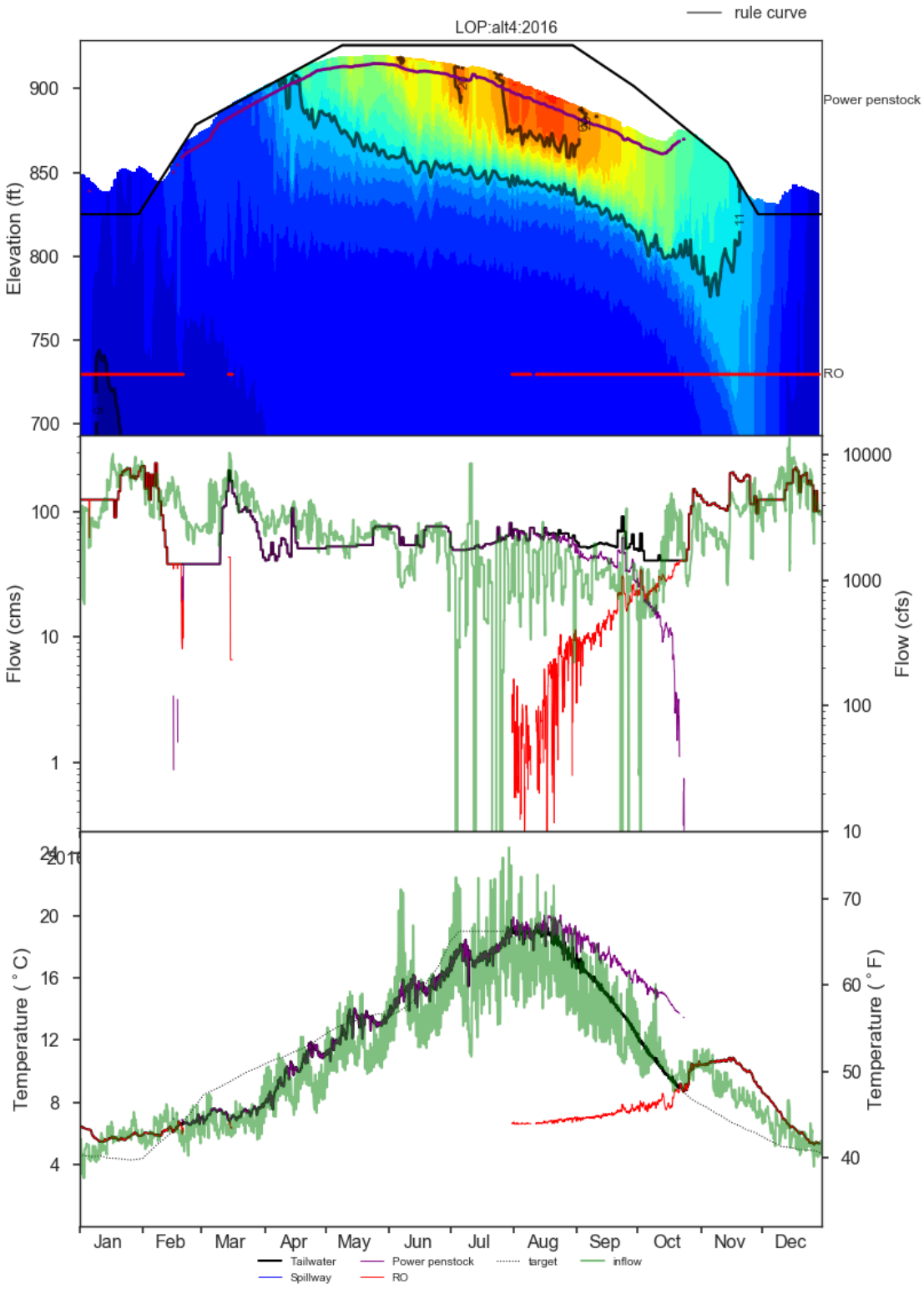


Figure 1-351. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 4 in 2016.

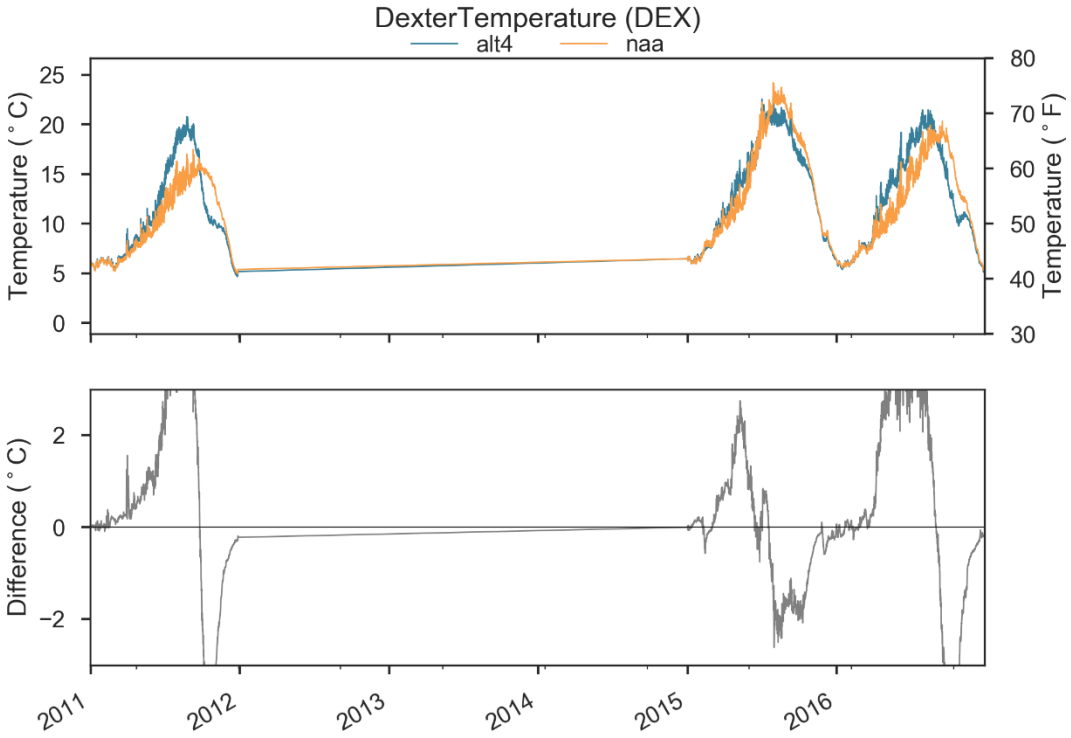


Figure 1-352. Comparison of DEX Outflow Temperatures in NAA and Alternative 4.

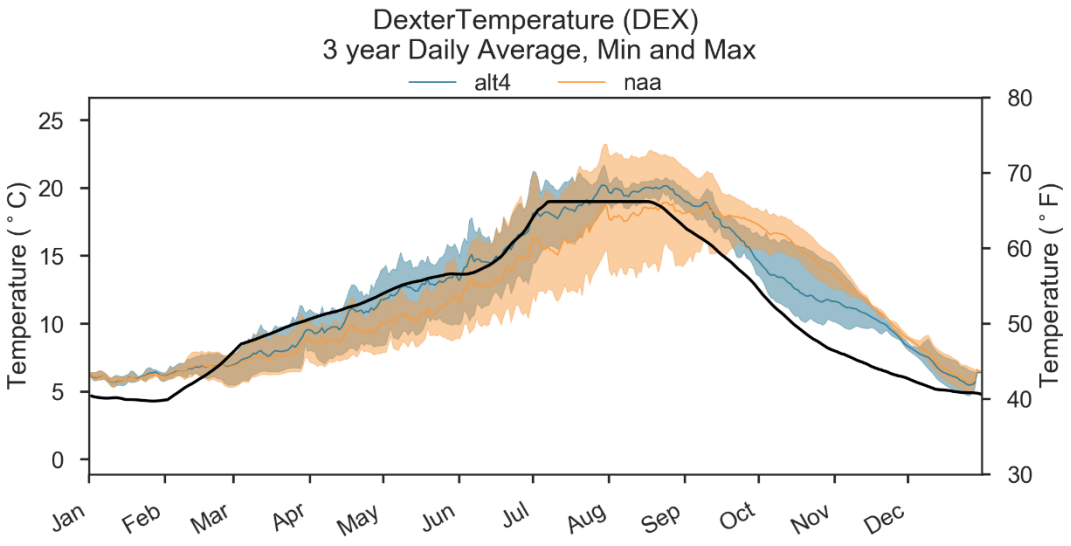


Figure 1-353. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target.

1.5.7.5 Mainstem Willamette River

Streamflow in the mainstem Willamette River under Alternative 4 was generally lower from April to mid-June and higher from mid-June to mid-September compared with NAA (Figure 1-354). However, these flow differences were primarily in 2015 and responsive to the Measure 30 rules that increase dam outflows in advance of heat wave events (Figure 1-355). These flow changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (Figure 1-356). Water temperatures at Salem were also affected by upstream dam operations and proposed SWS-FSS structures, which likely contributed to warmer temperatures seen in 2011 and 2015 (Figure 1-356, Figure 1-357). Water temperature differences between Alternative 4 and NAA were less than 2 degrees Celsius.

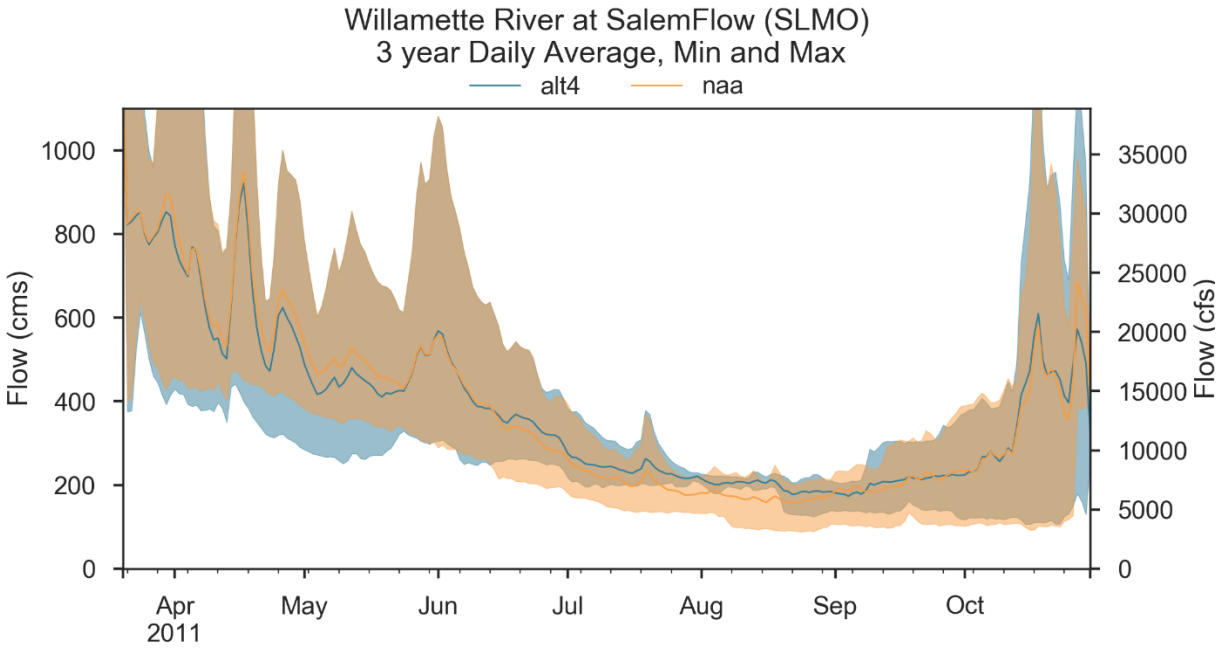


Figure 1-354. Streamflow Comparison of Daily Average, Min, Max Willamette River at SLMO under NAA and Alternative 4 Conditions.

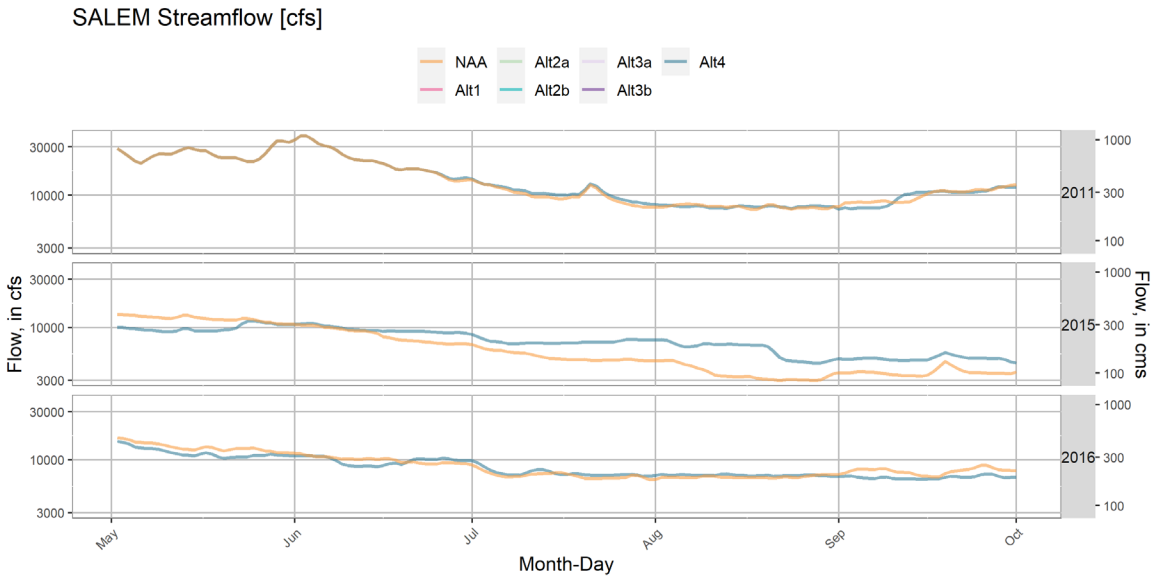


Figure 1-355. Streamflow Comparison Between Alternative 4 and NAA at Willamette River at SLMO.

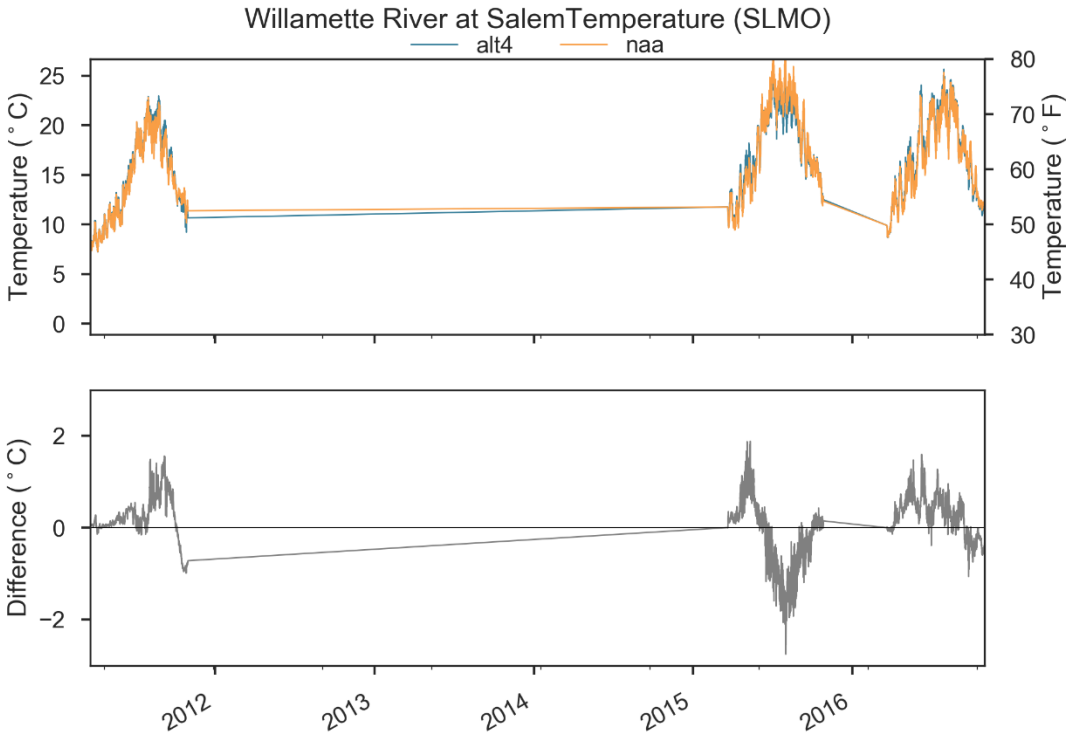


Figure 1-356. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 4.

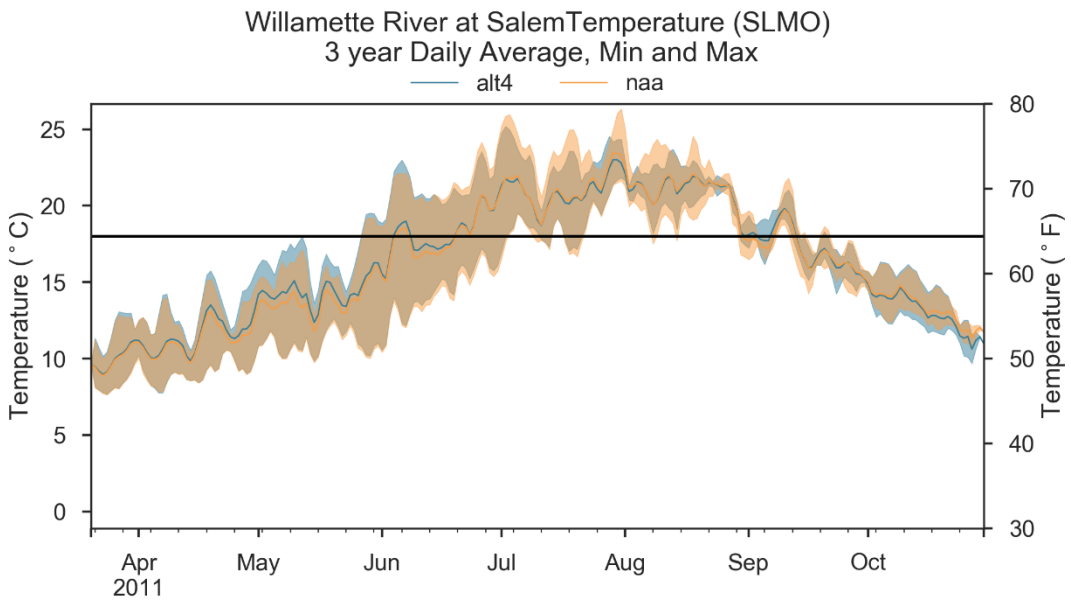


Figure 1-357. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4.

1.5.8 Alternative 5 – Preferred Alternative

Alternative 5 is based on Alternative 2b, See WV EIS Section 3.2 and Appendix B, Section 5.8 for a comparison of flow differences between Alternative 2b and Alternative 5. The following measures affected operations, lake storage, and water temperature:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to NAA mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.
- Construct temperature control structure at Detroit.
- Deep fall drawdown to 35’ over the regulating outlet at Green Peter, use of RO in fall, use spillway for surface spill in spring and summer.
- Deep spring and fall drawdown to 30 feet over the diversion tunnel at Cougar, with a limited refill window between June 15th and November 15th (essentially a delayed refill).
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.

HEC-ResSim simulations of lake levels and dam outflows were used as a basis for assessing the water temperature effects of Alternative 5 in 2011, 2015, and 2016 and are discussed in this section. The underlying assumptions in Alternative 5 were similar to Alternative 2b aside from

changes to the spring flow targets at Salem that are lower than BiOp dry year targets in years when water supply forecasted flows at Salem are projected to be less than 25% of normal. This provides additional spring storage in dry years allowing for targets that closely resemble BiOp flow targets to be met in dry summers. A full explanation of the HEC-ResSim analysis and findings can be found in Section 3.2 Hydrologic Processes and Technical Appendix B Hydrology and Hydraulics.

1.5.8.1 North Santiam Dams

1.5.8.1.1 Detroit

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Detroit Lake in Alternative 5 was identical to Alternative 2b in 2011, 2015, and 2016. Compared to NAA, Alternative 5 lake levels were generally higher in 2015 and 2016 aside from September-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-366, Figure 1-367, and Figure 1-368). The increased storage compared to NAA coincided with reduced outflows during spring and increased outflows in summer during 2015 and 2016 under Alternative 5. Total outflow in 2011 was generally similar in Alternative 5 and NAA at Detroit Lake. The proposed SWS and FSS in Alternative 5 allowed all outflow within powerhouse capacity (assumed at 4600 cfs) to be routed from a floating outlet through the Power outlets for temperature management, rather than the Spillway or URO flow for temperature management that was used in NAA (Figure 1-367).

THE FOLLOWING FIGURES HAVE BEEN REVISED IN THE FEIS

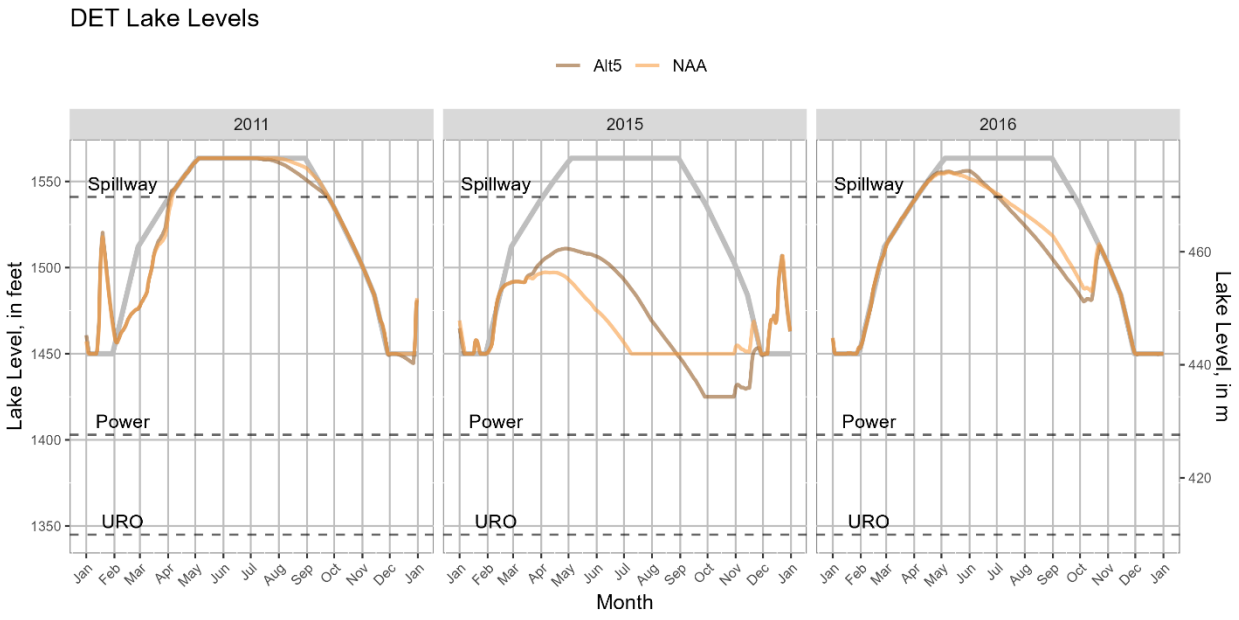


Figure 1-358. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 5 and NAA.

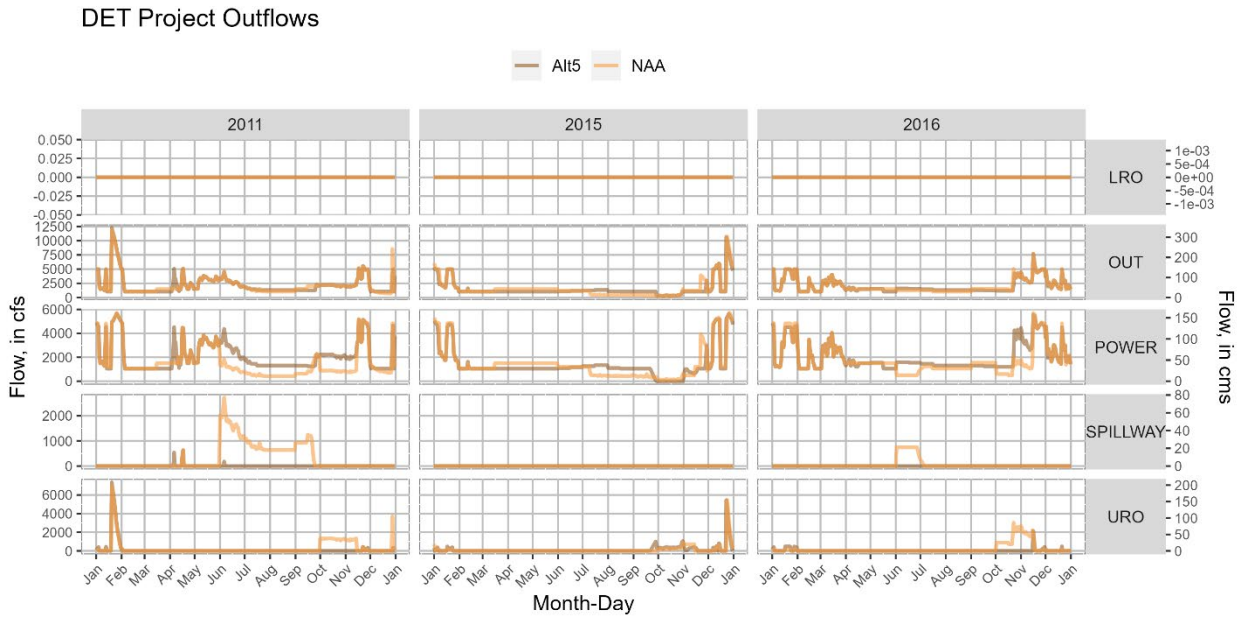


Figure 1-359. WV EIS HEC-ResSim Detroit Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5 and NAA.

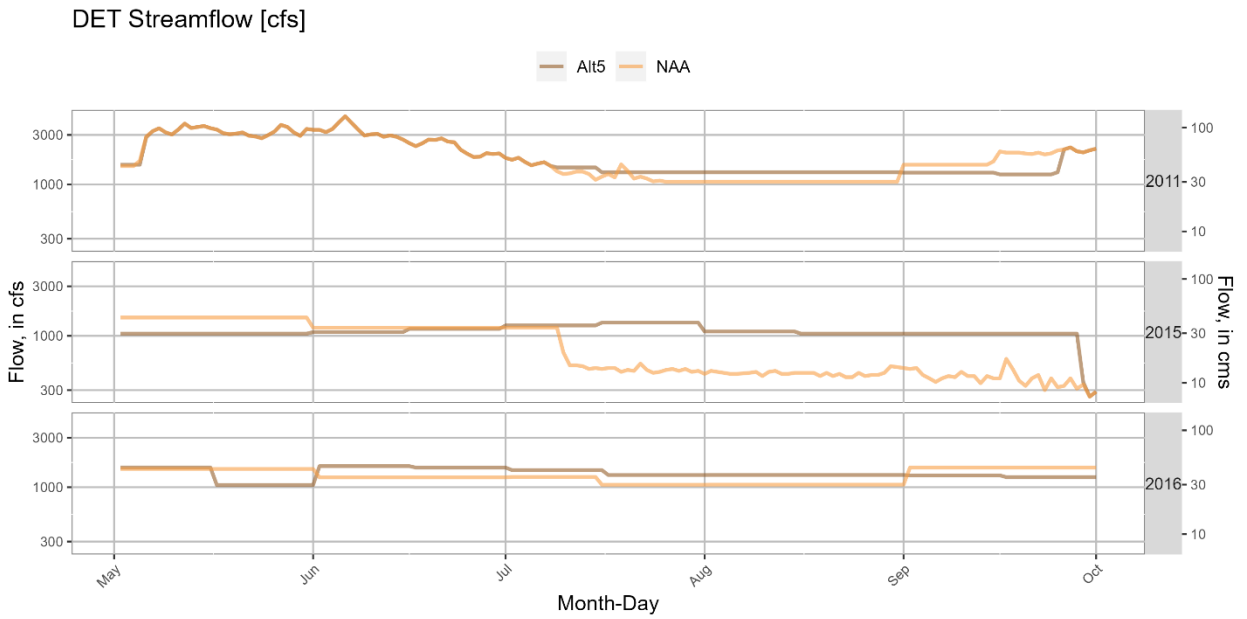


Figure 1-360. WV EIS HEC-ResSim Detroit Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5 and NAA.

END REVISED FIGURES

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-361, Figure 1-362, and Figure 1-363. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the Upper RO. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, the proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn (Figure 1-364, Figure 1-365).

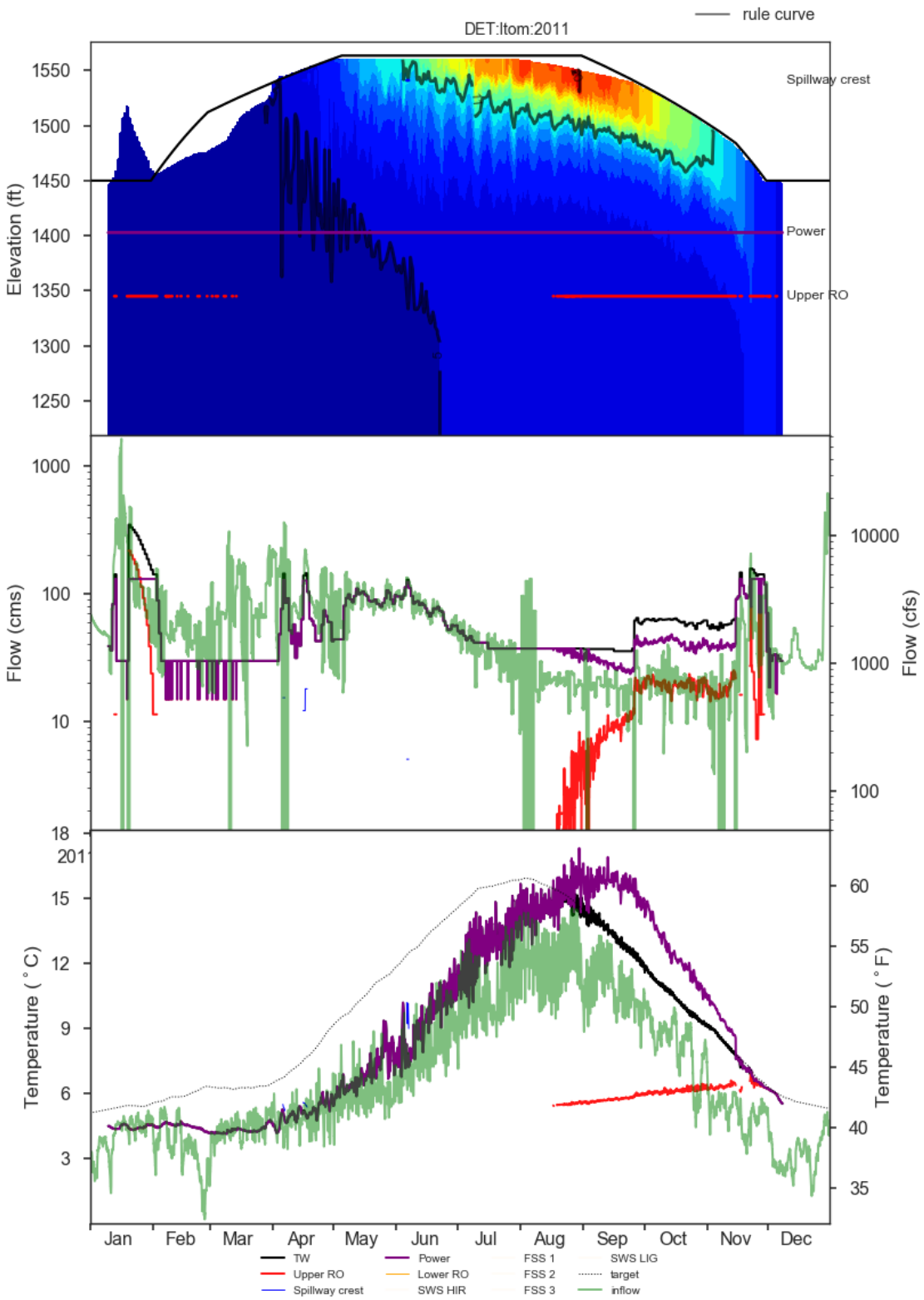


Figure 1-361. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 5 in 2011.

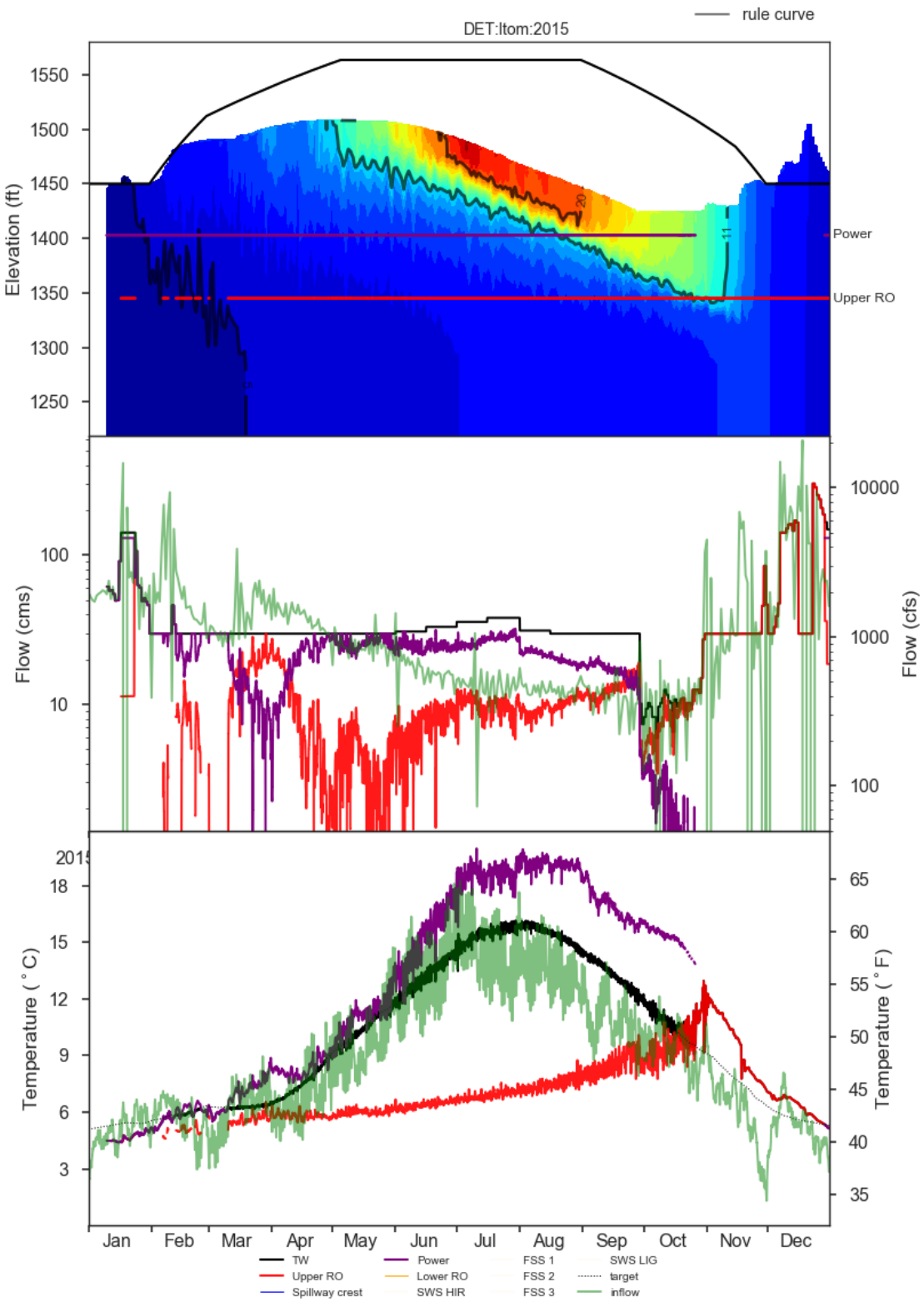


Figure 1-362. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 5 in 2015.

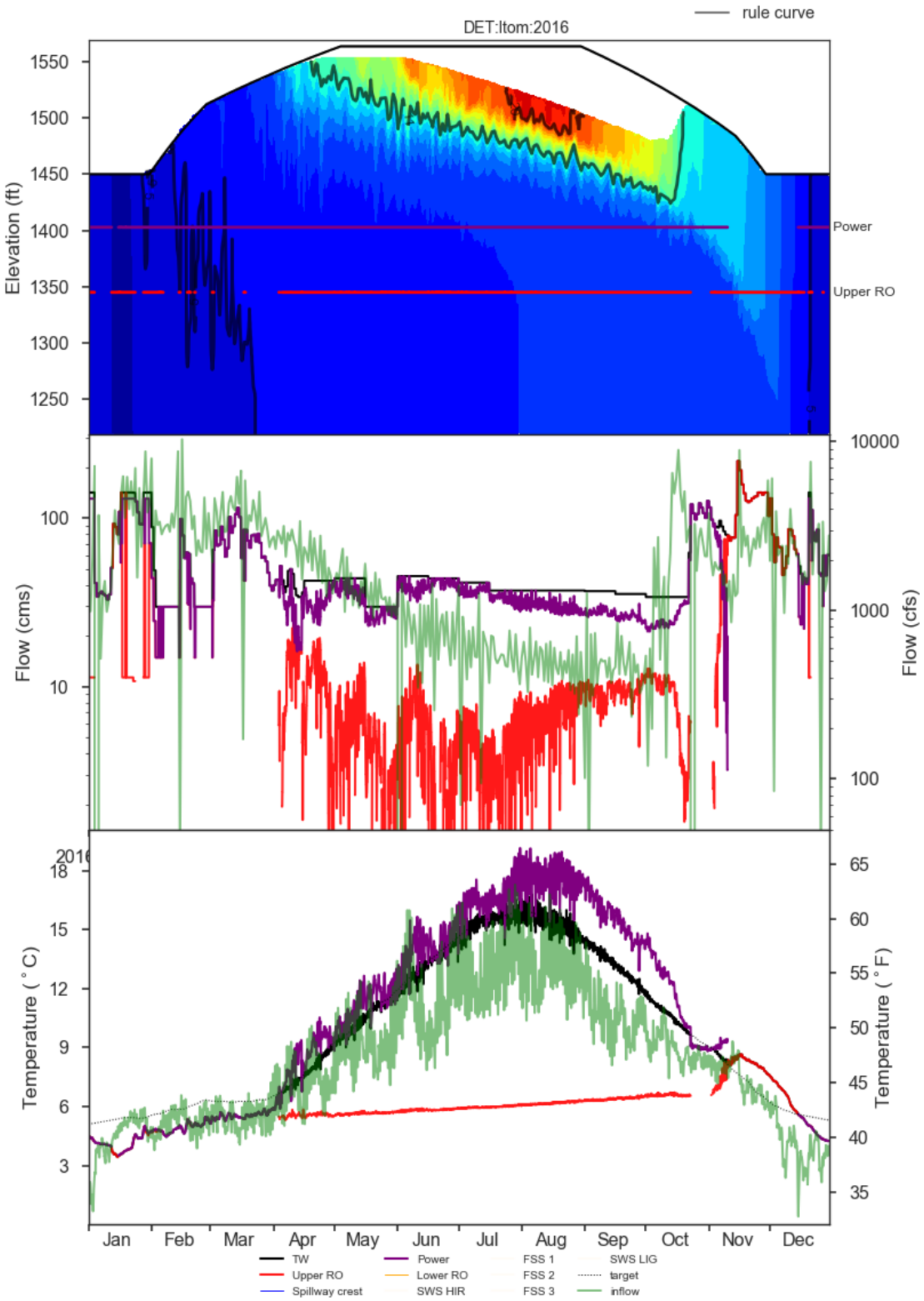


Figure 1-363. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 5 in 2016.

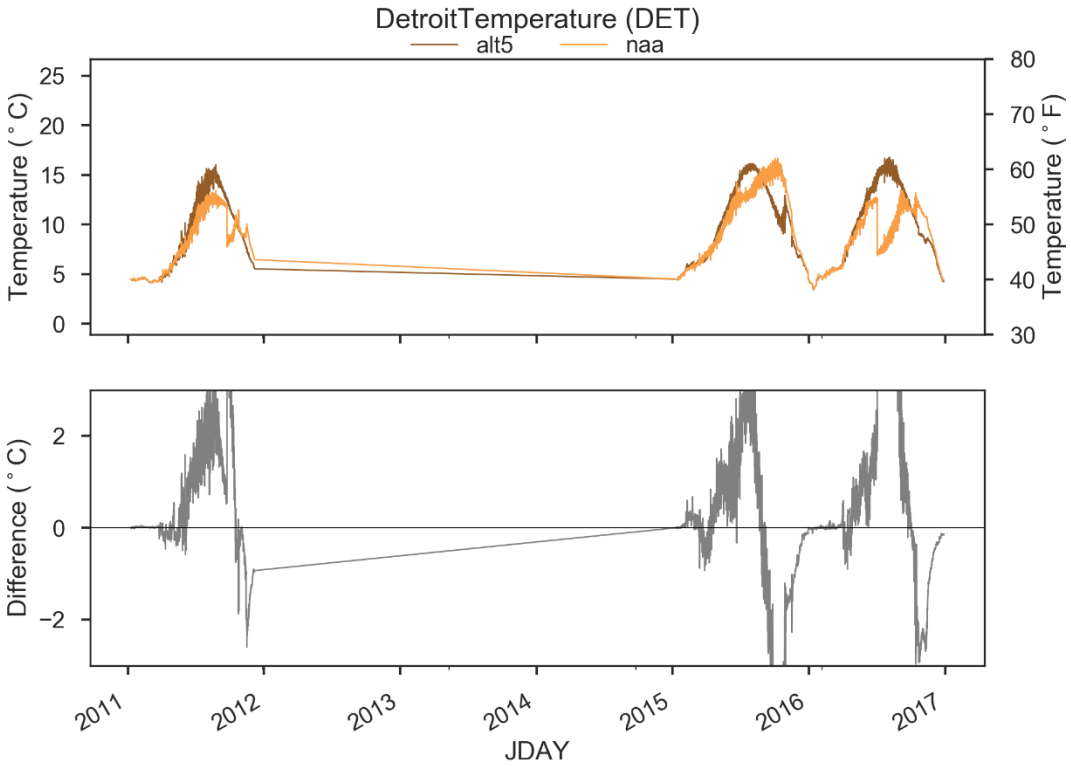


Figure 1-364. Comparison of DET outflow temperatures in NAA and Alternative 5.

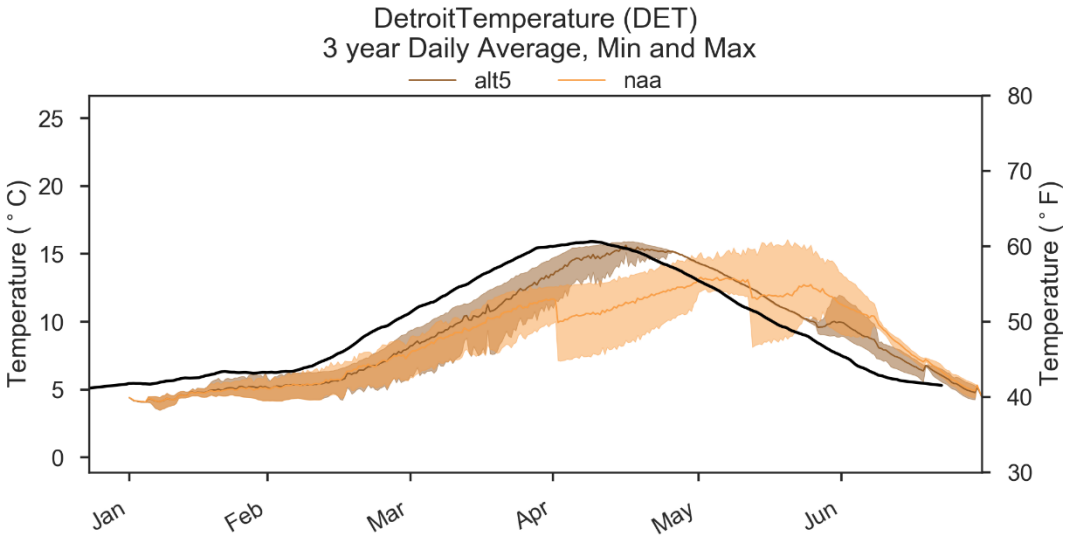


Figure 1-365. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 5. Black Line Indicates Temperature Target.

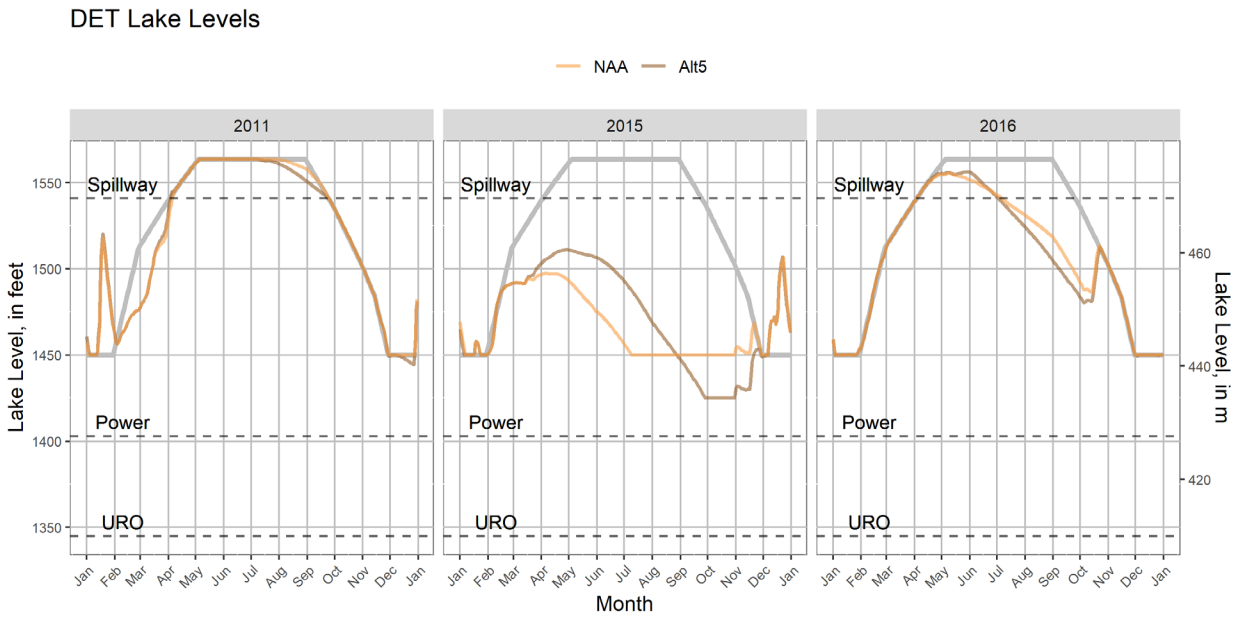


Figure 1-366. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 5 and NAA.

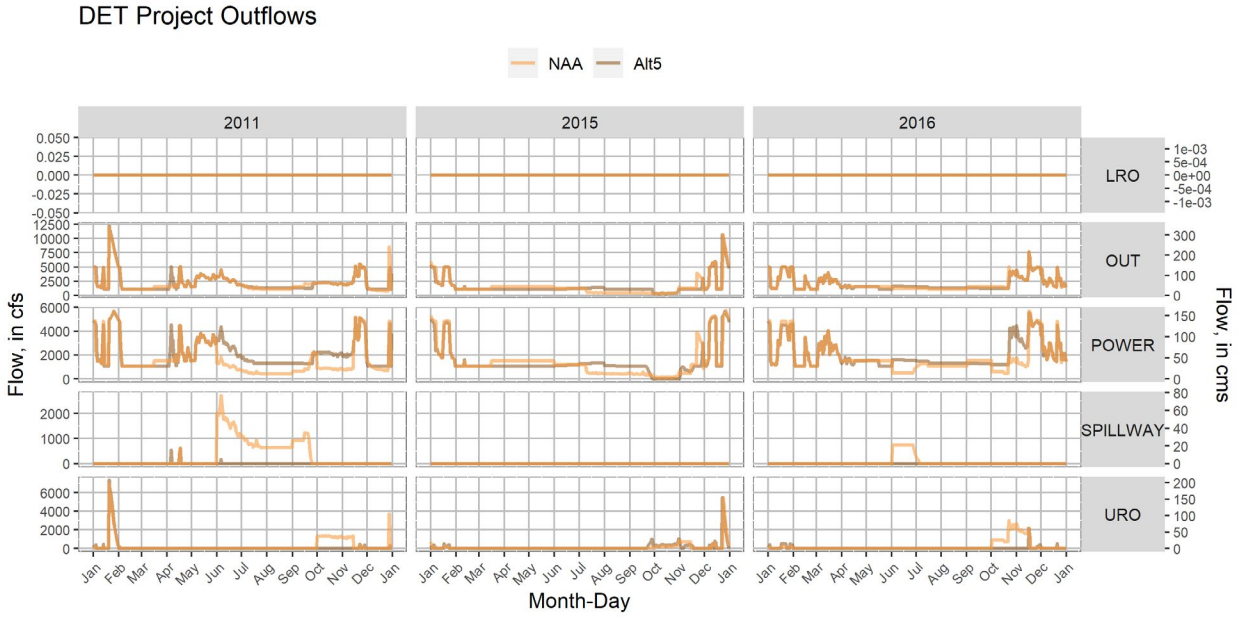


Figure 1-367. WV EIS HEC-ResSim Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5 and NAA.

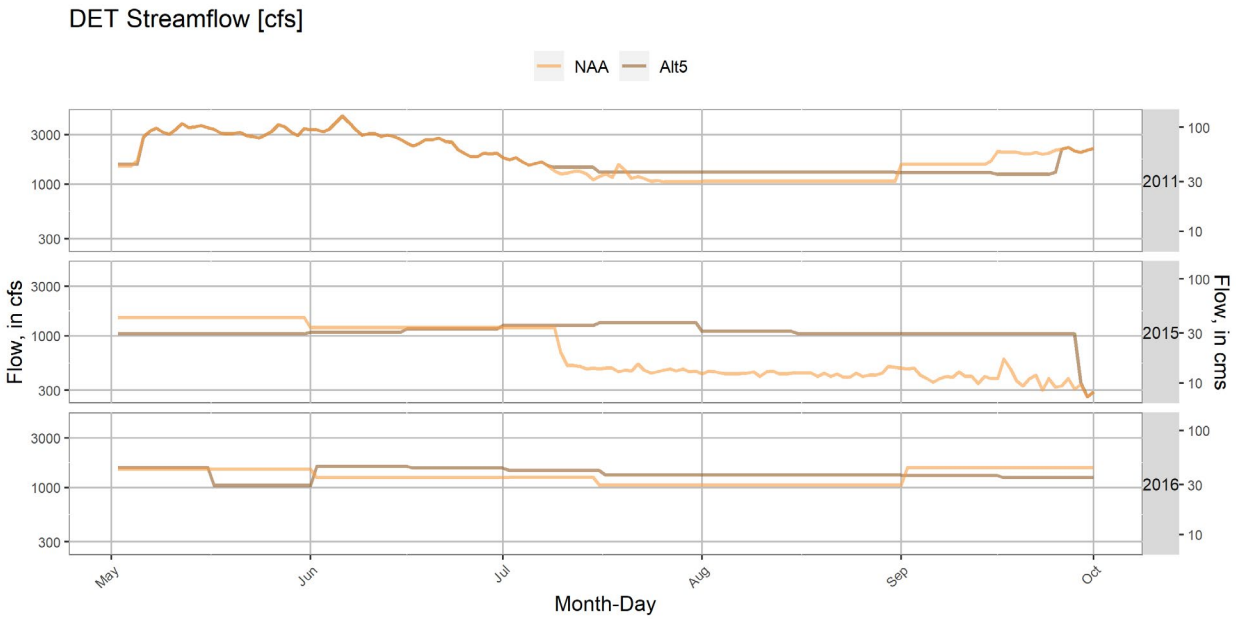


Figure 1-368. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 5 and NAA.

1.5.8.2 South Santiam Dams

1.5.8.2.1 Green Peter

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Green Peter in Alternative 5 was nearly identical to Alternative 2b in 2011, 2015, and 2016. Compared to NAA, Alternative 5 lake levels were generally higher in 2011, 2015, and 2016 aside from October-November during RO drawdown for fish passage (Figure 1-369, Figure 1-370, and Figure 1-371). Some increased storage in 2015 coincided with reduced outflows during spring and increased outflows in July-October comparing Alternative 5 to NAA. 2011 and 2016 operations were generally similar in Alternative 5 and NAA at Green Peter Lake January-June but followed increased outflows in July-October to draft the lake for fish passage operations through the ROs in autumn. The proposed operational temperature management through the spillway (during spring/summer) and RO (during autumn) in Alternative 5 led to increased outflow from these outlets and decreased power outflow compared to NAA (Figure 1-370).

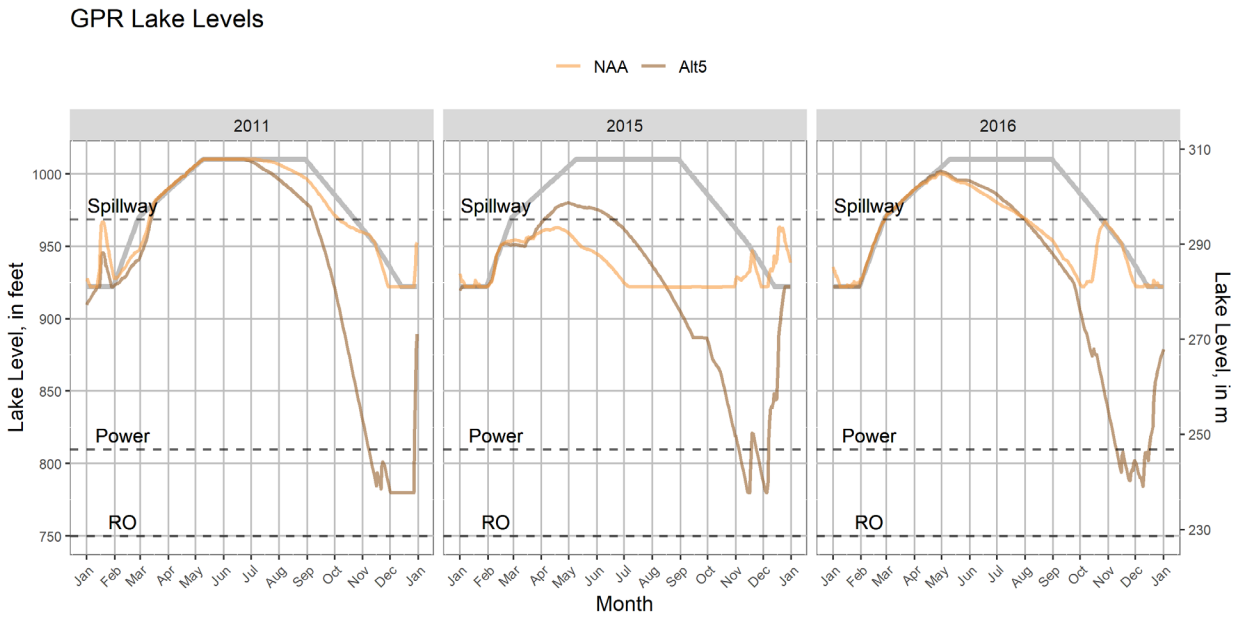


Figure 1-369. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 under Alternative 5 and NAA.

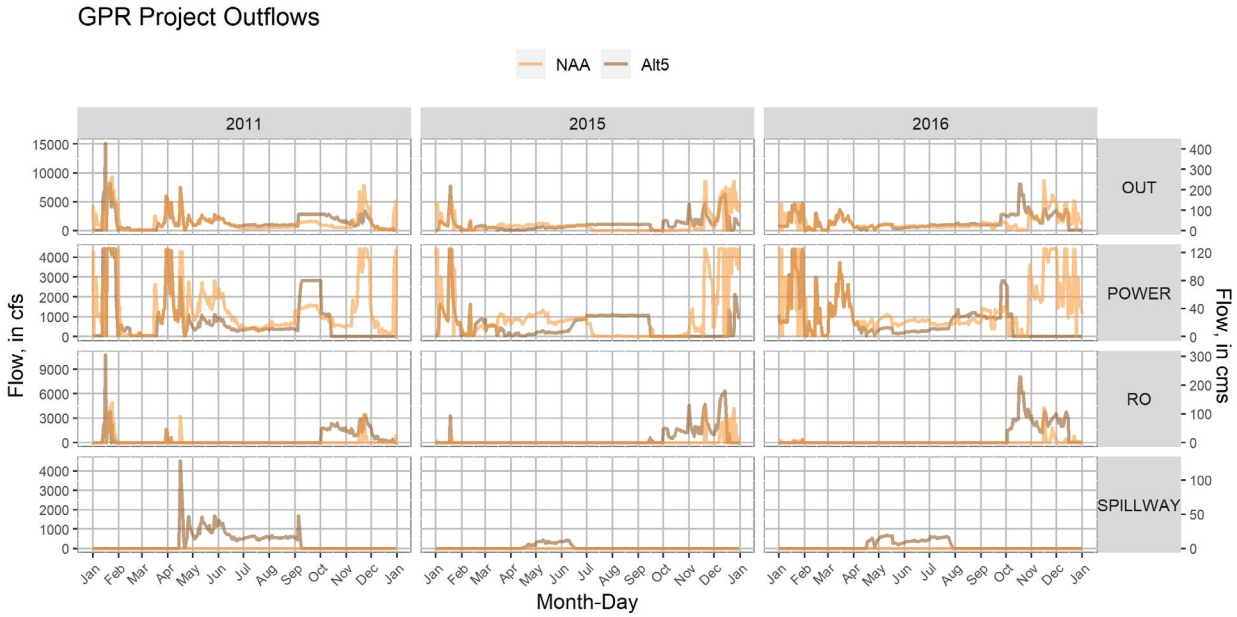


Figure 1-370. WV EIS HEC-ResSim Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5 and NAA.

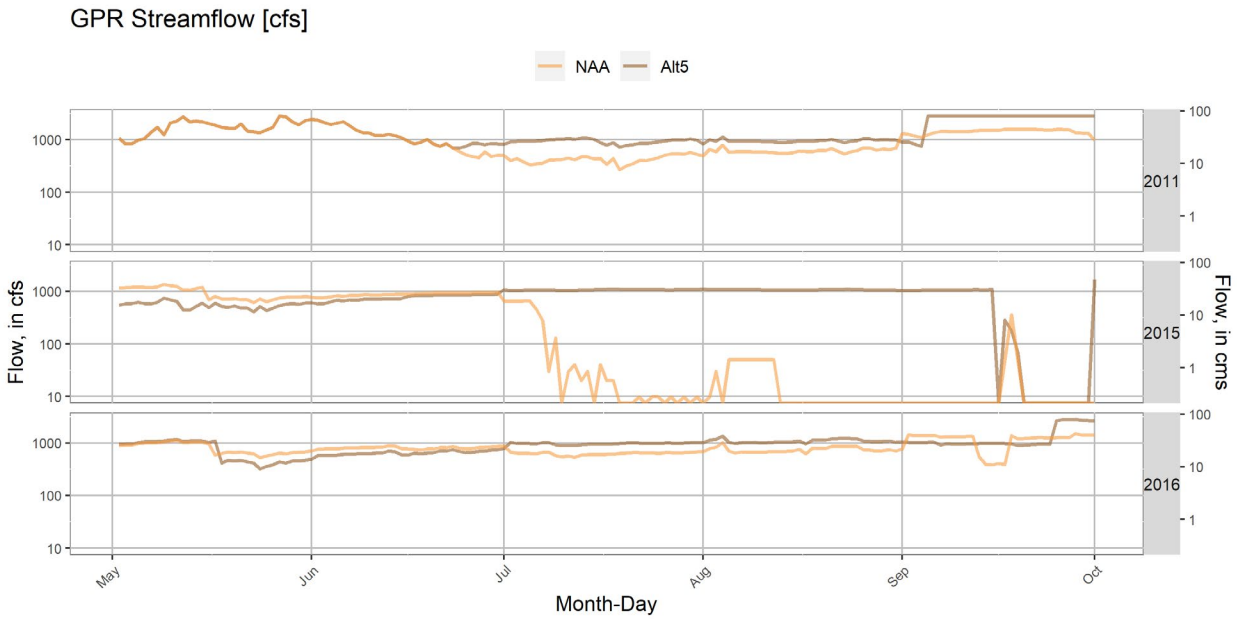


Figure 1-371. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-372, Figure 1-373, and Figure 1-374. Alternative 5 included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during autumn to mix releases from these non-power releases with relatively deep power penstock releases in an attempt to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and those outlets were submerged. Spillway access was limited in some years (2015 especially), which led to an abrupt drop in tailwater temperature when spillway access ended in mid-summer of those years. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam. Generally, the autumn fish passage operation (drawdown to the RO) resulted in cooler autumn temperatures (November-December) compared to NAA (Figure 1-375).

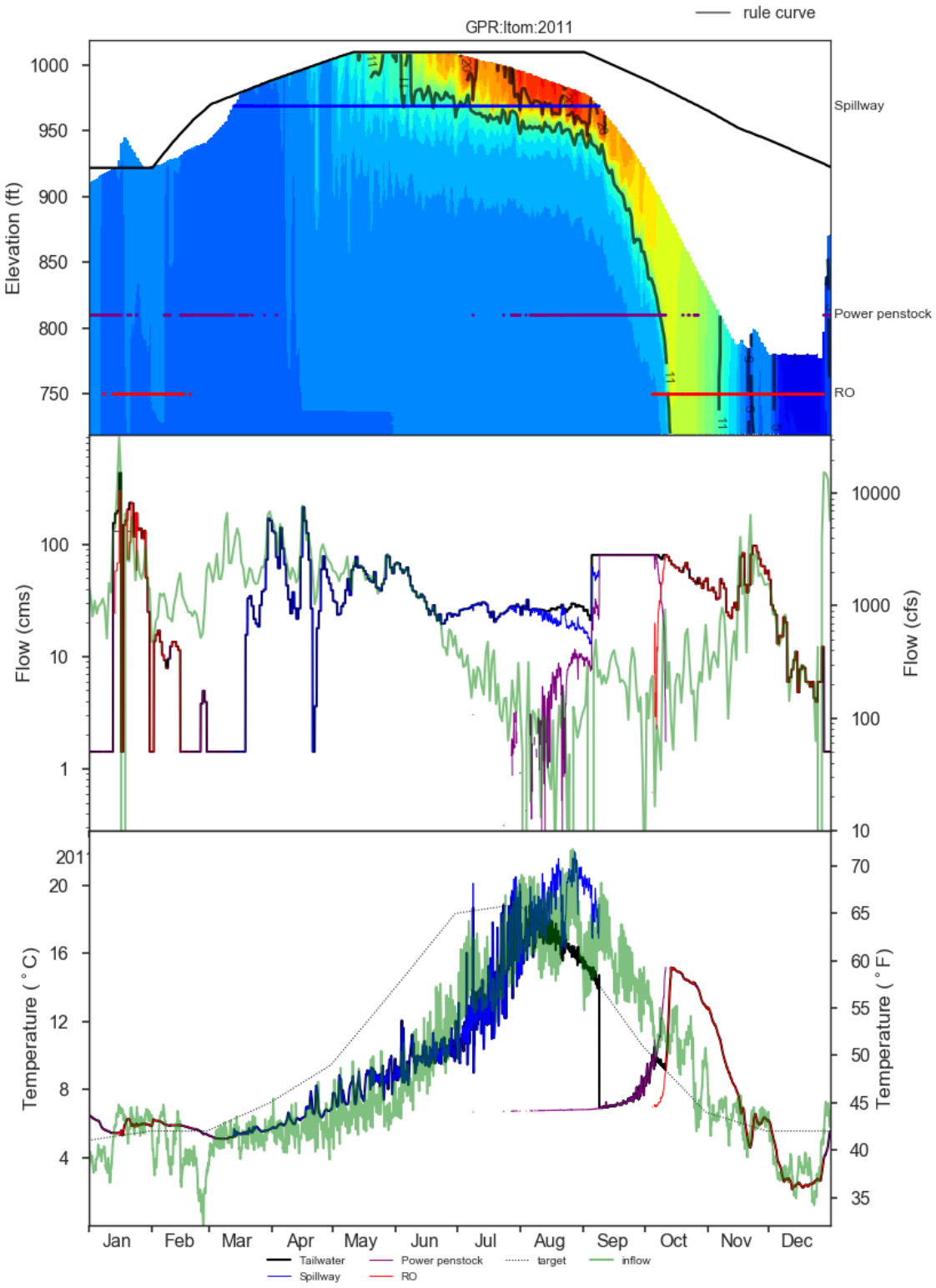


Figure 1-372. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 5 in 2011.

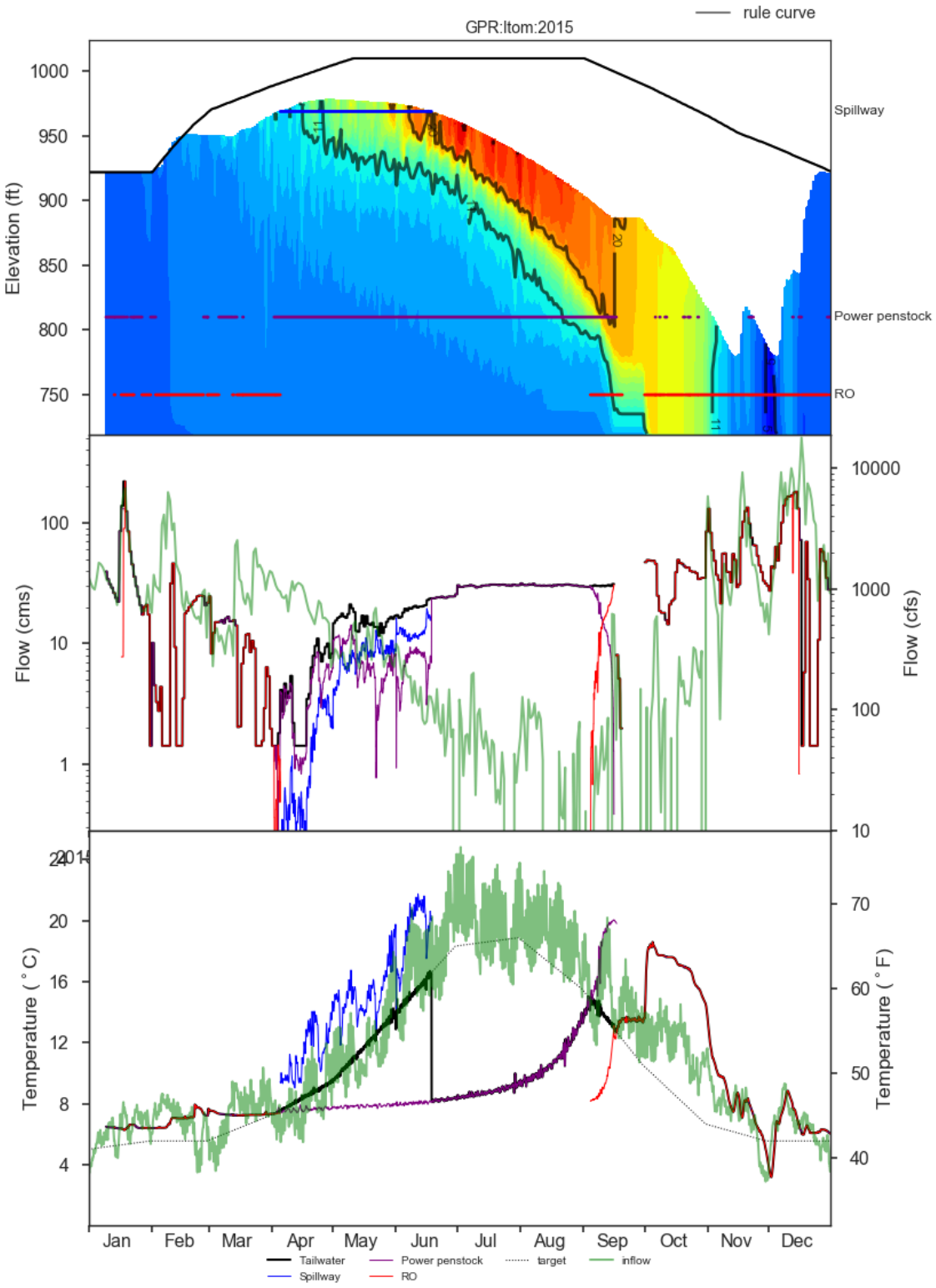


Figure 1-373. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 5 in 2015.

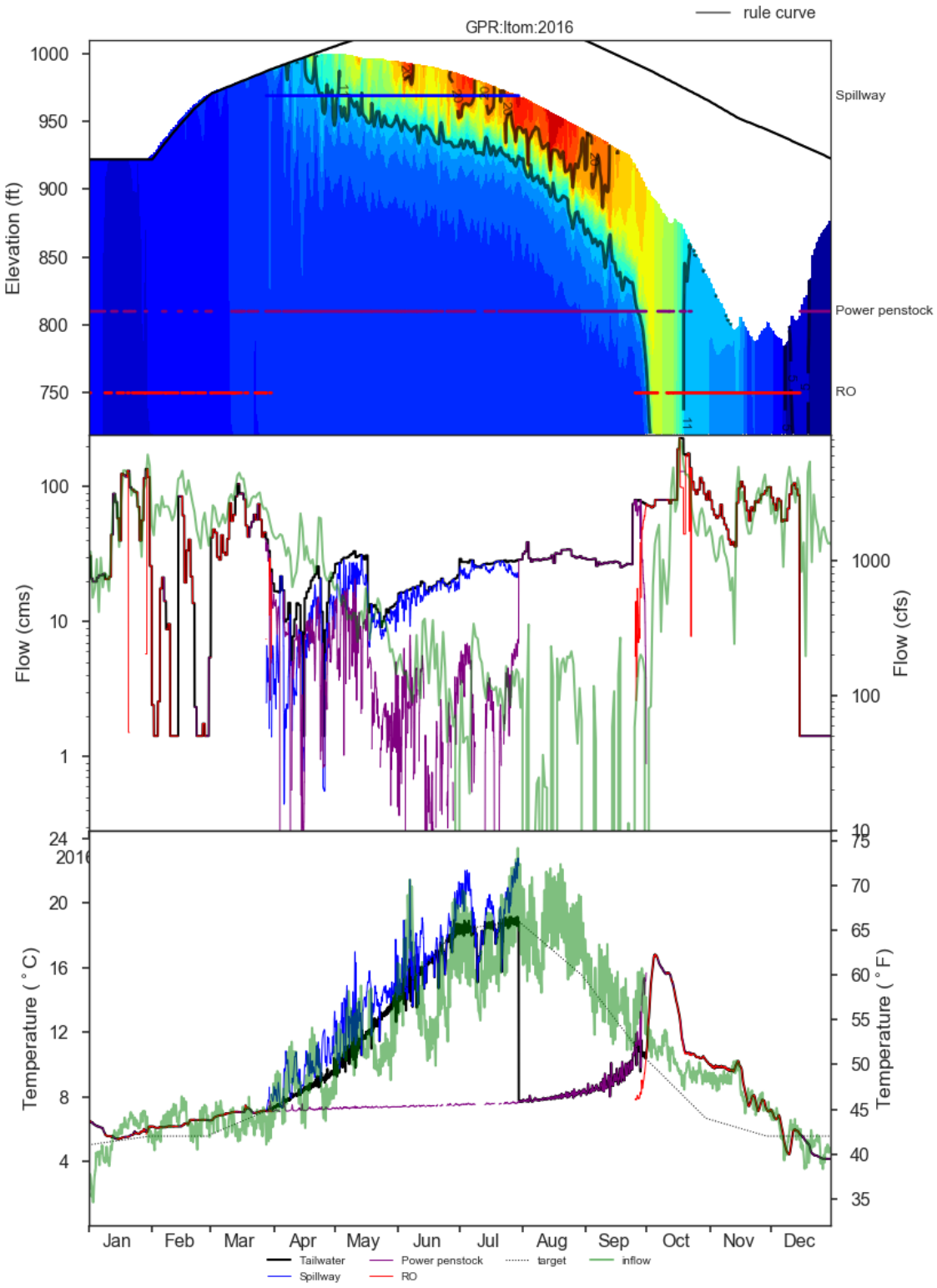


Figure 1-374. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 5 in 2016.

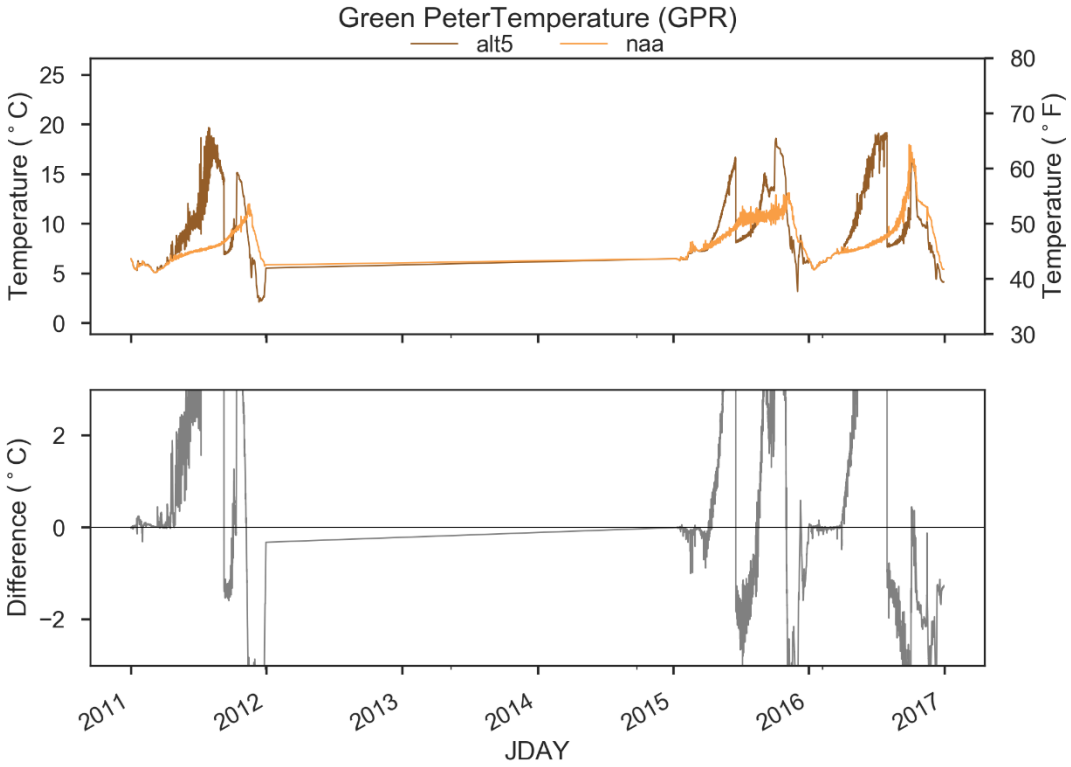


Figure 1-375. Comparison of GPR Outflow Temperatures in NAA and Alternative 5.

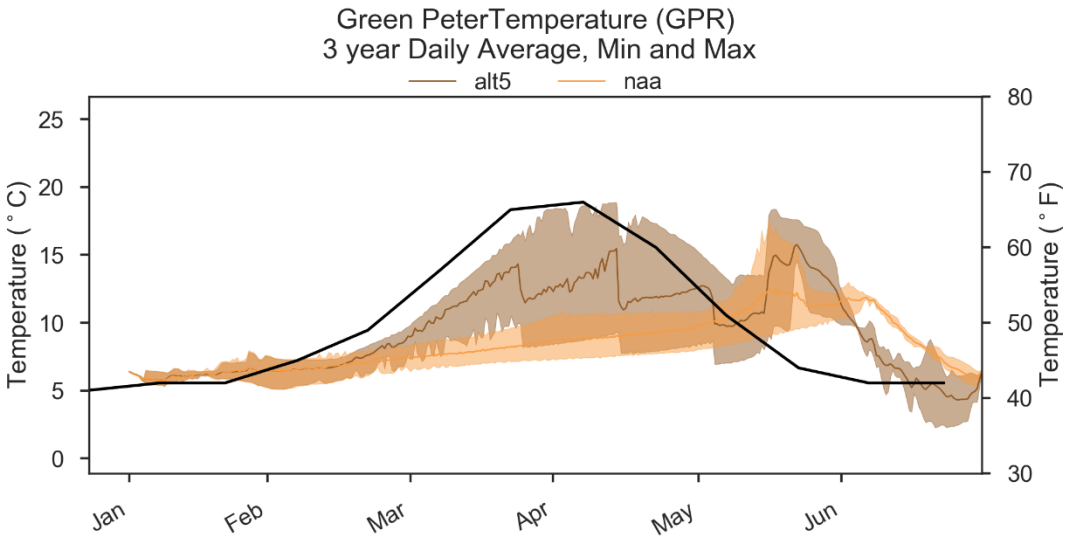


Figure 1-376. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 5. Black Line Indicates Temperature Target.

1.5.8.2.2 Foster

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Foster in Alternative 5 was nearly identical to Alternative 2b in 2011, 2015, and 2016. Compared to NAA, Alternative 5 lake levels were generally similar in 2011 and 2016 but increased in 2015 under Alternative 5 compared to NAA (Figure 1-377, Figure 1-378, and Figure 1-379). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam. The proposed modifications to the fish weir and FWWS in Alternative 5 resulted in lower outflow routed through the Power outlets for temperature management, especially during spring and summer, compared to NAA (Figure 1-378).

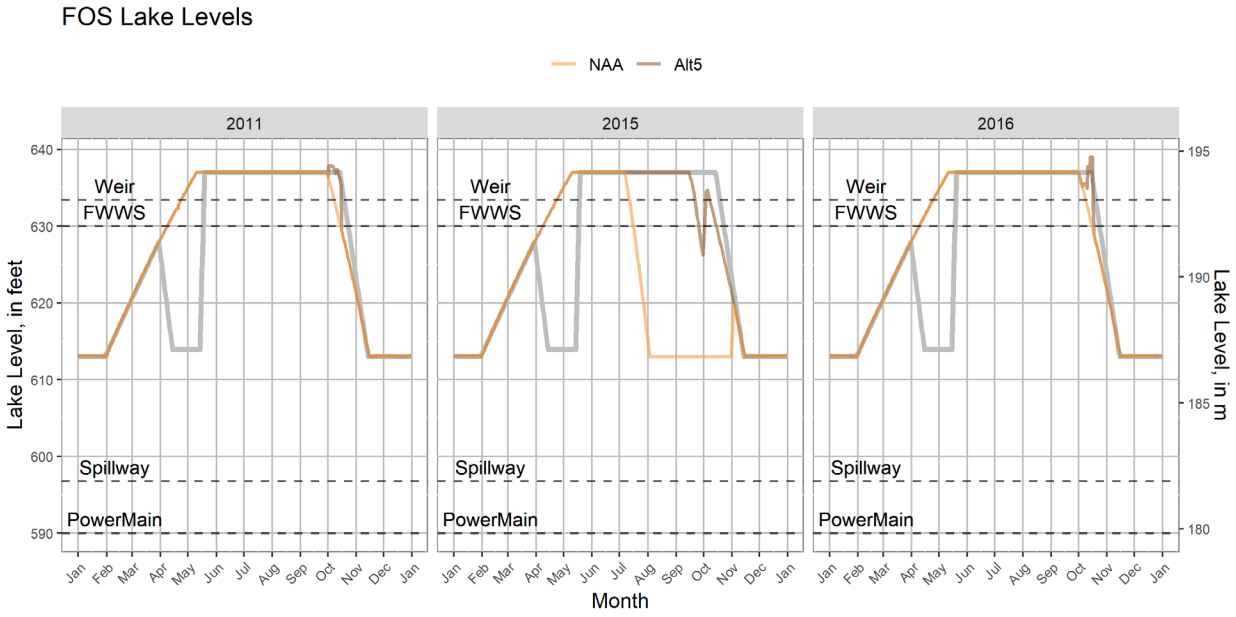


Figure 1-377. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 5 and NAA.

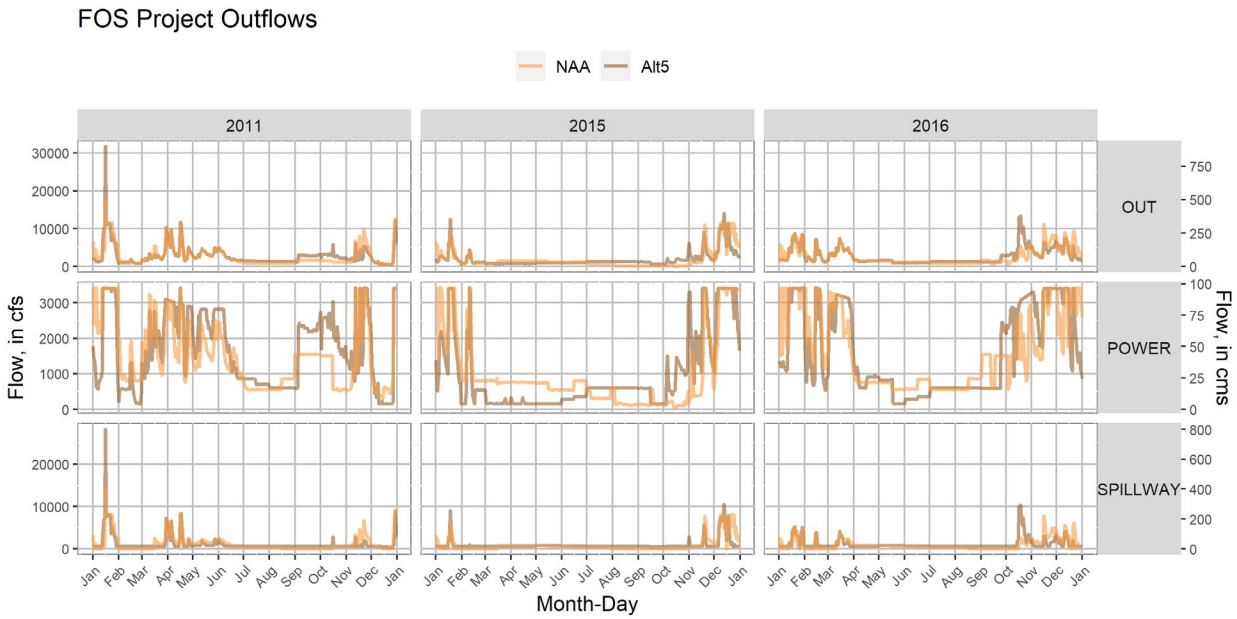


Figure 1-378. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5 and NAA.

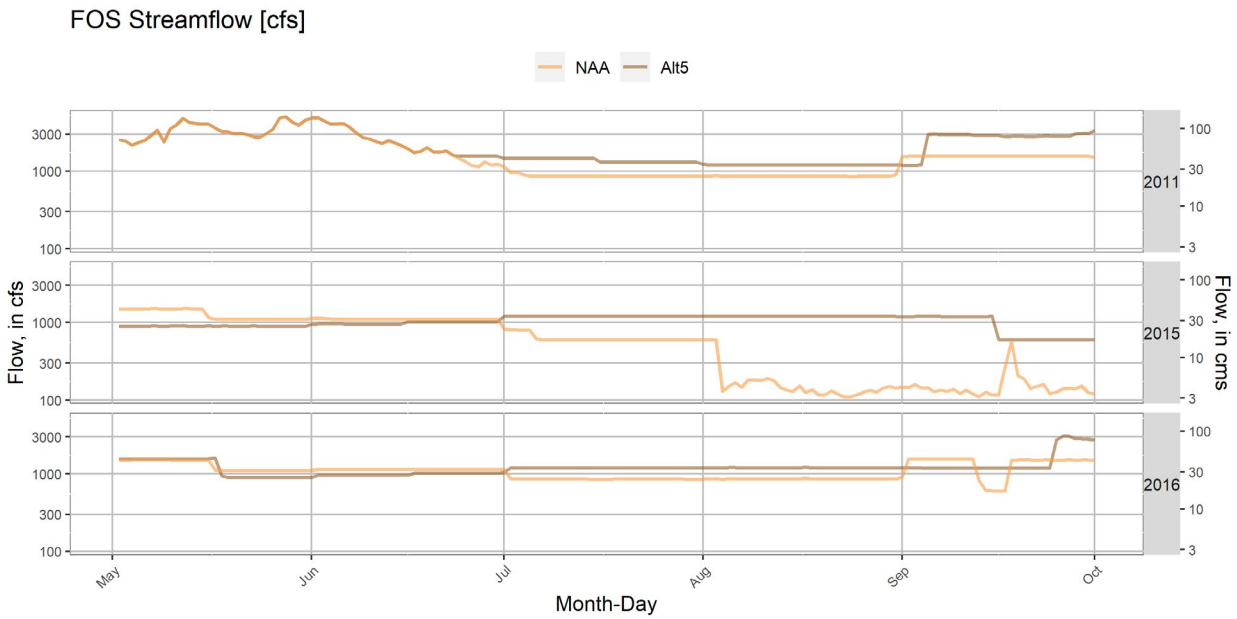


Figure 1-379. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-380, Figure 1-381, and Figure 1-382. Alternative 5 included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during

autumn to mix releases from these non-power releases with relatively deep power penstock releases in an attempt to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and those outlets were submerged. Spillway access was limited in some years (2015 especially), which led to an abrupt drop in tailwater temperature when spillway access ended in mid-summer of those years. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam (Figure 1-383 and Figure 1-384). Generally, the autumn fish passage operation (drawdown to the RO) resulted in cooler autumn temperatures (November-December) compared to NAA (Figure 1-384).

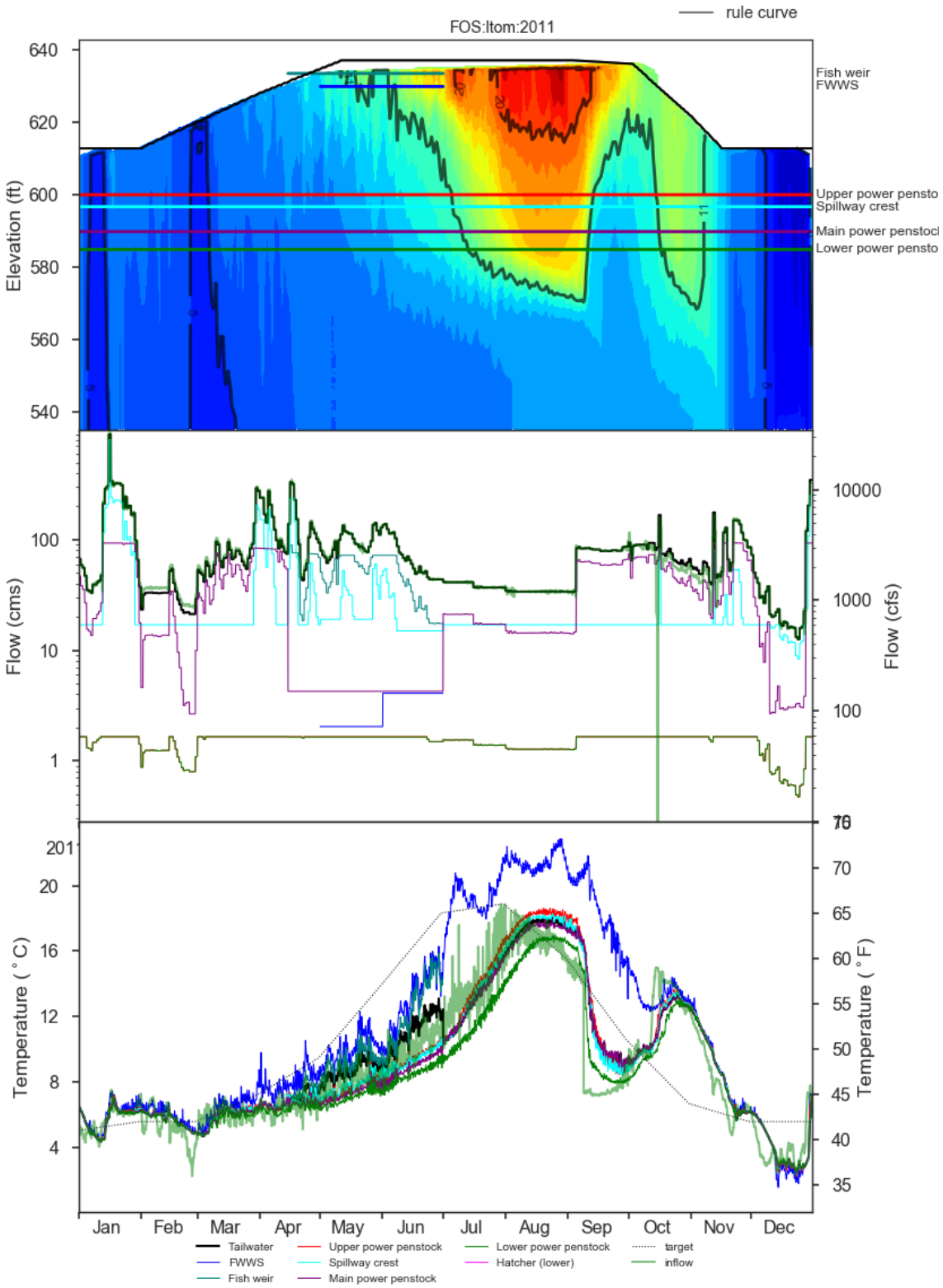


Figure 1-380. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 5 in 2011.

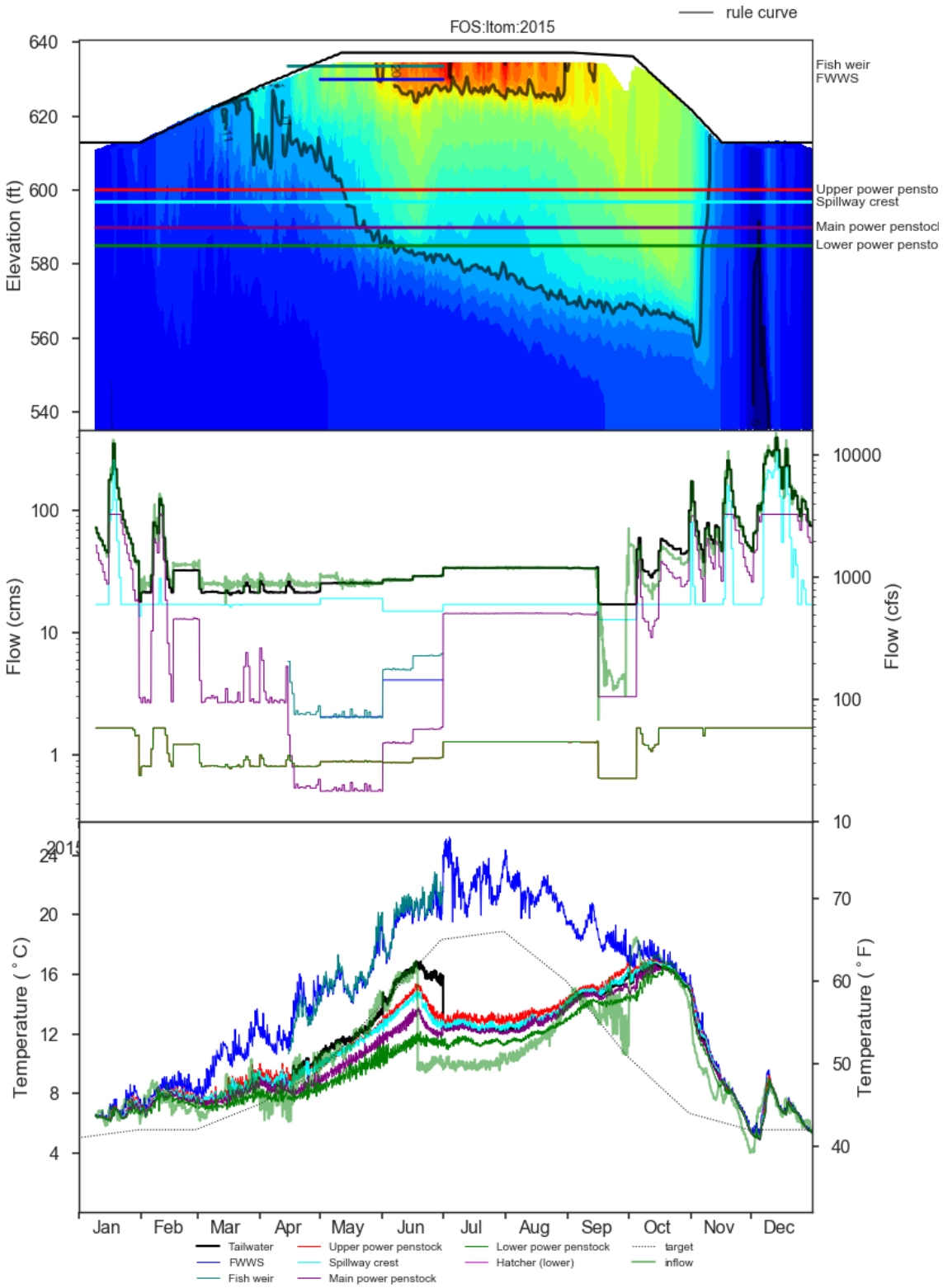


Figure 1-381. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 5 in 2015.

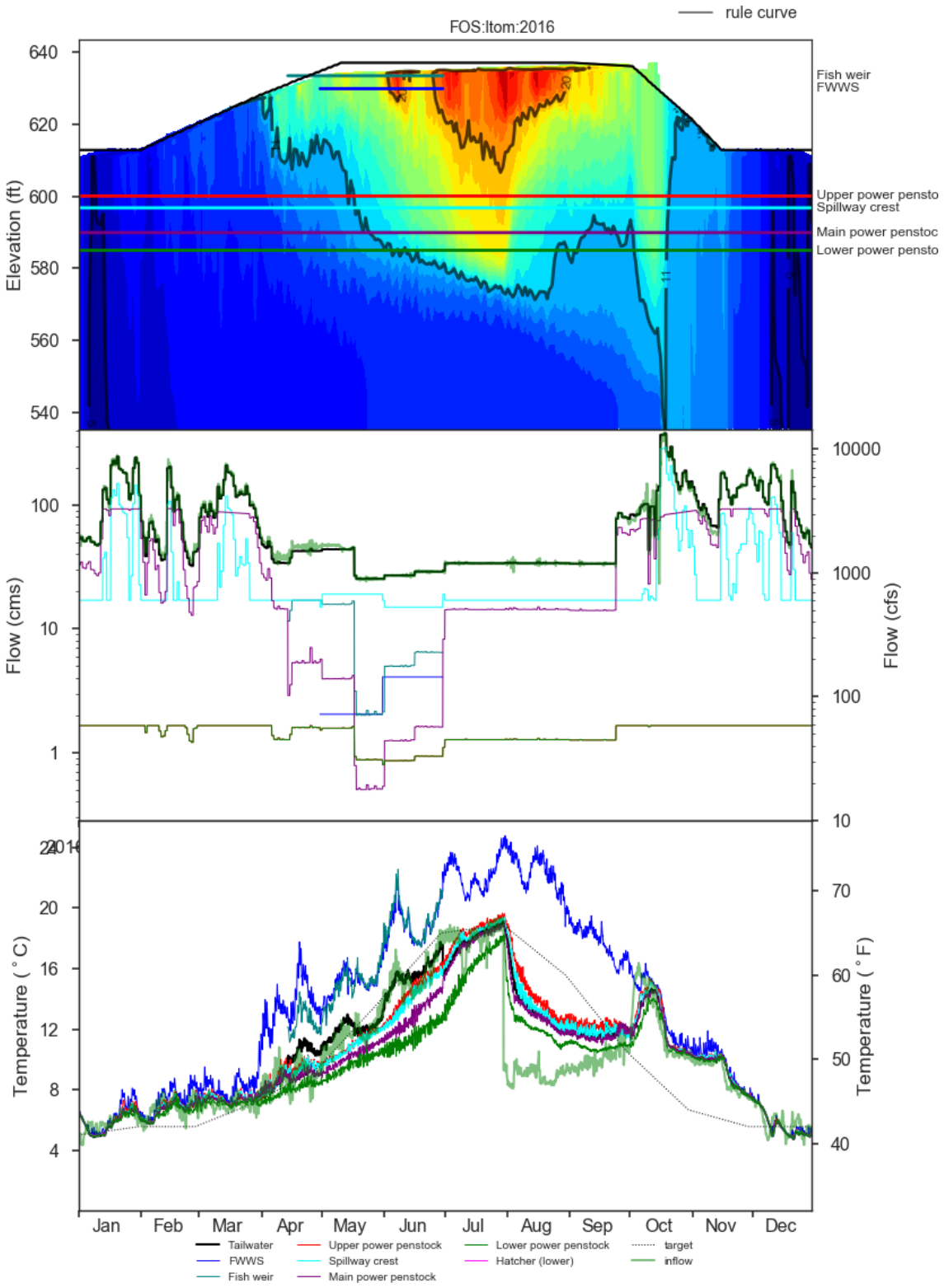


Figure 1-382. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 5 in 2016.

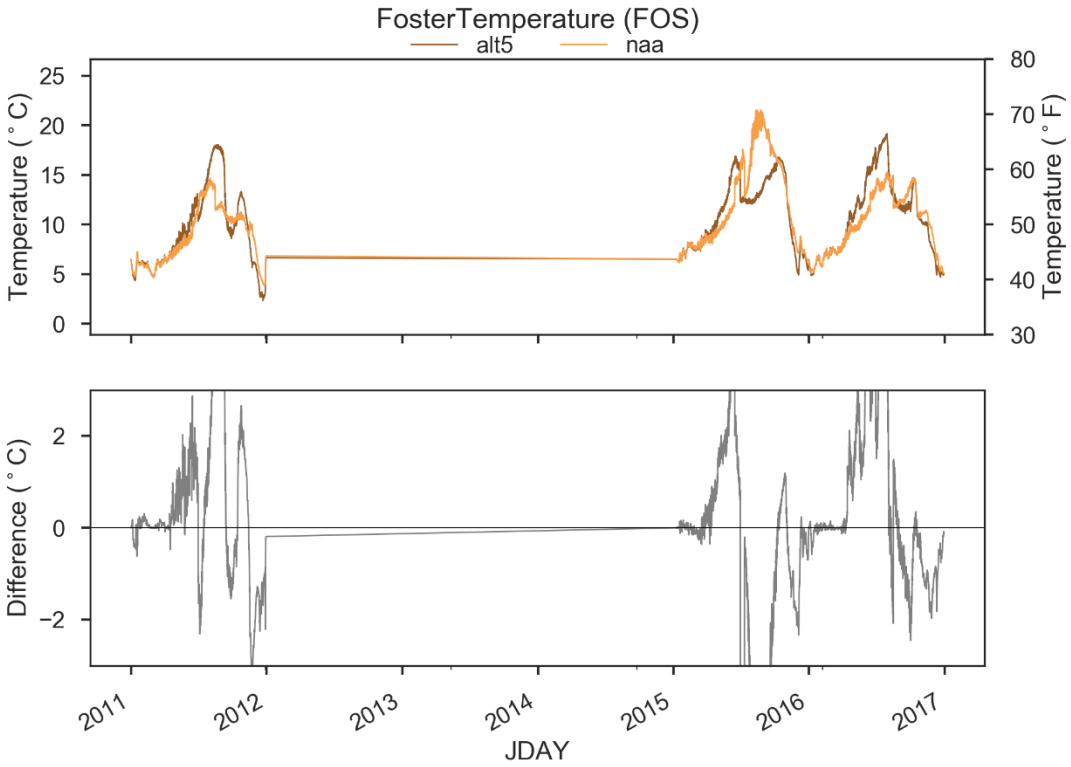


Figure 1-383. Comparison of FOS Outflow Temperatures in NAA and Alternative 5.

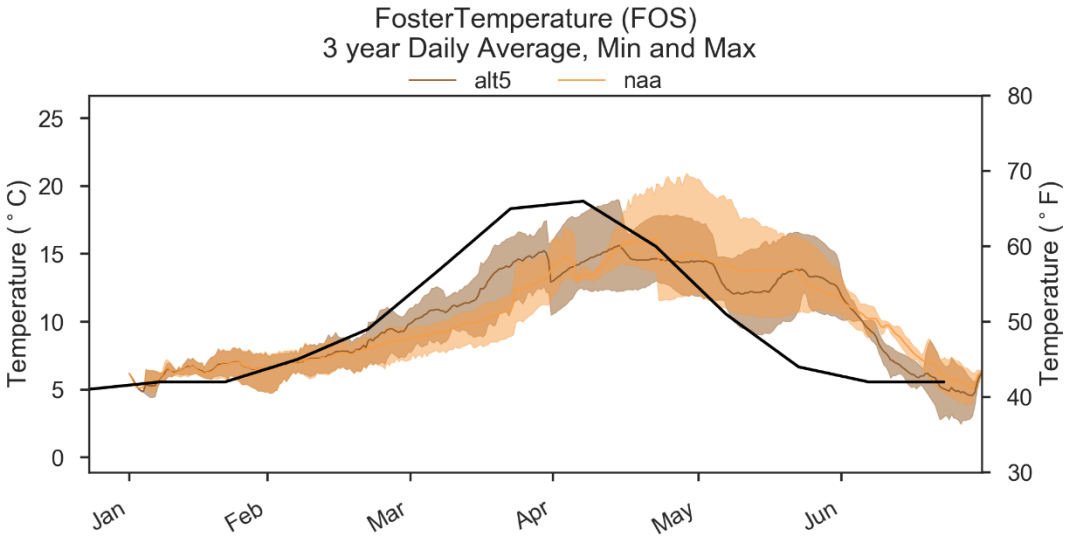


Figure 1-384. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 5. Black Line Indicates Temperature Target.

1.5.8.3 McKenzie Dams

1.5.8.3.1 Cougar

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Cougar in Alternative 5 was nearly identical to Alternative 2b in 2011, 2015, and 2016. Compared to NAA, Alternative 5 lake levels were lower in 2011, 2015, and 2016 to allow for proposed fish passage operations through the diversion tunnel (Figure 1-385, Figure 1-386, Figure 1-387). The decreased storage coincided with reduced outflows during spring and summer (Figure 1-385). Outflows were primarily routed through the diversion tunnel in Alternative 5, except when the lake refilled to about 30 feet above the RO intake (e.g., 2011). However, the Cougar 2011 model contained an error in which outflow was specified through the WTC4 outlet rather than the RO from julian day 202 to 280 while the lake level was above the RO intake. Due to the late discovery of this error, it is recommended to use Alternative 2b instead of Alternative 5 for 2011 at Cougar.

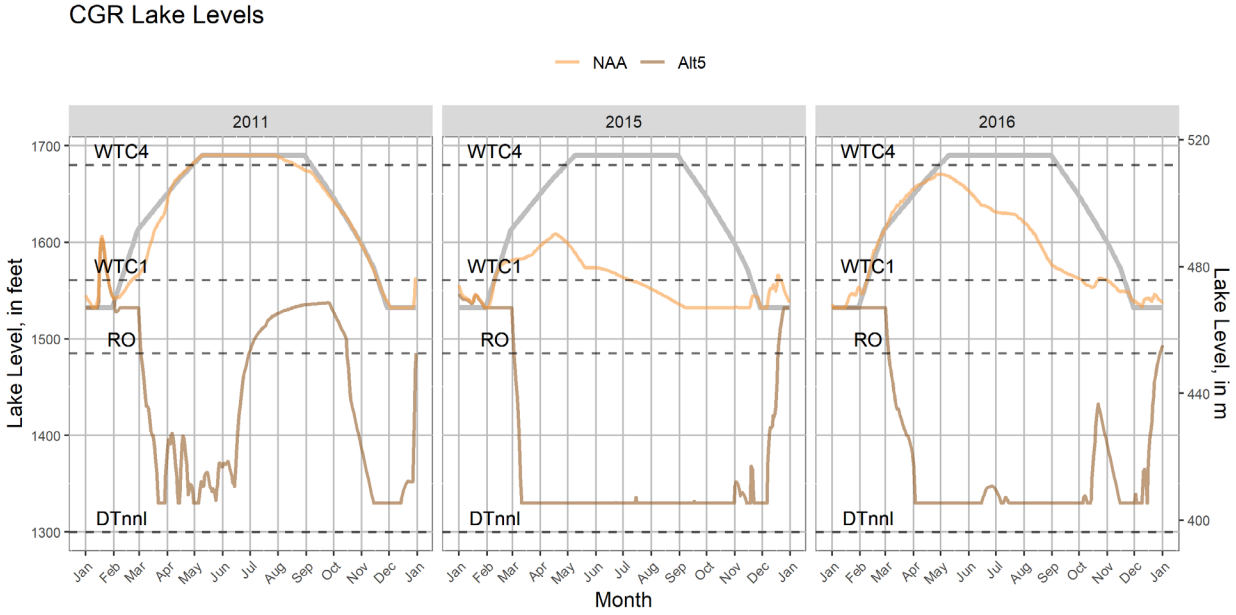


Figure 1-385. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 5 and NAA.

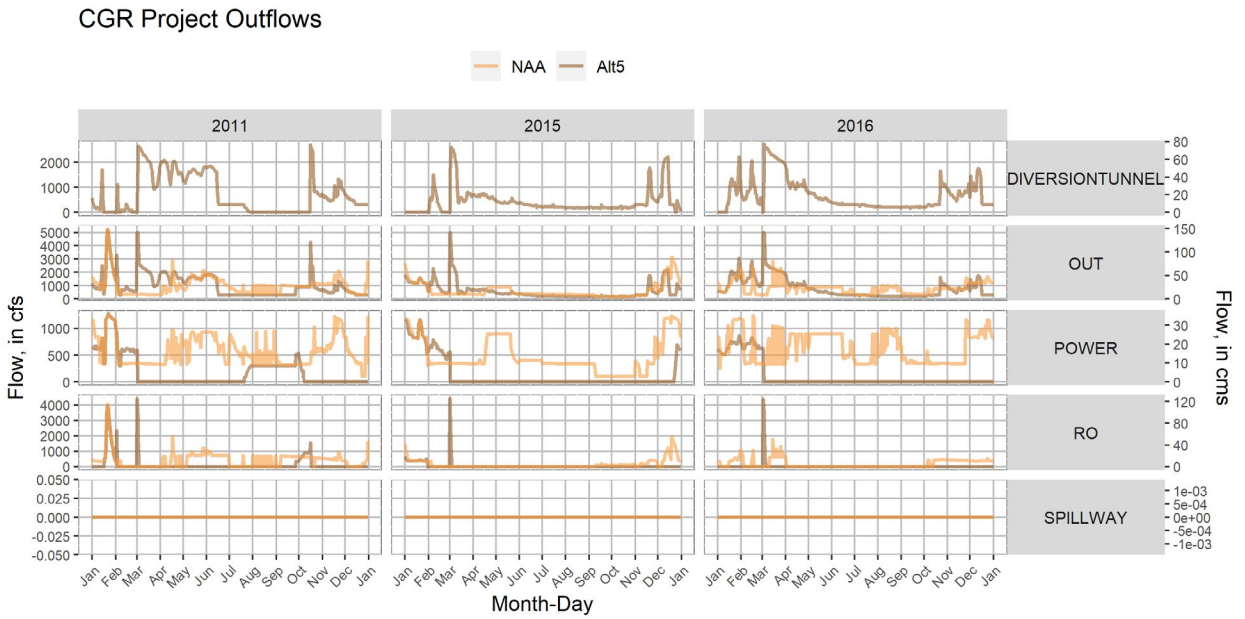


Figure 1-386. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5 and NAA.

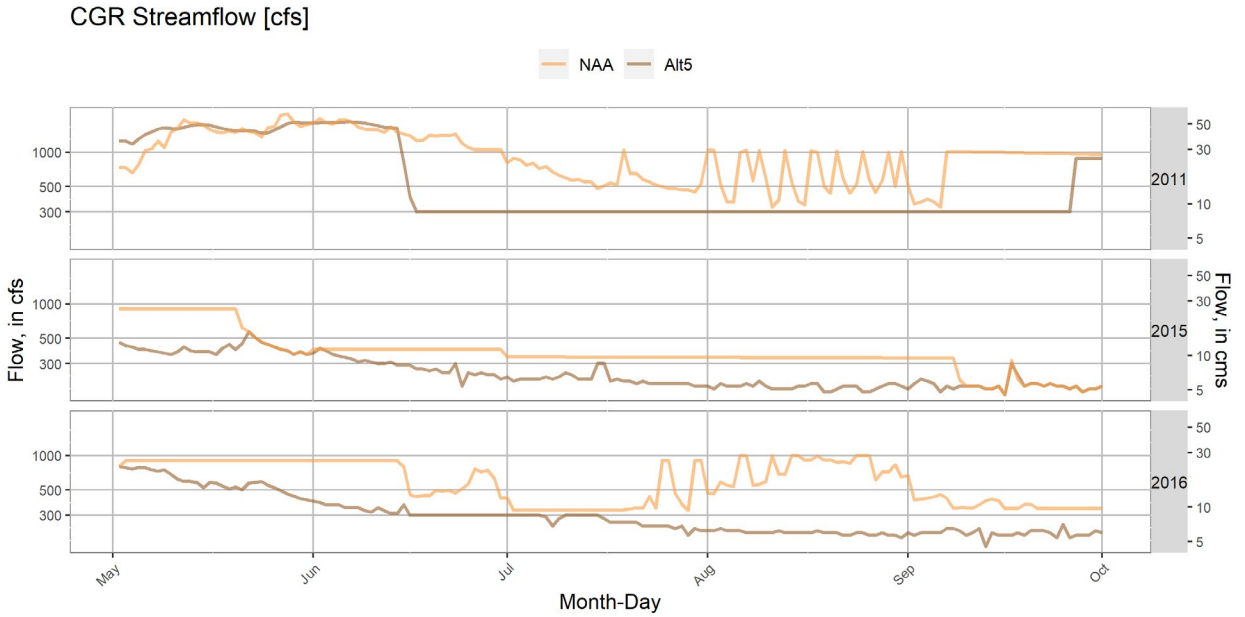


Figure 1-387. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Cougar Lake are shown in Figure 1-388, Figure 1-389, and Figure 1-390. The Cougar 2011 model contained an error in which outflow was specified through the

WTC4 outlet rather than the RO from julian day 202 to 280 while the lake level was above the RO intake. This resulted in warmer release temperature in Alternative 5 than Alternative 2b for 2011 at Cougar. Due to the late discovery of this error, it is recommended to use Alternative 2b instead of Alternative 5 for 2011 at Cougar. Outflow temperatures from Cougar Dam in Alternative 5 were cooler than NAA year-round in 2011, 2015, and 2016 as the lake surface area, volume, and residence time was reduced (Figure 1-391 and Figure 1-392).

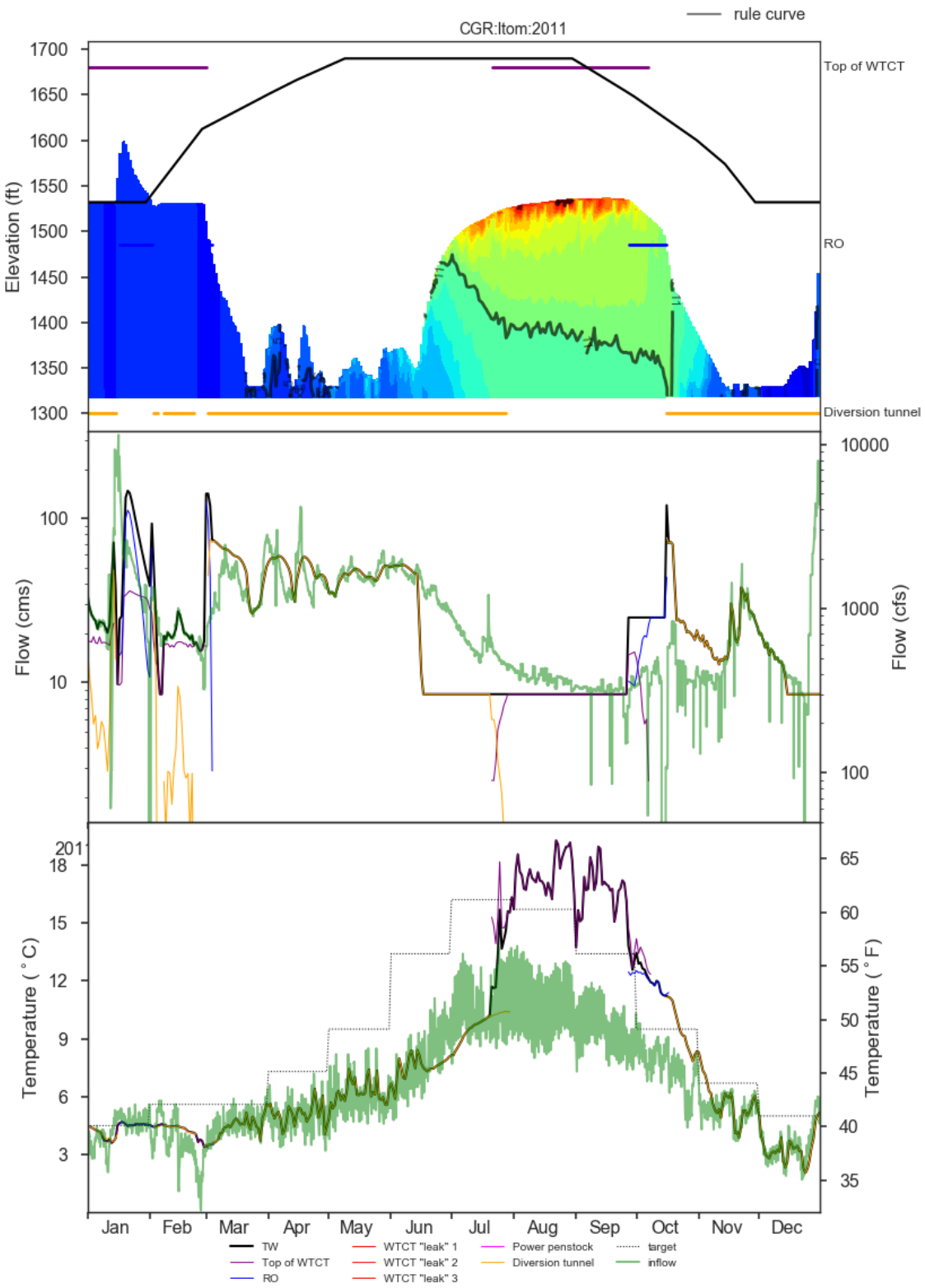


Figure 1-388. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 5 in 2011.

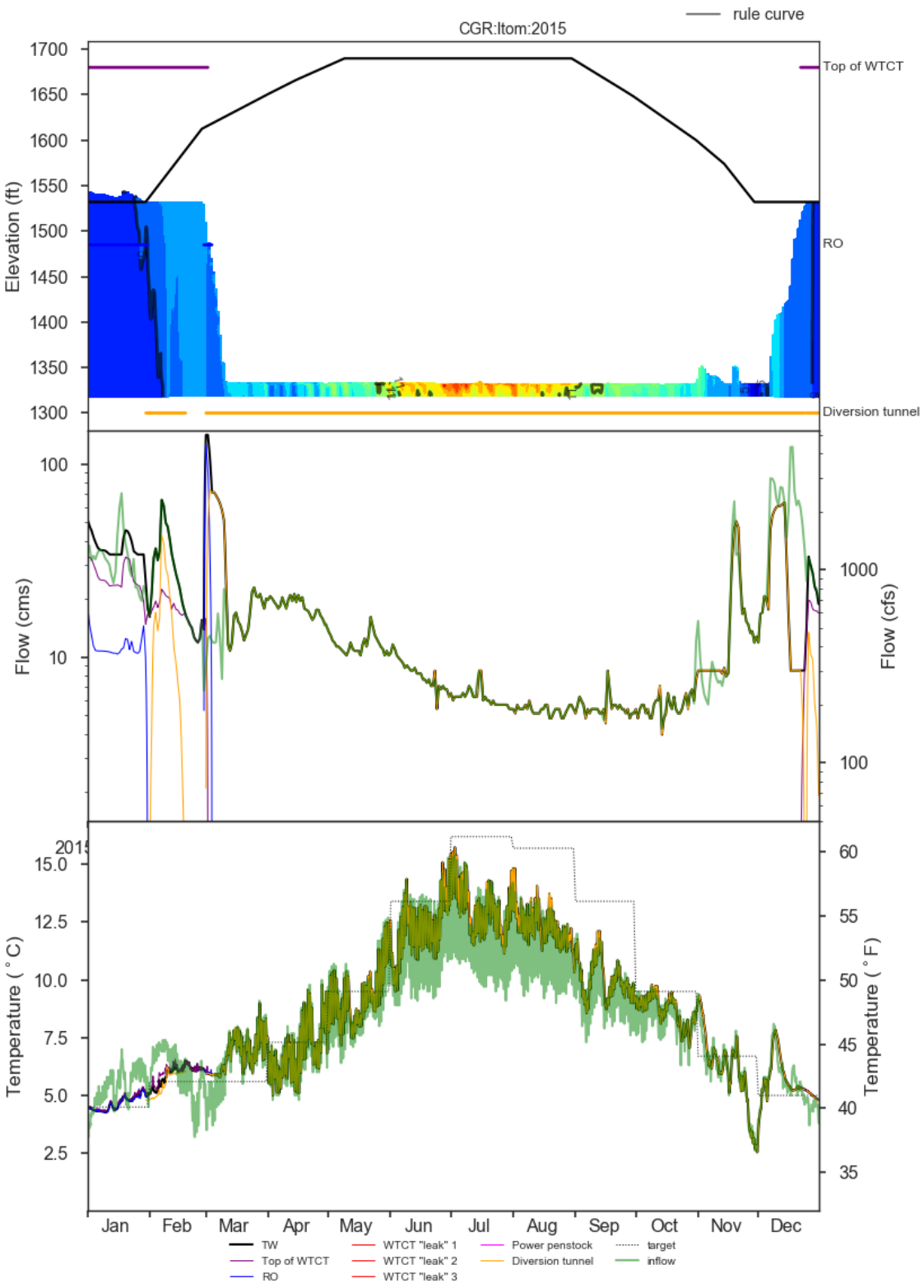


Figure 1-389. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 5 in 2015.

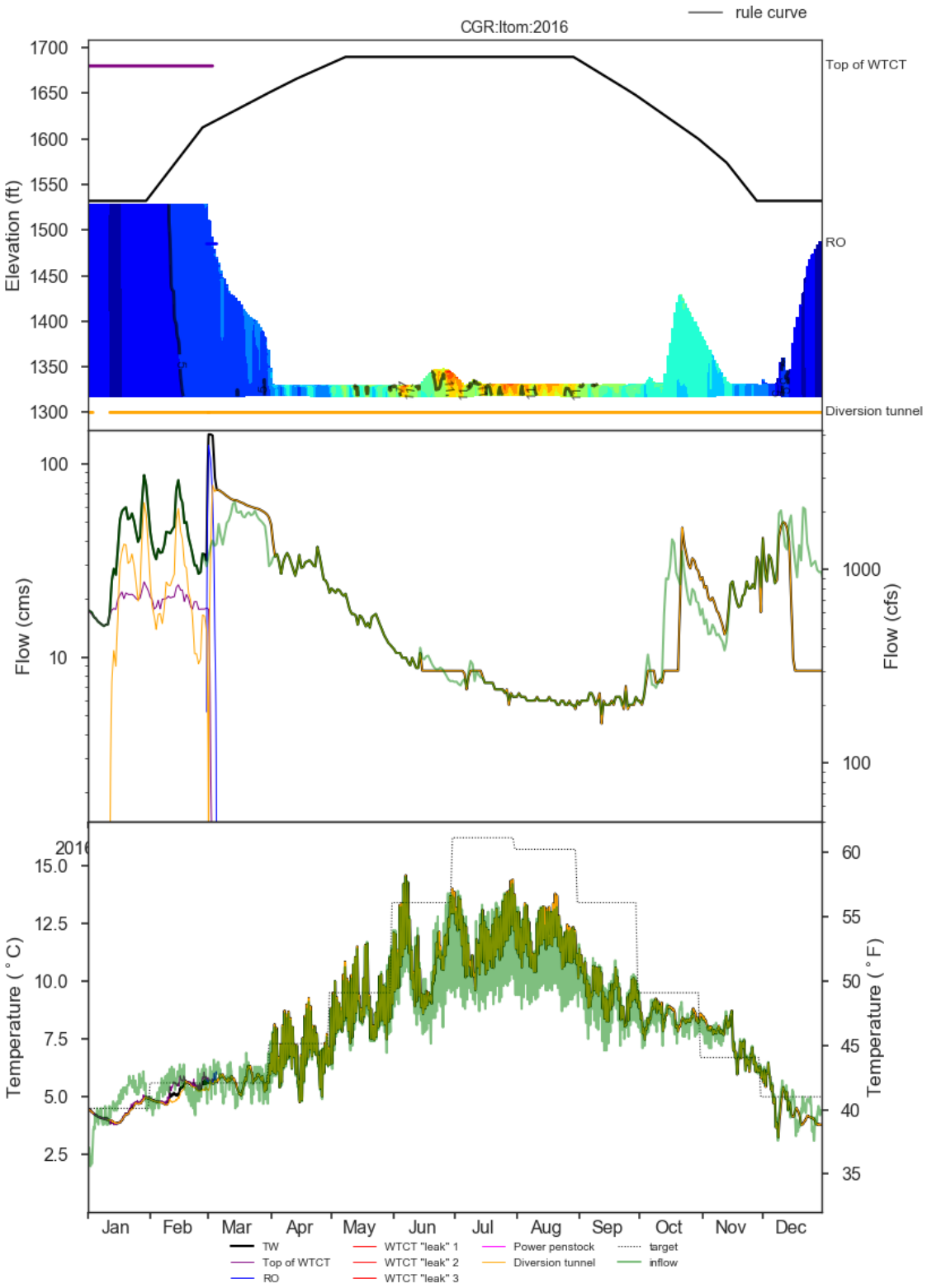


Figure 1-390. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 5 in 2016.

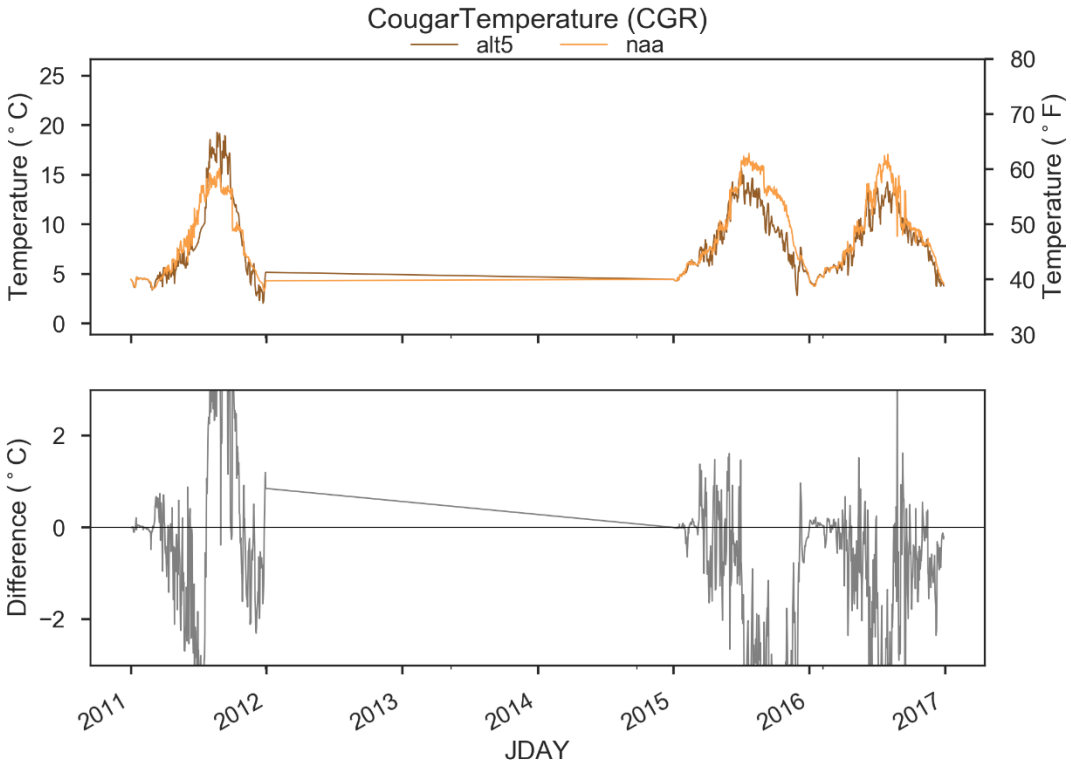


Figure 1-391. Comparison of CGR Outflow Temperatures in NAA and Alternative 5.

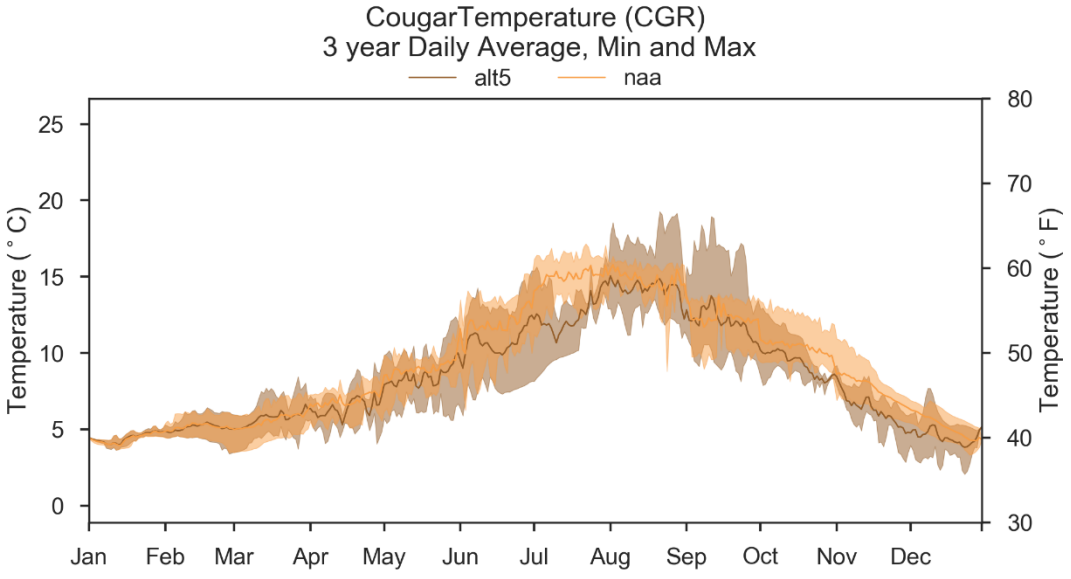


Figure 1-392. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 5. Black Line Indicates Temperature Target.

1.5.8.4 Middle Fork Willamette Dams

1.5.8.4.1 Hills Creek

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Hills Creek in Alternative 5 were nearly identical to Alternative 2b in 2011 and 2015. Operational differences between Alternative 5 and Alternative 2b in 2016 are likely a result of HEC-ResSim using Hills Creek to meet mainstem flow targets at Salem during September. Compared to NAA, Alternative 5 lake levels were generally increased in the refill periods of 2015 and 2016 (early summer) before the lake was drafted and the power pool was utilized for downstream flow augmentation (Figure 1-393, Figure 1-394, and Figure 1-395). The increased storage coincided with reduced outflows during spring and increased outflows in May-June during 2015 and August-October in 2016 (Figure 1-394). 2011 operations were generally similar in Alternative 5 and NAA at Hills Creek Lake.

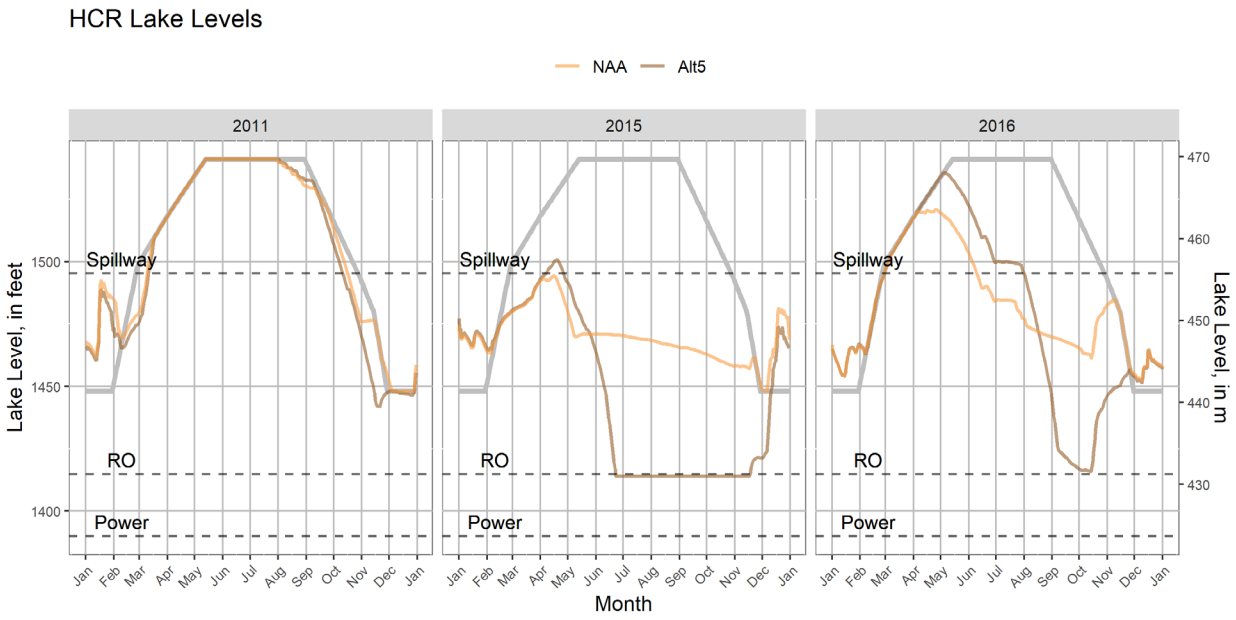


Figure 1-393. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 5 and NAA.

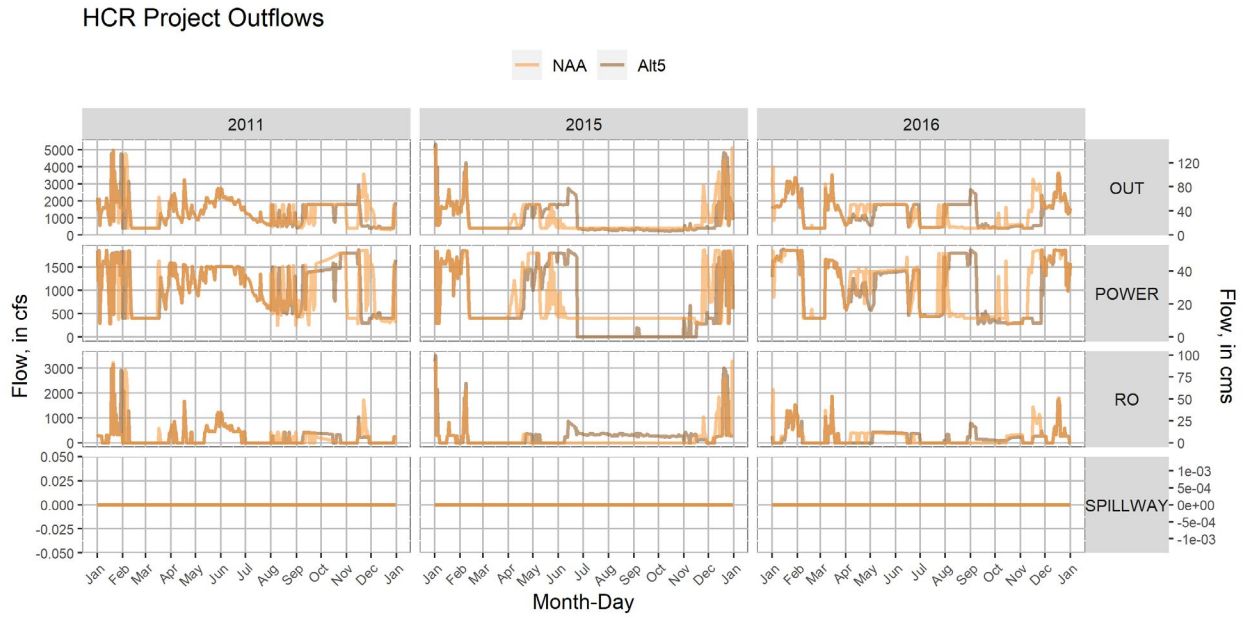


Figure 1-394. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5 and NAA.

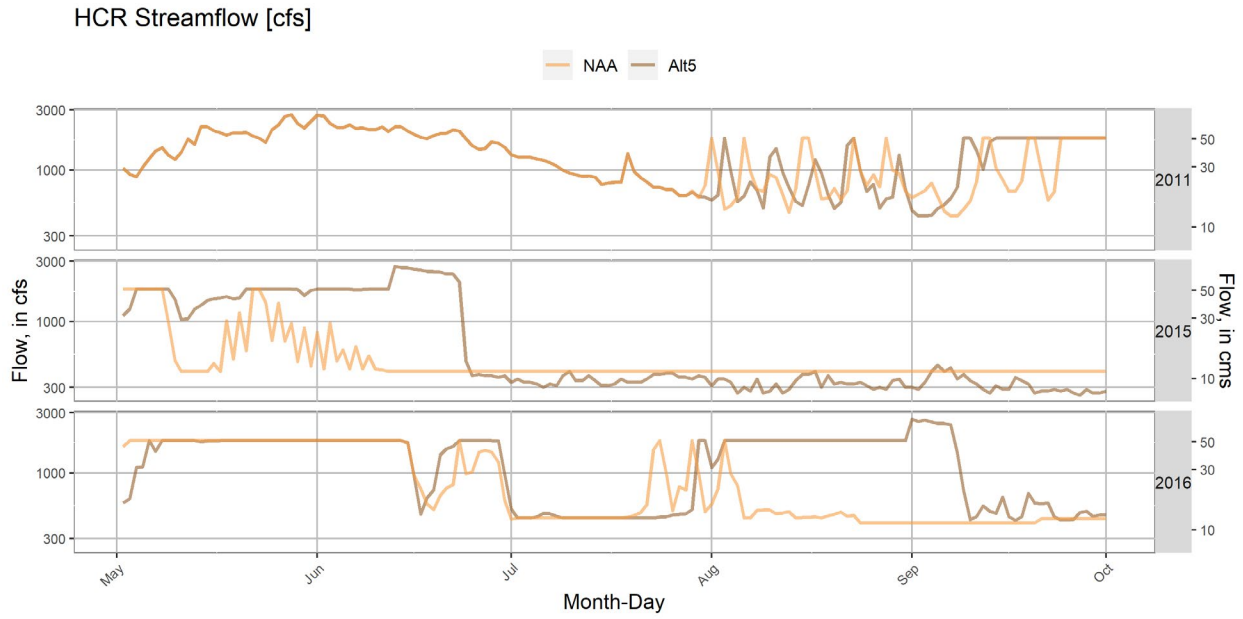


Figure 1-395. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 5 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 5 at Hills Creek Lake are shown in Figure 1-396, Figure 1-397, and Figure 1-398. The seasonal peak tailwater temperature under Alternative 5 was higher and occurred about one month earlier in 2015, which resulted in cooler tailwater

temperature during autumn of that year compared to NAA (Figure 1-399, Figure 1-400). 2016 outflow tailwater temperature in Alternative 5 was generally cooler than NAA in spring and summer but similar during autumn. Hills Creek tailwater temperatures in 2011 were generally similar in Alternative 5 and NAA.

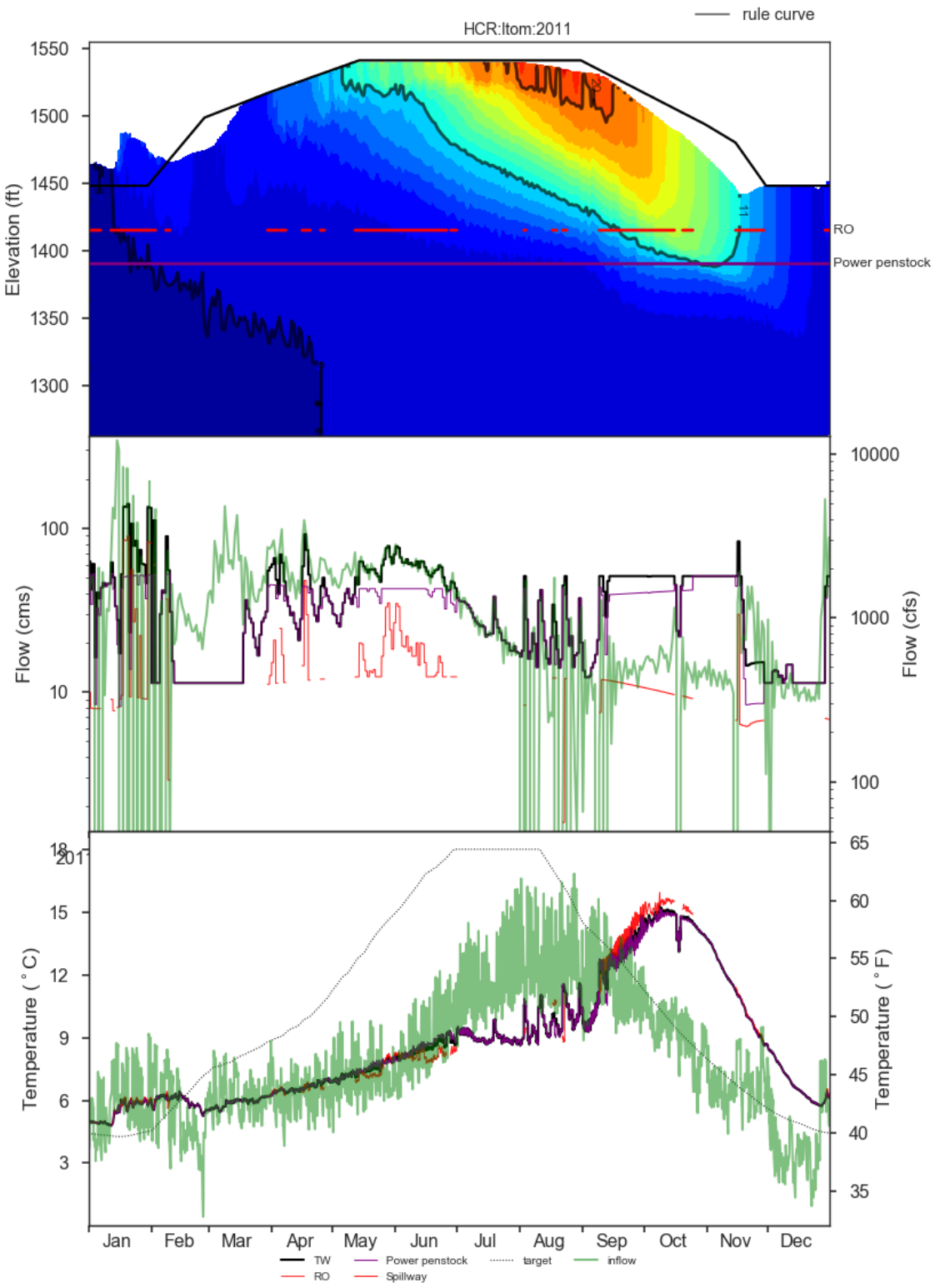


Figure 1-396. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 5 in 2011.

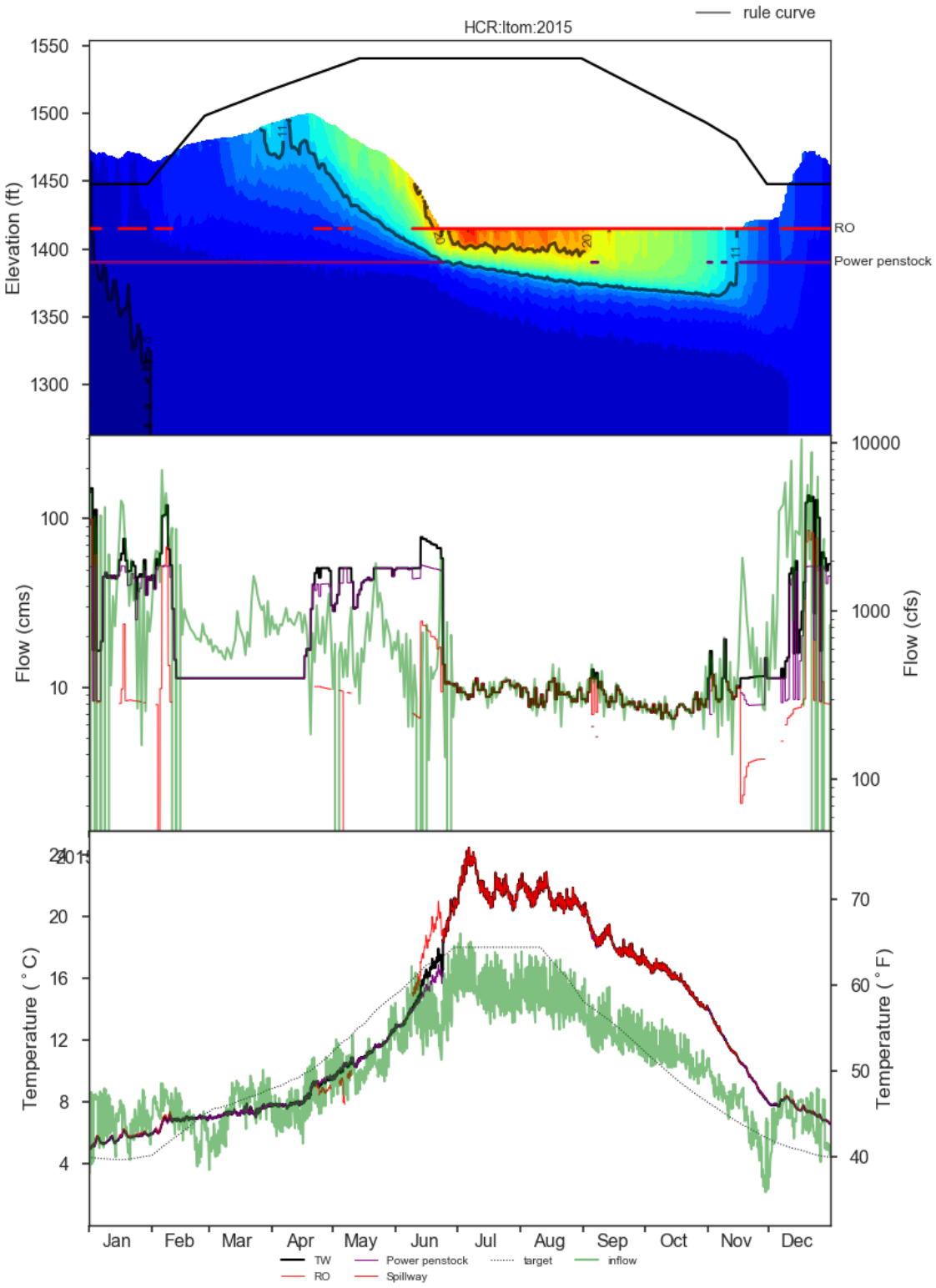


Figure 1-397. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 5 in 2015.

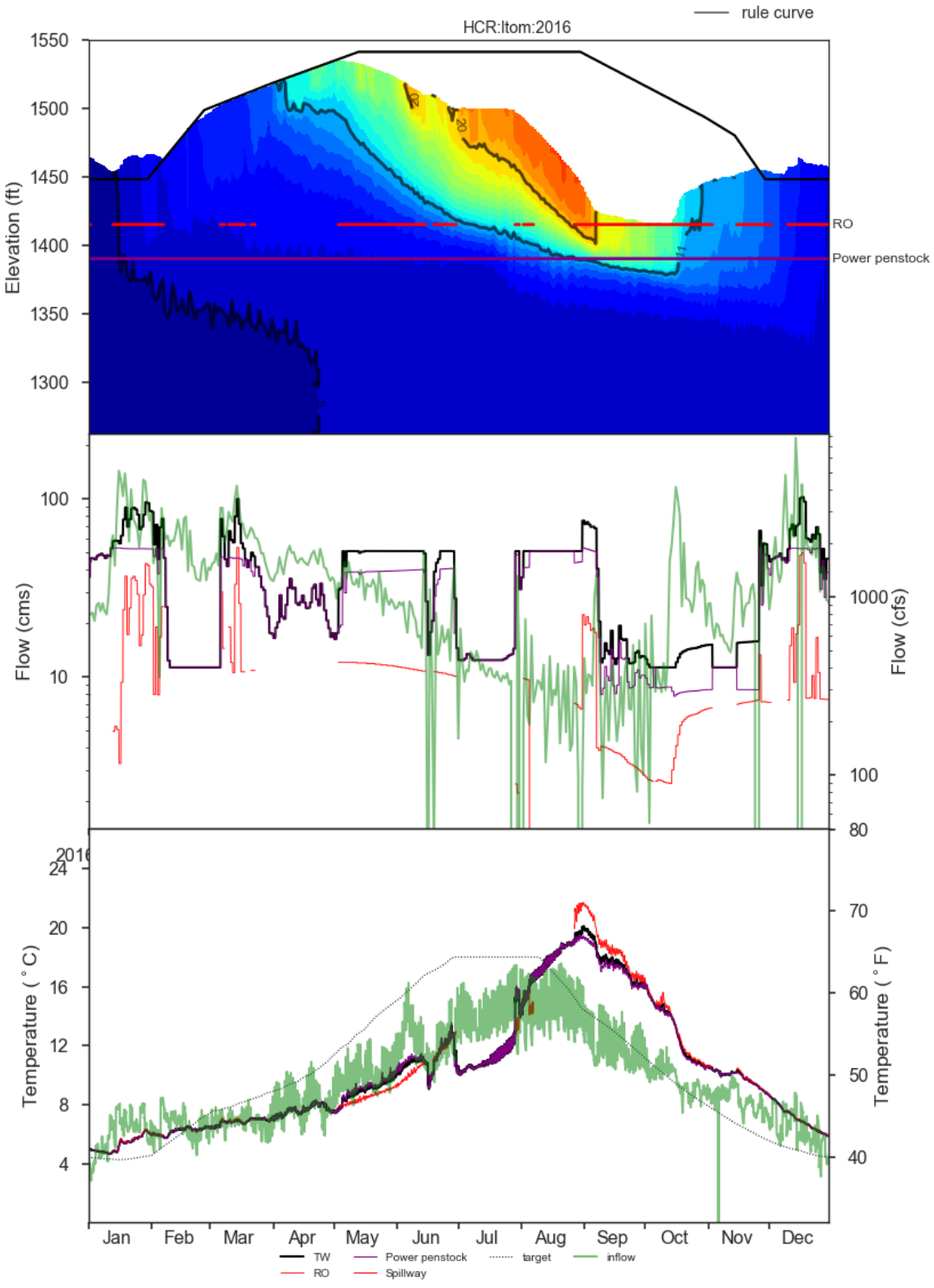


Figure 1-398. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 5 in 2016.

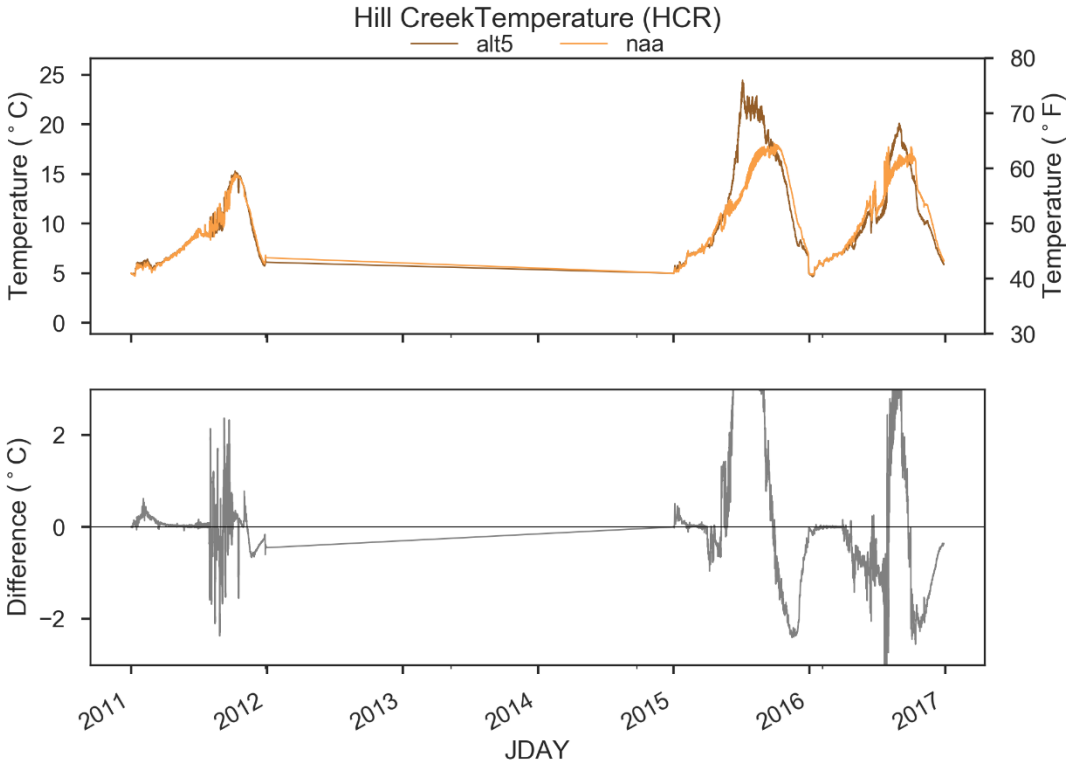


Figure 1-399. Comparison of HCR outflow temperatures in NAA and Alternative 5.

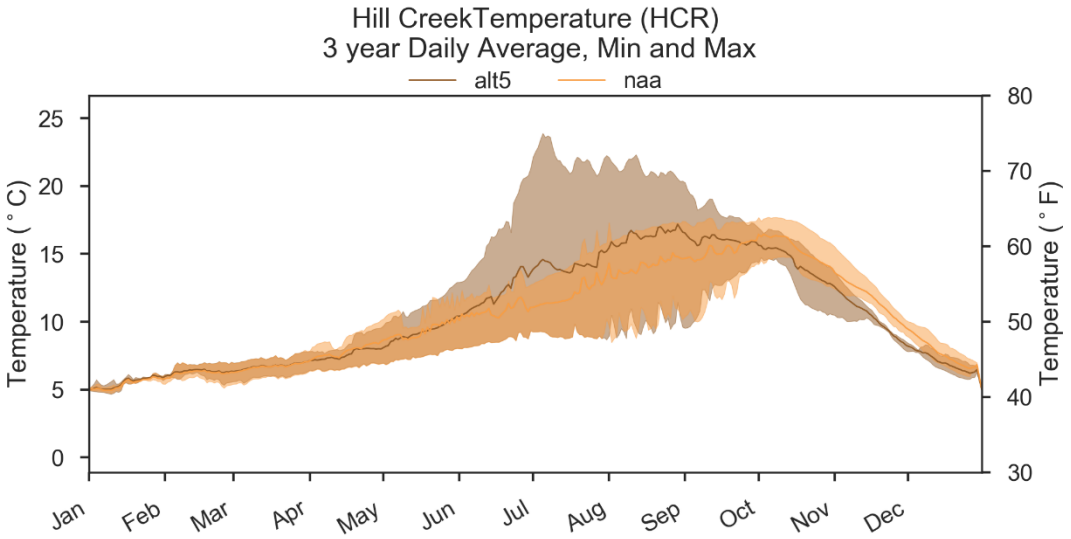


Figure 1-400. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 5. Black Line Indicates Temperature Target.

1.5.8.4.2 Lookout Point

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Lookout Point in Alternative 5 were similar to Alternative 2b and NAA in 2011, 2015, and 2016 (Figure 1-401, Figure 1-402, and Figure 1-403) aside from minor differences in timing of refill and release rates that were associated with upstream Hills Creek Dam operations.

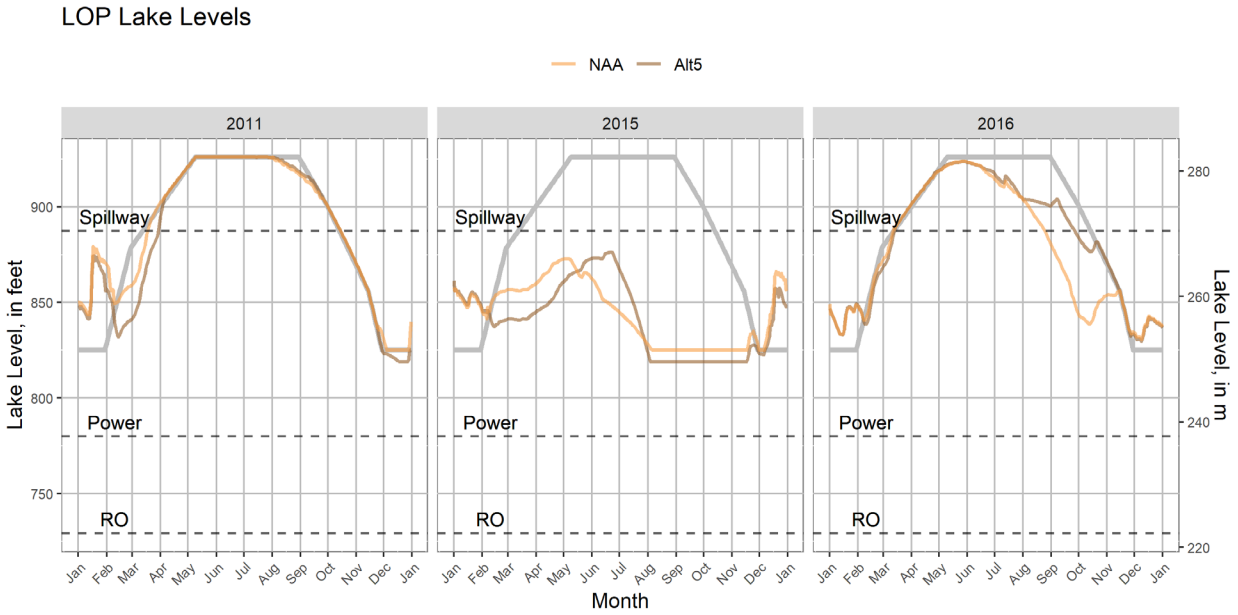


Figure 1-401. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 5 and NAA.

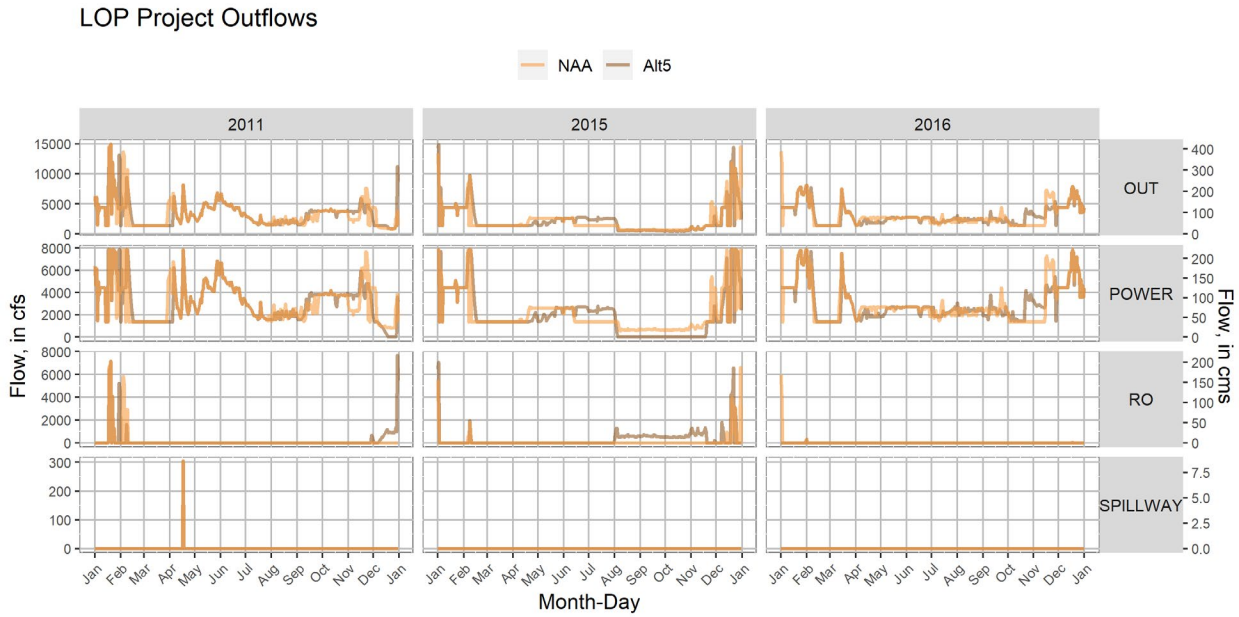


Figure 1-402. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 Alternative 5 and NAA.

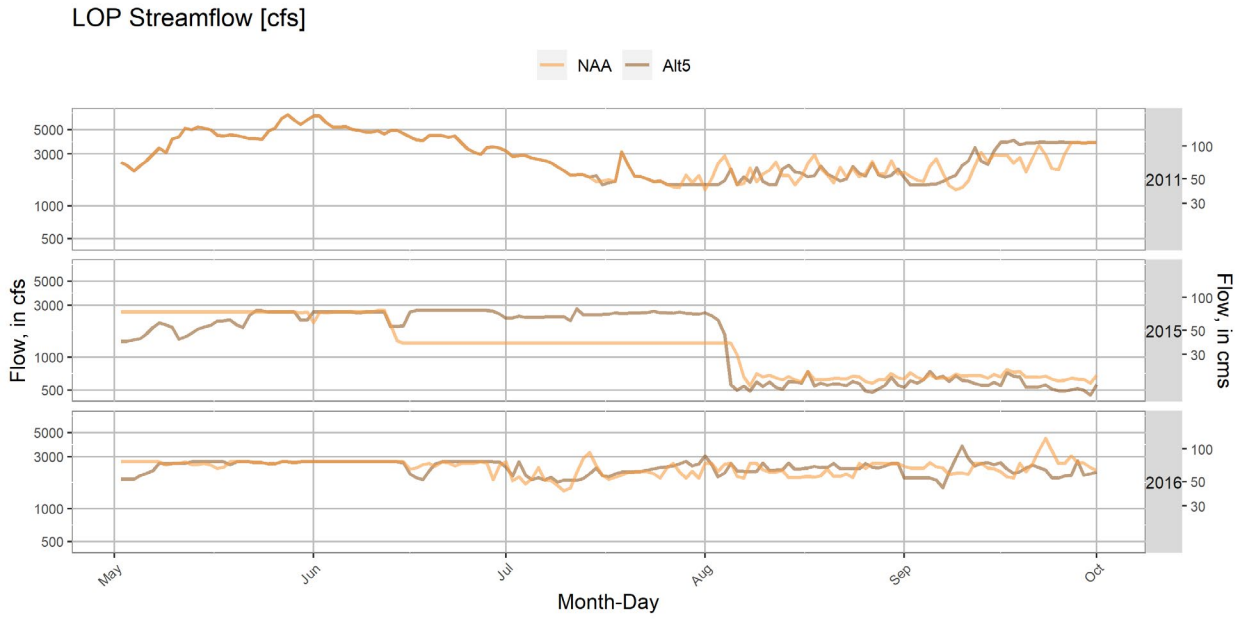


Figure 1-403. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Lookout Point Lake are shown in Figure 1-404, Figure 1-405, and Figure 1-406. The proposed FSC (and attraction pumps intended for fish collection) in Lookout Point Lake is currently assumed to have minimal effect on release temperature from the

relatively deep Lookout Point Penstocks, but has potential to result in mixing thermal layering and de-stratification in the forebay of Lookout Point Lake. Simulating this effect on water temperature was beyond the scope of the WV EIS. Generally, temperatures downstream of LOP-DEX were similar to NAA, aside from short-term differences in late summer of 2015 likely related to upstream Hills Creek operations (Figure 1-407, Figure 1-408).

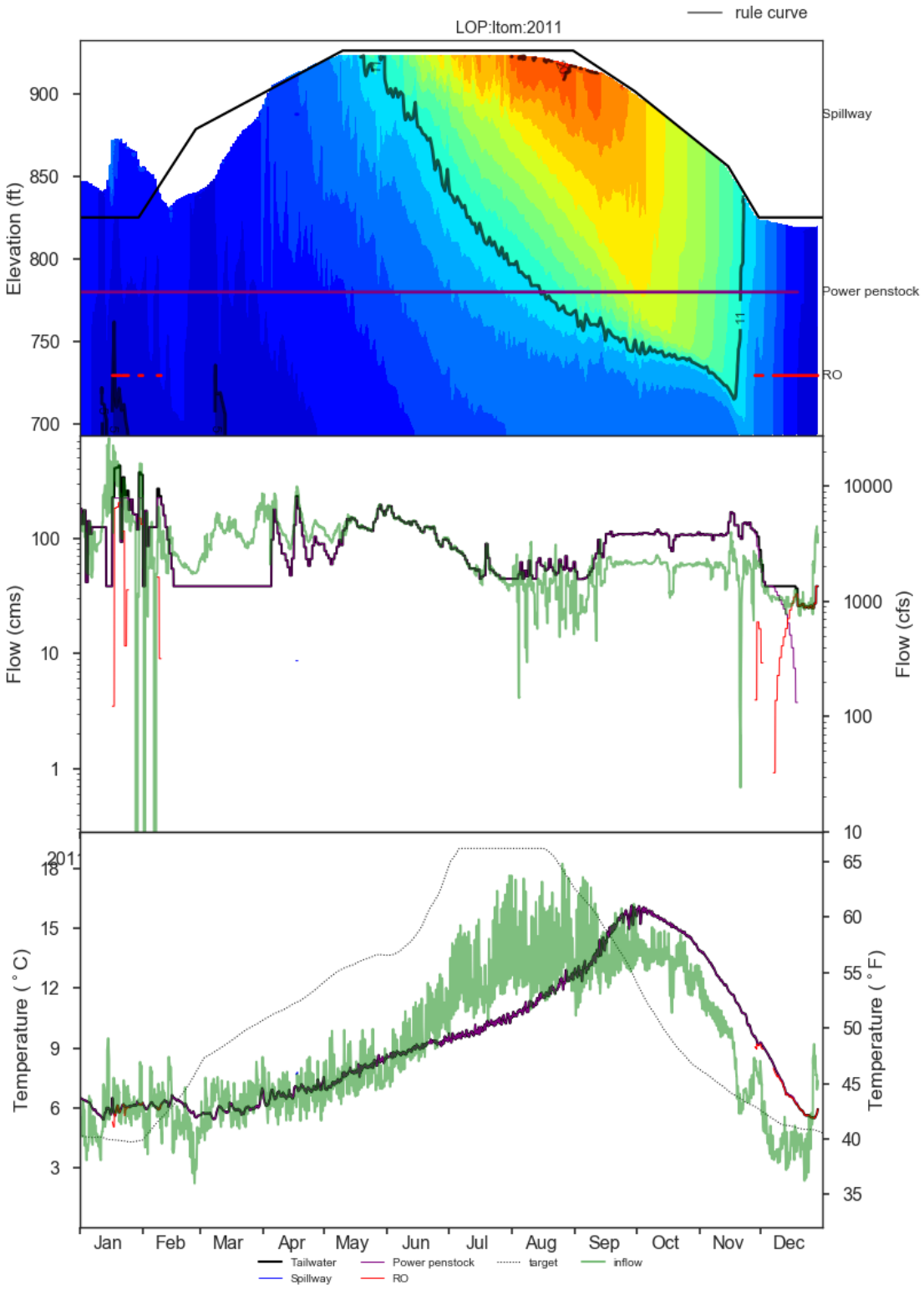


Figure 1-404. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 5 in 2011.

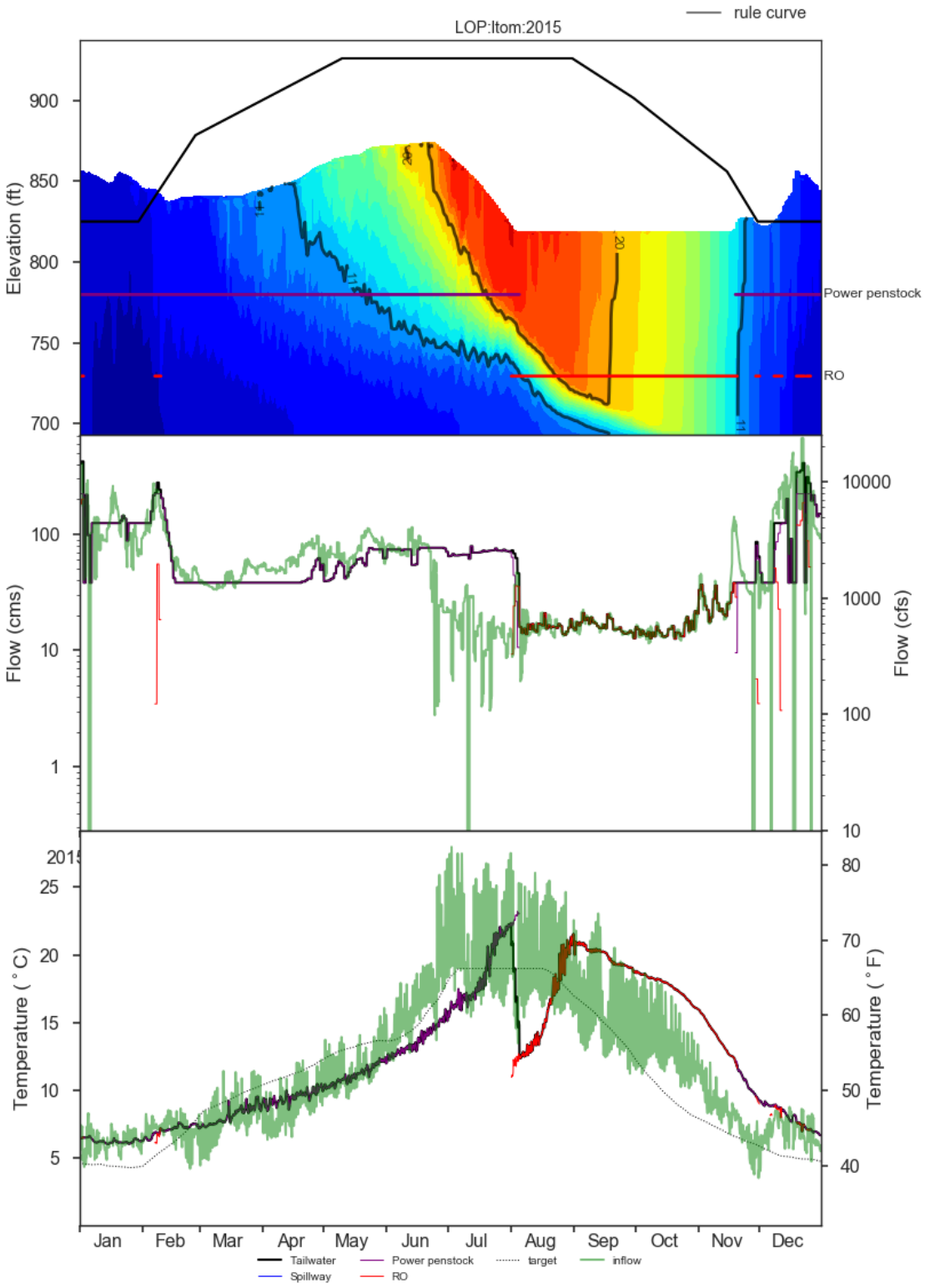


Figure 1-405. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 5 in 2015.

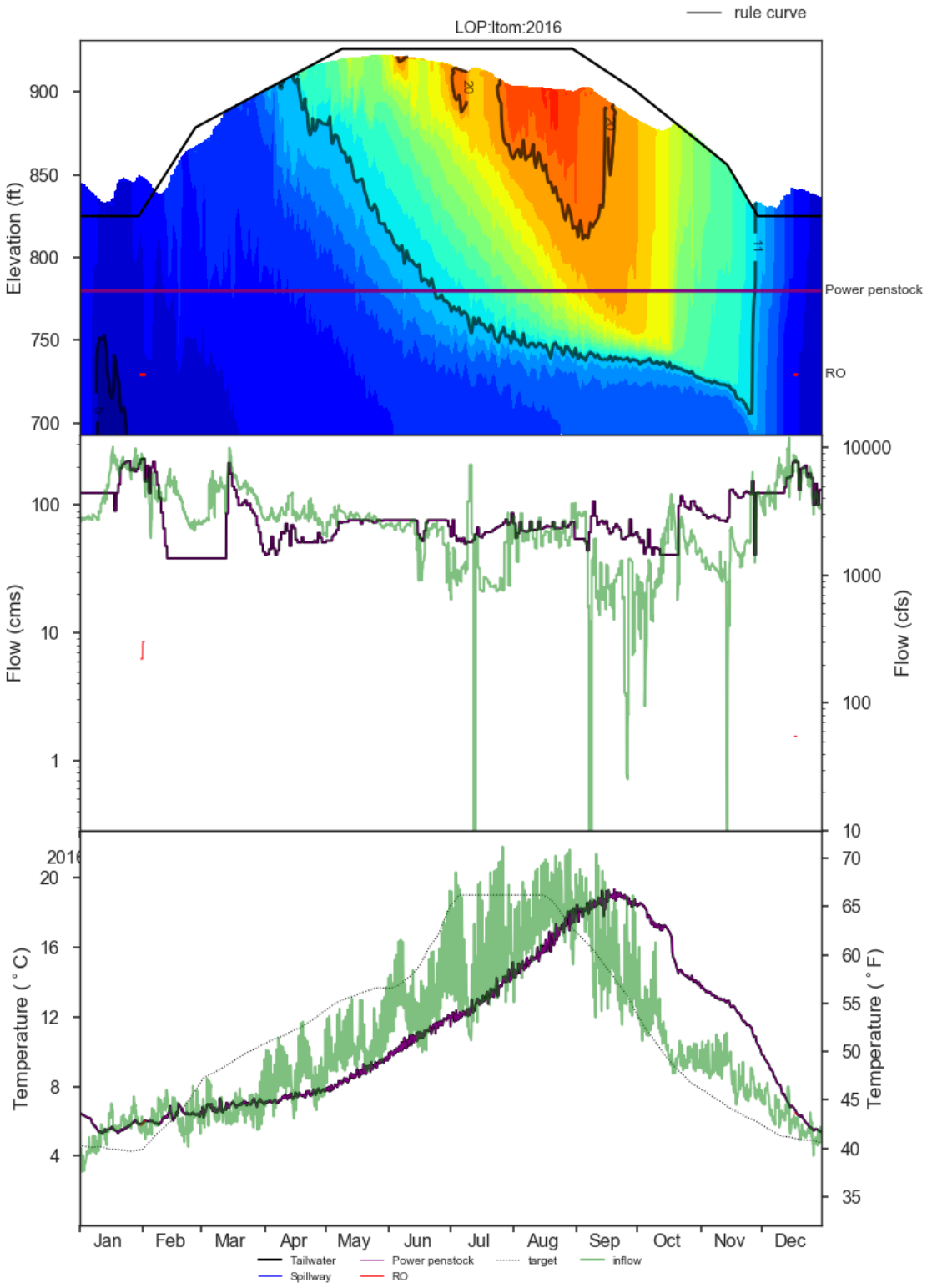


Figure 1-406. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 5 in 2016.

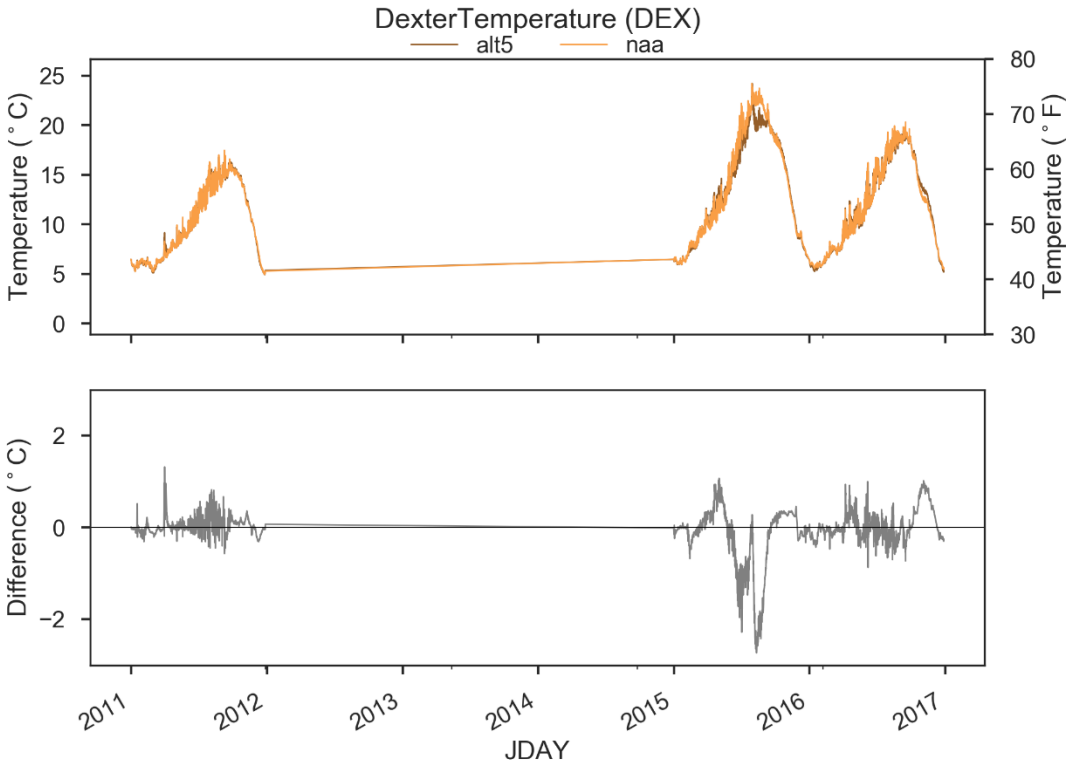


Figure 1-407. Comparison of DEX Outflow Temperatures in NAA and Alternative 5.

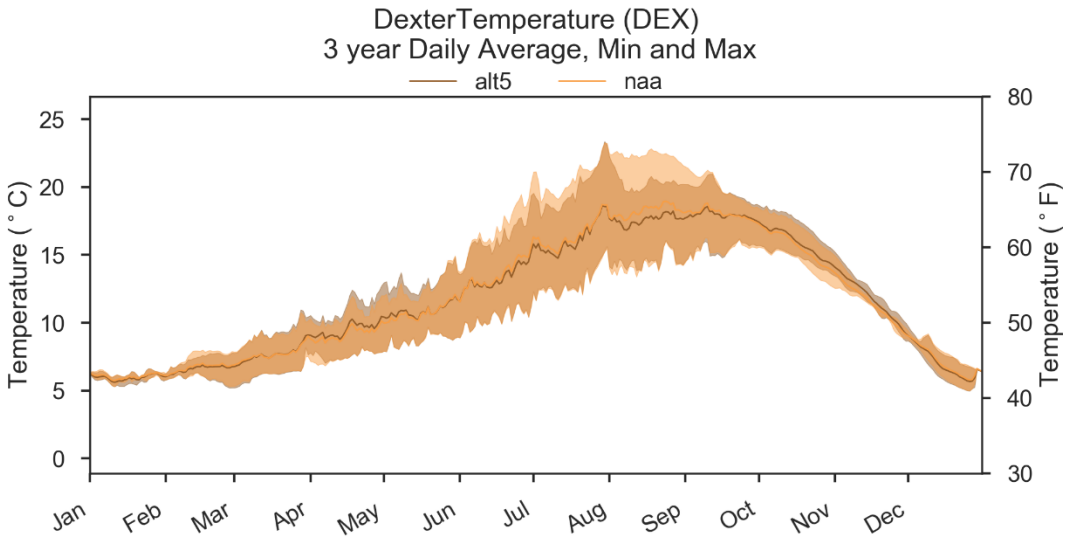


Figure 1-408. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 5. Black Line Indicates Temperature Target.

1.5.8.5 Mainstem Willamette River

Streamflow in Alternative 5 was nearly identical to Alternative 2b and NAA in 2011 and 2016. In 2015, alternative 5 streamflow was generally lower from April to mid-June and higher from mid-June to mid-September compared with NAA (Figure 1-1-409). Streamflow at Salem was generally similar May-September in Alternative 5 compared to Alternative 2b aside from a two-week period in August of 2015, where Alternative 5 resulted in lower streamflow than Alternative 2b. Similar to Alternative 2b, flow differences between Alternative 5 and NAA were primarily in 2015 and responsive to the Measure 30 dam outflow increases in advance of heat wave events (Figure 1-1-409). While temperature simulations are not available for Alternative 5, results would likely be similar to those in Alternative 2b, aside from differences provided in this section (Middle Fork Willamette operation changes in 2015 and 2016) and the two-week period in August of 2015. These flow changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (Figure 1-200, Figure 1-201). Water temperatures at Salem were also affected by upstream dam operations and the proposed SWS-FSS structure at Detroit Dam, which likely contributed to warmer temperatures seen in 2011 and 2015 comparing Alternative 2b to NAA. Overall water temperature differences between Alternative 2b and NAA were less than 2 degrees Celsius.

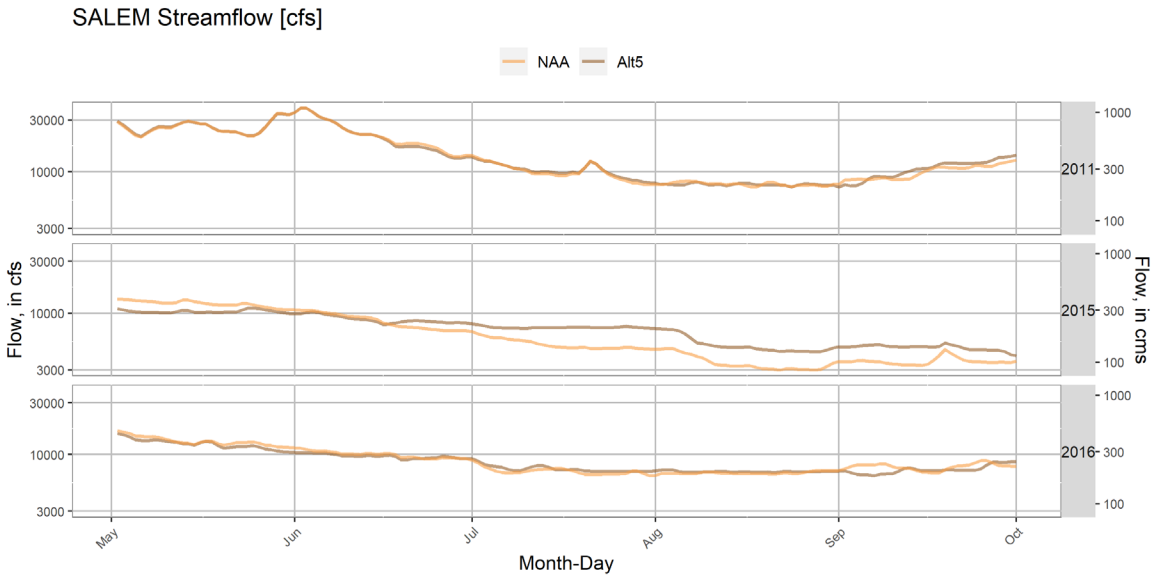


Figure 1-1-409. Streamflow Comparison Between Alternative 5 and NAA at Willamette River at SLMO.

1.5.9 Alternative 6 – Cease Hydropower Operations

Alternative 6 is based on Alternative 5 in the FEIS, with the following changes that (relative to NAA) affect operations, lake storage, and water temperature:

- Penstocks at Detroit, Big Cliff, Green Peter, Foster, Cougar, Hills Creek, Lookout Point, and Dexter dams pass flow through a modified penstock that is assumed to be controlled via cone valves instead of turbines.
- Construct temperature control structure at Detroit.
- Deep fall drawdown to 35' over the regulating outlet at Green Peter, use of RO in fall, use spillway for surface spill in spring and summer
- Deep spring and fall drawdown to 30 feet over the diversion tunnel at Cougar, with a limited refill window between June 15th and November 15th (essentially a delayed refill).
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.

RES-SIM simulations of lake levels and dam outflows were used as a basis for assessing the water temperature effects of Alternative 6 in 2011, 2015, and 2016 and are discussed in this section. The underlying assumptions in Alternative 6 were similar to Alternative 5. A full explanation of the RES-SIM analysis and findings can be found in the Section 3.2 Hydrologic Processes and Technical Appendix B Hydrology and Hydraulics.

1.5.9.1 NORTH SANTIAM DAMS

1.5.9.1.1 Detroit

RES-SIM Lake Levels and Outflows

Lake level and storage at Detroit Lake in Alternative 6 was nearly identical to NAA in 2011 and 2016. Alternative 6 Detroit Lake levels were similar to NAA in 2015 until July, when the pool was allowed to draft below minimum conservation pool (Figure 1-410). Total outflow in 2011, 2015, and 2016 was generally similar in Alternative 6 (Alt6) and NAA at Detroit Lake, aside from late summer of 2015 as mentioned above. The proposed SWS and FSS in Alternative 6 allowed all outflow within penstock capacity (assumed at 4600 cfs) to be routed from a floating outlet through the penstock outlets for temperature management, rather than the Spillway or URO flow for temperature management that was used in NAA (Figure 1-411).

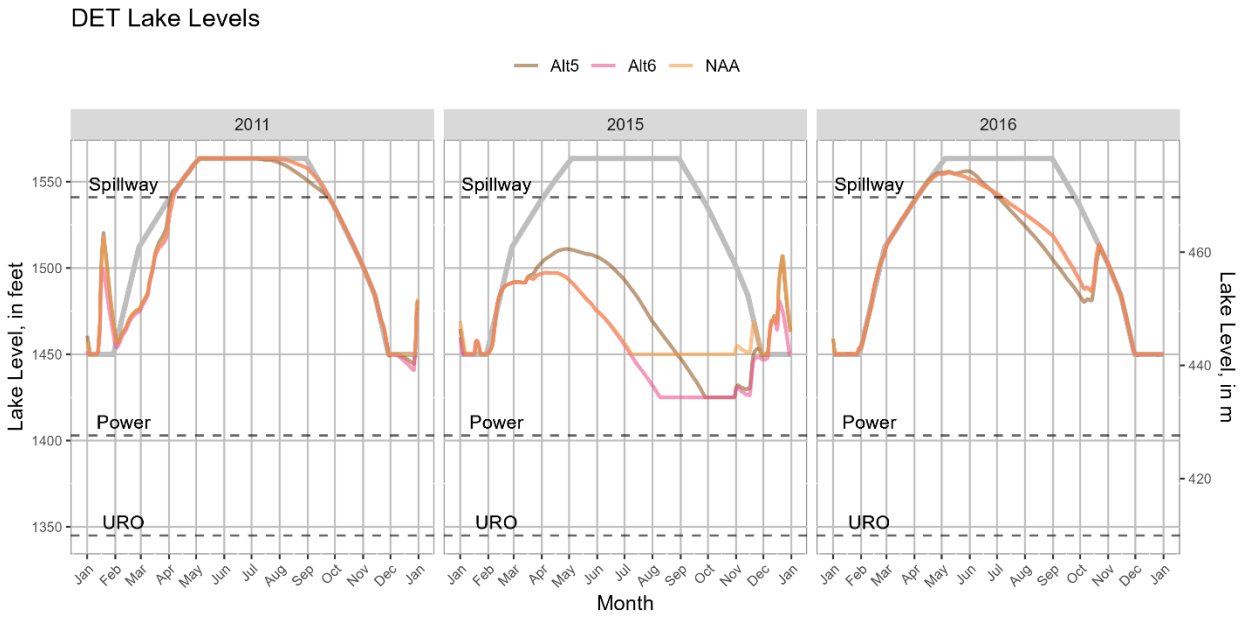


Figure 1-410 WV EIS RES-SIM Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

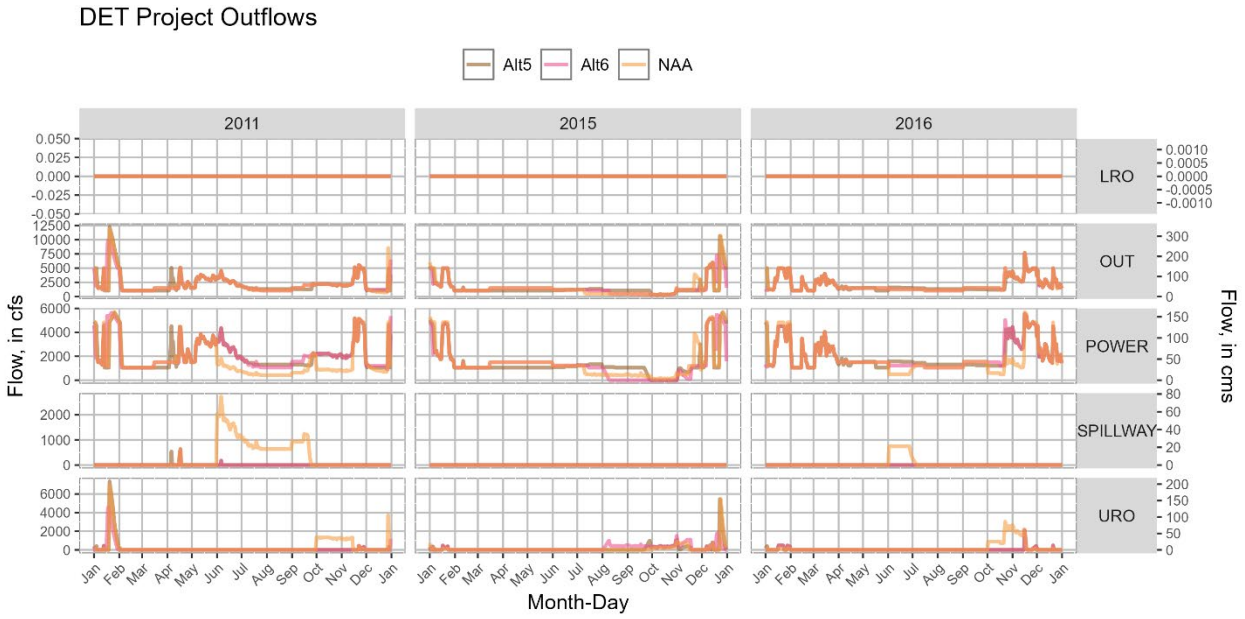


Figure 1-411. WV EIS RES-SIM Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

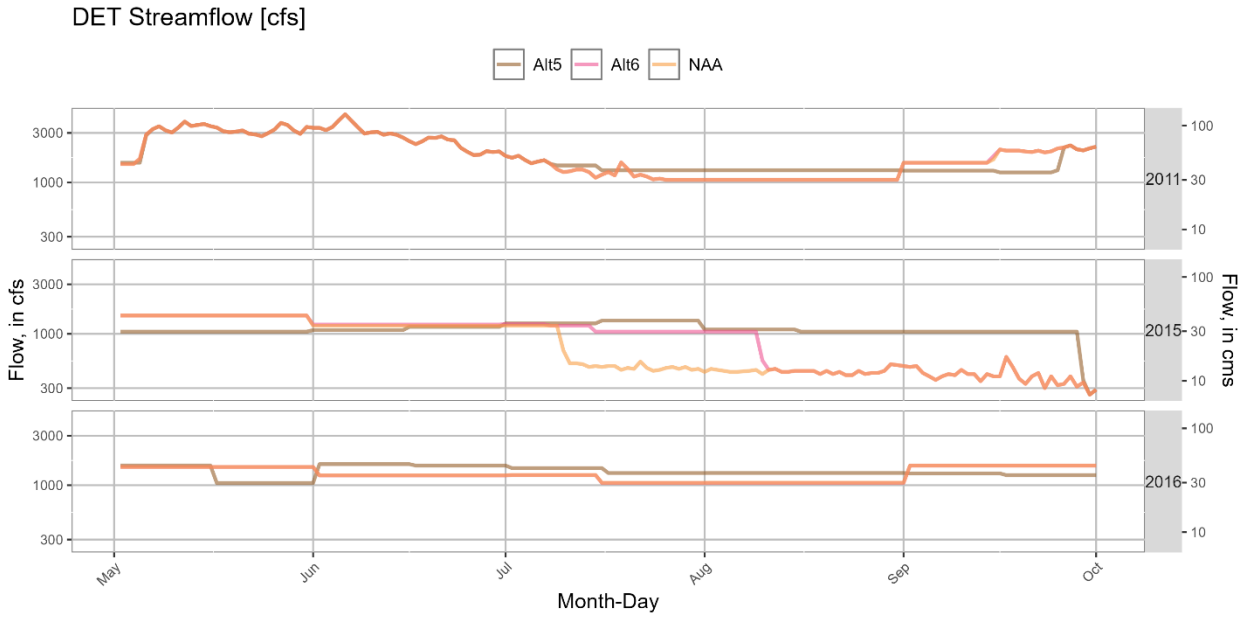


Figure 1-412. WV EIS RES-SIM Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

CE-QUAL-W2 Temperature

Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the Upper RO. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, the proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn (Figure 1-414). For Alt6 and Alt5, the lines in Figure 1-413 represent percent outflow from the SWS near-surface outlet.

Alternative 6 includes a Water Temperature Control tower at Detroit reservoir for water temperature management. Alternative 6 as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (Figure 1-570, Figure 1-571, Figure 1-572) in the 2011-year scenario an increase up to 4-degrees is observed from June until October as compared to the NAA. In the 2015-year scenario an increase up to 4-degrees is observed from May until August and then decreases up to 3 degrees in September and October (Figure 1-571). In the 2016-year scenario an increase up to 9-degrees is observed from May until September as compared to the NAA. For the average of the three years an increase up to 5-degrees is observed from May until September and then 0-degree change in October as compared to the NAA.

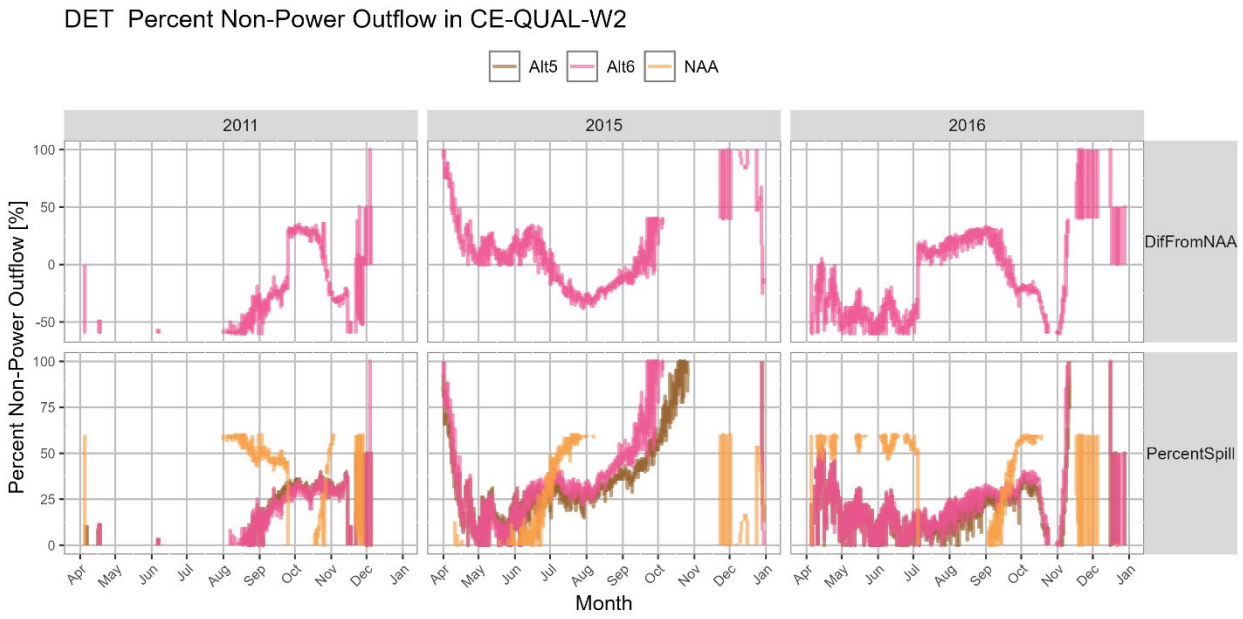


Figure 1-413. WV EIS Percent Spill Allocated in CE-QUAL-W2 Detroit Lake model for 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA. Note: For Alt6 and Alt5, the lines represent percent outflow from the SWS near-surface outlet.

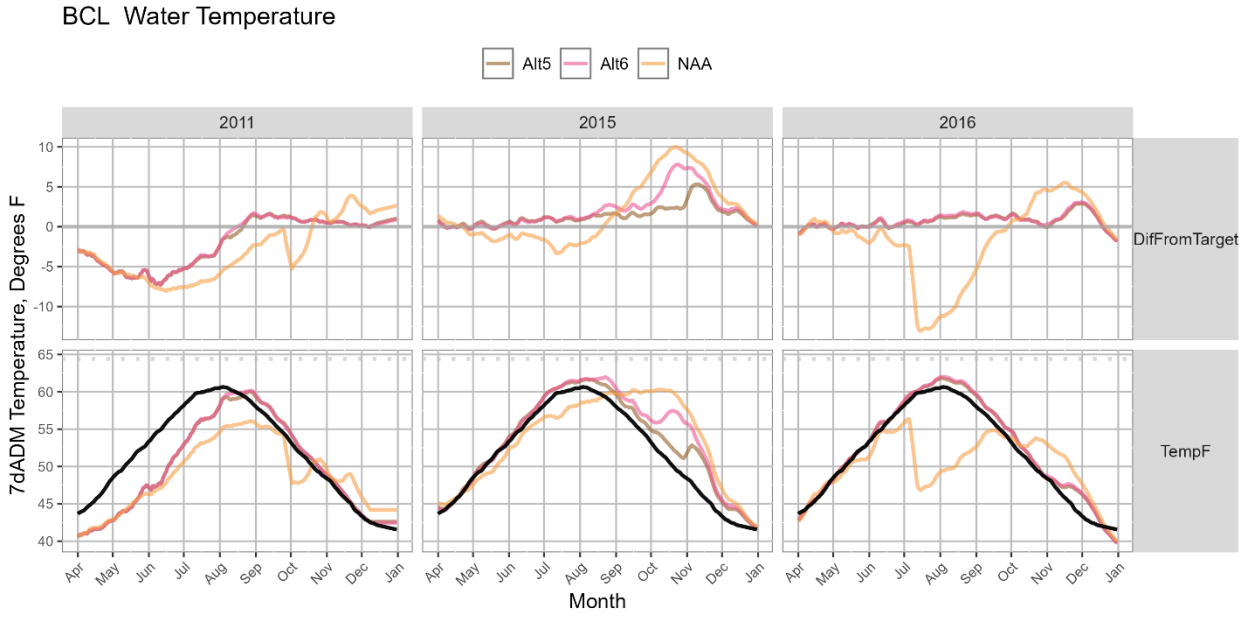


Figure 1-414. Comparison of Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023).

1.5.9.2 SOUTH SANTIAM DAMS

1.5.9.2.1 Green Peter

RES-SIM Lake Levels and Outflows

Lake level and storage at Green Peter in Alternative 6 was nearly identical to NAA in 2011, 2015, and 2016 aside from the October-November time frame with the RO drawdown for fish passage (Figure 1-369, Figure 1-370, and Figure 1-371). In Alternative 6 during 2015, the drawdown began in July. Outflow operations were generally similar in Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA at Green Peter Lake January-June, aside from 2015. Alternative 6 had higher outflows in July-October to draft the lake for fish passage operations through the ROs in autumn. The proposed operational temperature management through the spillway (during spring/summer) and RO (during autumn) in Alternative 6 led to increased outflow from these outlets from RES-SIM and decreased modified penstock outflow compared to NAA (Figure 1-370). However, the final blend between spillway, RO, and modified penstock outlets was determined by the CE-QUAL-W2 model (Figure 1-418).

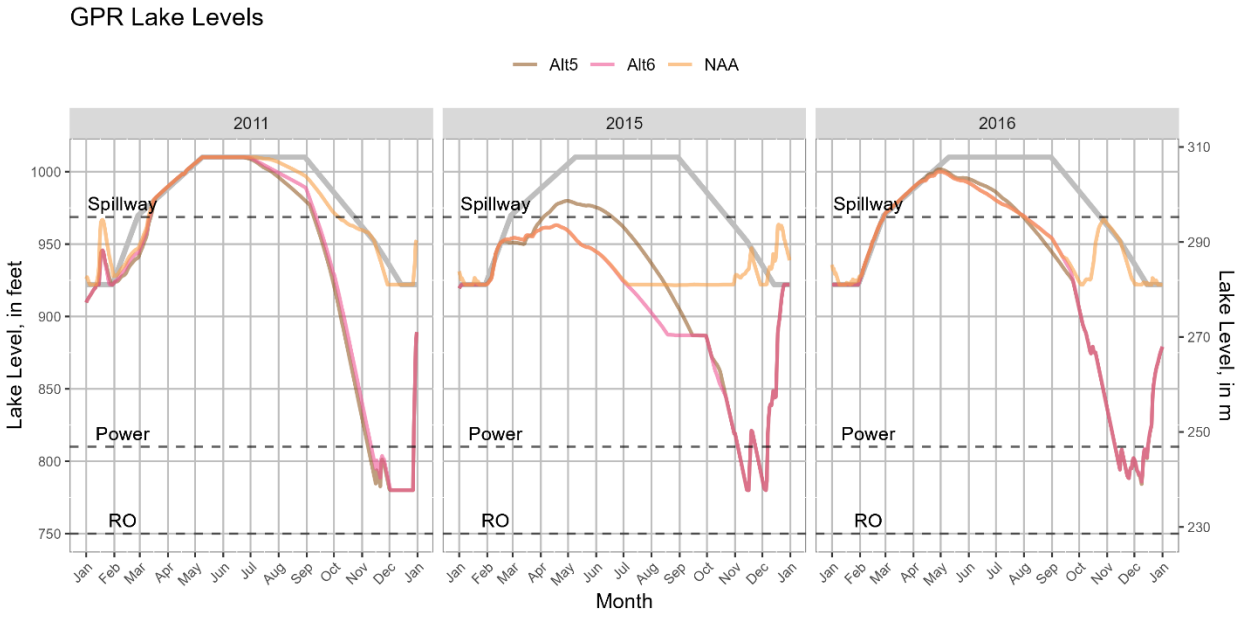


Figure 1-415 WV EIS RES-SIM Green Peter Lake Levels in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

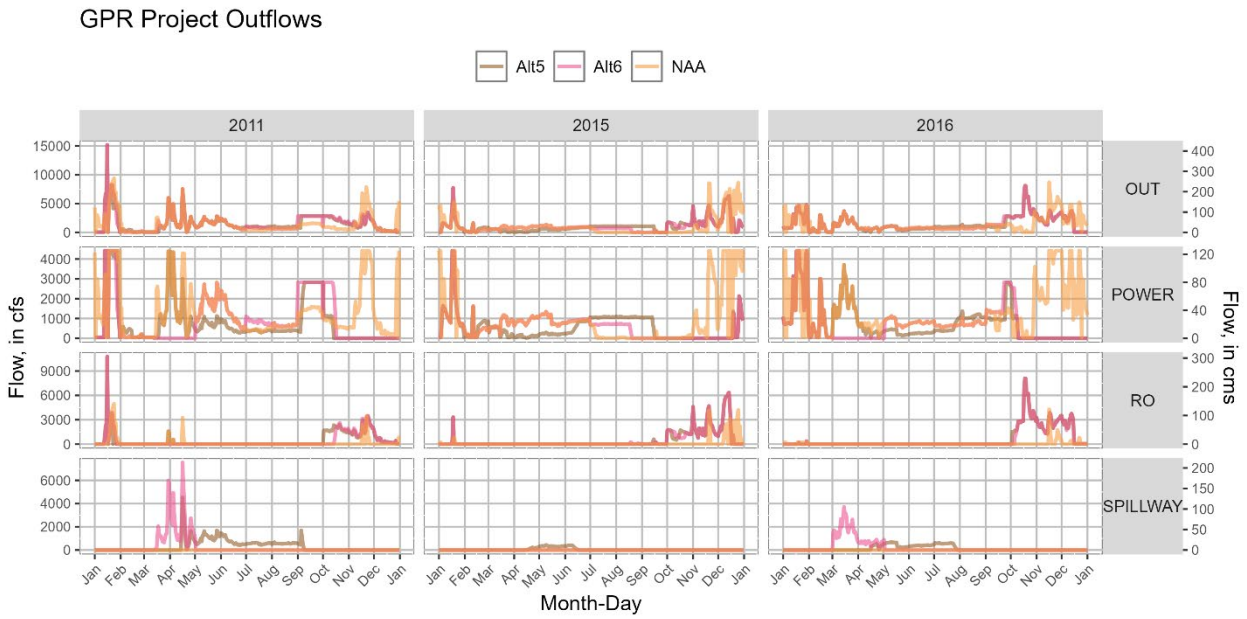


Figure 1-416. WV EIS RES-SIM Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

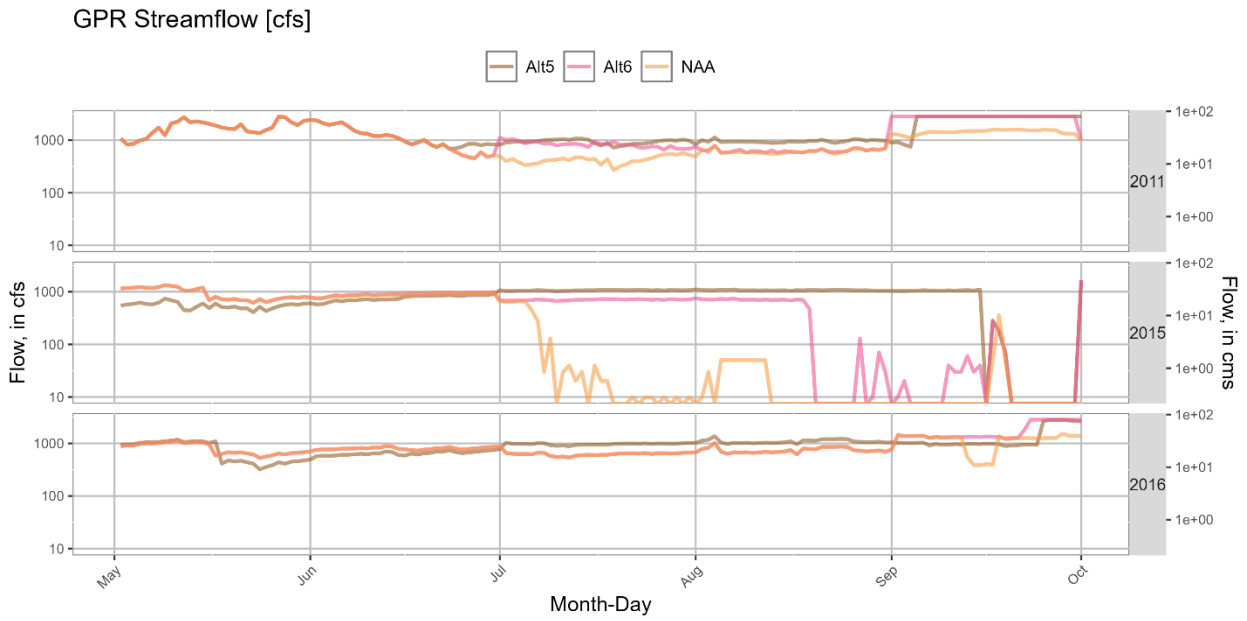


Figure 1-417. WV EIS RES-SIM Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

CE-QUAL-W2 Temperature

Alternative 6 included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during autumn to

mix releases from these non-penstock releases with relatively deep modified penstock releases in an attempt to meet the downstream temperature target (Figure 1-418, Figure 1-573). Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and those outlets were submerged. Spillway access was limited in 2015, which led to cool tailwater temperature when spillway access was not available. This was followed by a large peak in tailwater temperature in the 2015 scenario during October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam. Generally, the autumn fish passage operation (drawdown to the RO) resulted in cooler autumn temperatures (November-December) compared to NAA (Figure 1-573).

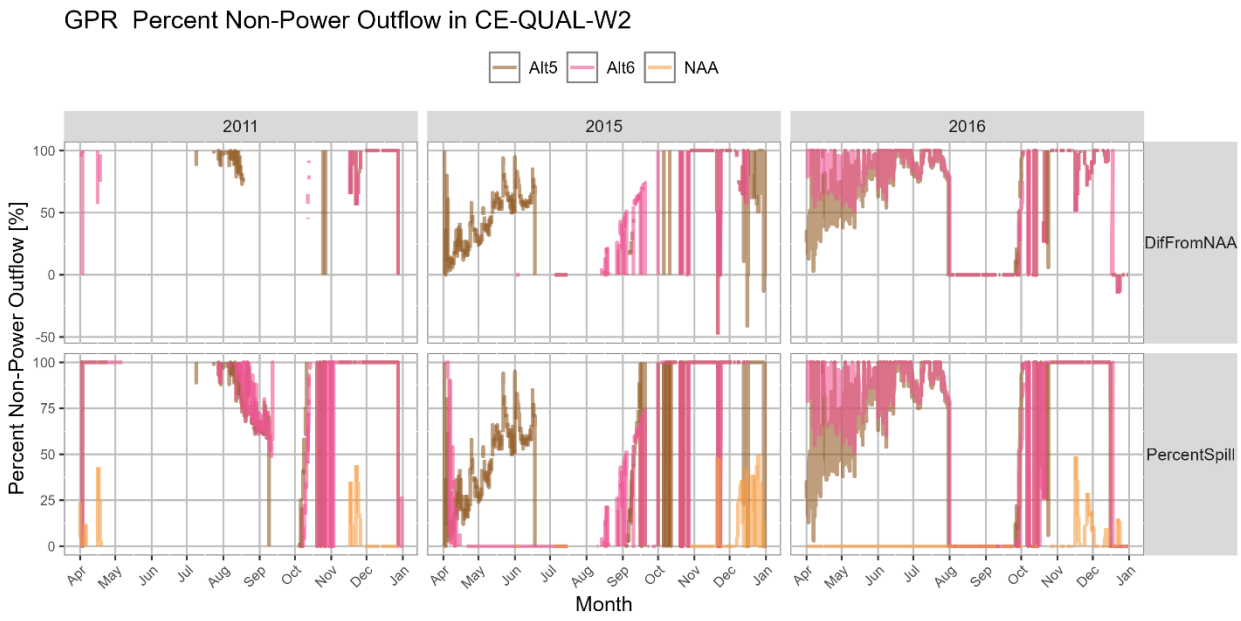


Figure 1-418. WV EIS Percent Spill Allocated in CE-QUAL-W2 Green Peter model for 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

Alternative 6 includes the use of the RO's to discharge colder water during fall and winter drawdown operations at Green Peter reservoir. An additional measure includes the use of the spillway for surface spill in the summer at Green Peter reservoir (Figure 1-573). Also a measure to modify existing outlets to allow releases at varying depths for temperature control specifically at Foster reservoir with a modification to the Facility Warm Water Supply (FWWS) pipe and fish weirs.

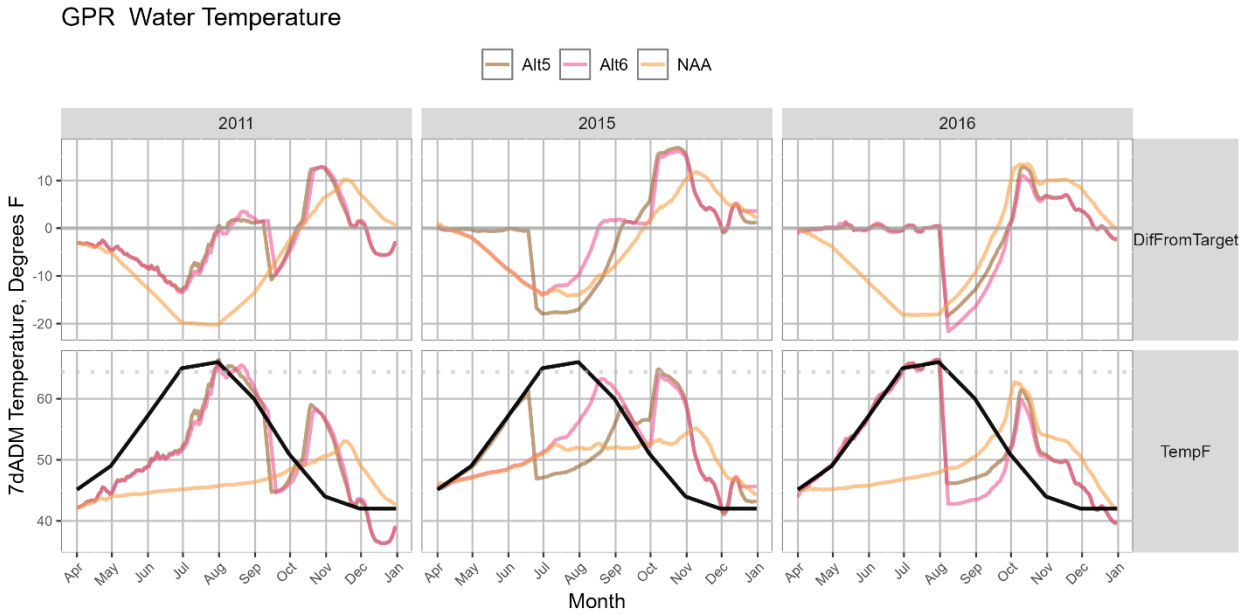


Figure 1-419. Comparison of Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Green Peter dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively.

1.5.9.2.2 Foster

RES-SIM Lake Levels and Outflows

Lake level and storage at Foster in Alternative 6 was nearly identical to Alternative 2b in 2011, 2015, and 2016. Compared to NAA, Alternative 6 lake levels were generally similar in 2011 and 2016 but increased in 2015 under Alternative 6 compared to NAA (Figure 1-377, Figure 1-378, and Figure 1-379). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam. The proposed modifications to the fish weir and FWWS in Alternative 6 resulted in lower outflow routed through the Power outlets for temperature management, especially during spring and summer, compared to NAA (Figure 1-378).

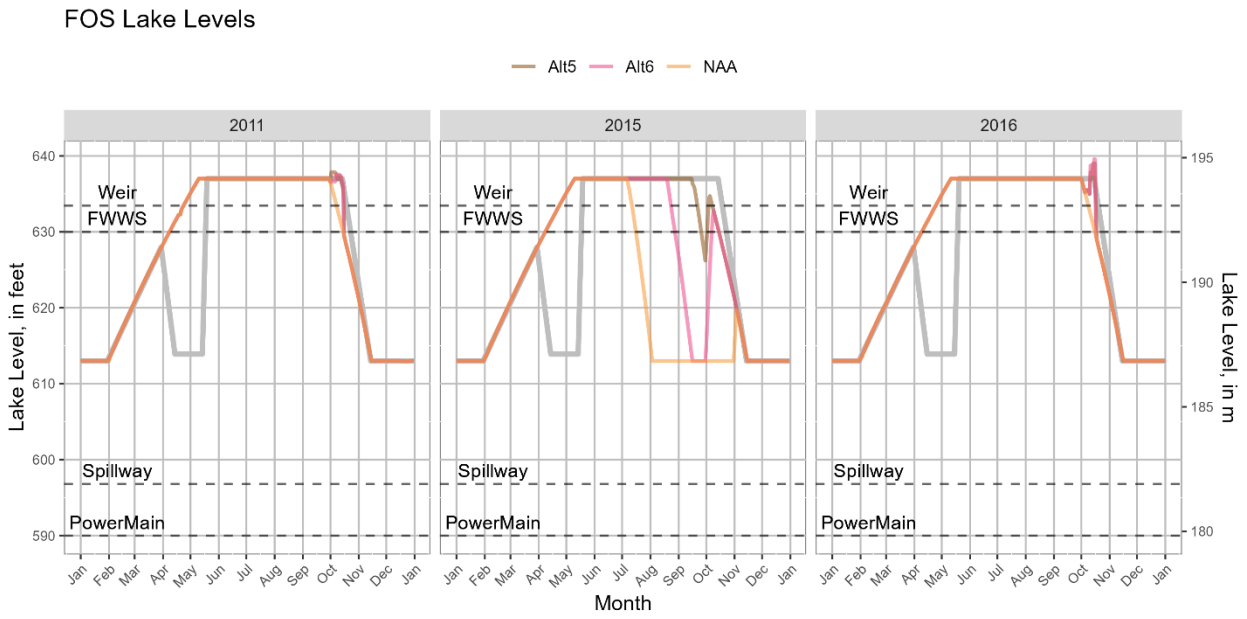


Figure 1-420 WV EIS RES-SIM Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

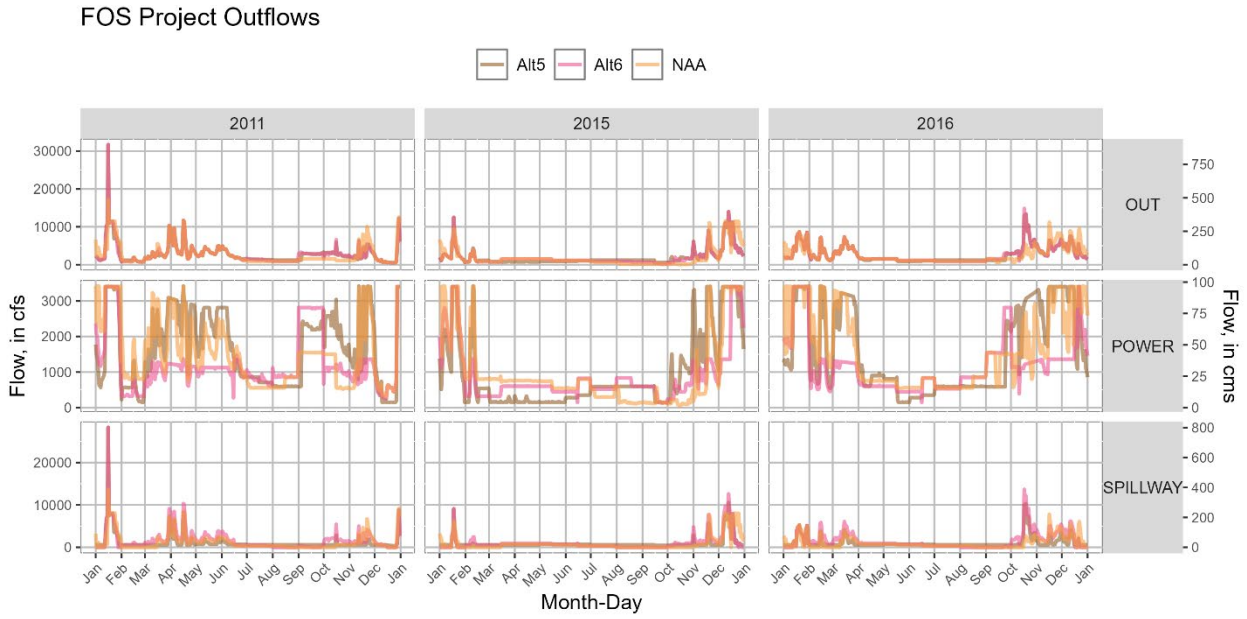


Figure 1-421. WV EIS RES-SIM Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

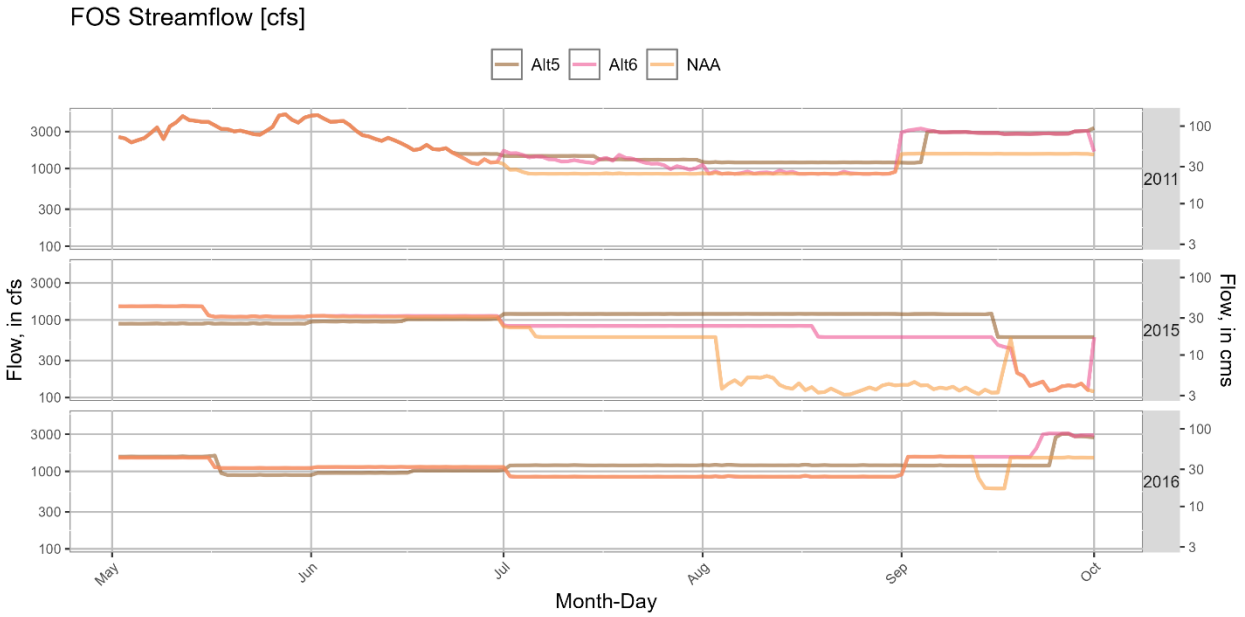


Figure 1-422. WV EIS RES-SIM Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

CE-QUAL-W2 Temperature

Alternative 6 included releases through the Foster spillway during spring-summer (when the lake was above the spillway crest) in an attempt to meet the downstream temperature target (Figure 1-423). Tailwater release temperatures below Foster generally matched the temperature target when sufficient warm or cool water was available at Green Peter and Foster and those outlets were submerged. Temperature management was limited at Foster, as Green Peter Dam releases determine a relatively large influence on Foster Lake temperature. Generally, Foster tailwater temperature follows the upstream outflow of Green Peter, warmer when Green Peter spillway access exists, then followed by a large peak in tailwater temperature typically during September-October as the lakes are drafted (Figure 1-574). Generally, the autumn fish passage operation (drawdown to the RO) resulted in cooler autumn temperatures (November-December) compared to NAA (Figure 1-574).

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO in Figure 1-571, Figure 1-574) in the 2011-year scenario would see an water temperature increase starting in May through October up to 10 degrees. In the 2015-year scenario an increase in water temperatures of 3 degrees from April to June, a decrease in temperatures from 1 to 7 degrees is observed from July to October. In the 2016-year scenario an increase up to 9 degrees from April to August and then decrease by 2 degree in September and October. Under Alternative 6, the average of the three years (2011, 2015, 2016) shows an increase of 1 to 5 degrees from April through September compared to NAA.

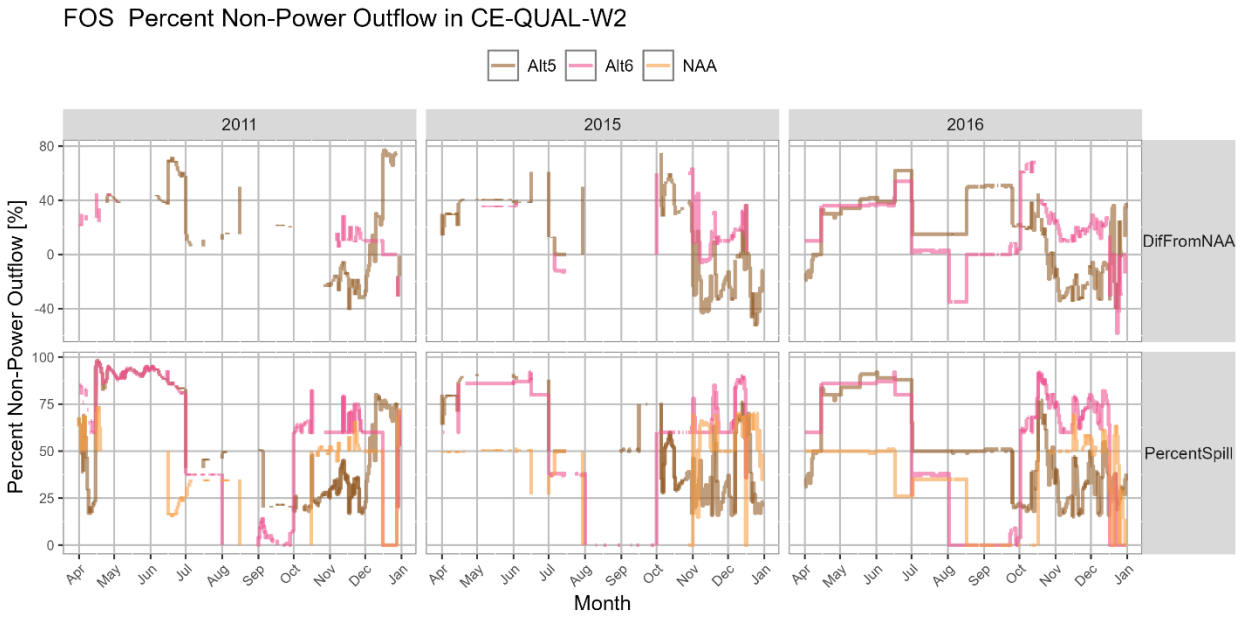


Figure 1-423. WV EIS Percent Spill Allocated in CE-QUAL-W2 Foster model for 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

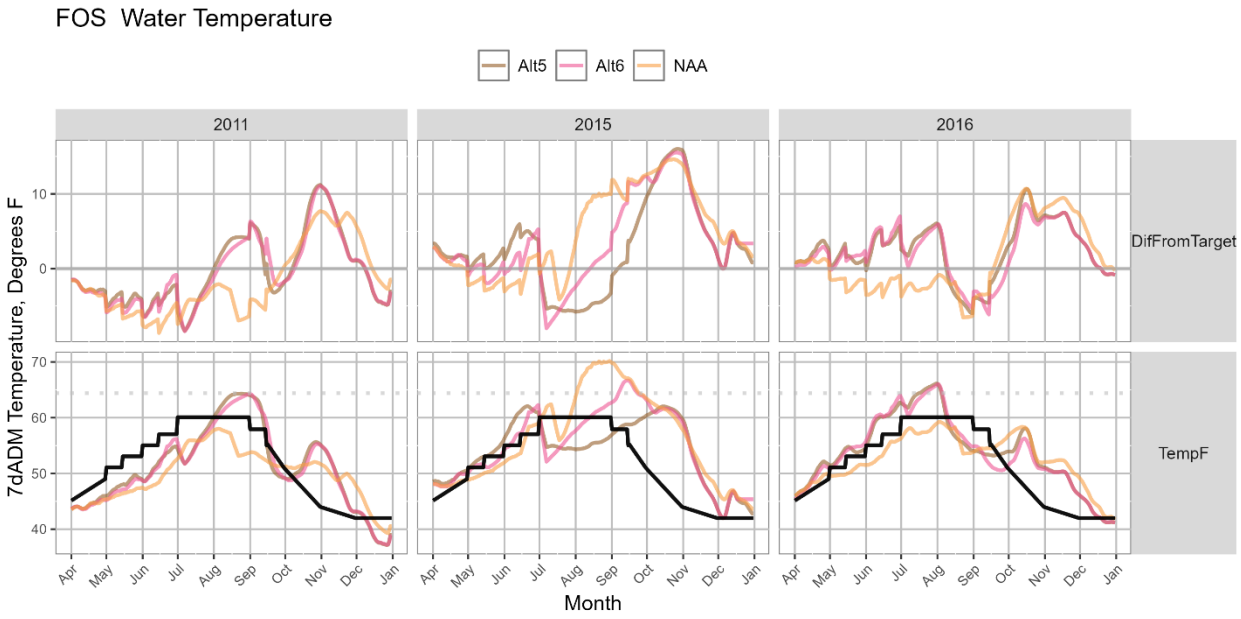


Figure 1-424. Comparison of Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively.

1.5.9.3 MCKENZIE DAMS

1.5.9.3.1 Cougar

RES-SIM Lake Levels and Outflows and CE-QUAL-W2 Temperature

Lake level and storage at Cougar in Alternative 6 was nearly identical to Alternative 5 in 2011, 2015, and 2016. Compared to NAA, Alternative 6 lake levels were lower in 2011, 2015, and 2016 to allow for proposed fish passage operations through the diversion tunnel (Figure 1-385, Figure 1-386, Figure 1-387). The decreased storage coincided with reduced outflows during spring and summer (Figure 1-385). Due to the exact match to Alternative 5 RES-SIM operations, the CE-QUAL-W2 model was not simulated for Cougar in Alternative 6 and no difference is expected from Alternative 5.

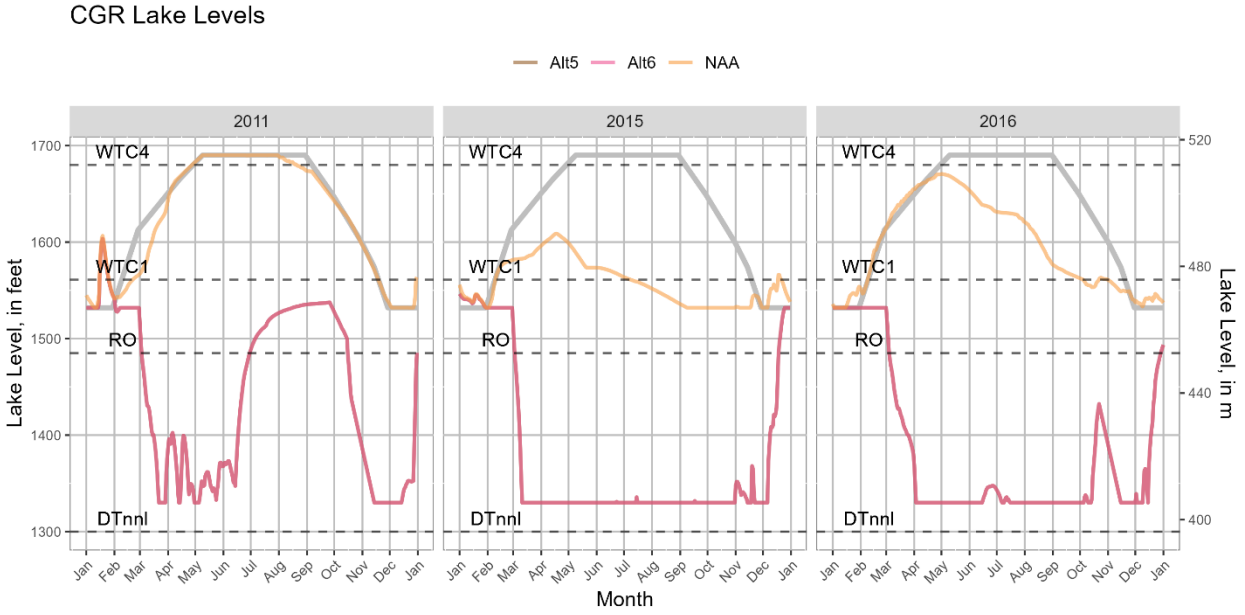


Figure 1-425 WV EIS RES-SIM Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

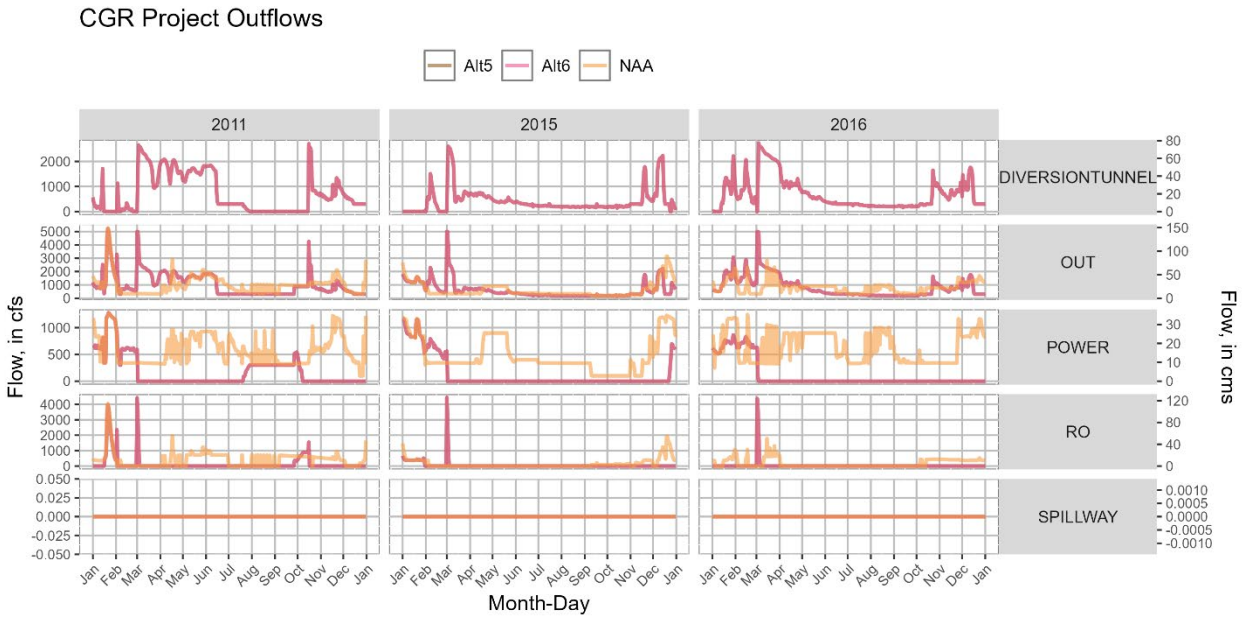


Figure 1-426. WV EIS RES-SIM Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

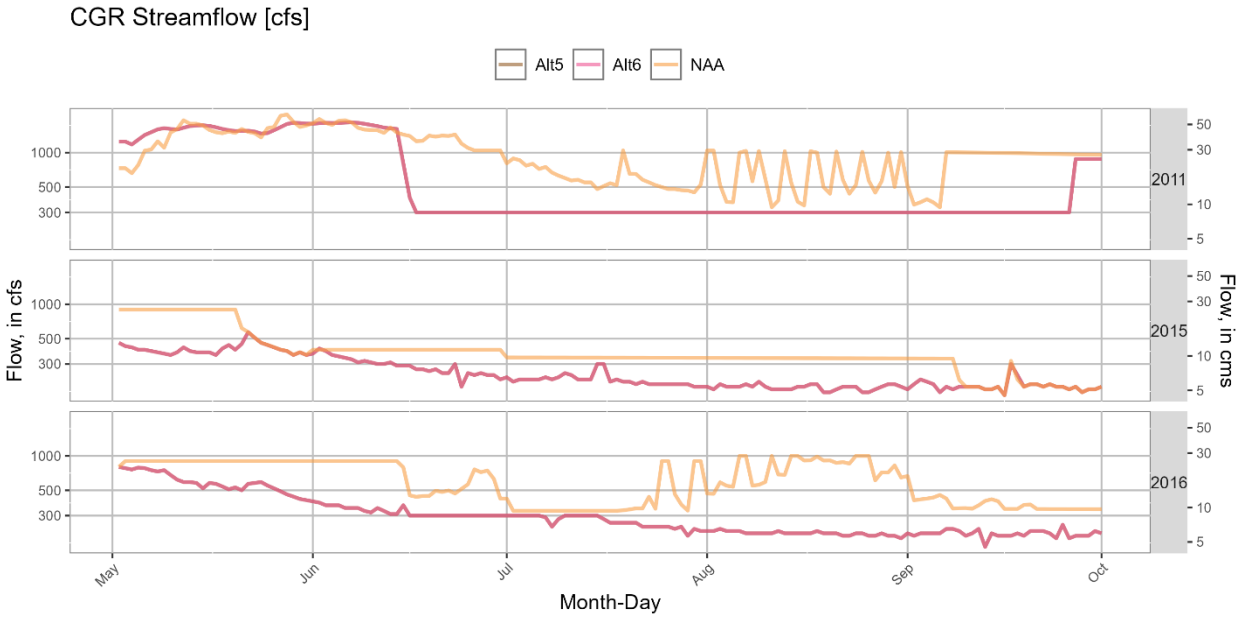


Figure 1-427. WV EIS RES-SIM Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

1.5.9.4 MIDDLE FORK WILLAMETTE DAMS

1.5.9.4.1 Hills Creek

RES-SIM Lake Levels and Outflows

Lake level and storage at Hills Creek in Alternative 6 were similar to Alternative 5 in 2011, 2015, and 2016. Operational differences between Alternative 6 and Alternative 5 in 2016 are likely a result of RES-SIM using Hills Creek to meet mainstem flow targets at Salem. Compared to NAA, Alternative 6 lake levels were generally lower in 2015 and 2016 (summer and autumn) before the lake was drafted and the power pool was utilized for downstream flow augmentation (Figure 1-393, Figure 1-394, and Figure 1-395). The increased storage coincided with reduced outflows during spring and increased outflows in June-December during 2015 and August-November in 2016 (Figure 1-394). 2011 operations were generally similar in Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA at Hills Creek Lake.

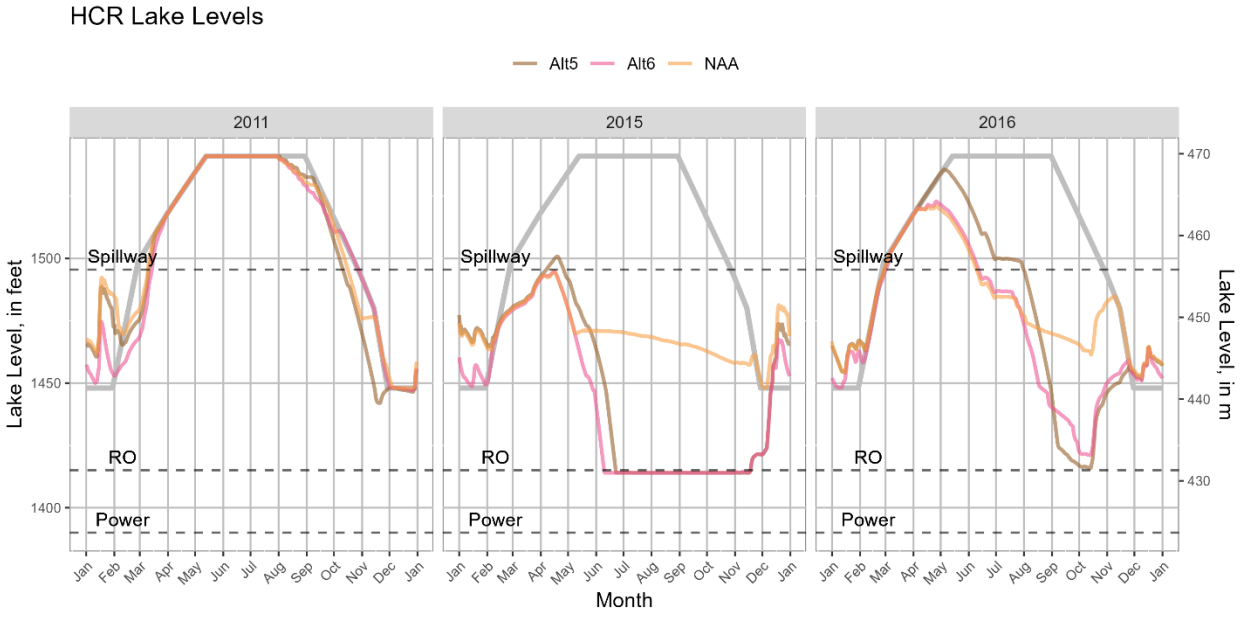


Figure 1-428 WV EIS RES-SIM Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

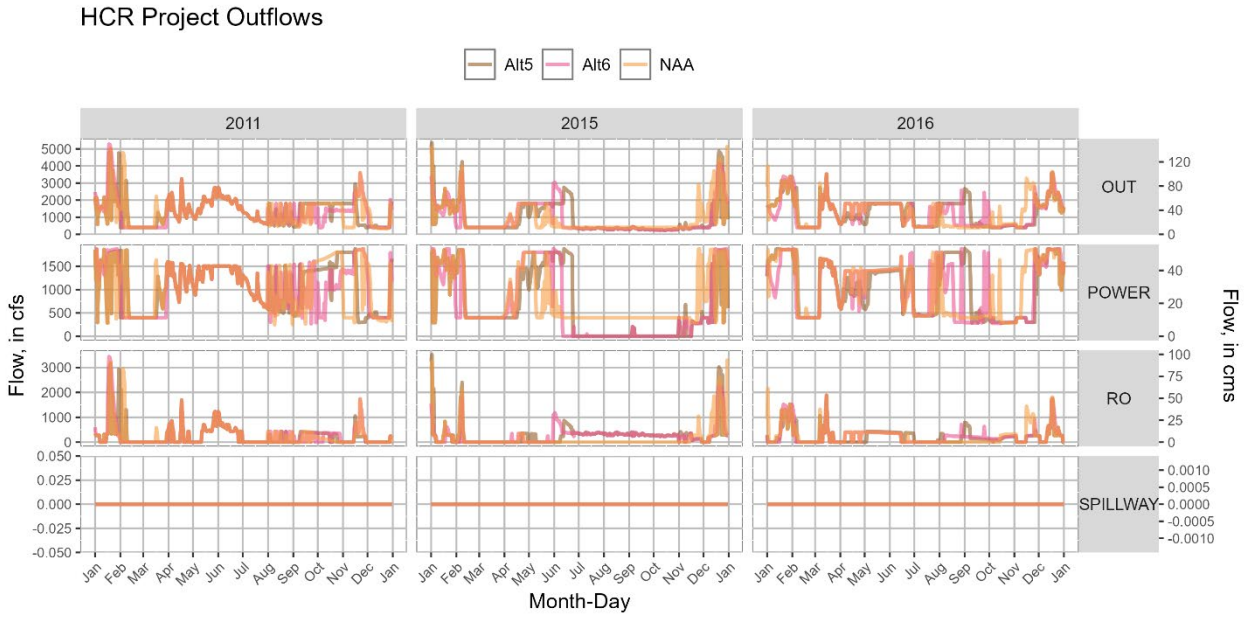


Figure 1-429. WV EIS RES-SIM Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

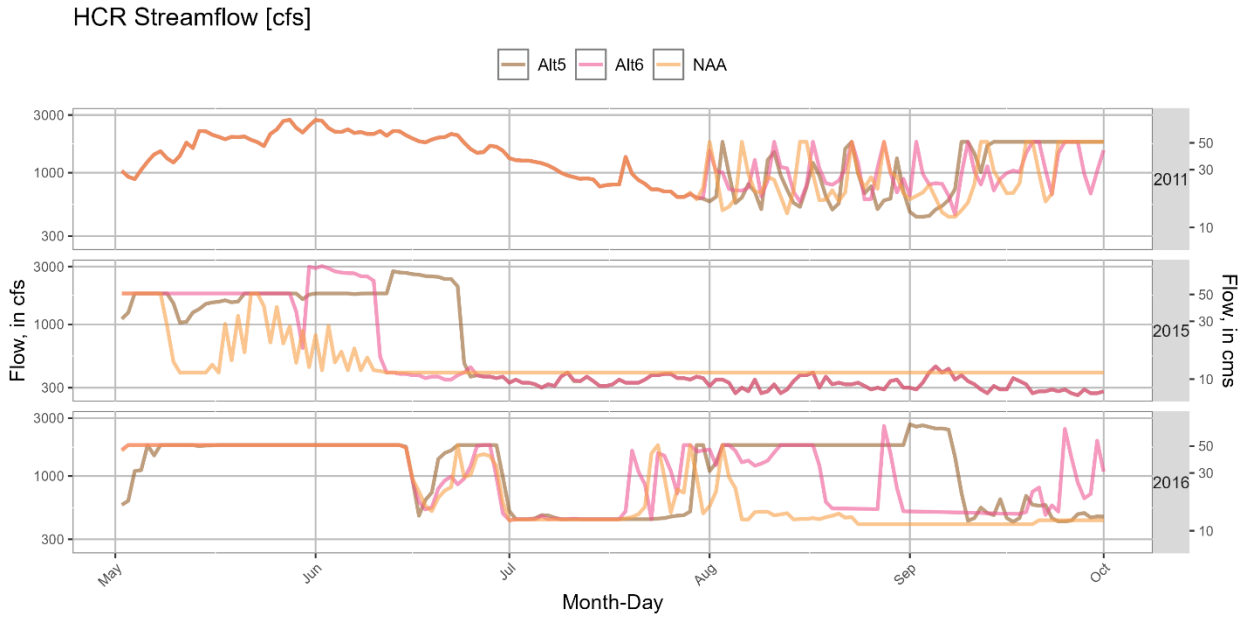


Figure 1-430. WV EIS RES-SIM Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

CE-QUAL-W2 Temperature

Hills Creek tailwater temperatures in 2011, 2015, and 2016 were generally similar in Alternative 6 (Alt6) and Alternative 5 (Alt5). Refer to Appendix D in the Final EIS for more details.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures (deg F) at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-571, Figure 1-577). The bottom chart compares NAA and Alternative 6 temperatures downstream of Hills Creek in 2011, 2015, and 2016. The top chart shows the temperature difference compared to the temperature target (Figure 1-577). In the 2011-year scenario there would be minimal temperature difference from April to October as compared to the NAA. In the 2015-year scenario, water temperature increases up to 17 degrees in May through September as compared to the NAA. In the 2016-year scenario, a water temperature increase is observed up to 5 degrees August-September, while a decreased of 2 degrees is observed October, compared to NAA. For the Average of the three years (2011, 2015, 2016) a water temperature decrease up to 6 degrees is observed in May to September, a temperature decrease of 1-degree occurs October.

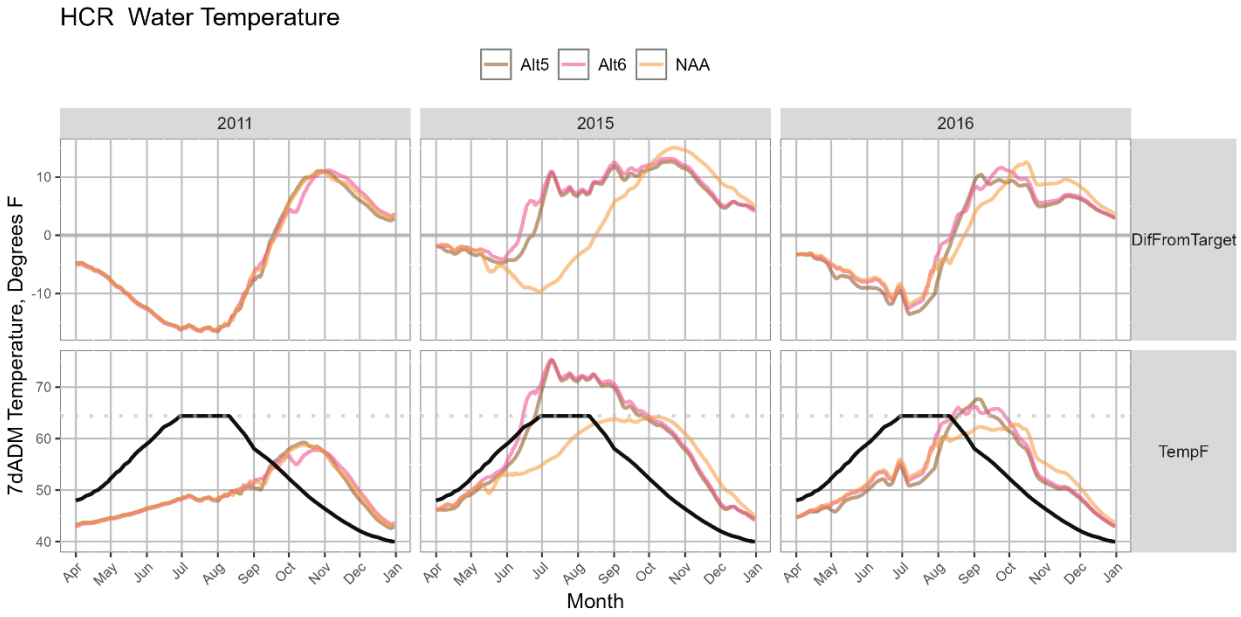


Figure 1-431. Comparison of Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively.

1.5.9.4.2 Lookout Point

RES-SIM Lake Levels and Outflows

Lake level and storage at Lookout Point in Alternative 6 were similar to NAA in 2011, 2015, and 2016 (Figure 1-401, Figure 1-402, and Figure 1-403) aside from minor differences in timing of refill and release rates that were associated with upstream Hills Creek Dam operations.

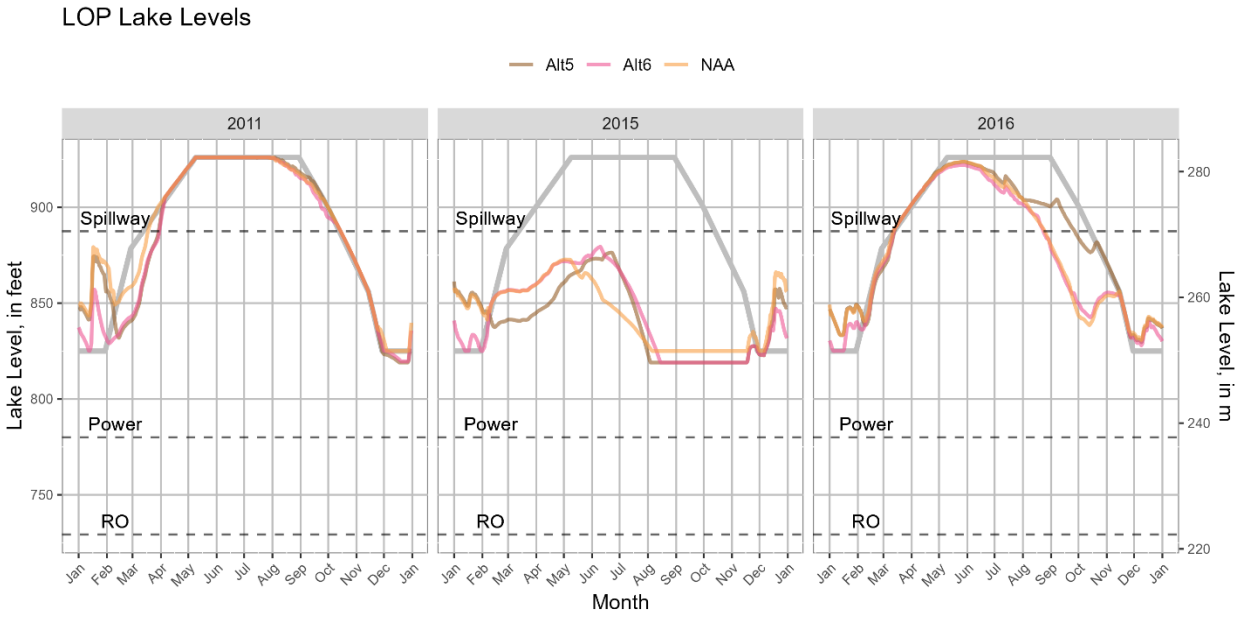


Figure 1-432 WV EIS RES-SIM Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

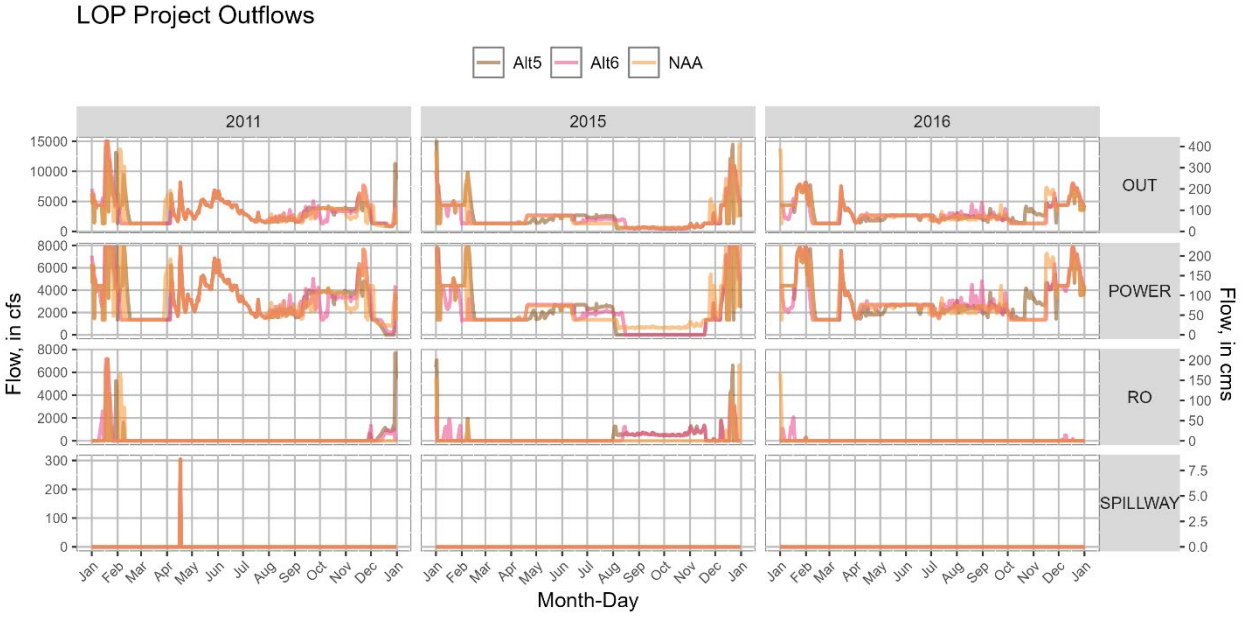


Figure 1-433. WV EIS RES-SIM Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

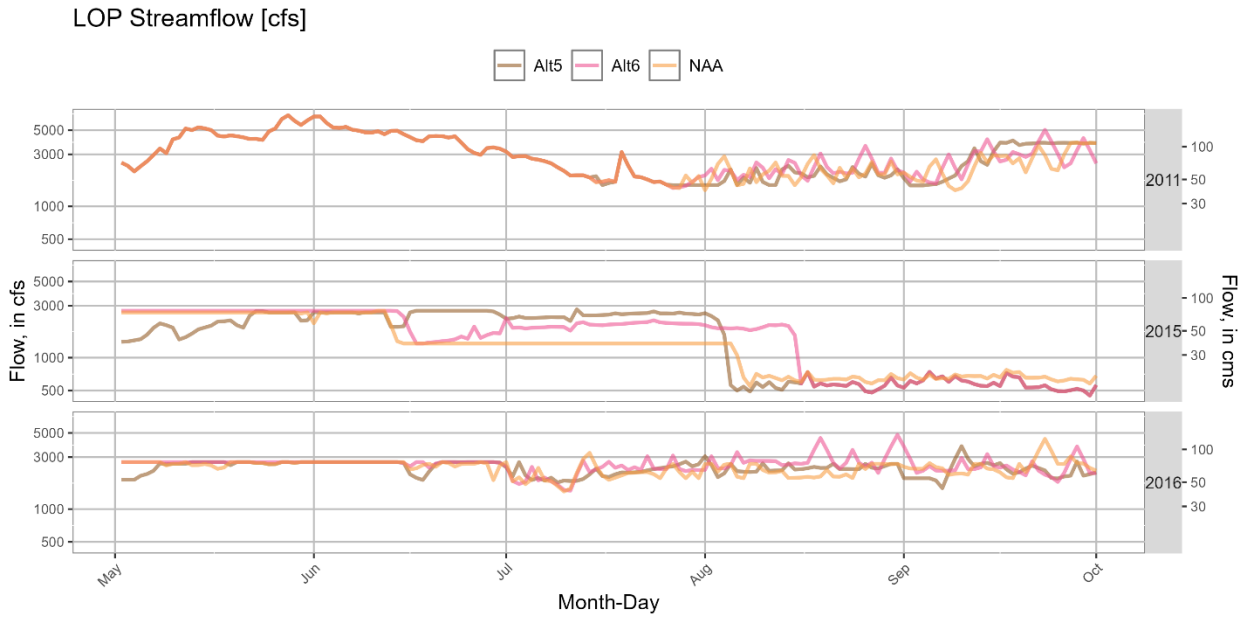


Figure 1-434. WV EIS RES-SIM Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

CE-QUAL-W2 Temperature

The proposed FSC (and attraction pumps intended for fish collection) in Lookout Point Lake in Alternative 6 is currently assumed to have minimal effect on release temperature from the relatively deep Lookout Point Penstocks, but has potential to result in mixing thermal layering and de-stratification in the forebay of Lookout Point Lake. Simulating this effect on water temperature was beyond the scope of the WV EIS. Generally, the percentage of non-power releases (spillway or RO) from Lookout Point was similar to Alternative 5 (Figure 1-435) and temperatures downstream of LOP-DEX were similar to NAA, aside from short-term differences in late summer of 2015 likely related to upstream Hills Creek operations (Figure 1-576).

Temperature results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-571, Figure 1-576) in the 2011-year scenario there would be no temperature difference from April to October. In the 2015-year scenario observes a 2-degree decrease in June and September. In the 2016-year scenario most months see no change in water temperatures except for August which decreases by 1 degree as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a water temperature decrease by 1 degrees is observed from June and September.

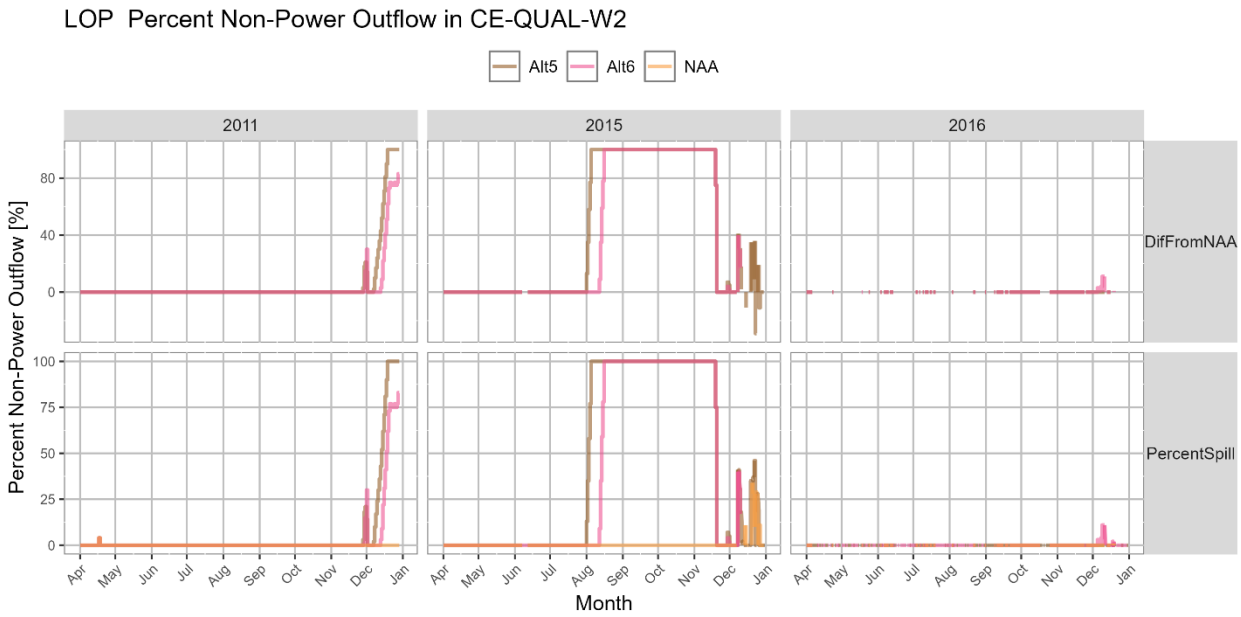


Figure 1-435. WV EIS Percent Spill Allocated in CE-QUAL-W2 Lookout Point model for 2011, 2015, and 2016 under Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA.

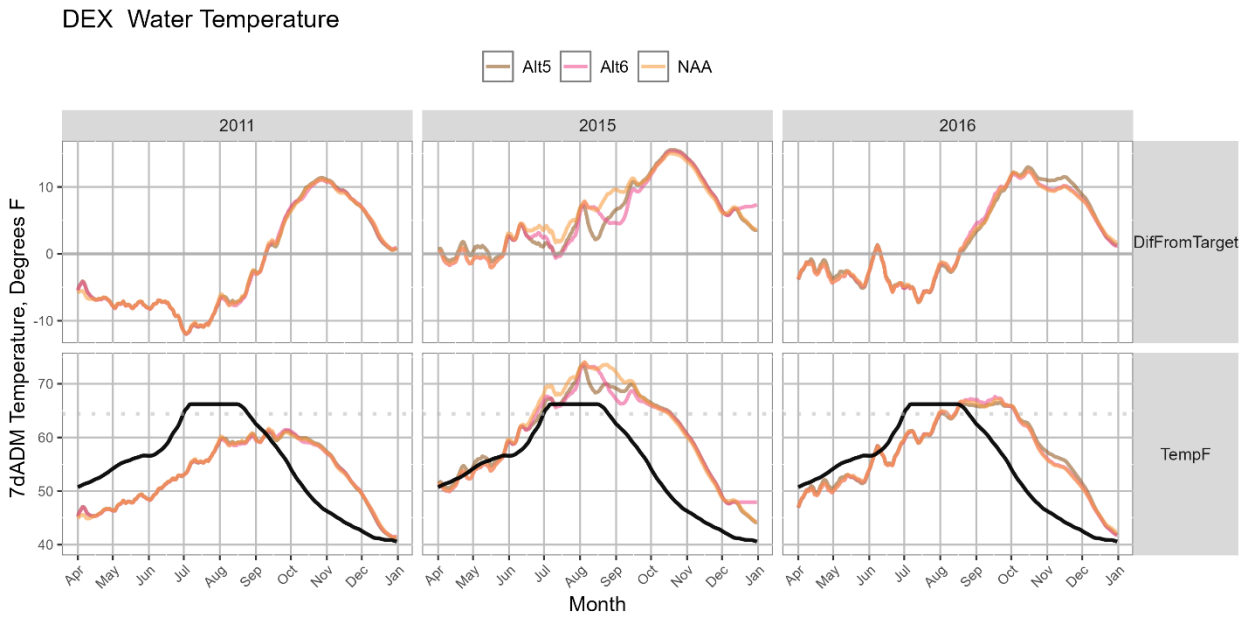


Figure 1-436. Comparison of Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively.

1.5.9.5 Mainstem Willamette River

Streamflow at Salem, Oregon in Alternative 6 was nearly identical to NAA in 2011 and 2016. In 2015, Alternative 6 streamflow was similar to NAA May-June and mid-August through October (Figure 1-1-409). While temperature simulations of river reaches downstream of the Willamette dams are not available for Alternative 6, results would likely be similar to those in Alternative 5, aside from minor potential differences in July-August of 2015. Water temperatures at Salem would also be affected by upstream dam operations, notably at Green Peter and Foster Dams, where summer and autumn downstream temperatures may be warmer compared to Alternative 5 and NAA. However, the potential effect of South Santiam temperature may have a minimal effect downstream at Salem, where streamflow in Alternative 6 would be greater than NAA and have a counter-effect on water temperature differences. Overall water temperature differences between Alternative 6 and NAA are likely to be less than 2 degrees F, similar to those seen in Alternative 5 or 2b (see Final EIS, Appendix D, Alternative 2b for more details).

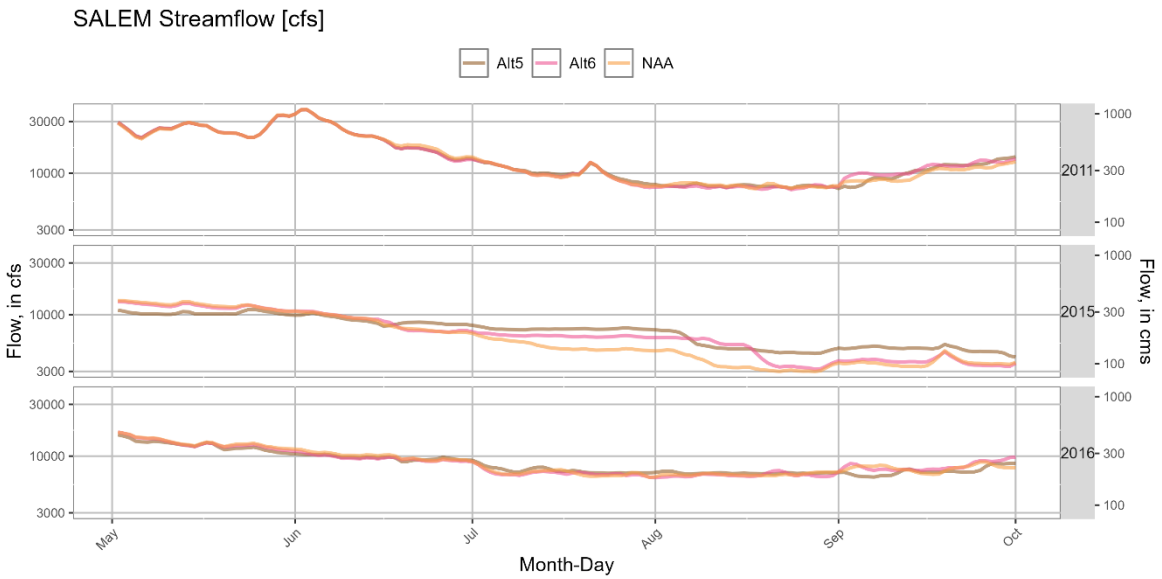


Figure 1-437. Streamflow Comparison Between Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA at Willamette River at SLMO.

1.5.10 Interim Operations (Near Term Operations Measure (NTOM))

NTOM is a combination of Alternatives 3a, 3b, 5, and injunction measures with the following measures that affected operations, lake storage, and water temperature:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less

than the NAA BiOp when those reservoirs are less than 90% full (similar to Alternatives 2a, 2b, 4, and 5).

- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature (similar to Alternatives 2a, 2b, 4, and 5).
- At Detroit, a spring spillway operation when lake is above 1541 ft from 1 April to 15 November. Prioritizing upper and lower ROs when lake elevation is below 1500 feet.
- At Green Peter, a spring spillway operation when lake is above spillway crest (971 ft) from mid-March until 01 May or for 30 days, whichever is longer.
- From early September to 15 December, a deep drawdown at Green Peter to 35 feet above the ROs (target elevation of 780 ft by early- to mid-November) with RO prioritization to improve downstream fish passage (similar to Measure 40 in Alternatives 2a, 2b, 3a, and 3b).
- Foster Dam includes a delayed refill and spring spillway use to improve downstream fish passage from 01-February to 15-June (lake elevation 613 ft. from February to May; lake elevation 637 ft. May to July). Summer fish weir use at Foster Dam from 16 June to late-July to improve downstream temperature management and upstream fish migration/passage. Utilize the spillway for improved downstream fish passage in the fall from 01-October to 15-December when the lake is at minimum conservation pool (613 feet).

HEC-ResSim simulations of lake levels and dam outflows were used as a basis for assessing the water temperature effects of NTOM in 2011, 2015, and 2016 and are discussed in this section. A full explanation of the HEC-ResSim analysis and findings can be found in Section 3.2 Hydrologic Processes and Technical Appendix B Hydrology and Hydraulics.

Revisions to NTOM DEIS temperature effects were made based on HEC-ResSim modeling for the FEIS. CE-QUAL-W2 water temperature simulations were not available for the FEIS due to the likelihood that further modeling analysis would lead to negligible or minor differences regarding effects between DEIS and FEIS results. Differences between ResSim NTOM DEIS and NTOM FEIS results were negligible at all locations except for the following that are summarized qualitatively below:

- Green Peter and Detroit Lakes will have lower lake levels during late summer in extreme dry years under NTOM FEIS interim operations compared to NTOM DEIS.
- Green Peter Lake will have slightly more days below spillway crest in extreme dry years (e.g., 2015) under NTOM FEIS compared to NTOM DEIS.
- NTOM FEIS updates would result in negligible temperature differences, when averaged across the three years previously simulated in CE-QUAL-W2 for the DEIS.

Unless stated otherwise (Detroit and Green Peter Dams), the figures in this section represent the NTOM DEIS HEC-RESSIM and CE-QUAL-W2 modeling and analysis and were not updated for the FEIS.

1.5.10.1 North Santiam Dams

1.5.10.1.1 Detroit

HEC-ResSim Lake Levels and Outflows

Compared to NAA, NTOM lake levels at Detroit were nearly identical except for September-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-438). The increased storage compared to NAA coincided with reduced outflows during spring and increased outflows in summer during 2015 and 2016 under NTOM. Total outflow in 2011 was generally similar in NTOM and NAA at Detroit Lake (Figure 1-440). Compared to NAA, NTOM allocated more spill to the spillway and ROs during spring and fall, respectively (Figure 1-439). Updates to NTOM for the FEIS resulted in no change from previous NTOM DEIS results in 2011 and 2016. However, 2015 NTOM FEIS lake levels were more similar to NAA until July, when the power pool was utilized to meet downstream flow rules, at which point all outflows would be routed to the power penstock (about 25 feet from the lake surface).

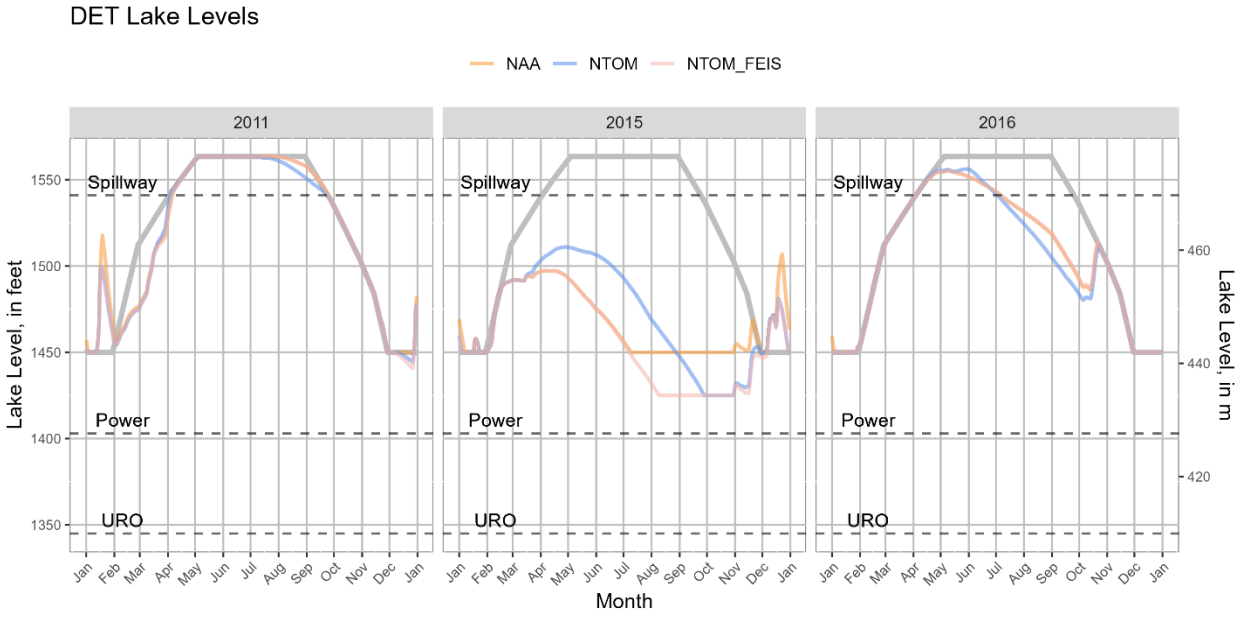


Figure 1-438. WV EIS HEC-ResSim Detroit Lake Levels in 2011, 2015, and 2016 under NTOM (DEIS), NTOM_FEIS (FEIS), and NAA.

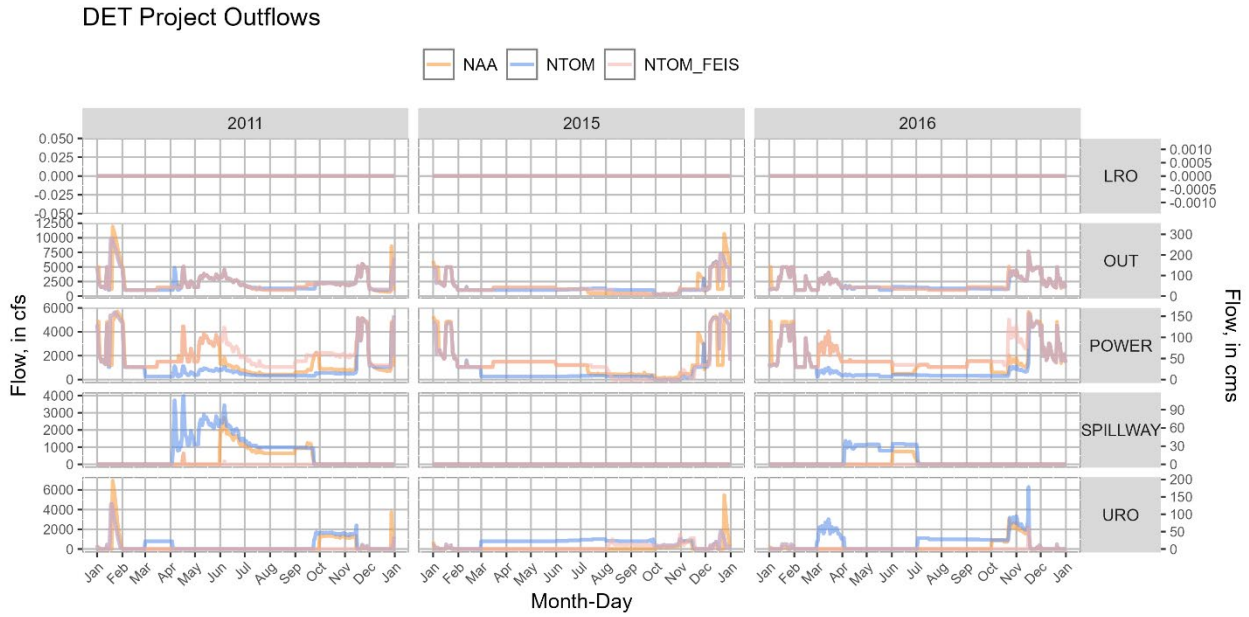


Figure 1-439. WV EIS HEC-ResSim Gate-Specific Outflows in 2011, 2015, and 2016 under NTOM (DEIS), NTOM_FEIS (FEIS), and NAA.

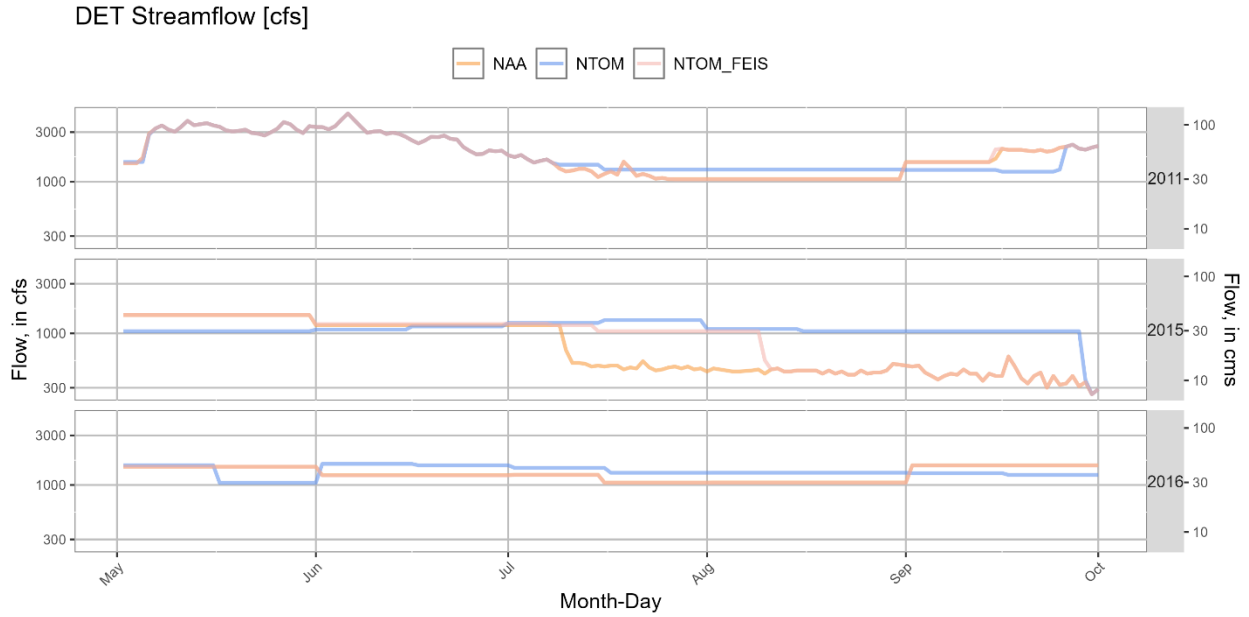


Figure 1-440. WV EIS HEC-ResSim Detroit Total Outflow in 2011, 2015, and 2016 under NTOM (DEIS), NTOM_FEIS (FEIS), and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-441, Figure 1-442, and Figure

1-443. Tailwater release temperatures generally followed the temperature target more closely than NAA due to increase operational temperature management (Figure 1-444, Figure 1-445).

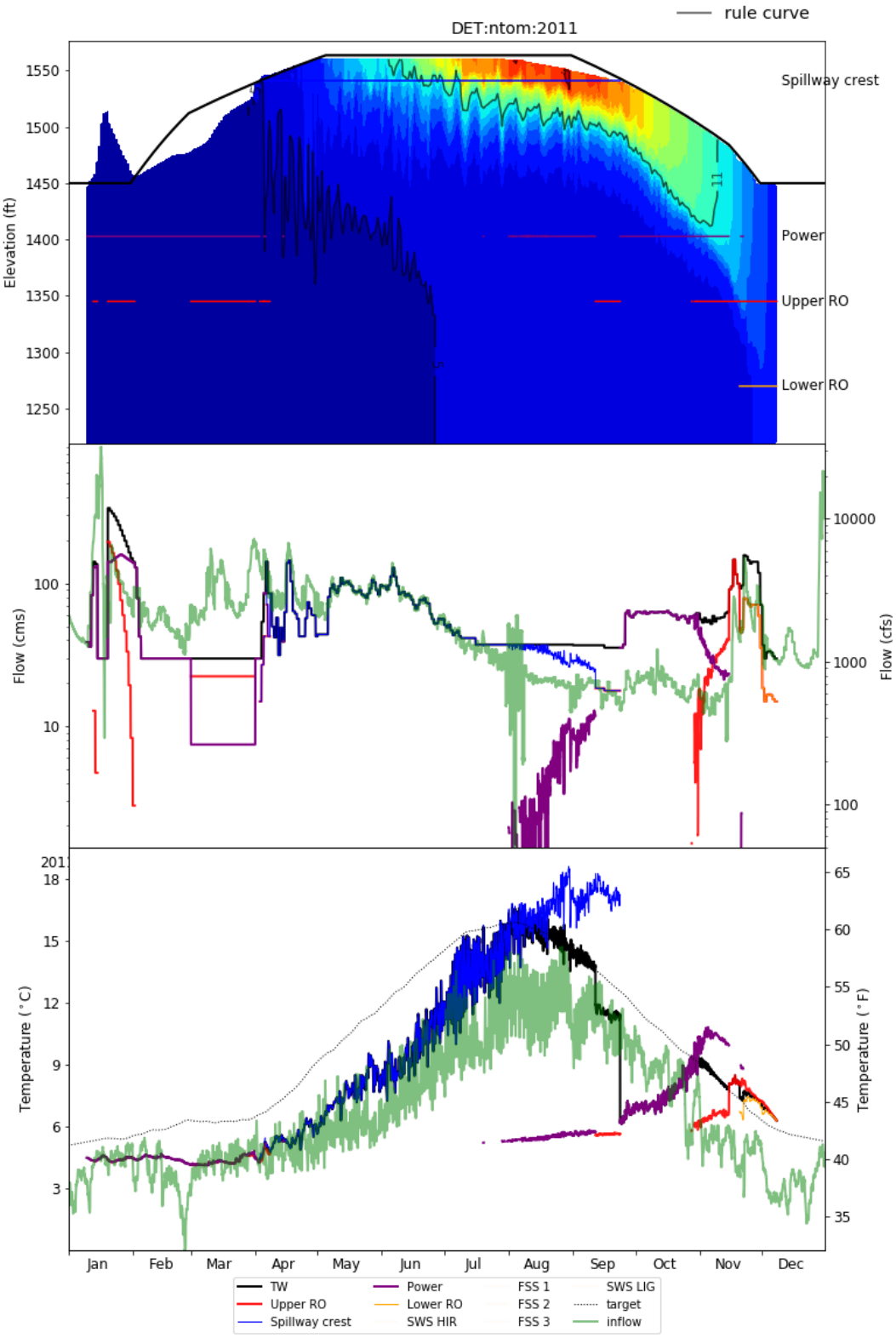


Figure 1-441. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under NTOM in 2011.

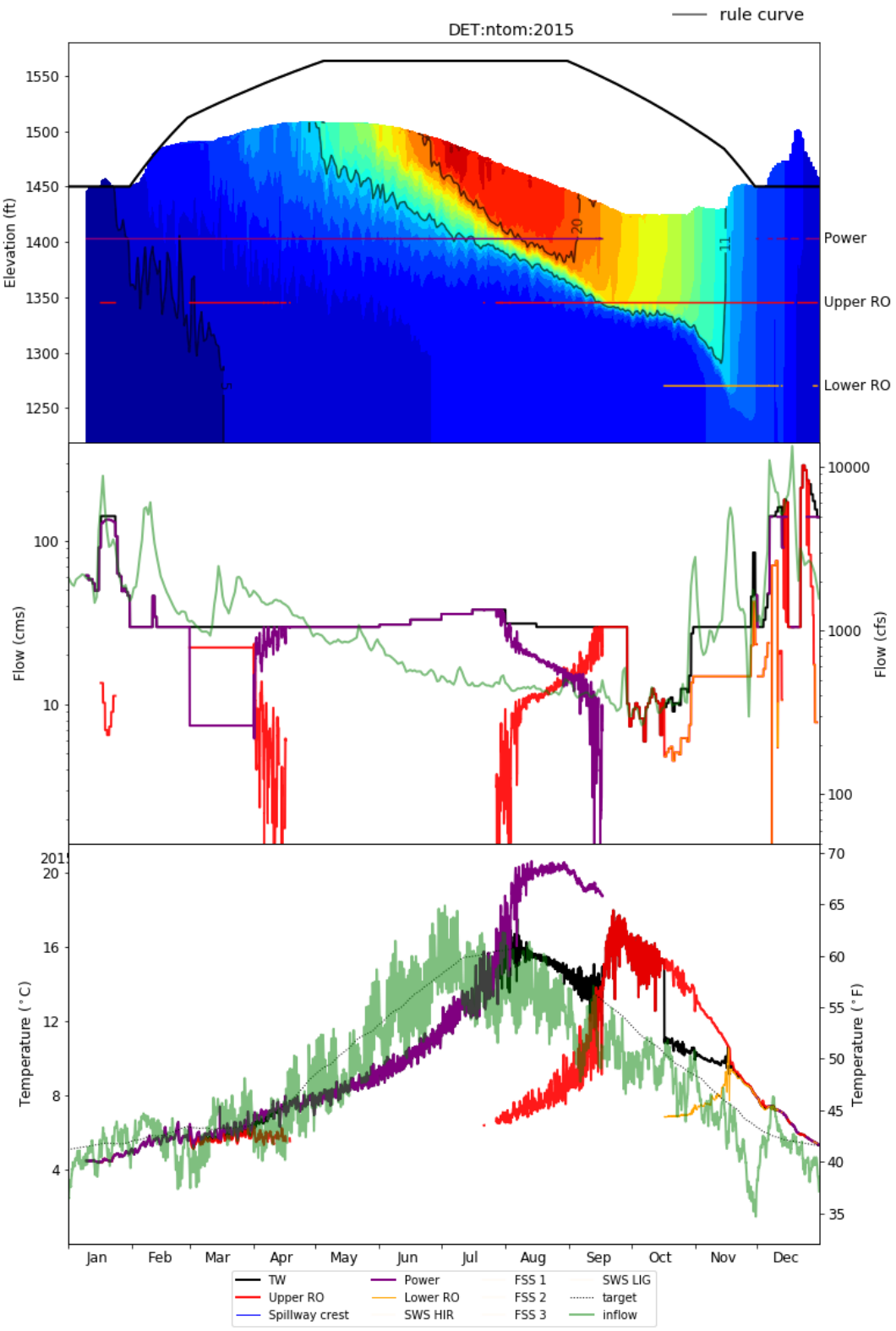


Figure 1-442. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under NTOM in 2015.

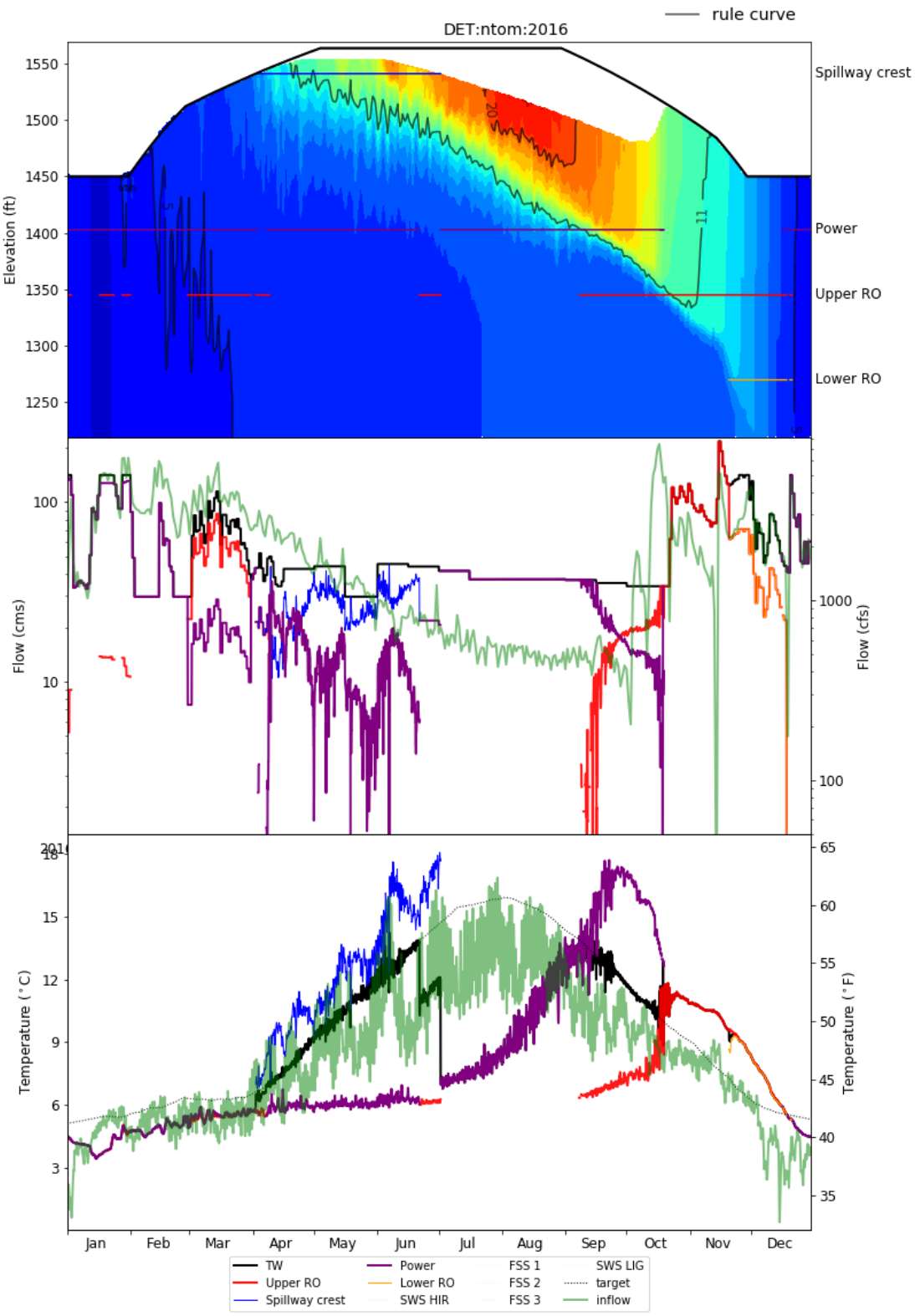


Figure 1-443. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under NTOM in 2016.

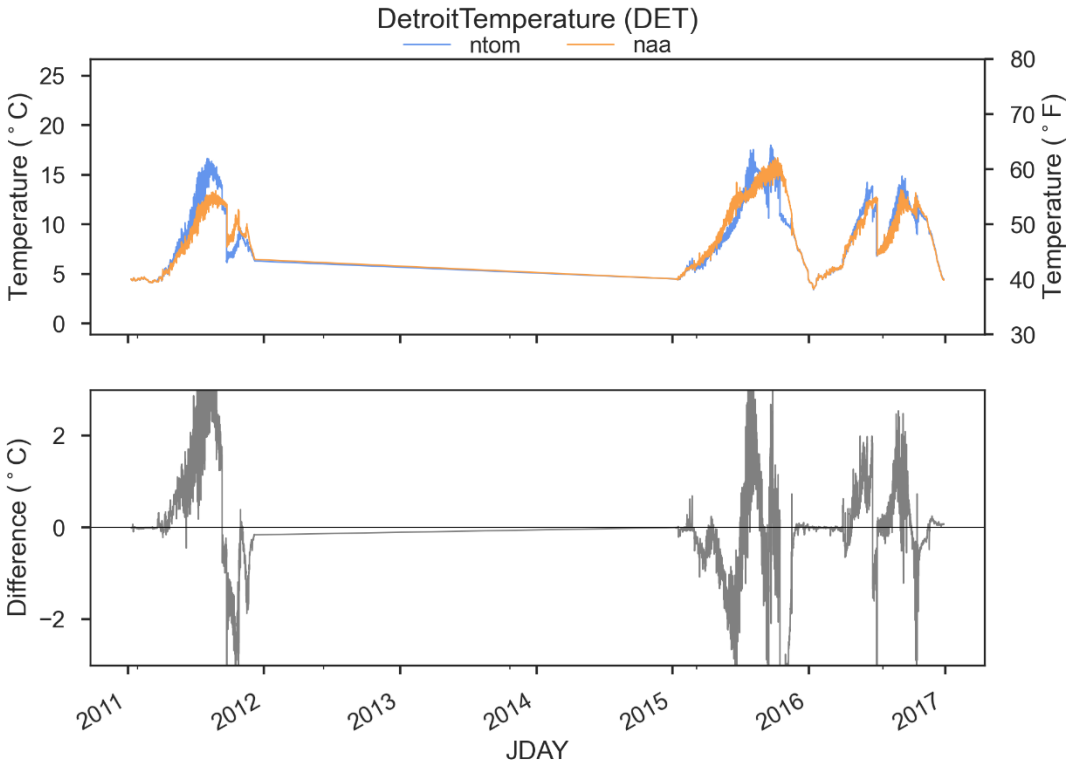


Figure 1-444. Comparison of DET outflow temperatures in NAA and NTOM.

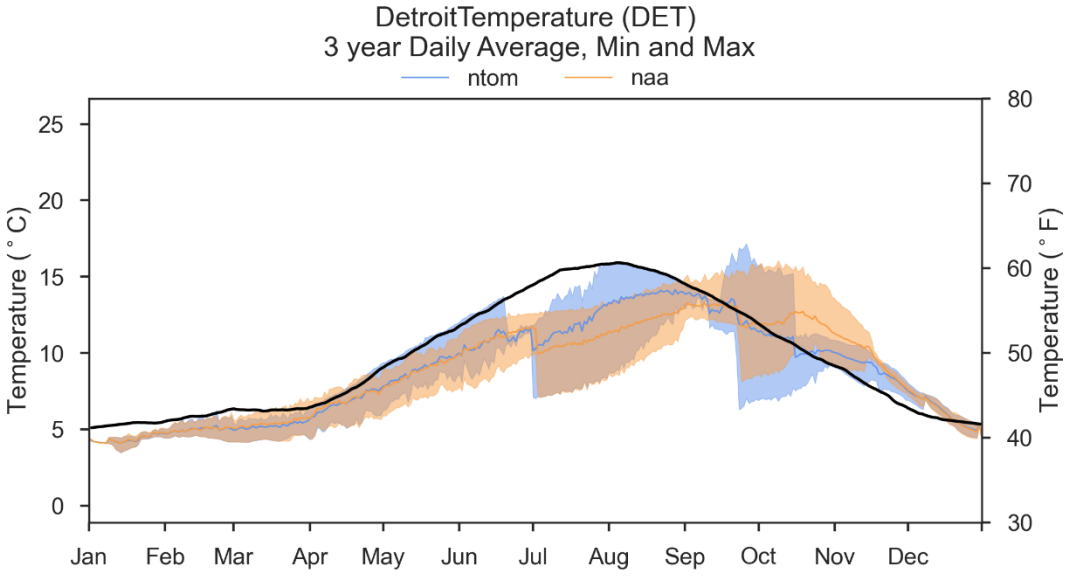


Figure 1-445. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. Black Line Indicates Temperature Target.

1.5.10.2 South Santiam Dams

1.5.10.2.1 Green Peter

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Green Peter in NTOM was lower from mid-summer through autumn compared to NAA due to deep drawdowns for fish passage (Figure 1-446). Some increased storage in 2015 coincided with reduced outflows during spring and increased outflows in July-October comparing NTOM to NAA. 2011 and 2016 operations were generally similar in NTOM and NAA at Green Peter Lake January-June but followed increased outflows in July-October to draft the lake for fish passage operations through the ROs in autumn. The proposed operational temperature management through the spillway (during spring) and RO (during autumn) in NTOM led to increased outflow from these outlets and decreased power outflow compared to NAA (Figure 1-447, Figure 1-448).

Updates to NTOM for the FEIS resulted in no change from previous NTOM DEIS results in 2011 and 2016. However, 2015 NTOM FEIS lake levels were more similar to NAA until July, when the operational rules (power pool utilization to meet downstream flow rules, deep drawdown) closely match NTOM DEIS after mid-August.

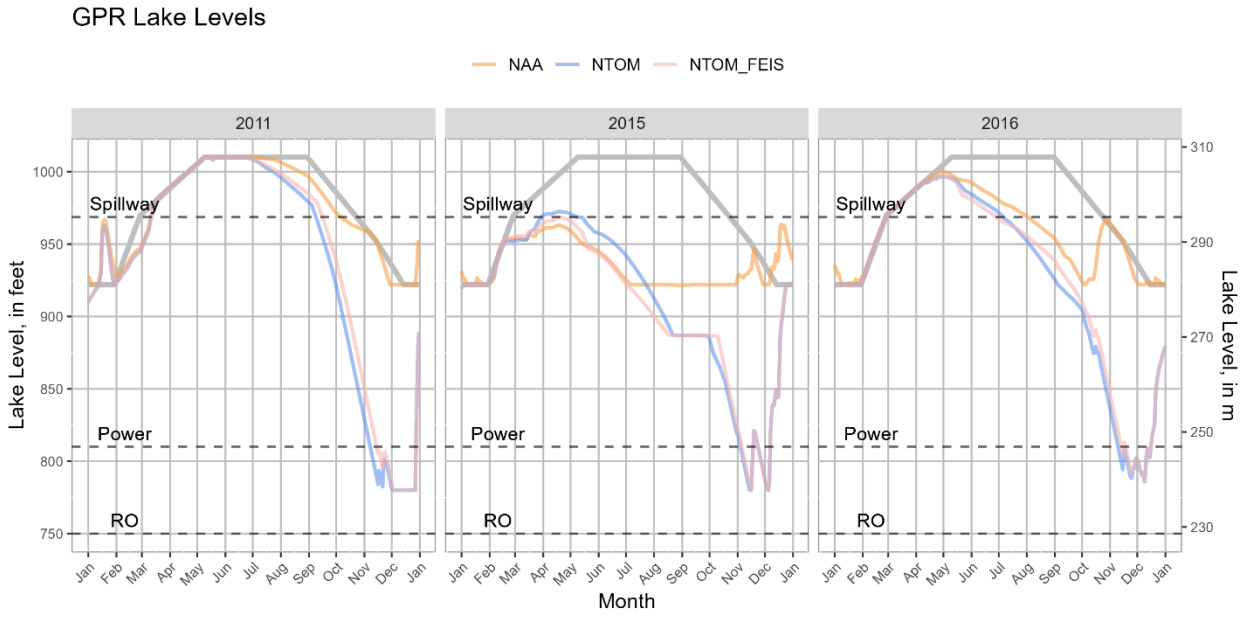


Figure 1-446. WV EIS HEC-ResSim Green Peter Lake Levels in 2011, 2015, and 2016 under NTOM (DEIS), NTOM_FEIS (FEIS), and NAA.

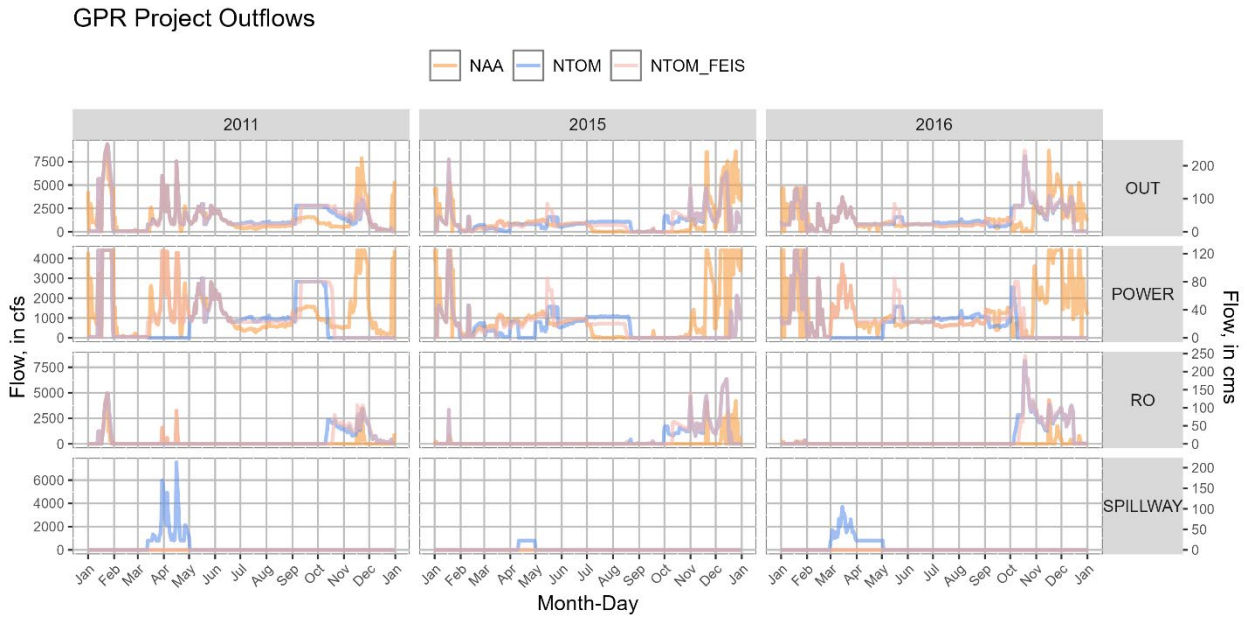


Figure 1-447. WV EIS HEC-ResSim Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under NTOM (DEIS), NTOM_FEIS (FEIS), and NAA.

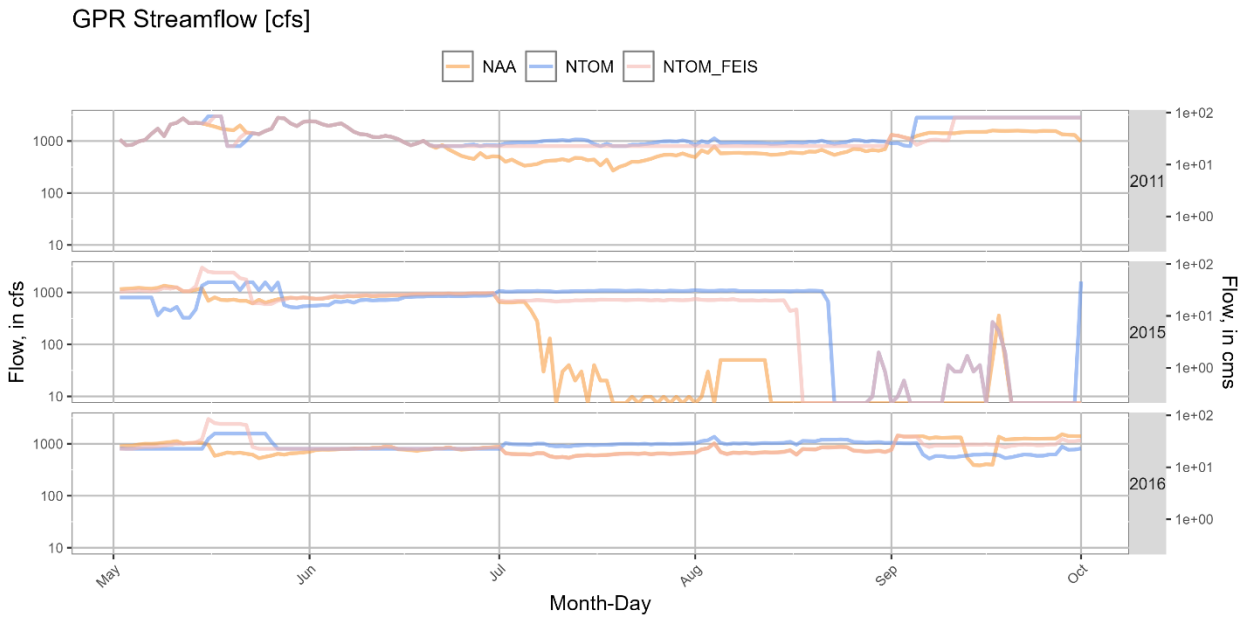


Figure 1-448. WV EIS HEC-ResSim Green Peter Dam Total Outflow in 2011, 2015, and 2016 under NTOM (DEIS), NTOM_FEIS (FEIS), and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-449, Figure 1-450, and Figure

1-451. NTOM included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during autumn to mix with relatively deep power penstock releases in to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and those outlets were submerged. However, spillway access was limited in all 3 years, leading to an abrupt drop in tailwater temperature when spillway access ended in mid-summer. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam (Figure 1-452, Figure 1-453).

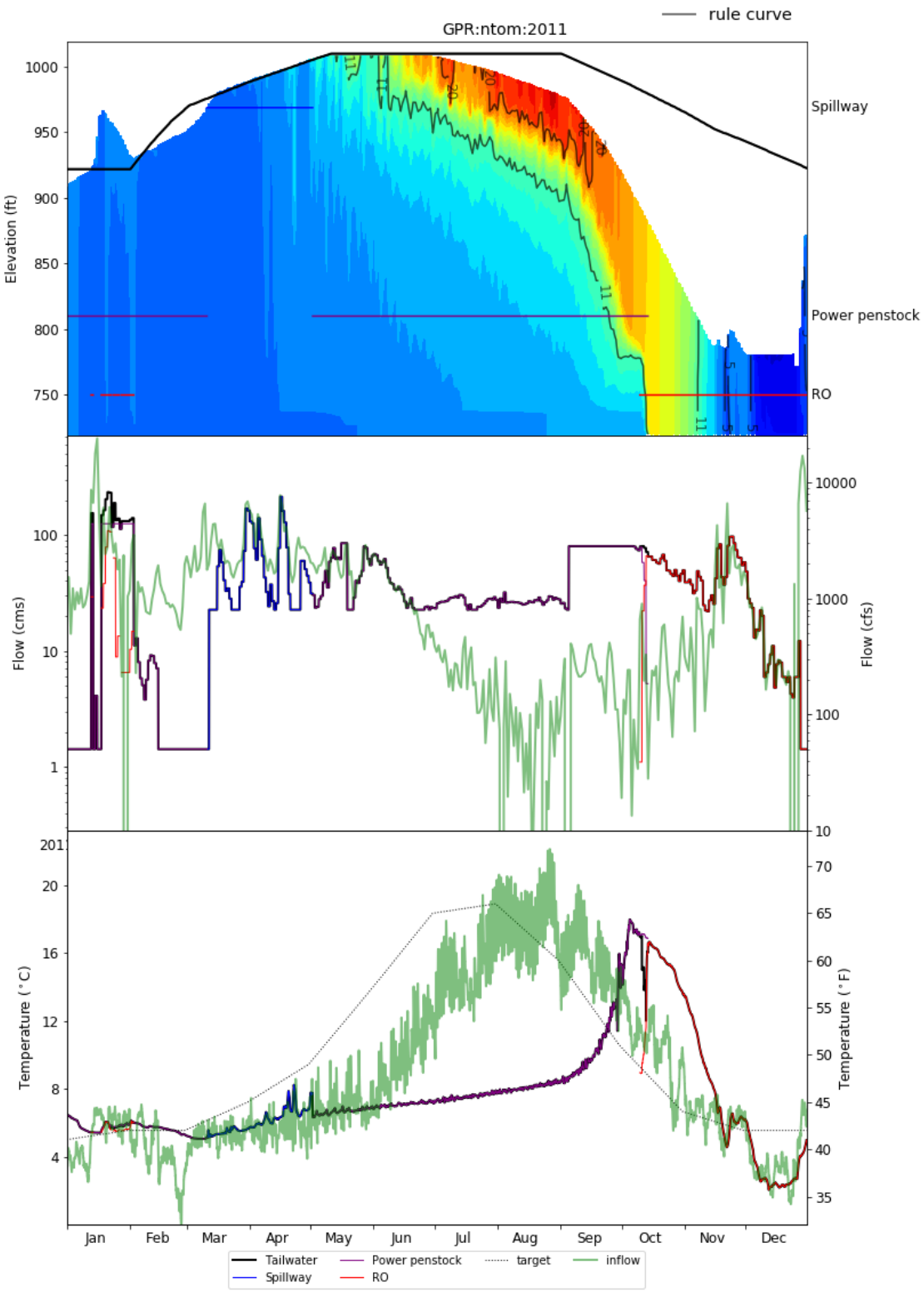


Figure 1-449. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under NTOM in 2011.

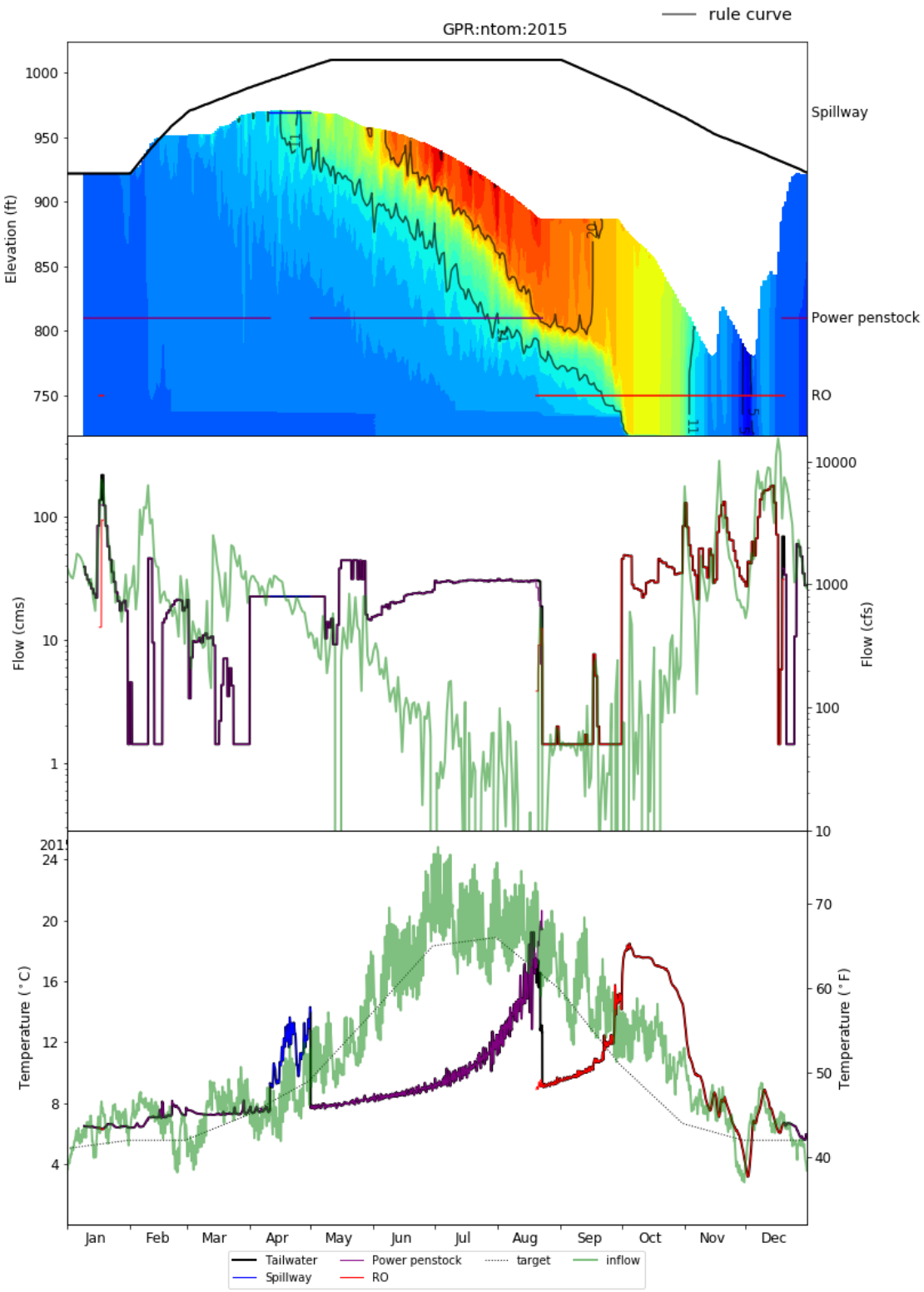


Figure 1-450. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under NTOM in 2015.

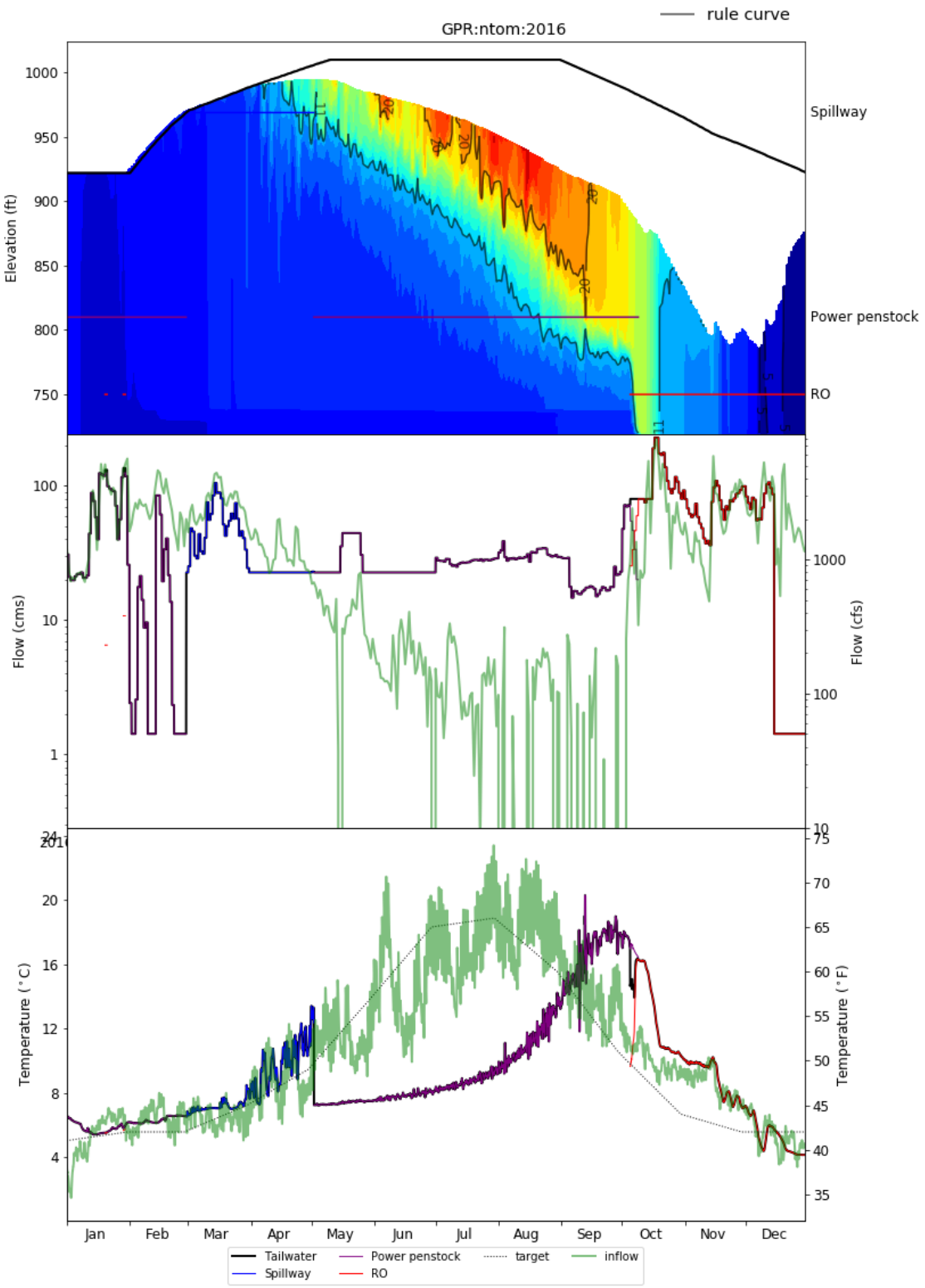


Figure 1-451. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under NTOM in 2016.

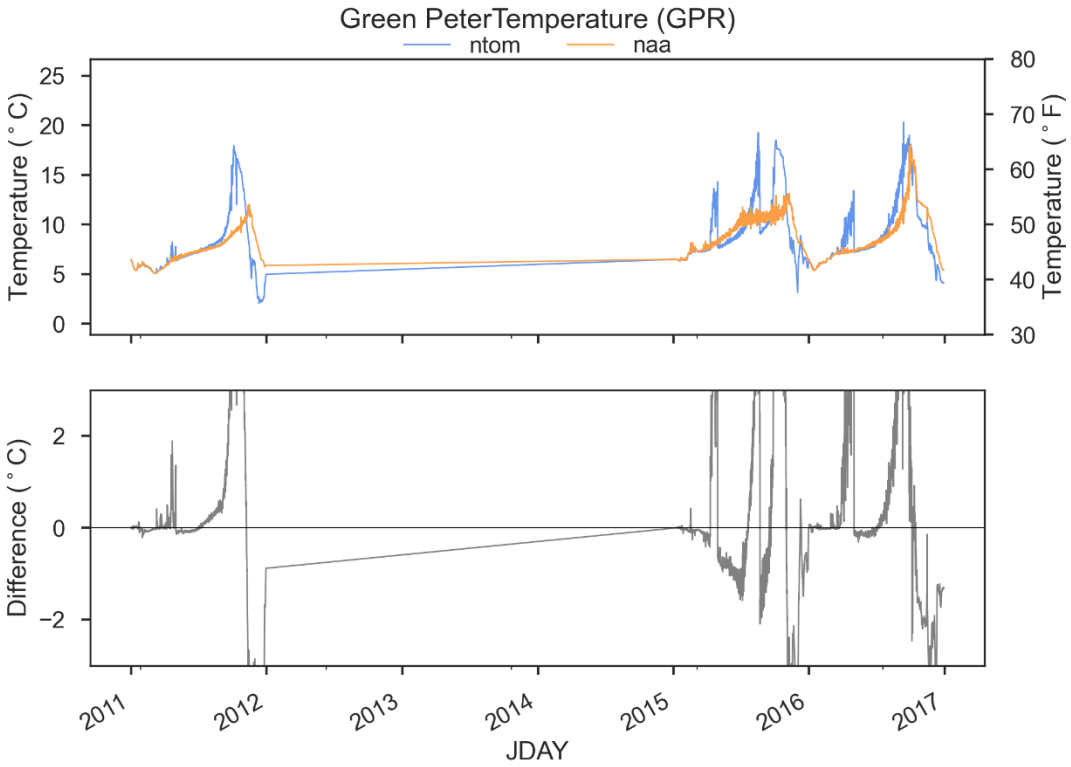


Figure 1-452. Comparison of GPR Outflow Temperatures in NAA and NTOM.

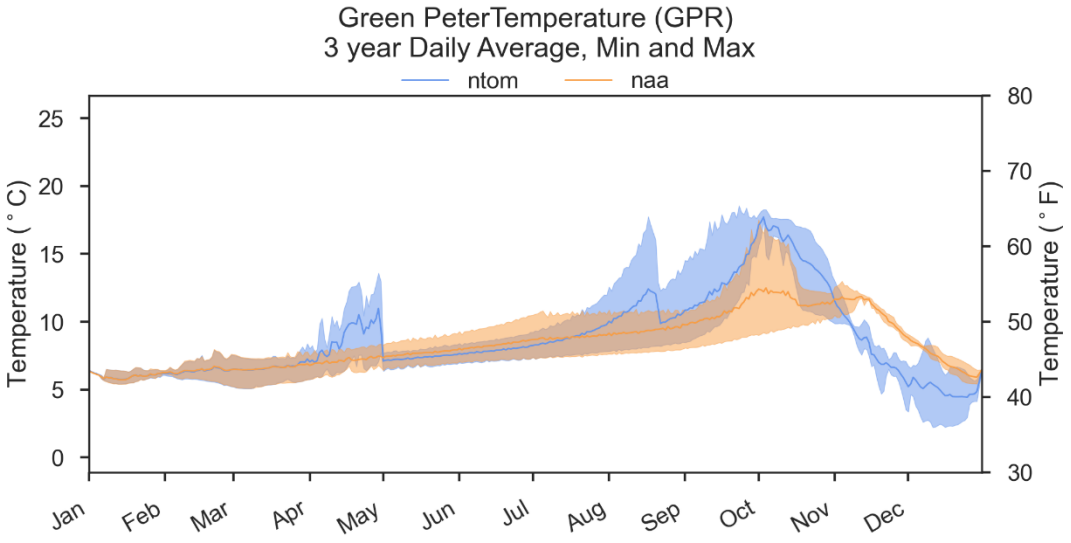


Figure 1-453. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. Black Line Indicates Temperature Target.

1.5.10.2.2 Foster

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Foster in NTOM were generally similar in 2011 and 2016 but increased in 2015 under NTOM compared to NAA (Figure 1-454). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam (Figure 1-456). Night-time spillway and fish weir use for fish passage and temperature management resulted in lower outflow routed through the Power outlets, especially during spring and summer, compared to NAA (Figure 1-455).

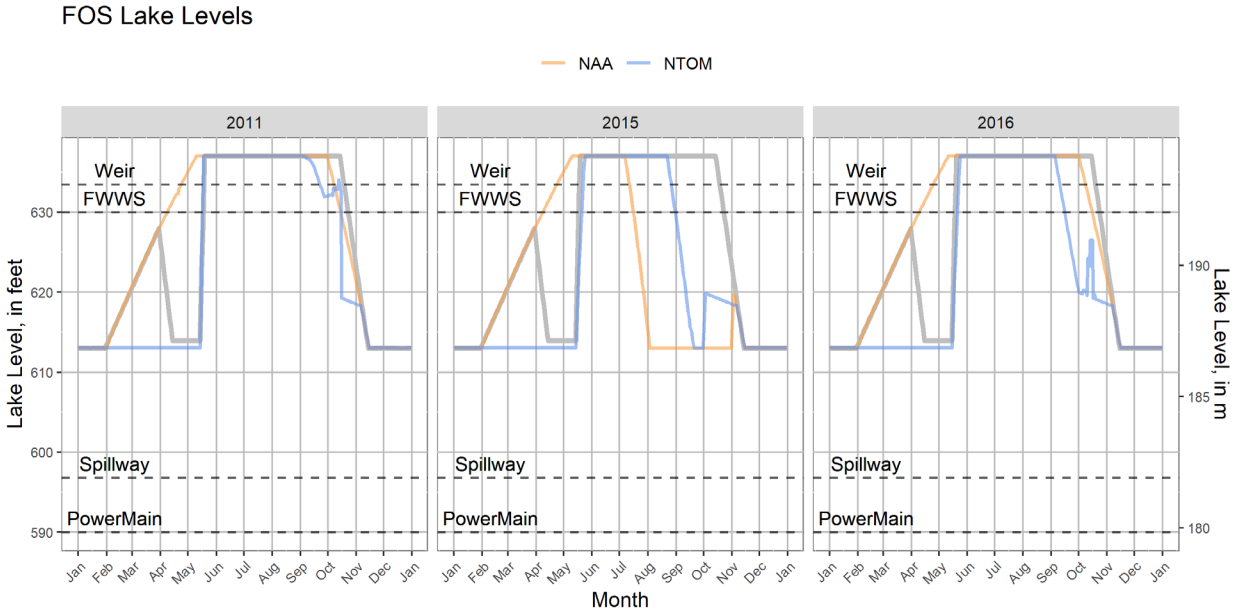


Figure 1-454. WV EIS HEC-ResSim Foster Lake Levels in 2011, 2015, and 2016 Under NTOM and NAA.

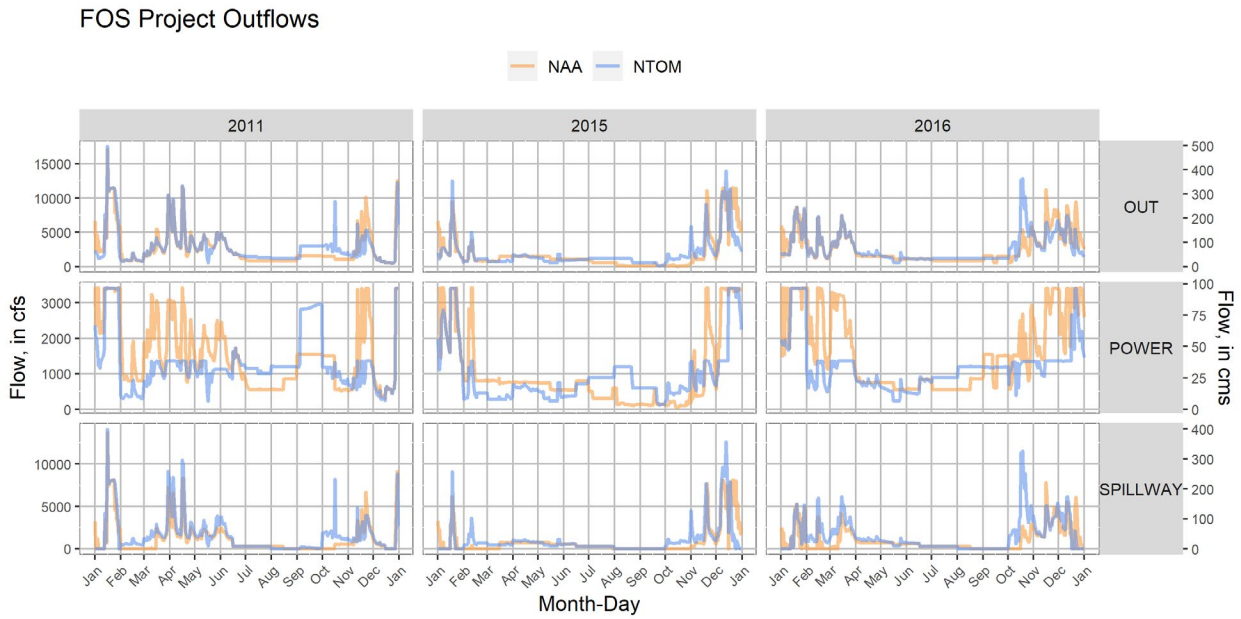


Figure 1-455. WV EIS HEC-ResSim Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under NTOM and NAA.

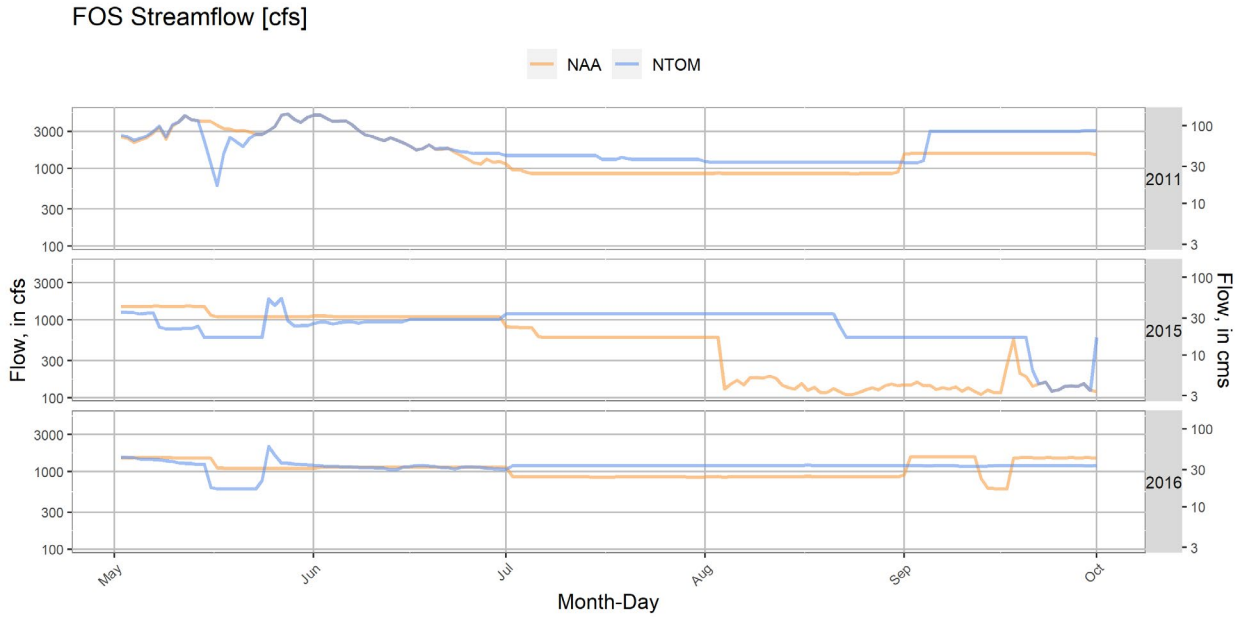


Figure 1-456. WV EIS HEC-ResSim Foster Dam Total Outflow in 2011, 2015, and 2016 under NTOM and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-457, Figure 1-458, and Figure 1-459. Foster Lake temperature was affected by Green Peter Dam operations (increased spill in NTOM)

release temperatures (Figure 1-460, Figure 1-461), generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the temperature pattern (Sullivan and Rounds, 2021).

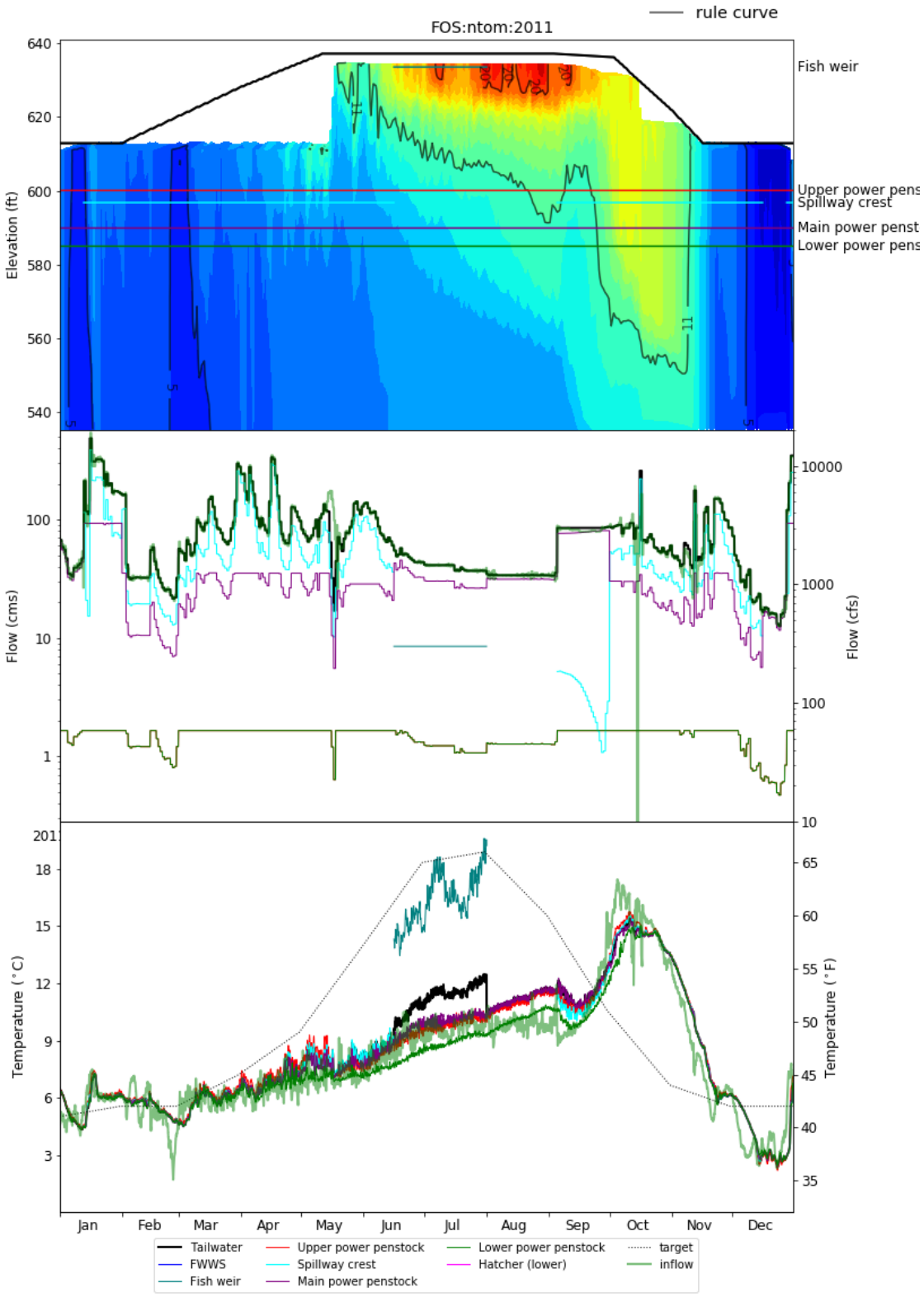


Figure 1-457. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under NTOM in 2011.

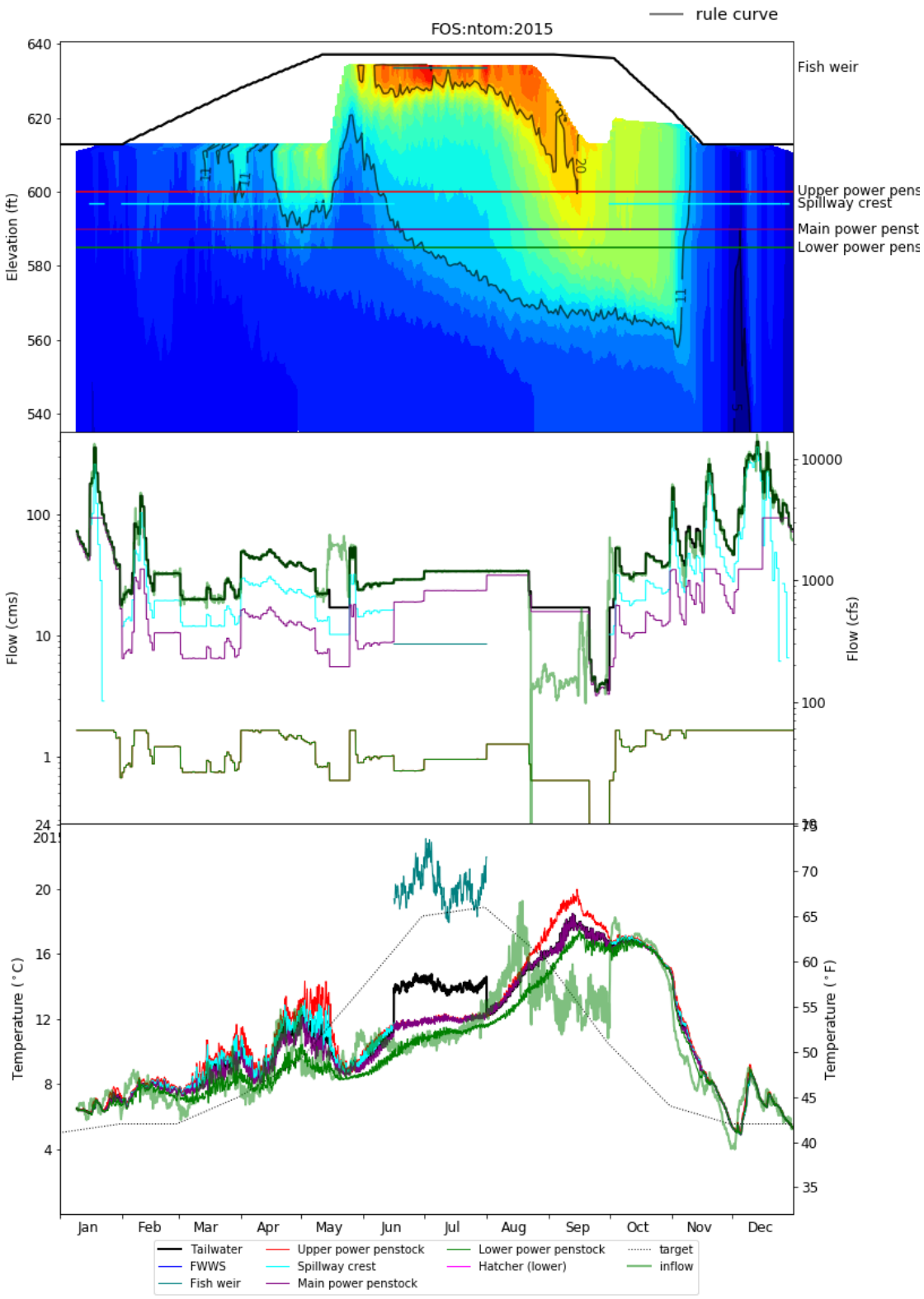


Figure 1-458. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under NTOM in 2015.

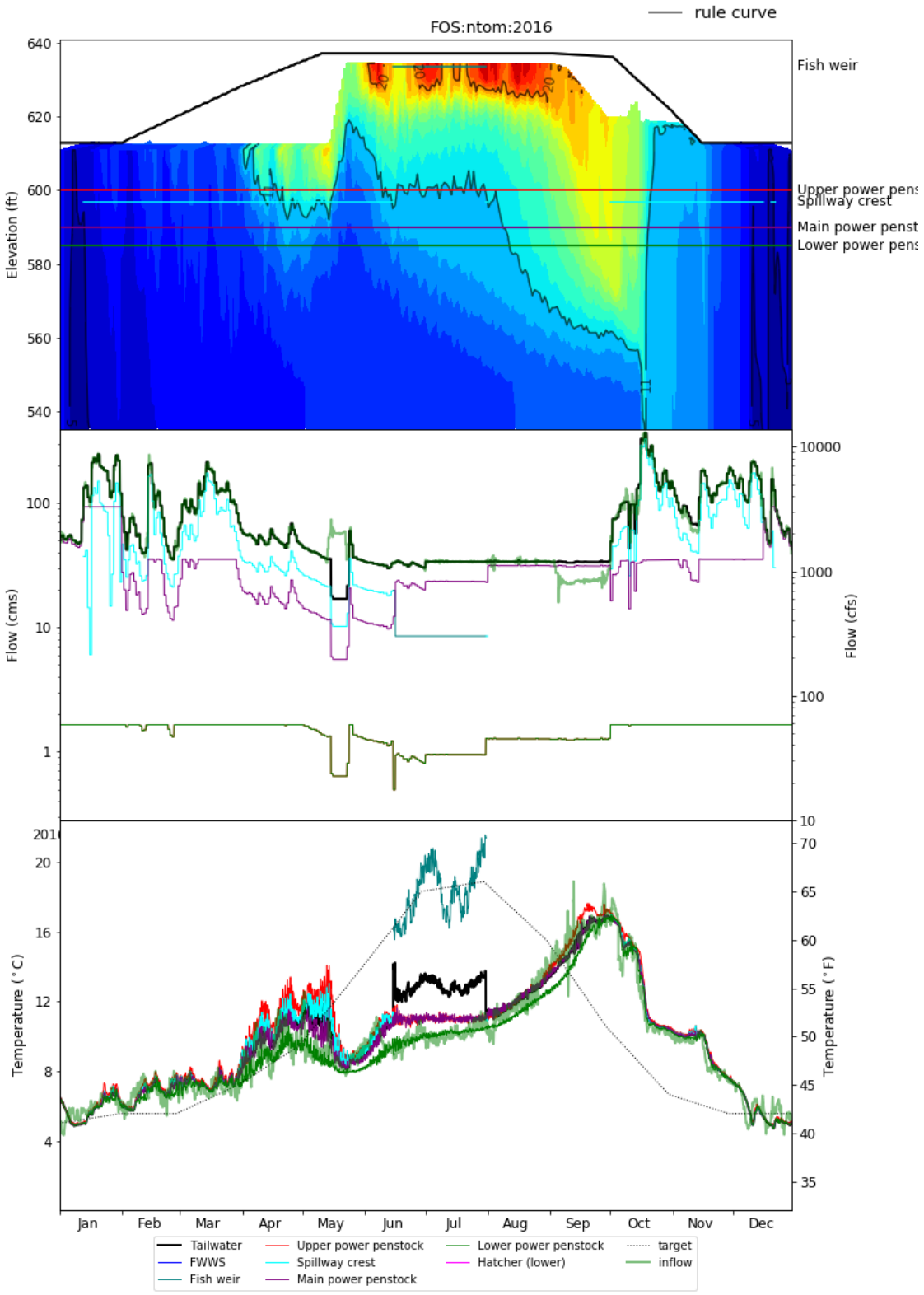


Figure 1-459. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under NTOM in 2016.

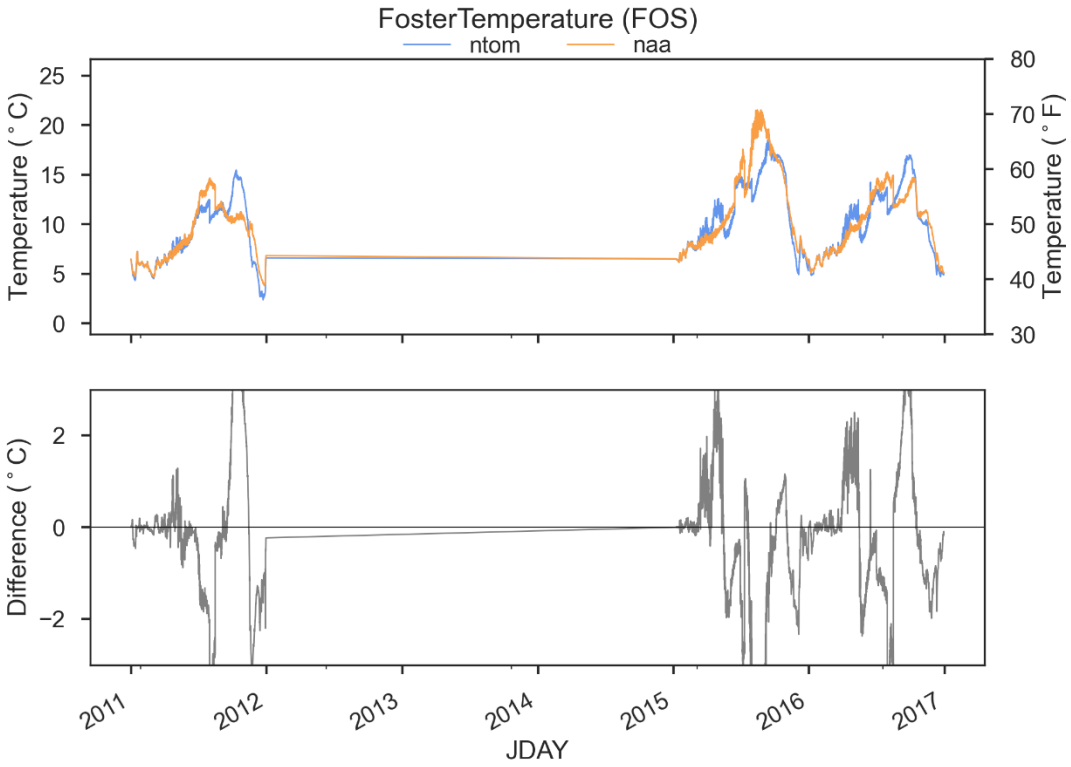


Figure 1-460. Comparison of FOS outflow temperatures in NAA and NTOM.

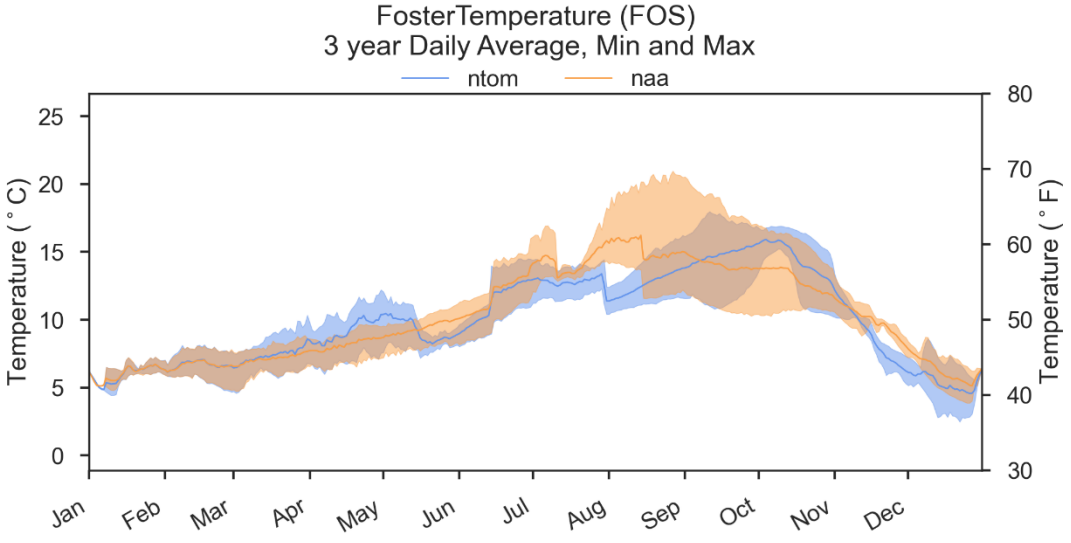


Figure 1-461. Comparison of FOS 3-year daily Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. Black Line Indicates Temperature Target.

1.5.10.3 McKenzie Dams

1.5.10.3.1 Cougar

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Cougar in NTOM were lower compared to NAA in 2011, 2015, and 2016 to allow for fish passage operations through the RO (Figure 1-462, Figure 1-463, and Figure 1-464). The decreased storage coincided with reduced outflows during spring and summer (Figure 1-463). Outflows were primarily routed through the RO in NTOM, except when the lake refilled to about 30 feet above the RO intake (e.g., 2011).

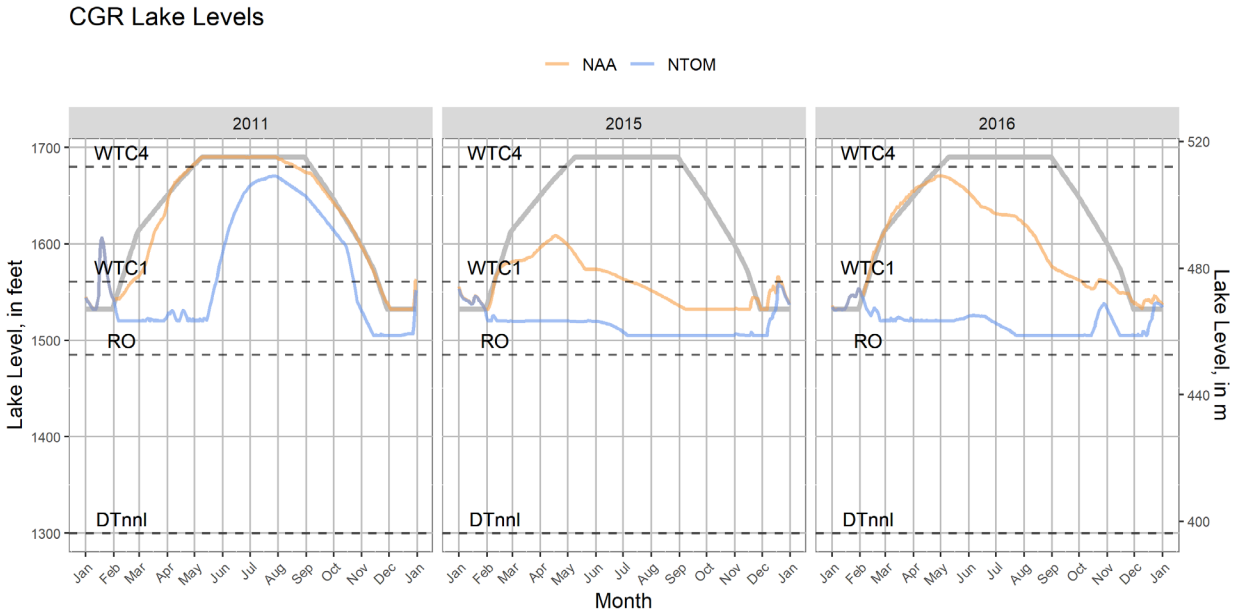


Figure 1-462. WV EIS HEC-ResSim Cougar Lake Levels in 2011, 2015, and 2016 Under NTOM and NAA.

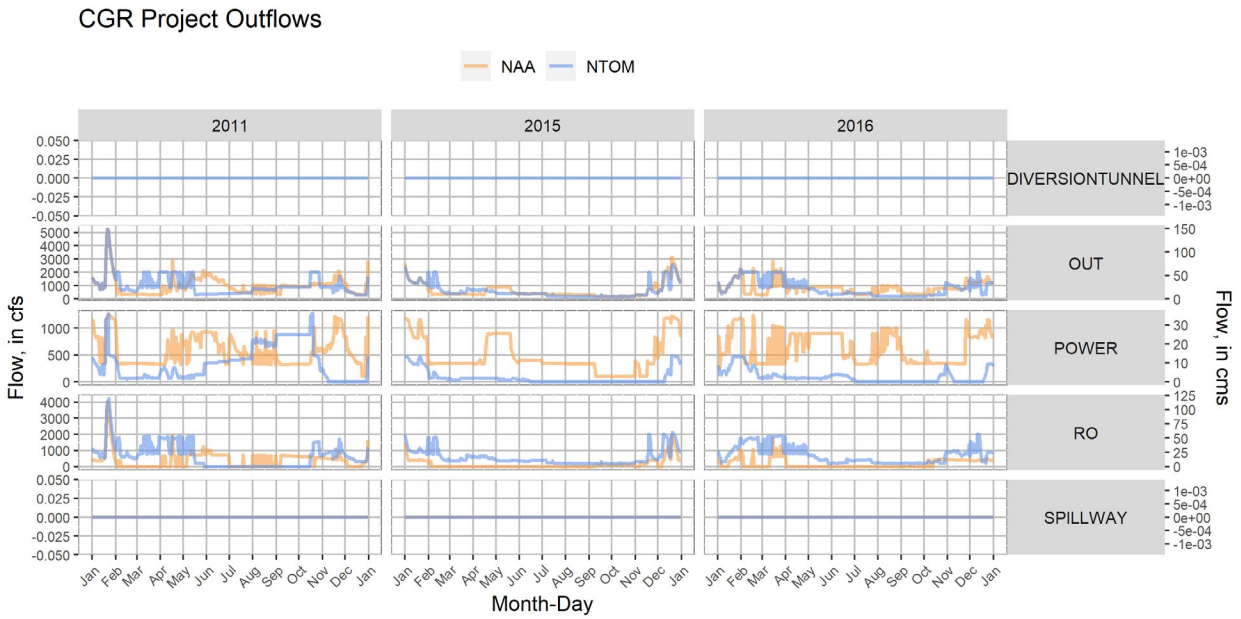


Figure 1-463. WV EIS HEC-ResSim Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under NTOM and NAA.

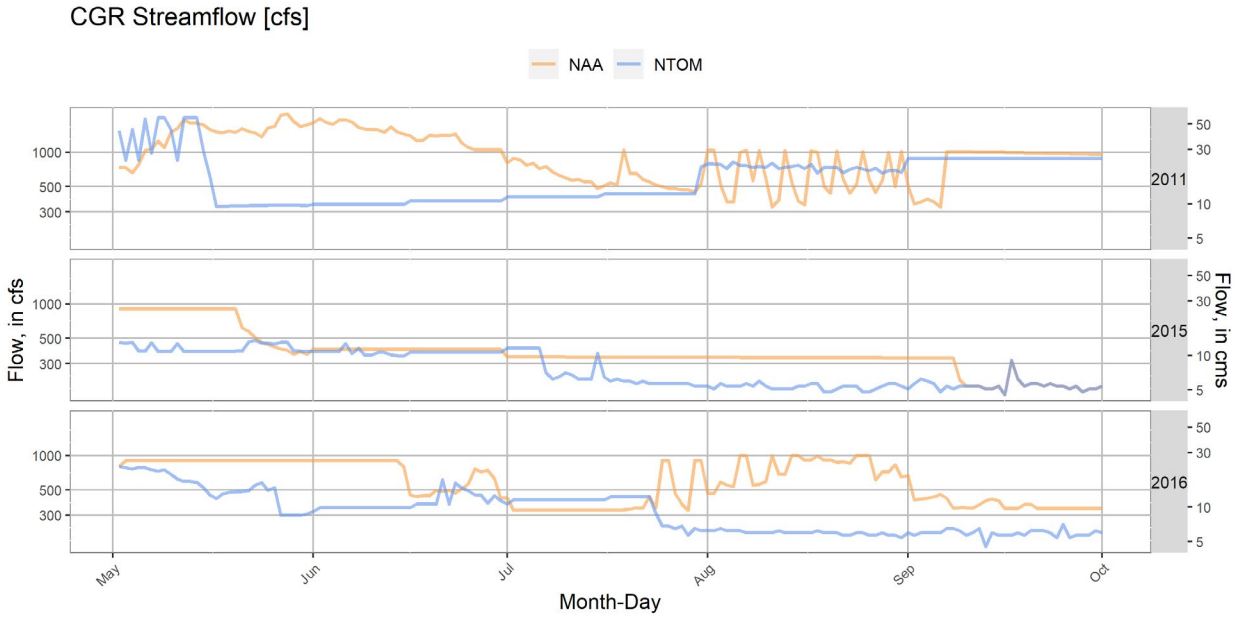


Figure 1-464. WV EIS HEC-ResSim Cougar Dam Total Outflow in 2011, 2015, and 2016 under NTOM and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Cougar Lake are shown in Figure 1-465, Figure 1-466, and Figure 1-467. Outflows were generally similar in NTOM compared to NAA in 2011 and 2016. However,

2015 was not able to fill (due to the lower inflows) above the lowest elevation for the WTCT to function due to fish passage operations (Figure 1-468 and Figure 1-469).

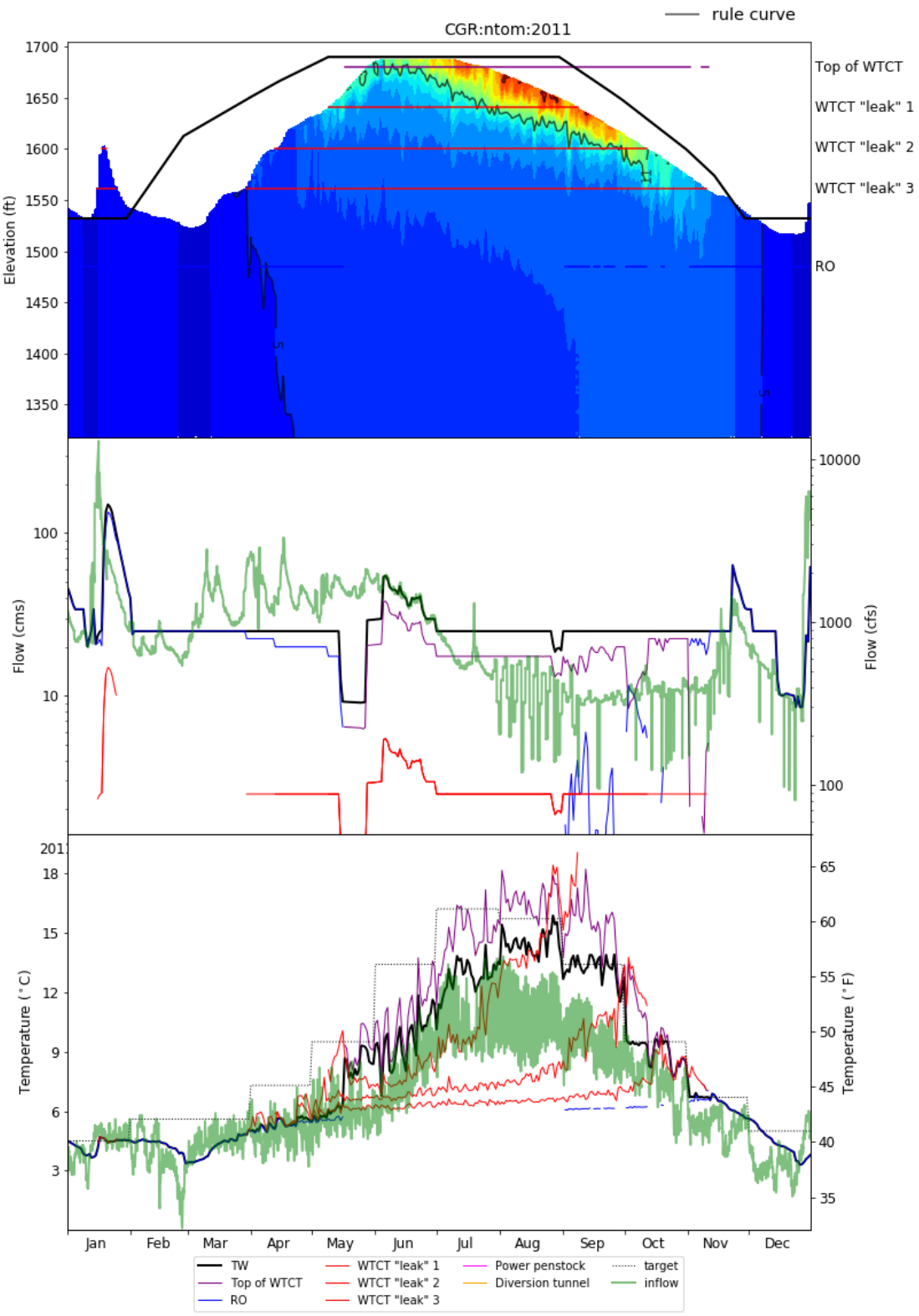


Figure 1-465. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under NTOM in 2011.

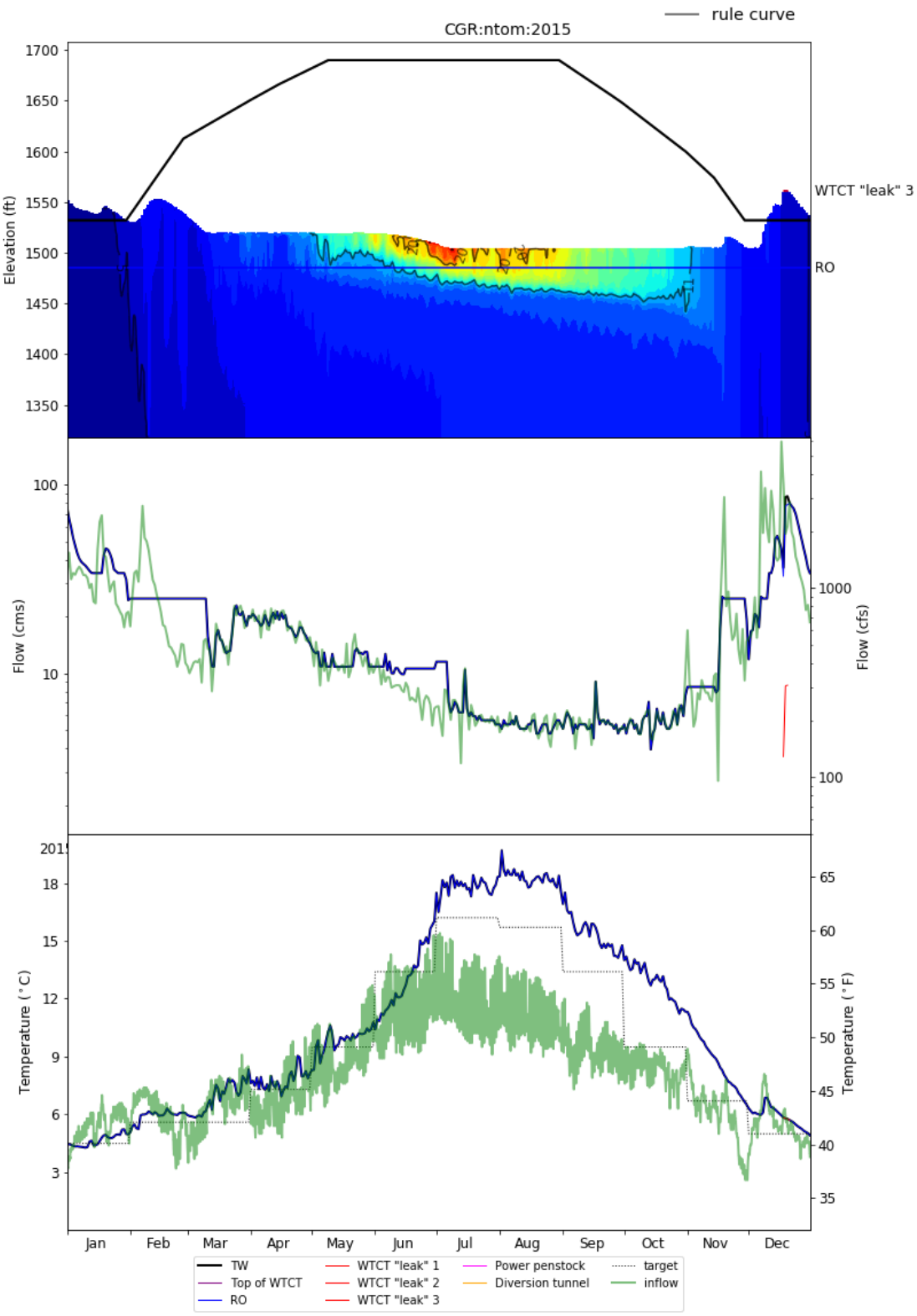


Figure 1-466. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under NTOM in 2015.

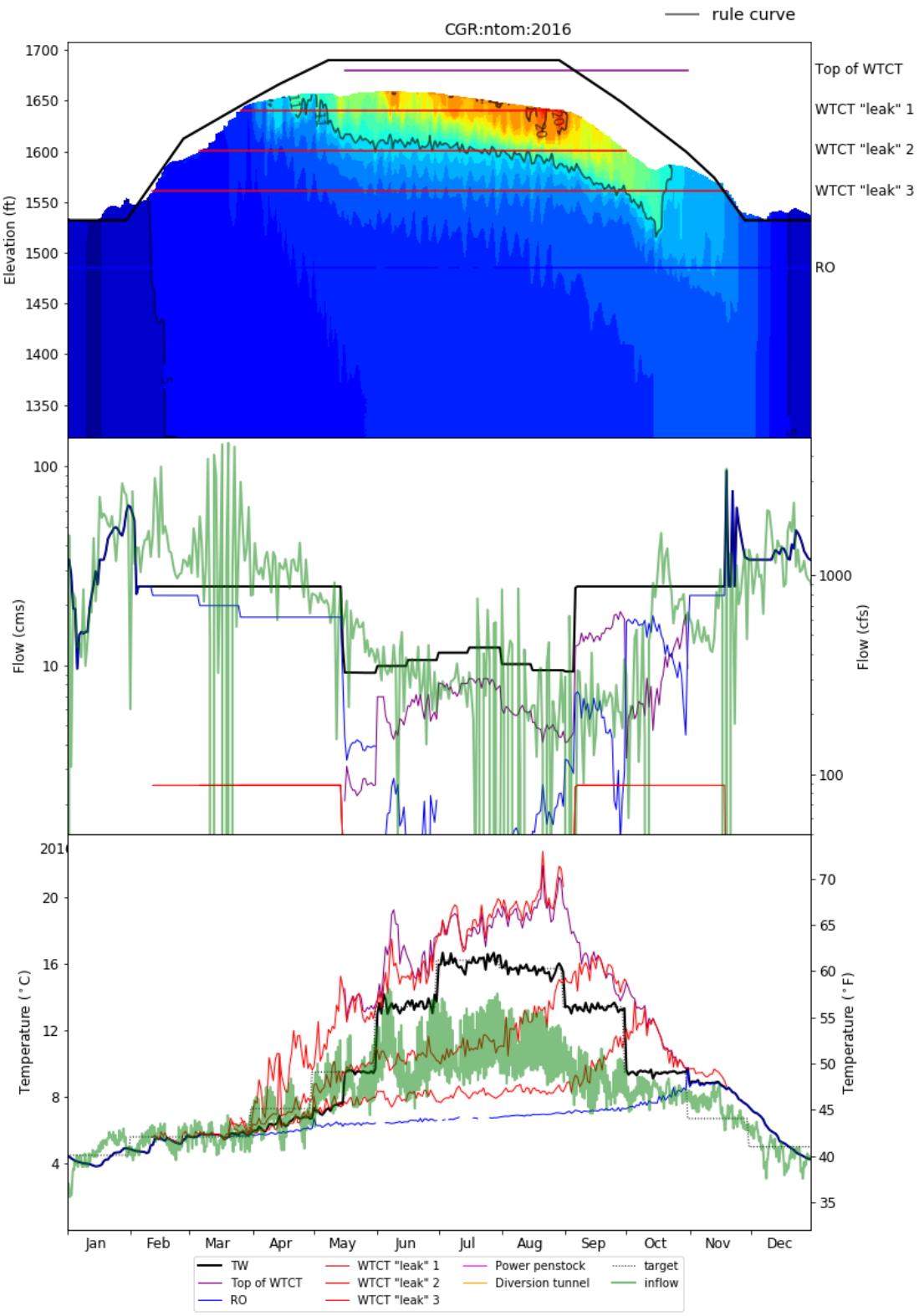


Figure 1-467. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under NTOM in 2016.

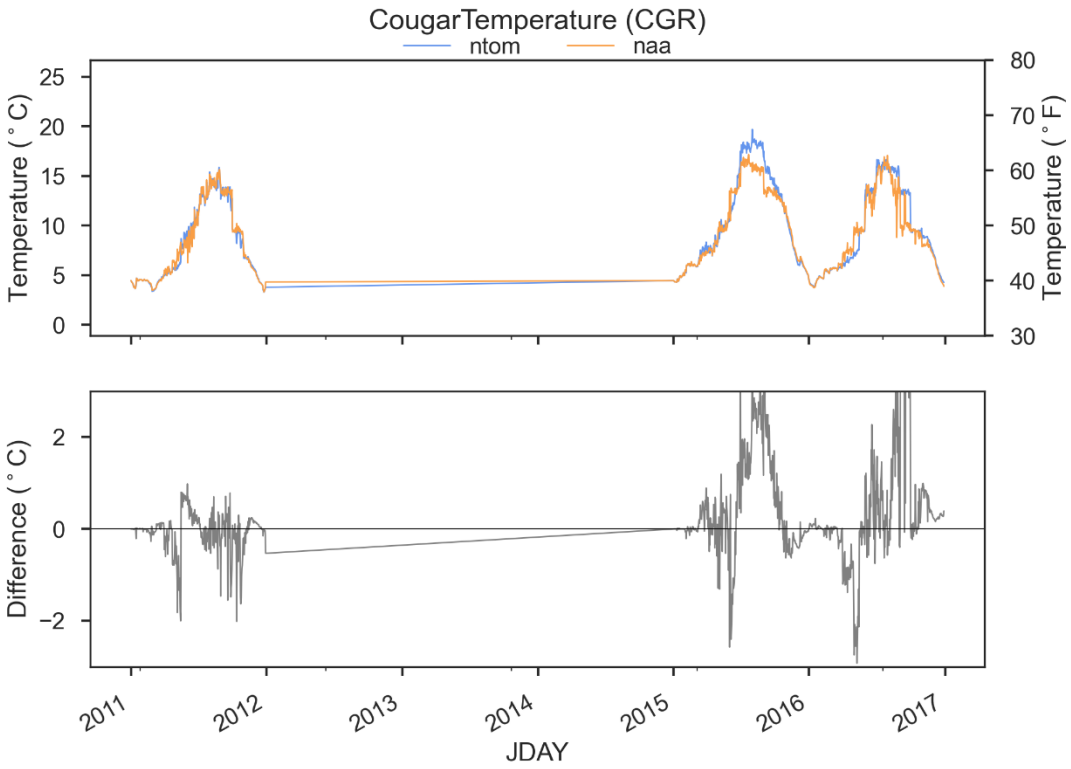


Figure 1-468. Comparison of CGR Outflow Temperatures in NAA and NTOM.

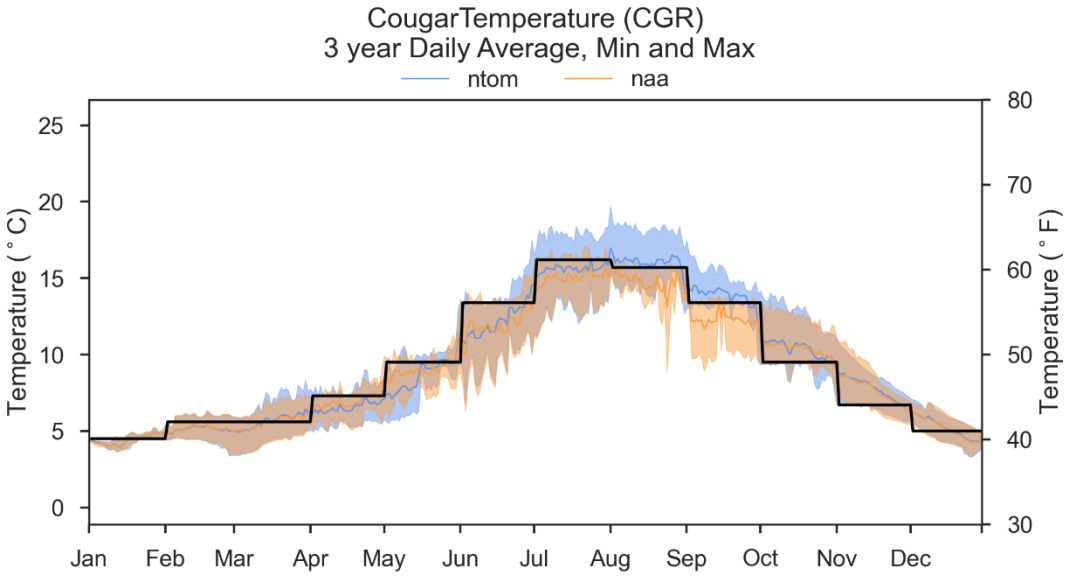


Figure 1-469 Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. Black Line Indicates Temperature Target.

1.5.10.4 Middle Fork Willamette Dams

1.5.10.4.1 Hills Creek

HEC-ResSim Lake Levels and Outflows

Lake level and storage at Hills Creek in NTOM were similar to NAA in 2011 and 2015. Operational differences between NTOM and NAA in 2016 are likely a result of lower Hills Creek to meet mainstem flow targets at Salem during September. Compared to NAA, Alternative 5 lake levels were generally increased in the refill periods of 2015 and 2016 (early summer) before the lake was drafted and the power pool was utilized for downstream flow augmentation (Figure 1-470, Figure 1-471, and Figure 1-472). The increased storage coincided with reduced outflows during spring and increased outflows in May-June during 2015 and August-October in 2016 (Figure 1-472). 2011 and 2015 operations were generally similar in NTOM and NAA at Hills Creek Lake.

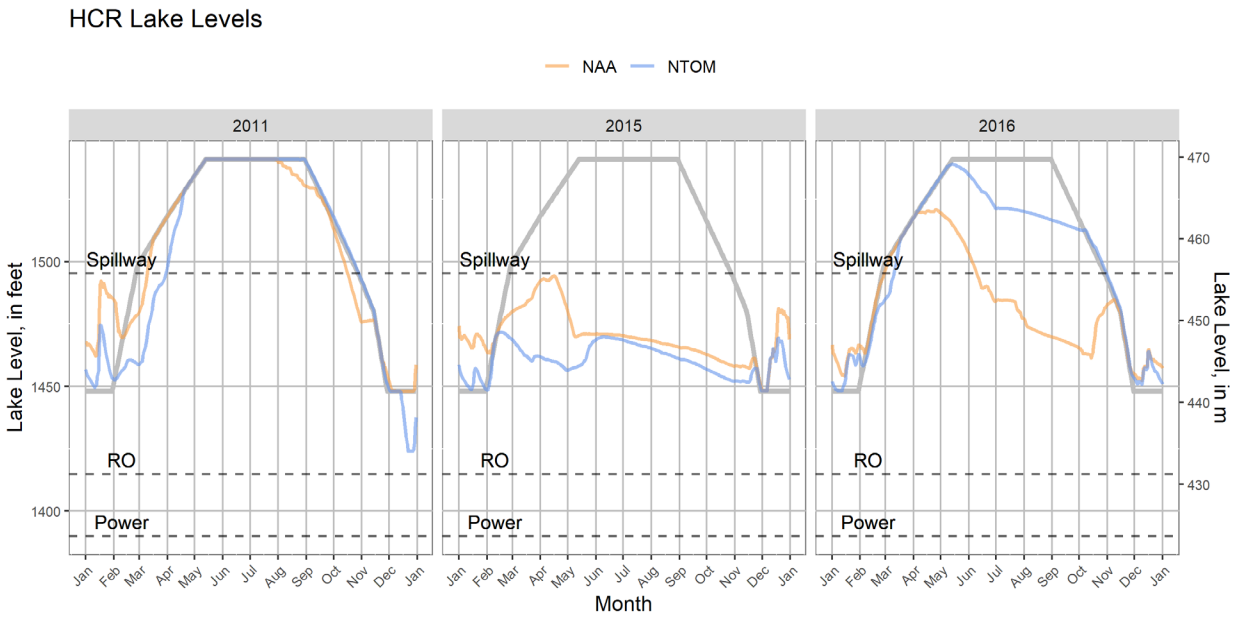


Figure 1-470. WV EIS HEC-ResSim Hills Creek Lake Levels in 2011, 2015, and 2016 Under NTOM and NAA.

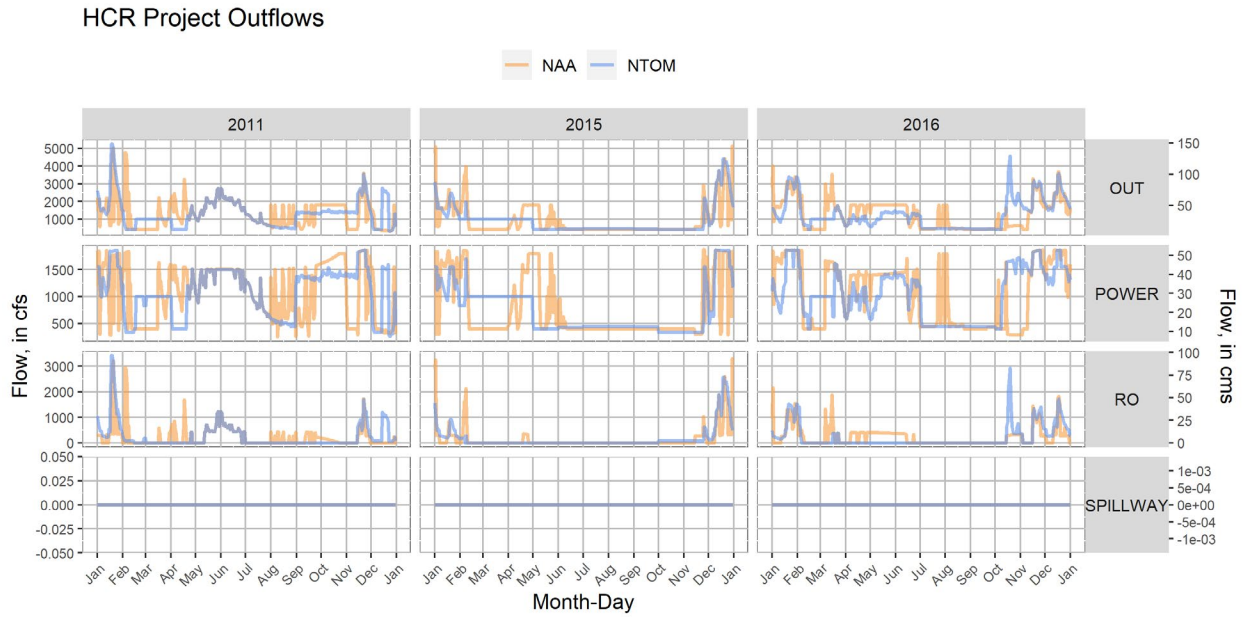


Figure 1-471. WV EIS HEC-ResSim Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under NTOM and NAA.

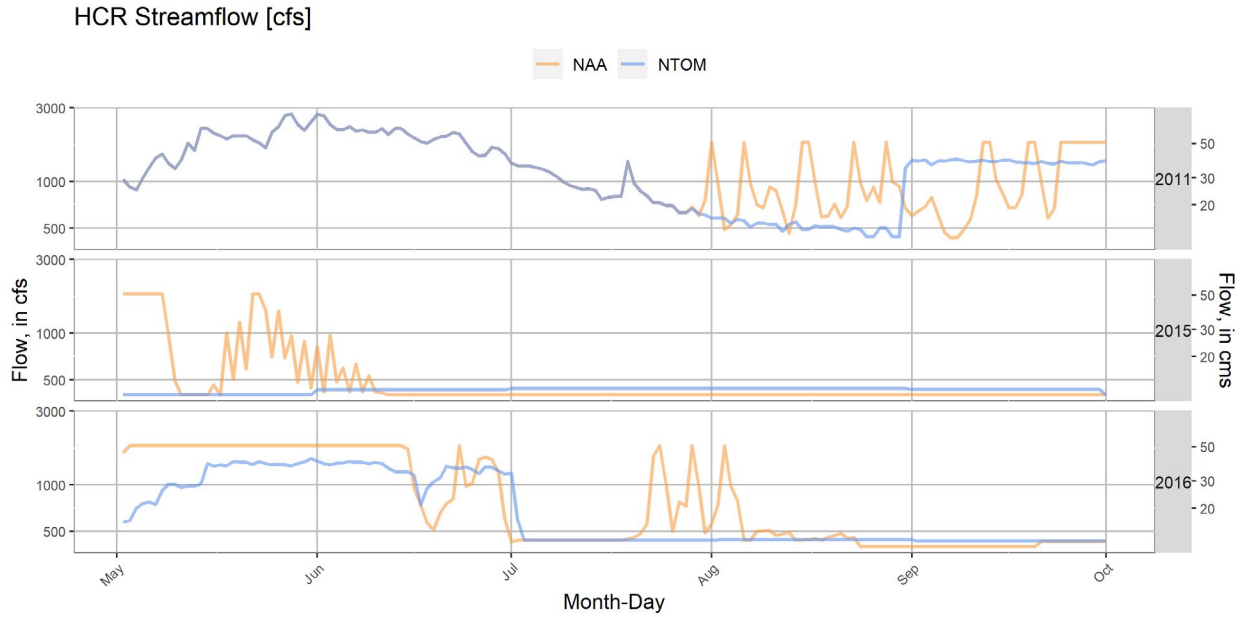


Figure 1-472. WV EIS HEC-ResSim Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under NTOM and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in NTOM at Hills Creek Lake are shown in Figure 1-473, Figure 1-474, and

Figure 1-475. Tailwater release temperatures generally matched NAA in 2011, 2015, but were cooler than NAA in 2016 due to lake elevation differences (Figure 1-476, Figure 1-477).

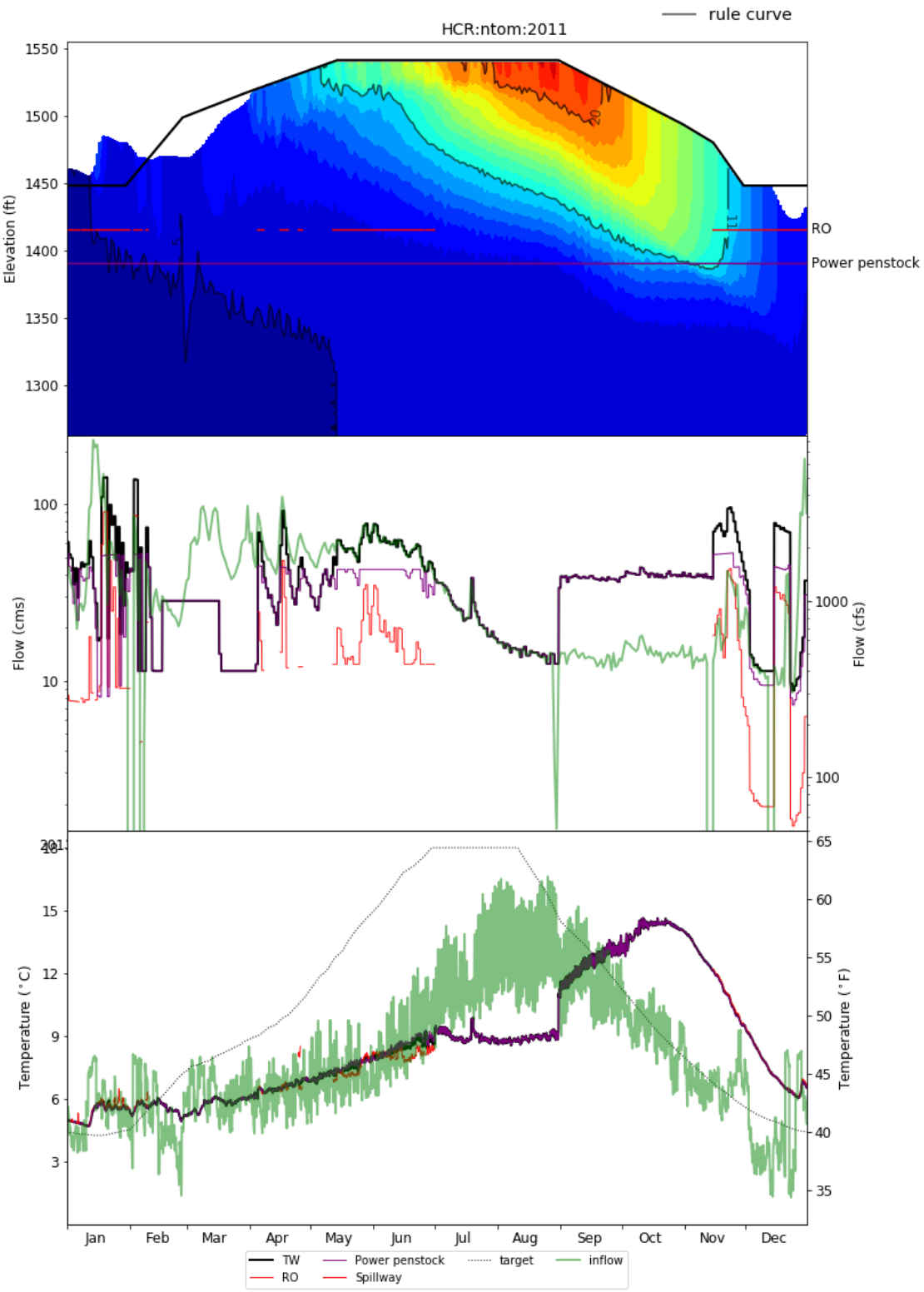


Figure 1-473. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under NTOM in 2011.

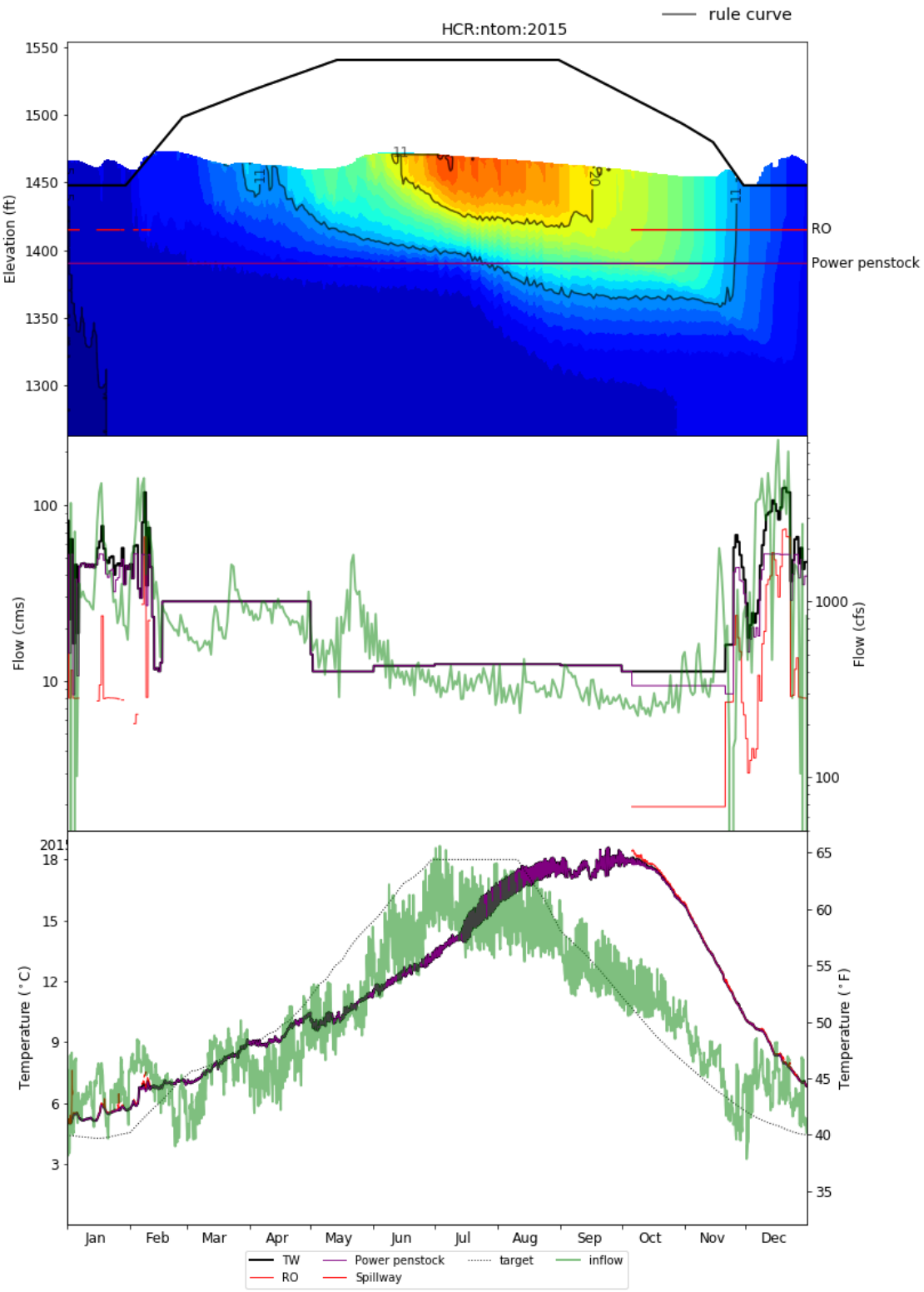


Figure 1-474. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under NTOM in 2015.

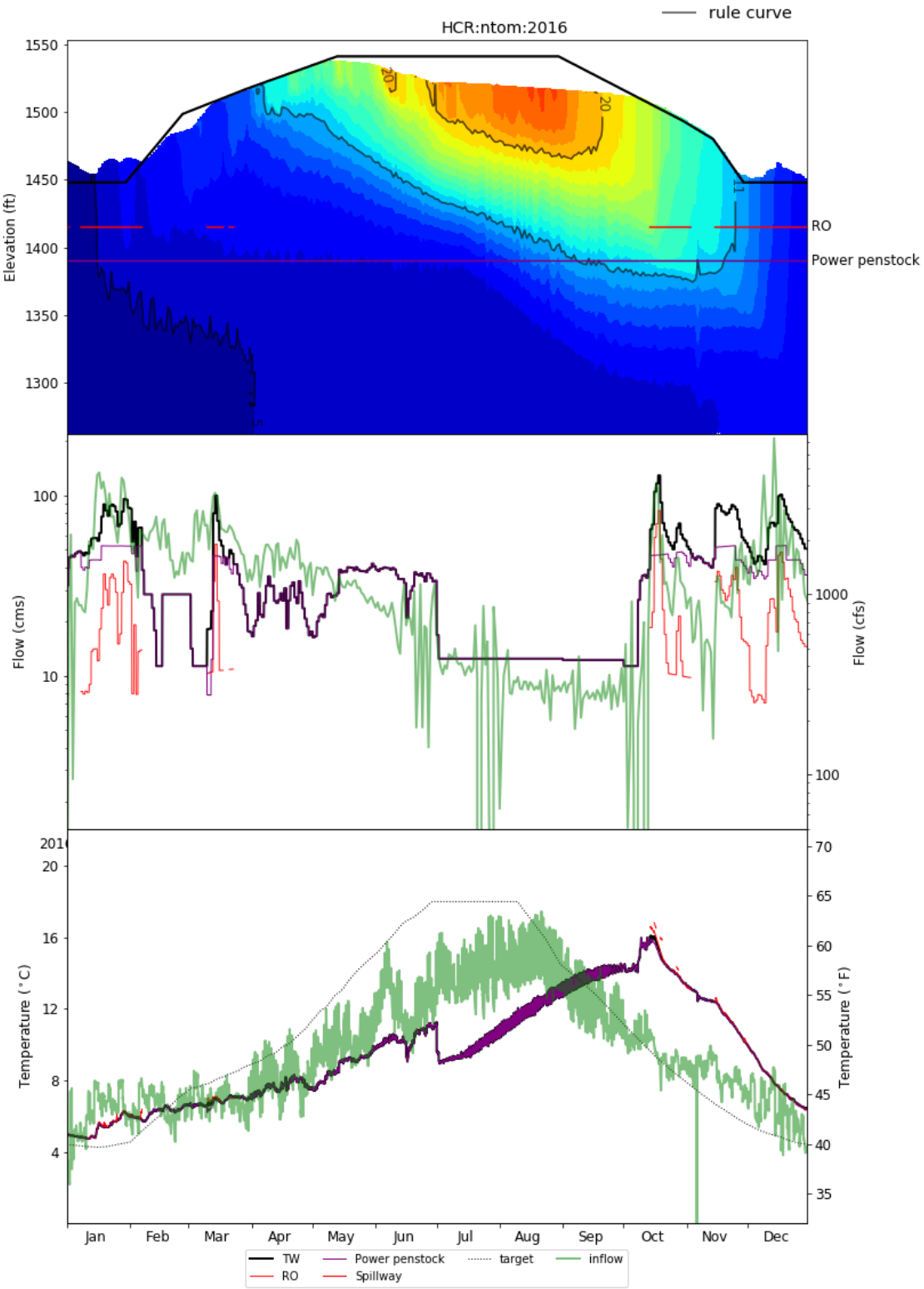


Figure 1-475. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under NTOM in 2016.

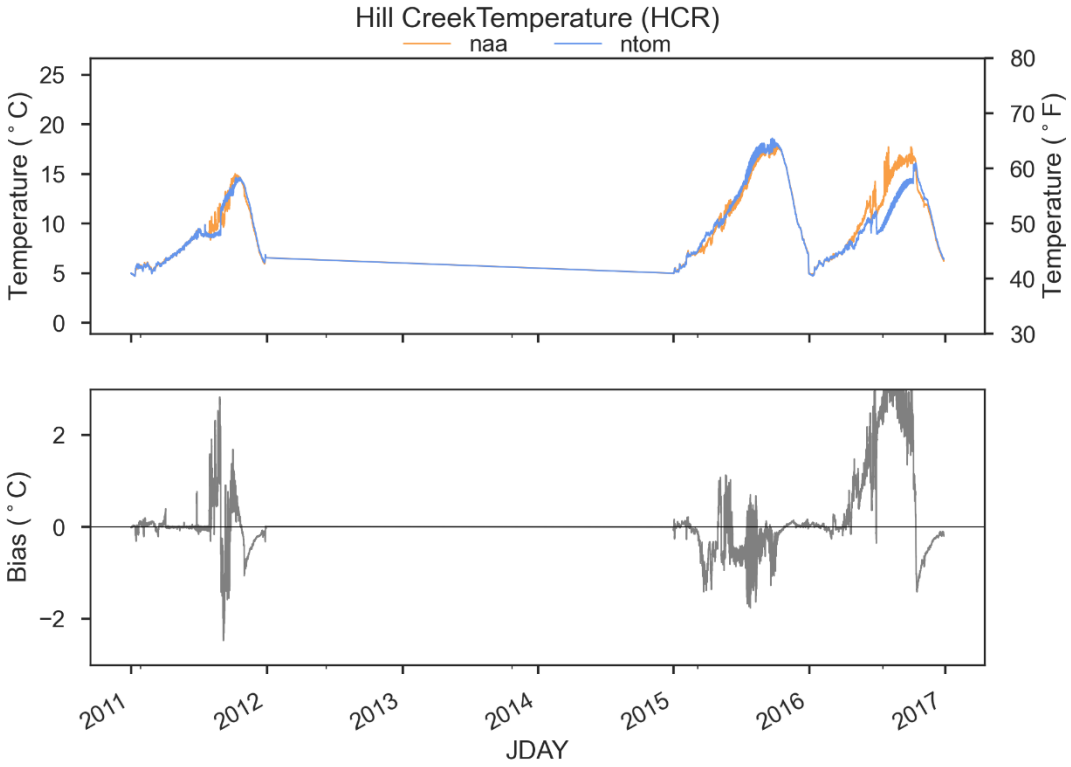


Figure 1-476. Comparison of HCR outflow temperatures in NAA and NTOM.

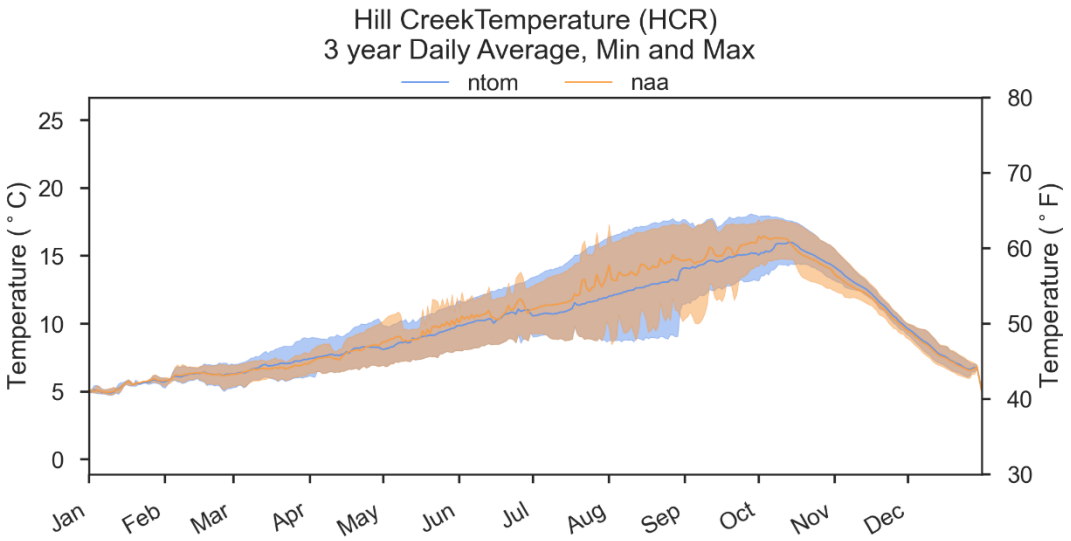


Figure 1-477. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. Black Line Indicates Temperature Target.

1.5.10.4.2 Lookout Point

HEC-ResSim Lake Levels and Outflows

Compared to NAA, Lake level and storage at Lookout Point in NTOM was reduced in 2011 and 2016, and increased in 2015 to allow for fish passage and temperature management operations during spring (Figure 1-478, Figure 1-479, and Figure 1-480). Deep fall drawdowns in 2011, 2015, and 2016 resulted in increased outflow during the draft period and reduced pool elevations compared to NAA.

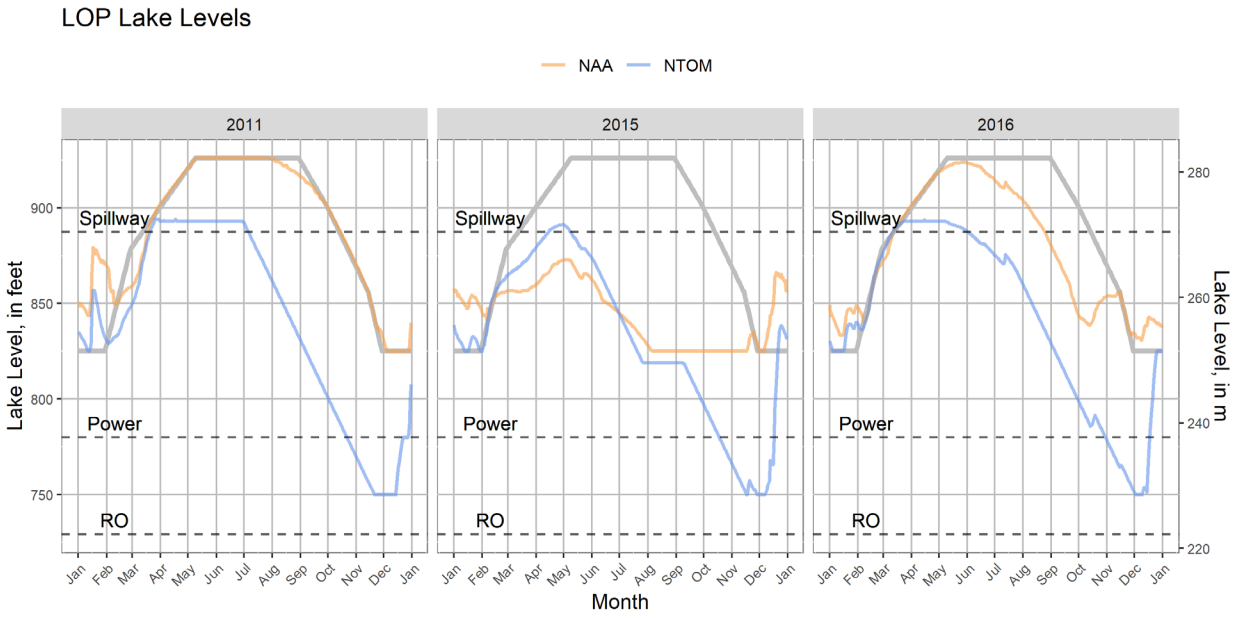


Figure 1-478. WV EIS HEC-ResSim Lookout Point Lake Levels in 2011, 2015, and 2016 Under NTOM and NAA.

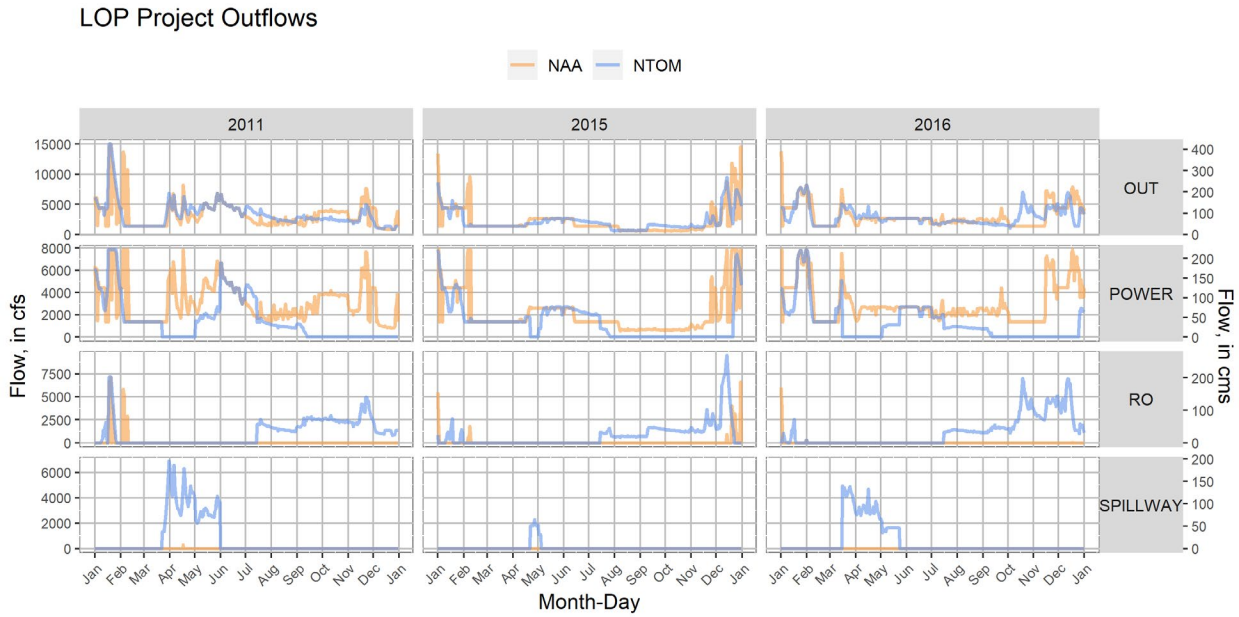


Figure 1-479. WV EIS HEC-ResSim Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 in NTOM and NAA.

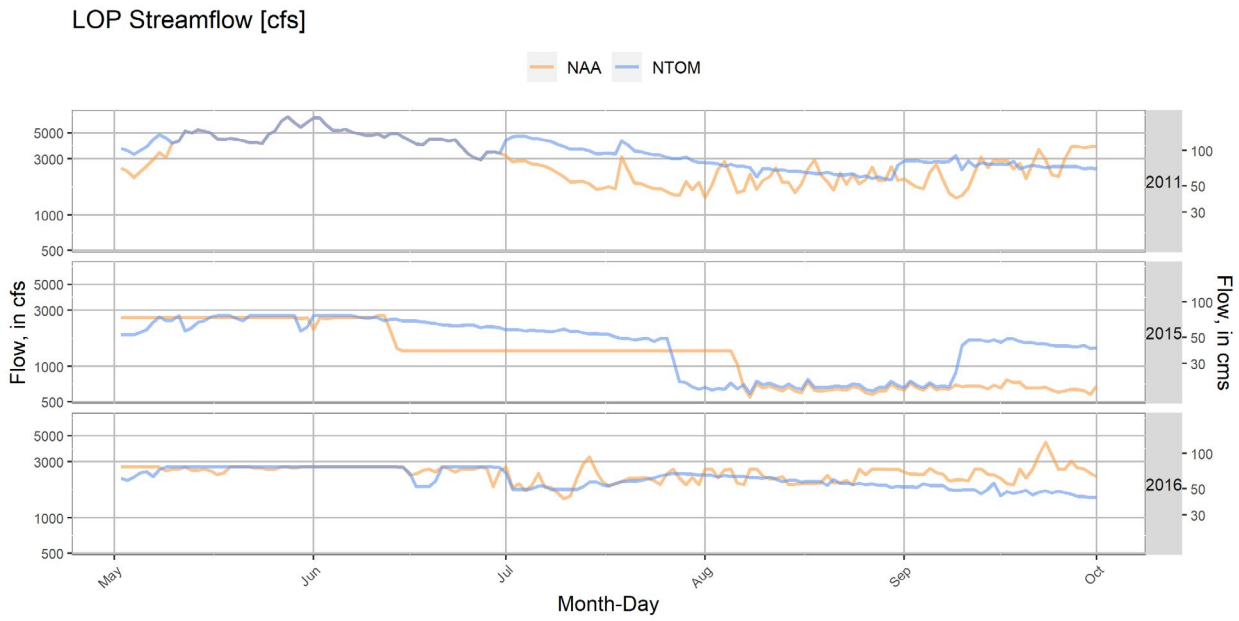


Figure 1-480. WV EIS HEC-ResSim Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under NTOM and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Lookout Point Lake in NTOM are shown in Figure 1-481, Figure 1-482, and Figure 1-483. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, NTOM operational changes led to

temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn in 2011, 2015, and 2016 (Figure 1-484, Figure 1-485) as measured below Dexter Dam.

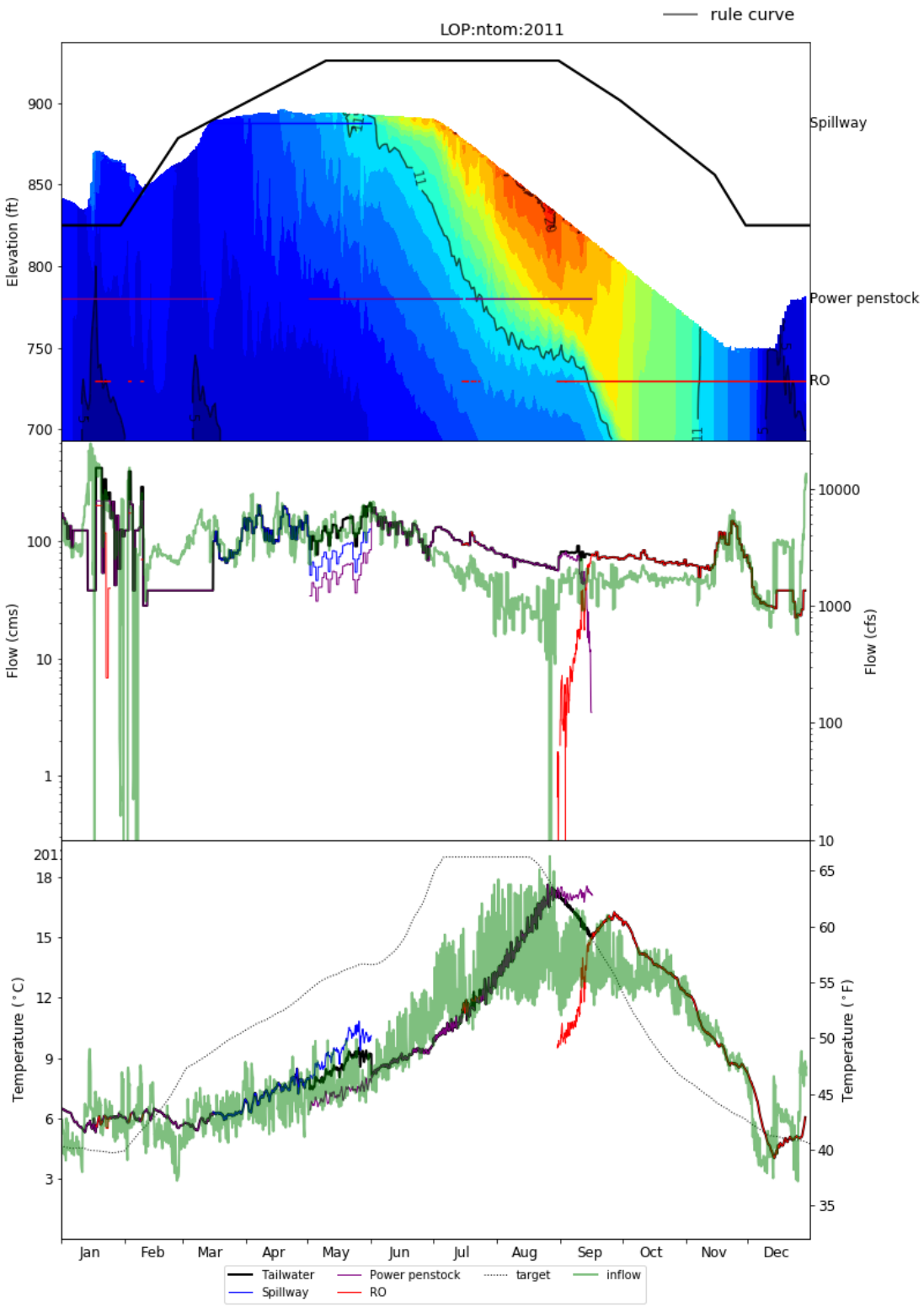


Figure 1-481. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under NTOM in 2011.

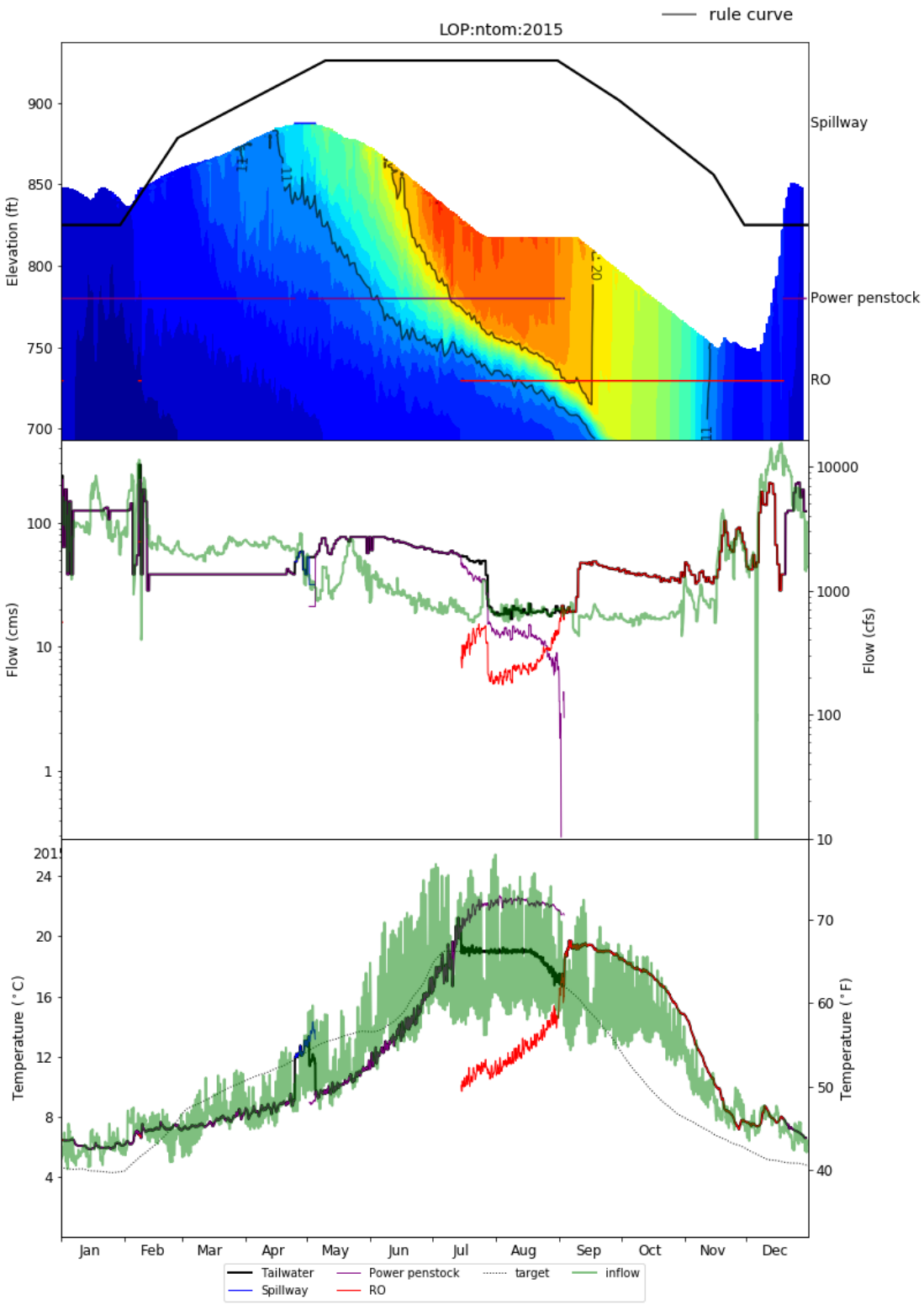


Figure 1-482. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under NTOM in 2015.

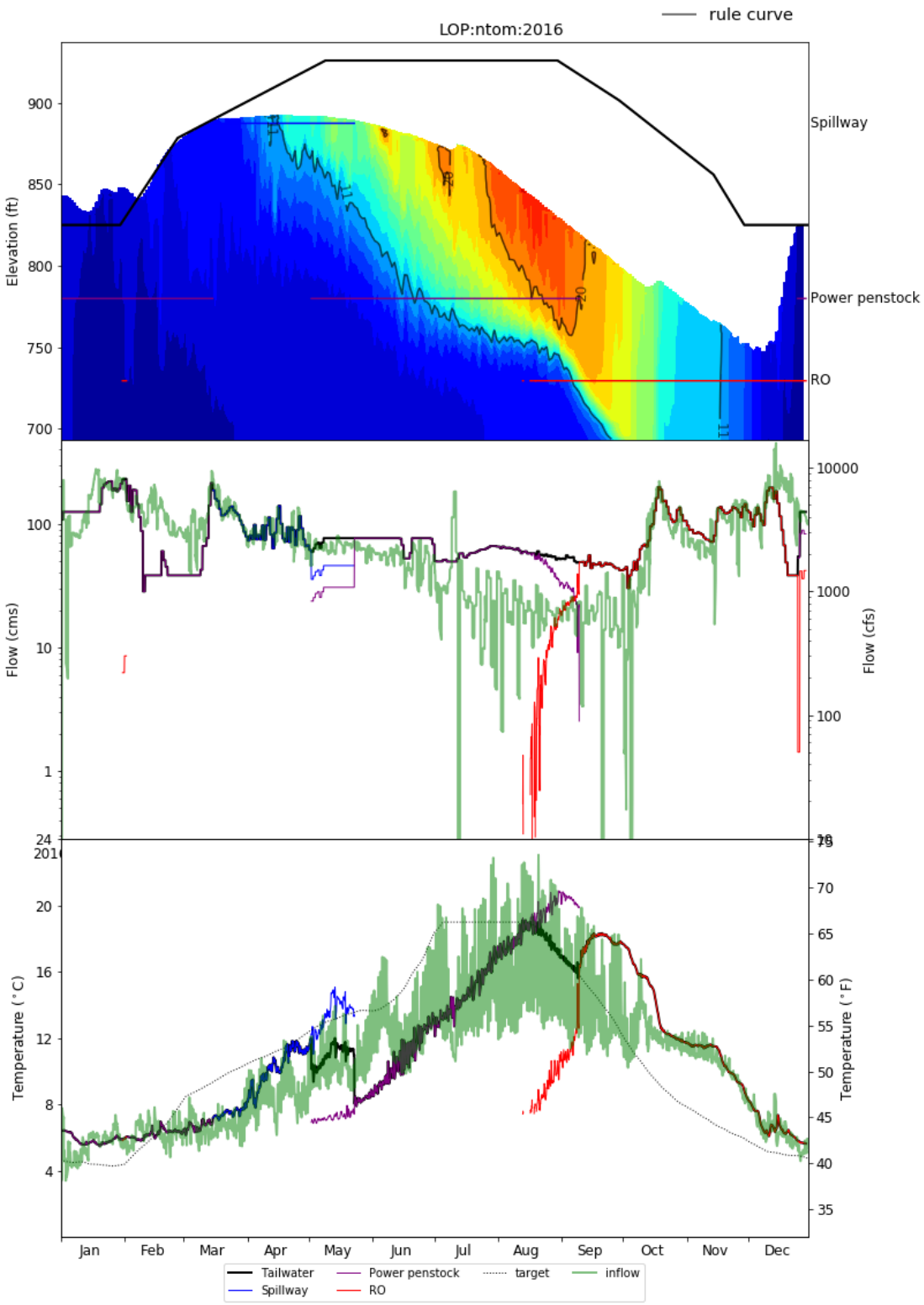


Figure 1-483. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under NTOM in 2016.

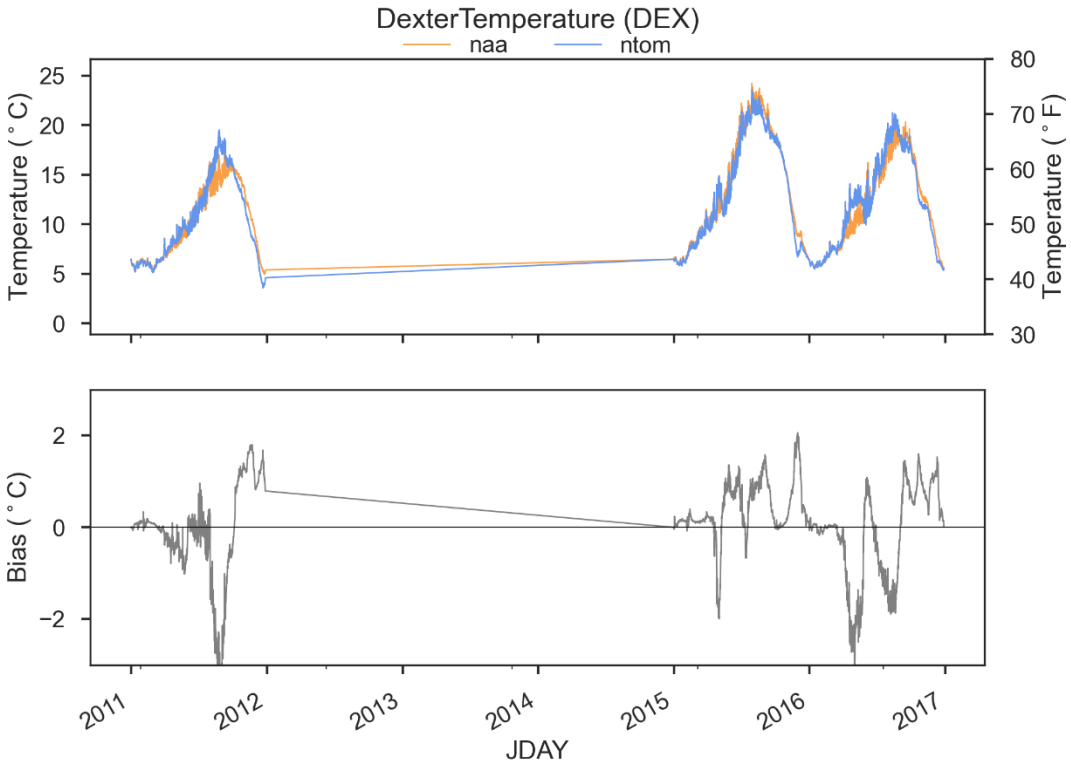


Figure 1-484. Comparison of DEX Outflow Temperatures in NAA and NTOM.

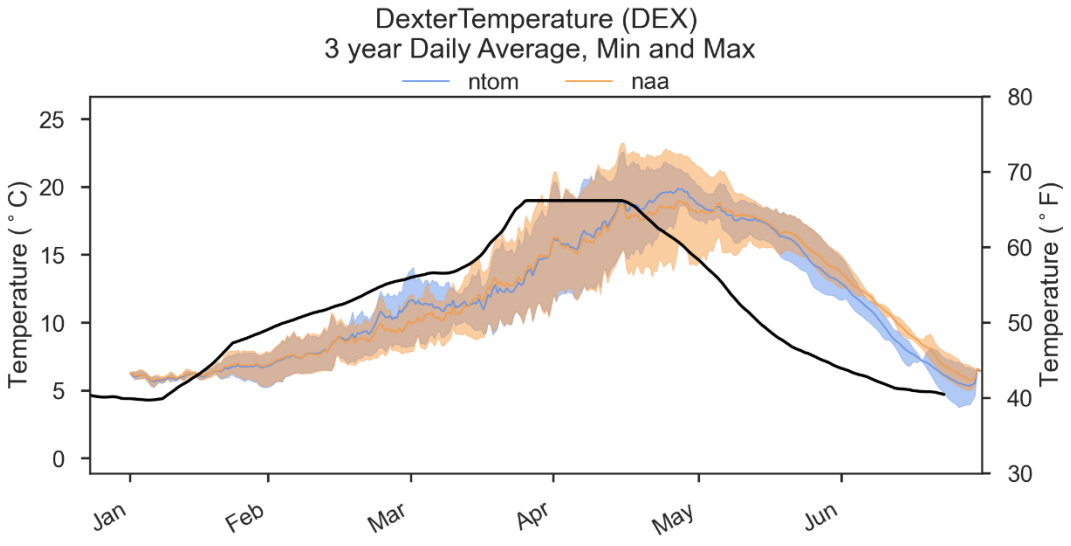


Figure 1-485. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and NTOM. Black Line Indicates Temperature Target.

1.5.10.5 Mainstem Willamette River

Streamflow in NTOM was nearly identical to NAA in 2011 and 2016. In 2015, NTOM streamflow was generally lower from April to mid-June and higher from mid-June through September compared with NAA (Figure 1-486). These operational WV system changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (Figure 1-488, Figure 1-488). Overall water temperature differences between NTOM and NAA were less than 2 degrees Celsius (Figure 1-487).

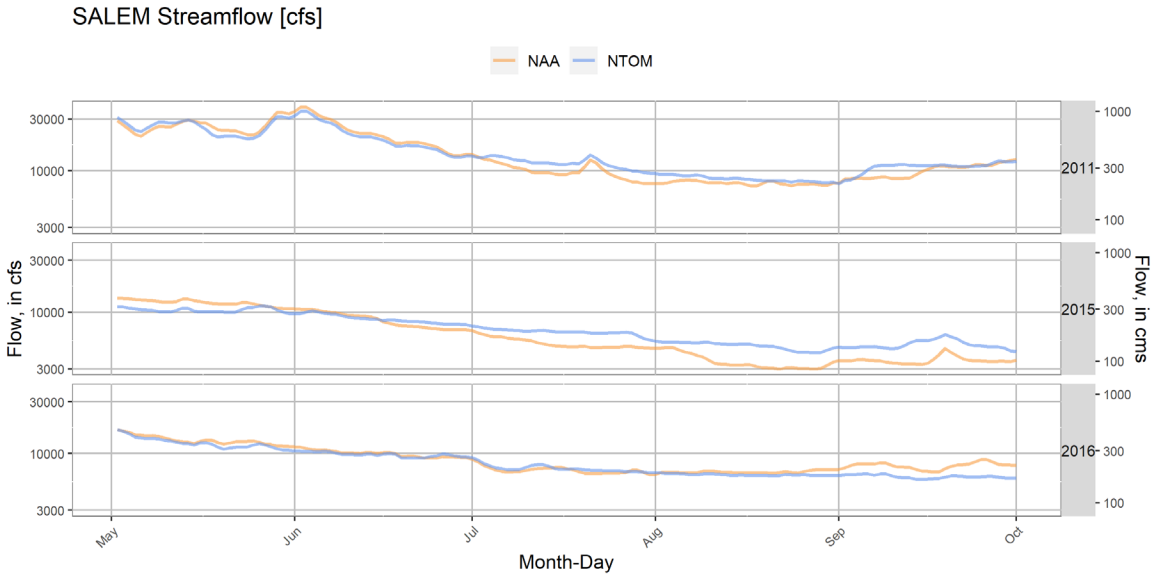


Figure 1-486. Streamflow Comparison Between NTOM and NAA at Willamette River at SLMO.

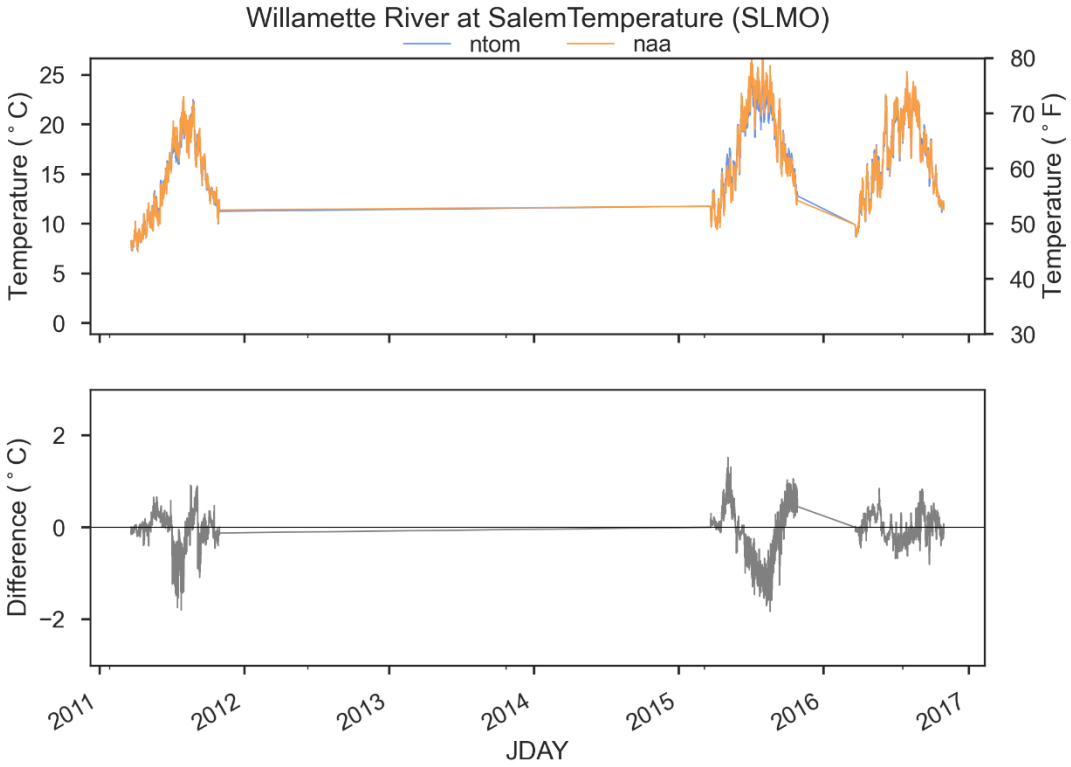


Figure 1-487. Comparison of Willamette River at SLMO Water Temperatures in NAA and NTOM.

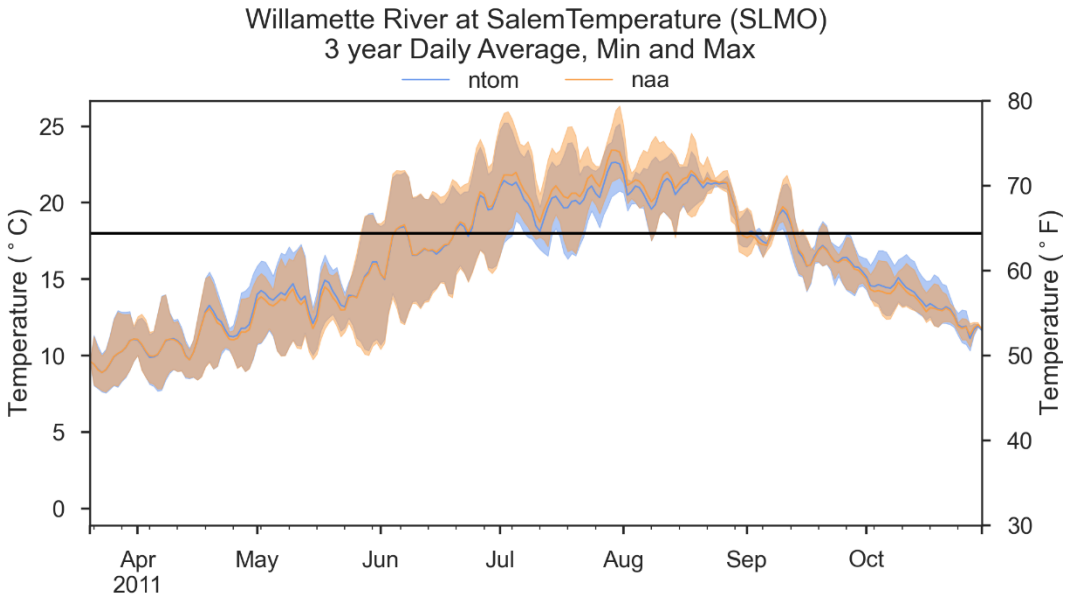


Figure 1-488. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and NTOM.

1.5.11 Interim Operations (i.e., Near Term Operations Measure (NTOM))

Interim Operations are based on Interim Operations (also referred to as Near-Term Operations Measure (NTOM) in Final EIS, Appendix D) with updates to include deep fall/winter drawdown at Detroit Dam and Reservoir and use of the 2008 Biological Opinion minimum flow targets basin wide. RES-SIM simulations of lake levels and dam outflows were used as a basis for assessing the water temperature effects of Interim Operations in 2011, 2015, and 2016 and are discussed in this section. A full explanation of the RES-SIM analysis and findings can be found in the Section 3.2 Hydrologic Processes and Technical Appendix B Hydrology and Hydraulics.

1.5.11.1 NORTH SANTIAM DAMS

1.5.11.1.1 Detroit

RES-SIM Lake Levels and Outflows

Lake level and storage at Detroit Lake in Interim Operations (RevIntOps) was nearly identical to NAA in 2011 and 2016. Interim Operations Detroit Lake levels were similar to NAA in 2015 until July, when the pool was allowed to draft below minimum conservation pool (Figure 1-438). Operations and total outflow in 2011, 2015, and 2016 was generally similar in RevIntOps and NAA at Detroit Lake, aside from late summer of 2015 as mentioned above (Figure 1-439, Figure 1-440).

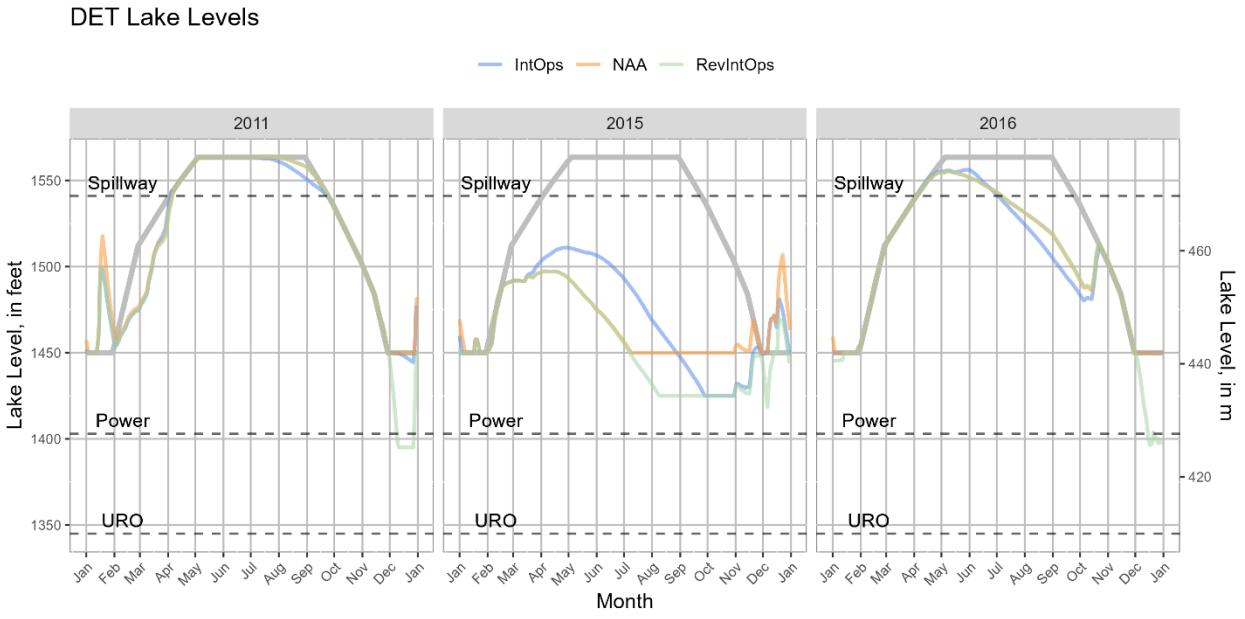


Figure 1-489 WV EIS RES-SIM Detroit Lake Levels in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

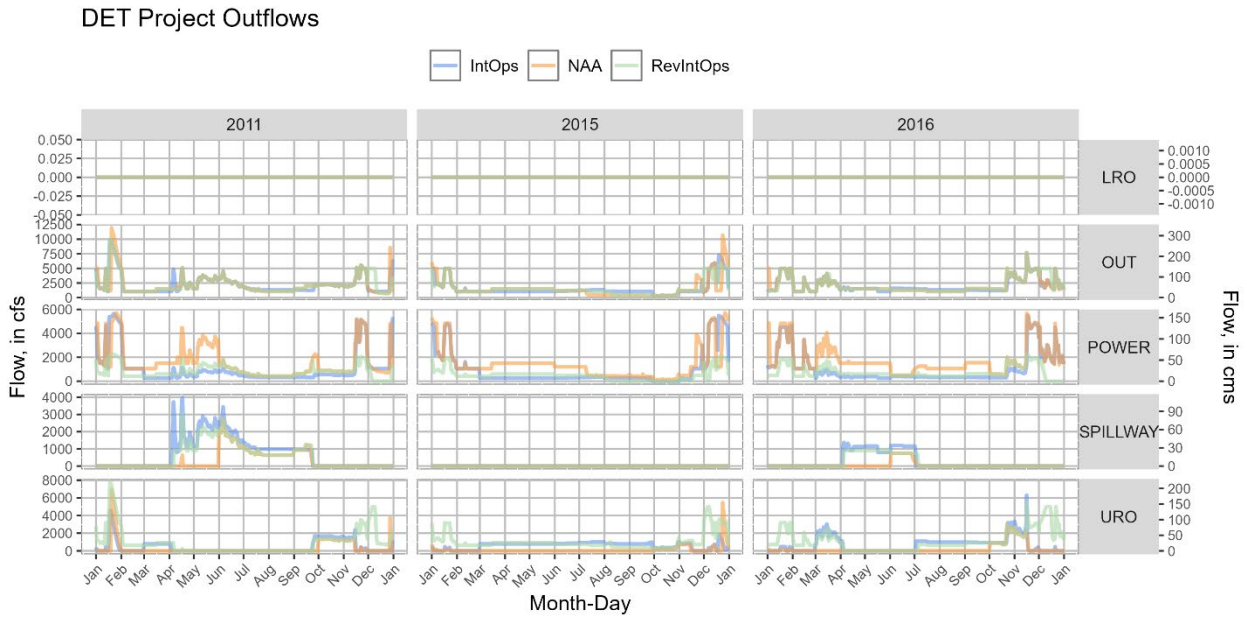


Figure 1-490. WV EIS RES-SIM Gate-Specific Outflows in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

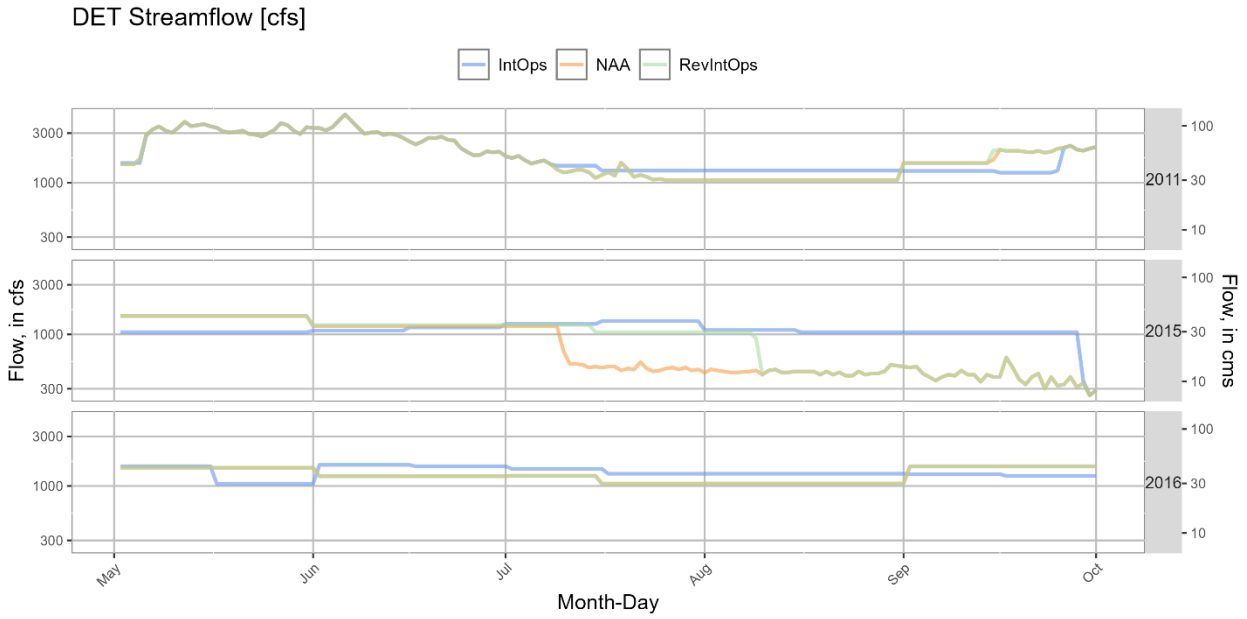


Figure 1-491. WV EIS RES-SIM Detroit Total Outflow in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

CE-QUAL-W2 Temperature

Tailwater release temperatures generally followed the temperature target similar to IntOps and NAA, aside from 2015. Some increased operational temperature management was available in

RevIntOps compared to NAA (Figure 1-492), however the spillway was not available for use in 2015 due to higher minimum flow requirements during spring (Figure 1-438, Figure 1-580). This led to warmer downstream temperature in RevIntOps during August and September of 2015 compared to IntOps and NAA (Figure 1-580).

Interim Operations includes increased spillway and RO use compared to NAA for fish passage and water temperature management. Interim Operations is compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO in Figure 1-593, Figure 1-594) in the 2011-year scenario an increase up to 3-degrees F is observed from June until October as compared to the NAA. In the 2015-year scenario a decrease of as much as 1 degree F (July) and an increase up to 7-degrees F (August-October). The 2016-year scenario was generally within 1 degree of NAA throughout the year. For the average of the three years an increase up to 2-degrees F is observed from May to September compared to the NAA.

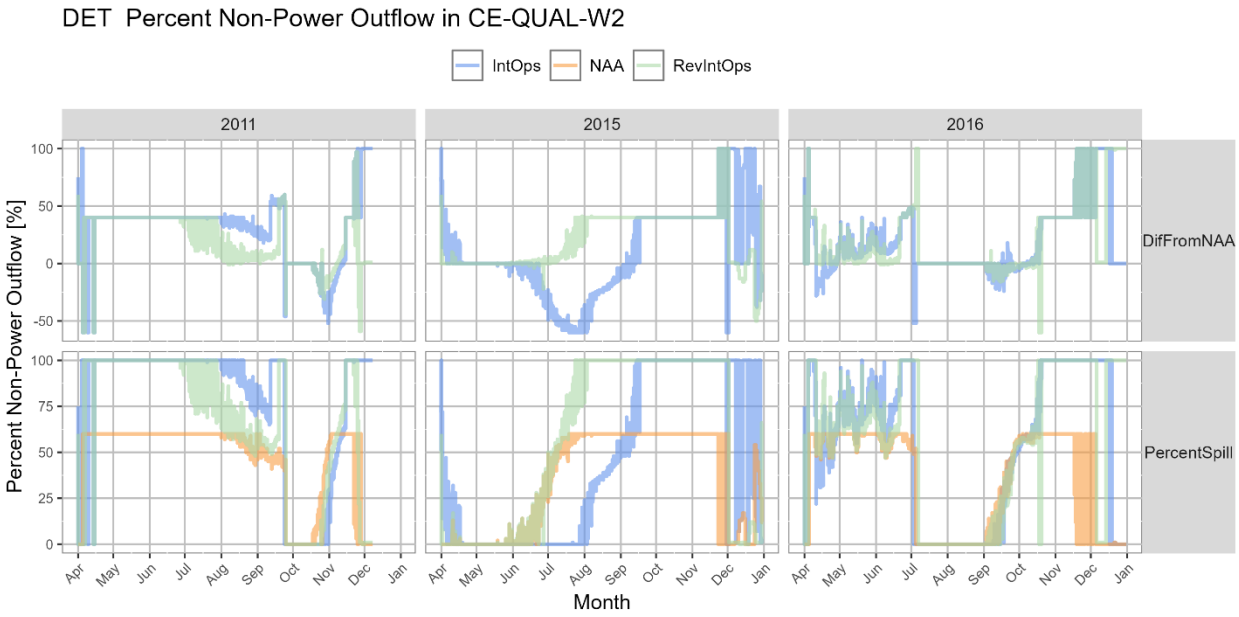


Figure 1-492. WV EIS Percent Spill Allocated in CE-QUAL-W2 Detroit Lake model for 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

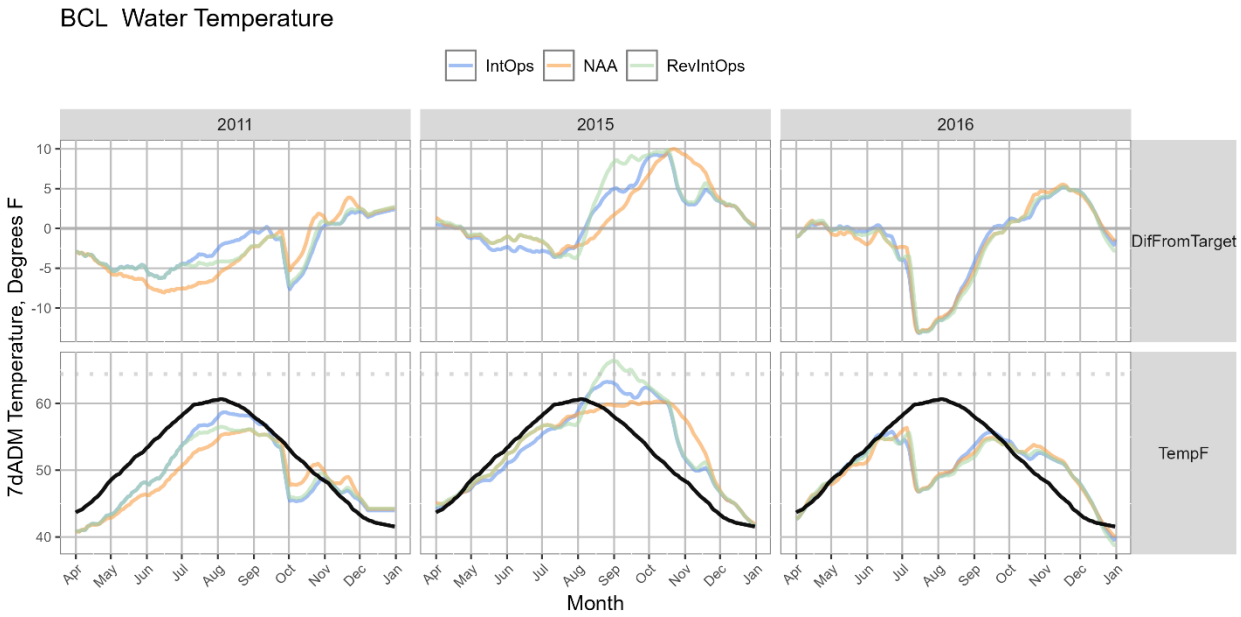


Figure 1-493. Comparison of Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028).

1.5.11.2 SOUTH SANTIAM DAMS

1.5.11.2.1 Green Peter

RES-SIM Lake Levels and Outflows

Lake level and storage at Green Peter in Interim Operations (RevIntOps) was nearly identical to Interim Operations (IntOps) and included deep drawdowns for fish passage (Figure 1-446). The proposed operational temperature management through the spillway (during spring) and RO (during autumn) in RevIntOps led to increased outflow from these outlets and decreased power outflow compared to NAA (Figure 1-447, Figure 1-448).

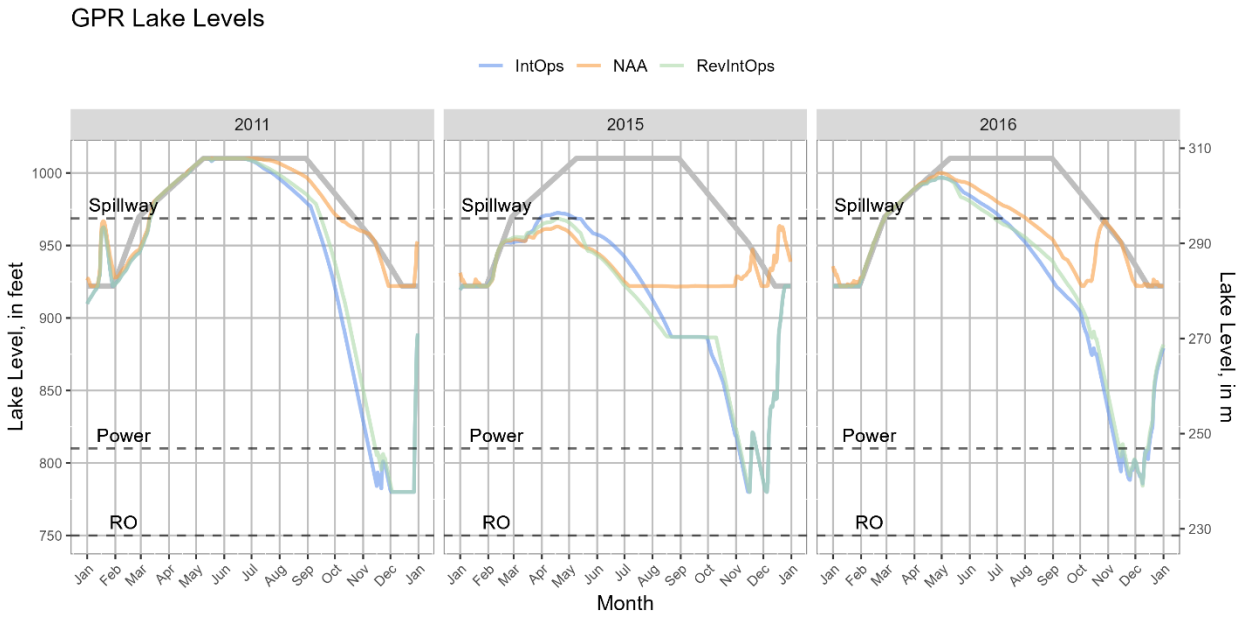


Figure 1-494 WV EIS RES-SIM Green Peter Lake Levels in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

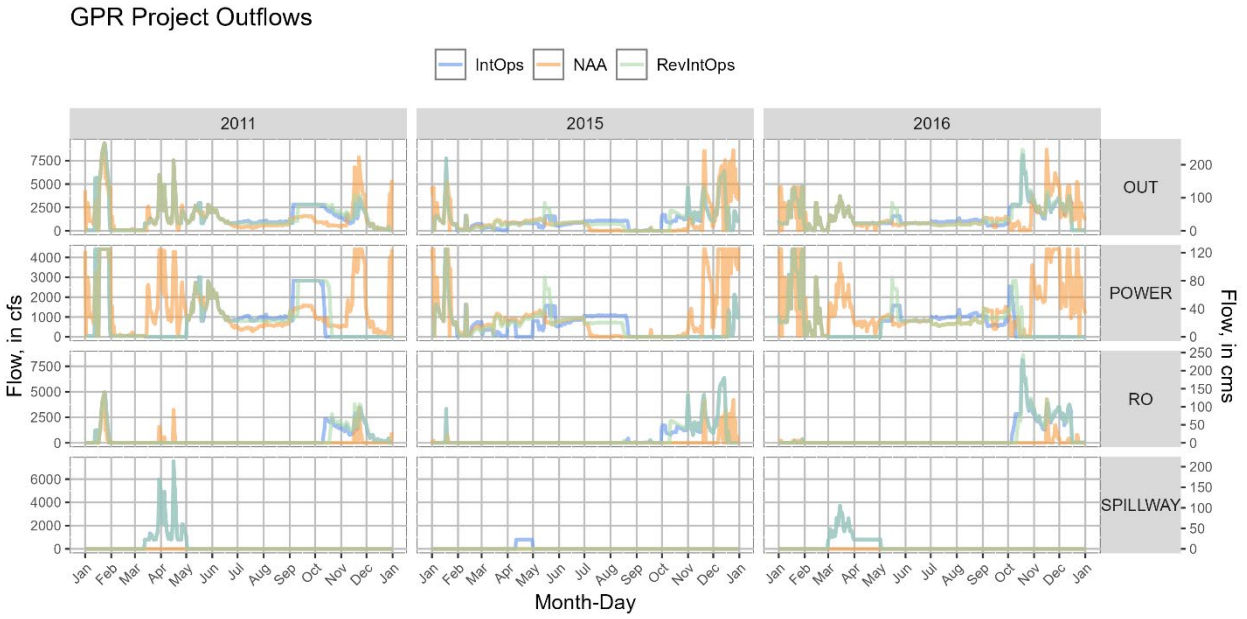


Figure 1-495. WV EIS RES-SIM Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

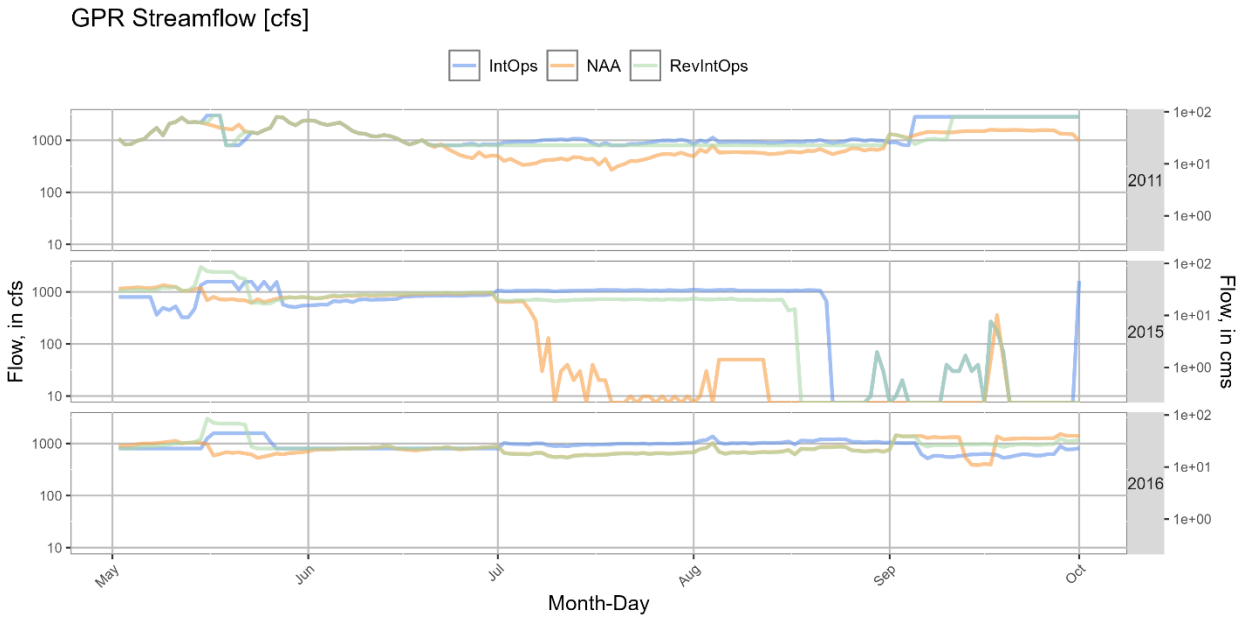


Figure 1-496. WV EIS RES-SIM Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

CE-QUAL-W2 Temperature

Interim Operations included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during autumn to mix with relatively deep power penstock releases in to meet the downstream temperature target (Figure 1-492). Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and those outlets were submerged (Figure 1-580). However, spillway access was limited in all 3 years, leading to an abrupt drop in tailwater temperature when spillway access ended in mid-summer. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermocline in Green Peter forebay.

Interim Operations is compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Santiam gaging site below Green Peter Dam (GPRO) and on the South Santiam below Foster Dam (SSFO) in (Figure 1-593, Figure 1-594). Downstream of Green Peter, temperature would generally be warmer than NAA in April-May (due to spillway use), similar to NAA in June-July, and warmer in September-October (as the epilimnion is drafted). Overall, these results are nearly identical to IntOps (see NTOM in the Final EIS, Appendix D).

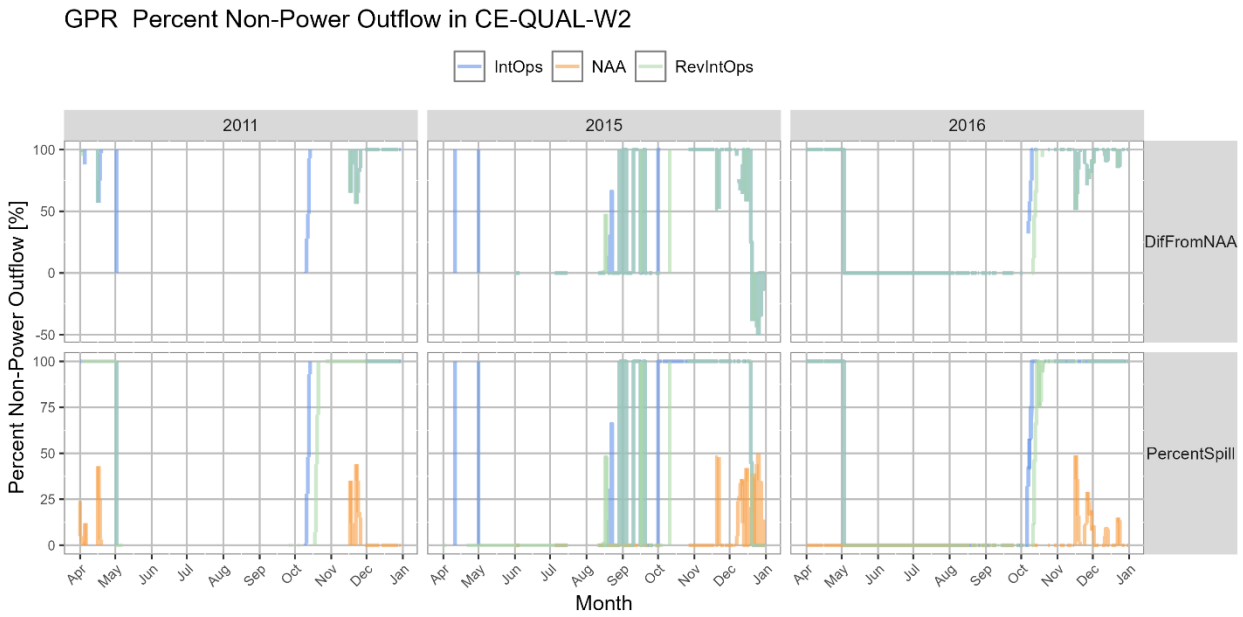


Figure 1-497. WV EIS Percent Spill Allocated in CE-QUAL-W2 Green Peter Lake model for 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

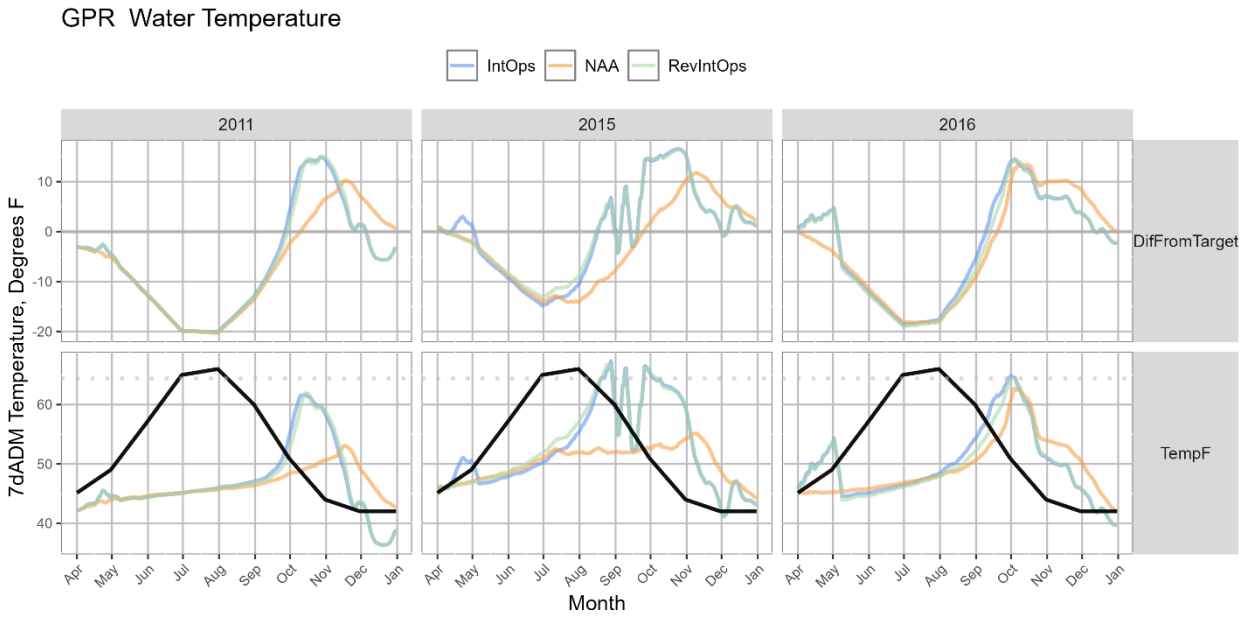


Figure 1-498. Comparison of Interim Operations (RevIntOps) for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Green Peter dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028).

1.5.11.2.2 Foster

RES-SIM Lake Levels and Outflows

Lake level and storage at Foster in Interim Operations were generally similar in 2011 and 2016 but increased in 2015 under Interim Operations compared to NAA (Figure 1-454). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam (Figure 1-456). Night-time spillway and fish weir use for fish passage and temperature management resulted in lower outflow routed through the Power outlets, especially during spring and summer, compared to NAA (Figure 1-455).

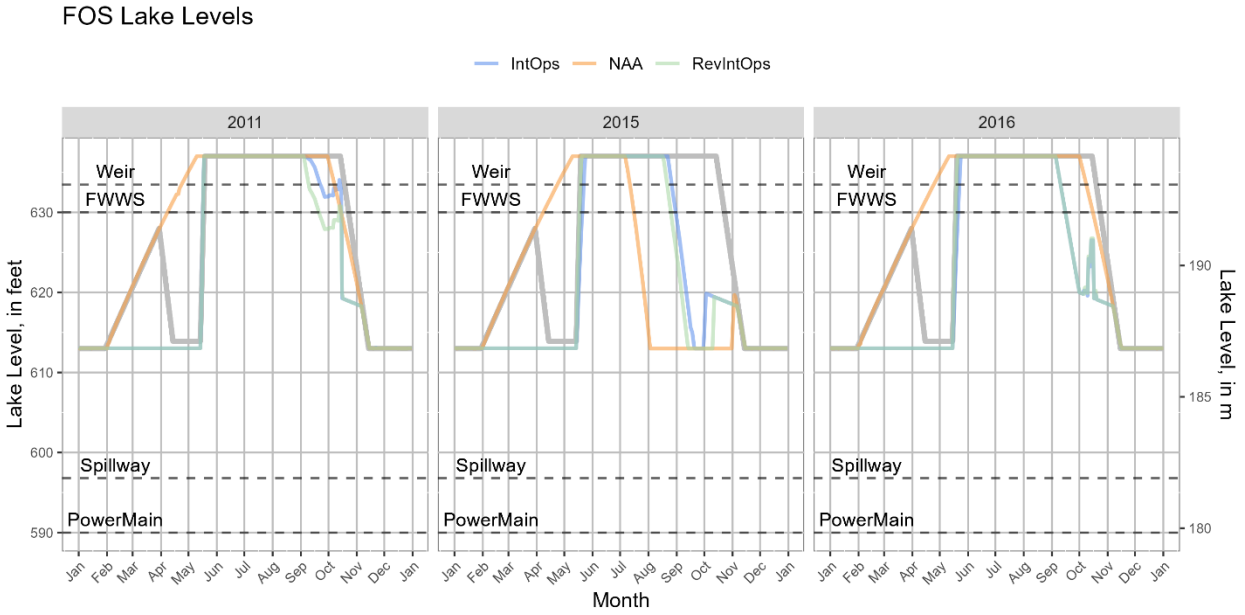


Figure 1-499 WV EIS RES-SIM Foster Lake Levels in 2011, 2015, and 2016 Under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

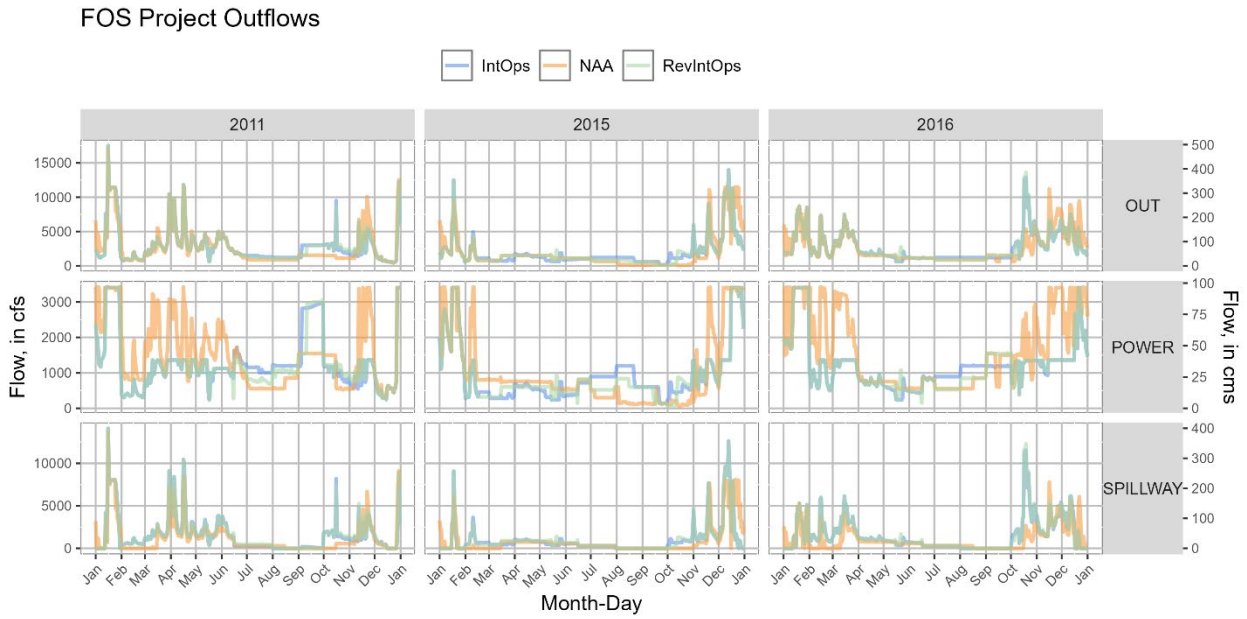


Figure 1-500. WV EIS RES-SIM Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

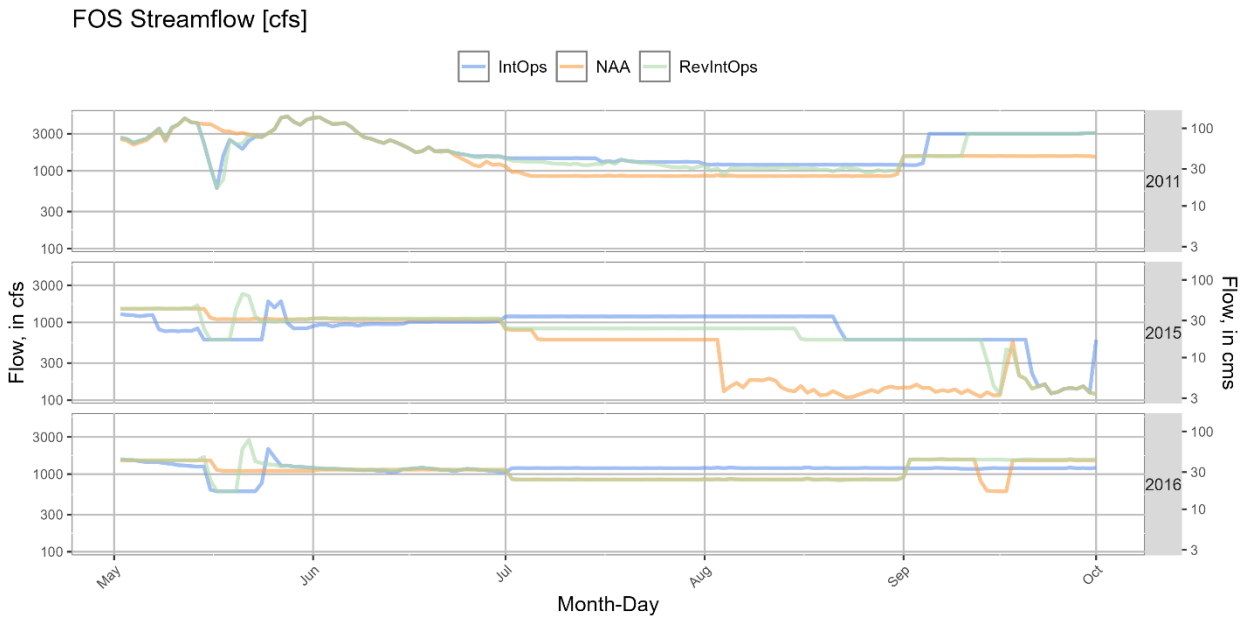


Figure 1-501. WV EIS RES-SIM Foster Dam Total Outflow in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

CE-QUAL-W2 Temperature

Overall, Foster lake simulated temperature results are nearly identical to IntOps (see NTOM in the Final EIS, Appendix D). Foster Lake temperature was affected primarily by Green Peter Dam

operations (increased spill in Interim Operations (RevIntOps)) and release temperatures (Figure 1-582), generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the temperature pattern (Sullivan and Rounds, 2021). Additionally, spillway and fish weir usage was expanded from NAA in Interim Operations for downstream fish passage and temperature control at Foster Dam.

On a monthly basis, Interim Operations was 1 to 3 degrees F warmer than NAA in April -June below Foster in 2015 and 2016 (SSFO in Figure 1-593, Figure 1-594). During the deep draft at Green Peter Dam in July-August, higher release rates from the deeper power intakes resulted in cooler temperature downstream below Foster compared to NAA (monthly values ranging from 2 to 8 degrees F cooler; Figure 1-594). Below Foster, this effect was followed immediately by warmer release rates (up to 5 degrees F on a monthly average basis compared to NAA) as the epilimnion was drafted to the power and RO intakes until this warmer water was exhausted; coinciding with the Green Peter pool level achieving the target elevation of 780 ft in late October-November. At this point in the year, release temperature below Green Peter and Foster Dams was relatively cooler than NAA due to the smaller Green Peter reservoir volume and shorter residence time.

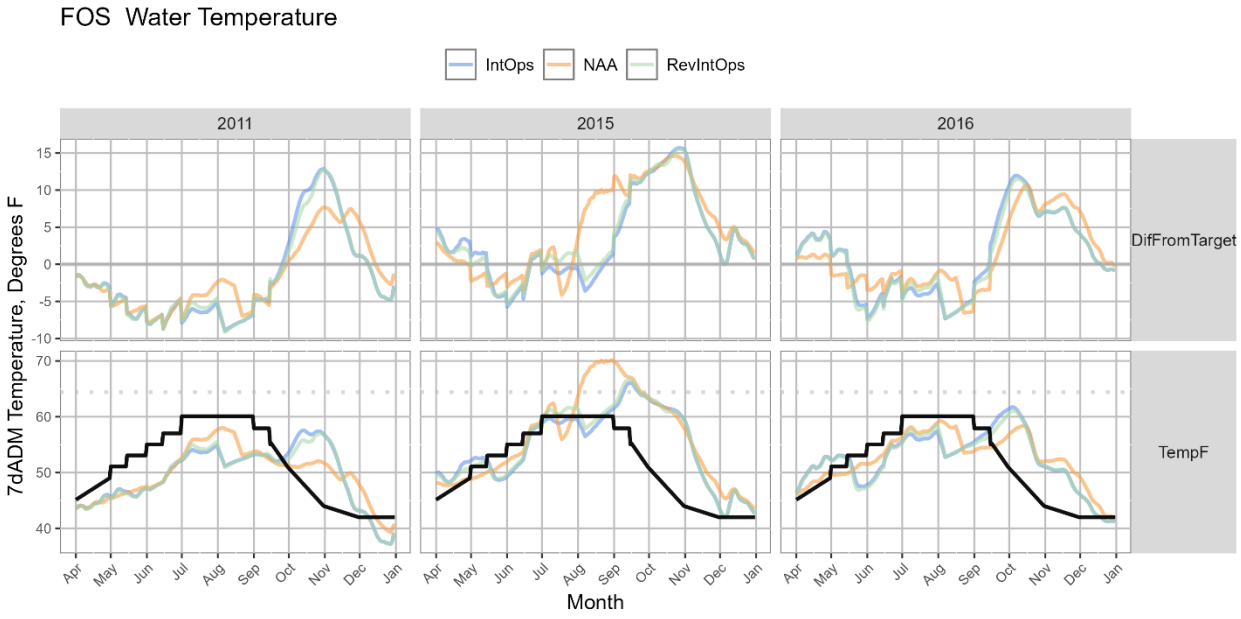


Figure 1-502. Comparison of Interim Operations (RevIntOps) for 2011, 2015, 2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028).

1.5.11.3 MCKENZIE DAMS

1.5.11.3.1 Cougar

RES-SIM Lake Levels and Outflows and CE-QUAL-W2 Temperature

Lake level and storage at Cougar in Interim Operations (RevIntOps) were nearly identical to Interim Operations (IntOps) (Figure 1-462, Figure 1-463, and Figure 1-464) and downstream simulated temperature (Figure 1-583). Further details are available in the Final EIS, Appendix D, NTOM description.

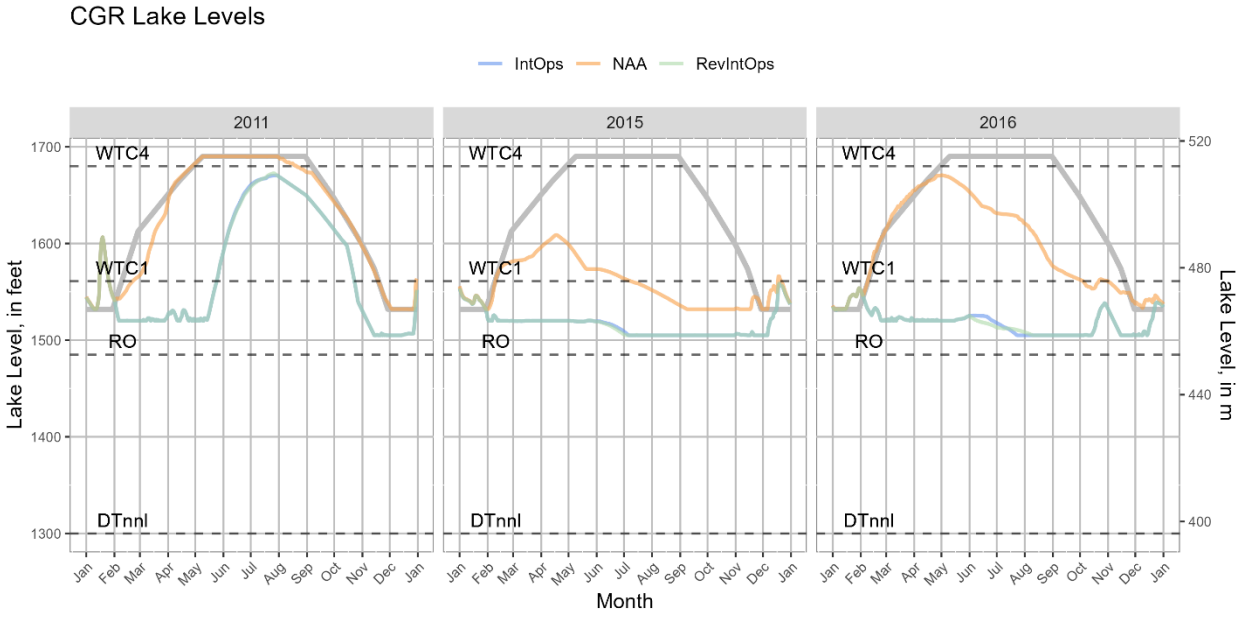


Figure 1-503 WV EIS RES-SIM Cougar Lake Levels in 2011, 2015, and 2016 Under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

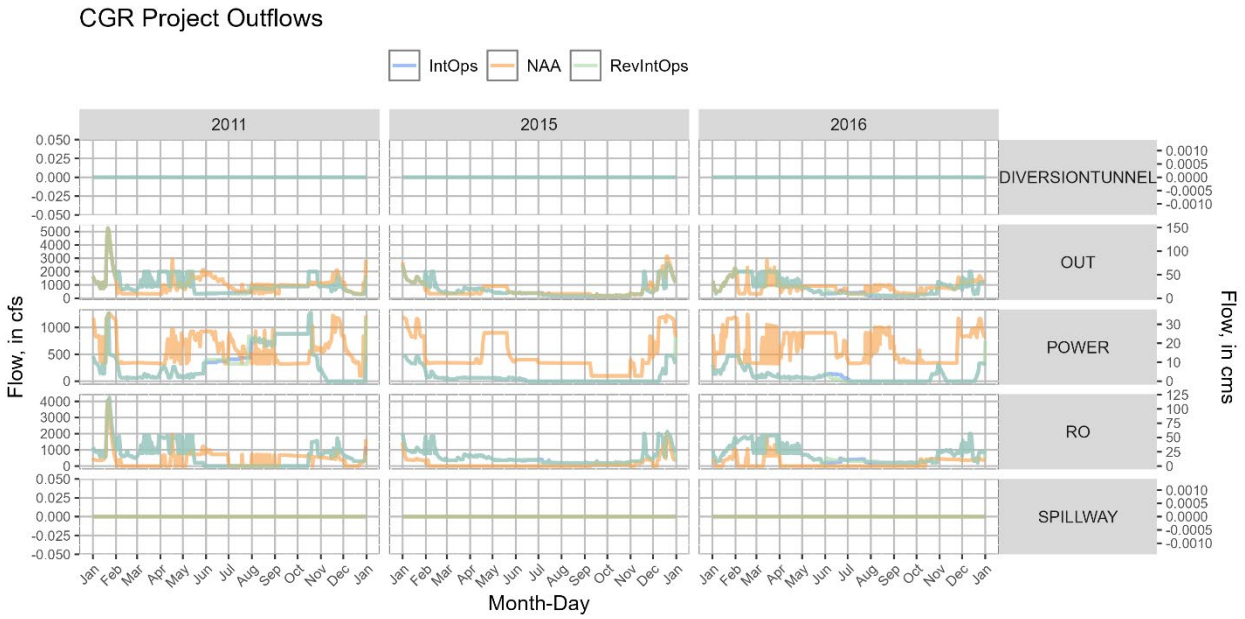


Figure 1-504. WV EIS RES-SIM Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

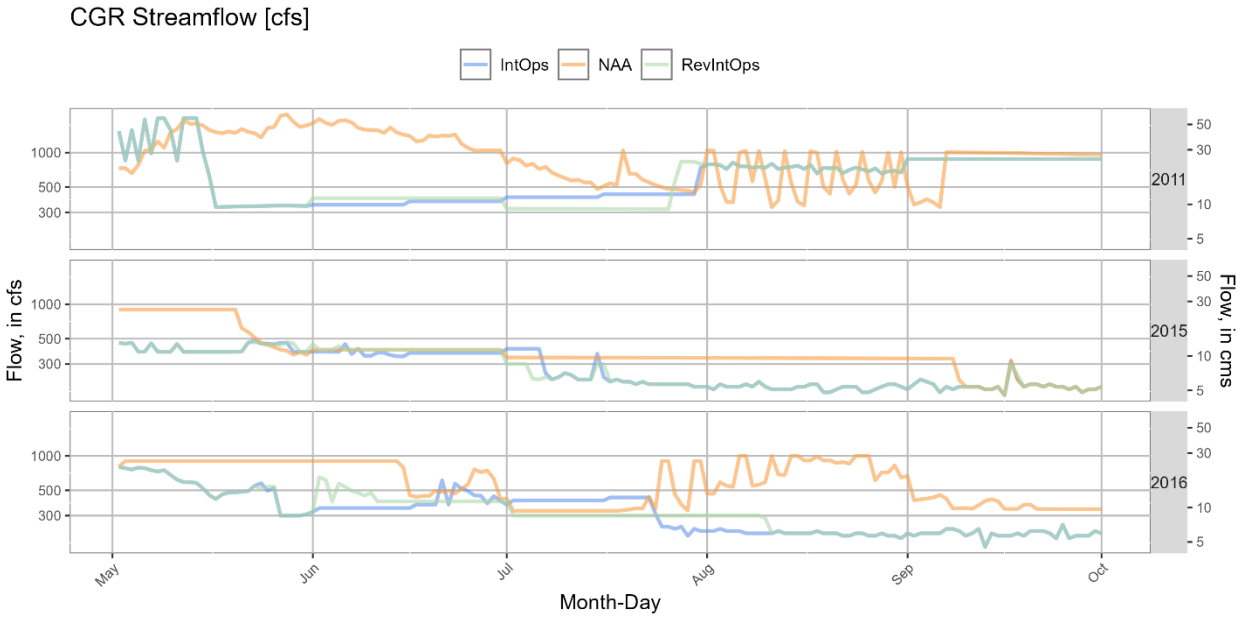


Figure 1-505. WV EIS RES-SIM Cougar Dam Total Outflow in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

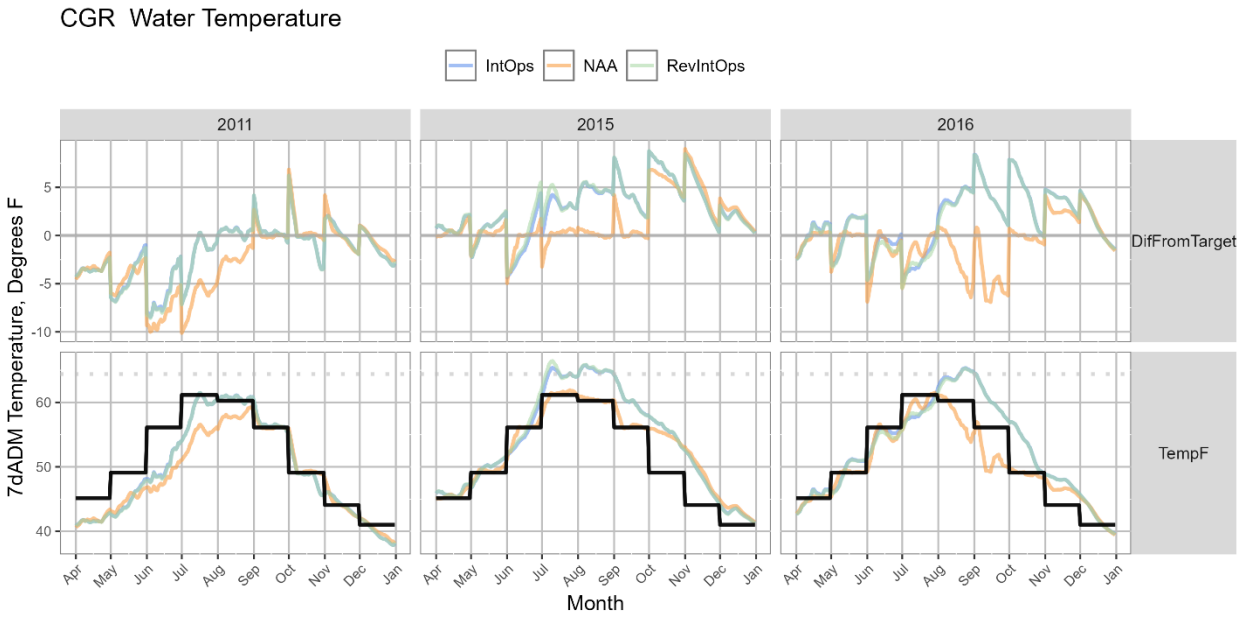


Figure 1-506. Comparison of Interim Operations (RevIntOps) for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028).

1.5.11.4 MIDDLE FORK WILLAMETTE DAMS

1.5.11.4.1 Hills Creek

RES-SIM Lake Levels and Outflows and CE-QUAL-W2 Temperature

Lake level and storage at Hills Creek in Interim Operations (RevIntOps) were nearly identical to Interim Operations (IntOps) (Figure 1-470, Figure 1-471, and Figure 1-472) and downstream simulated temperature (Figure 1-584). Further details are available in the Final EIS, Appendix D, NTOM description.

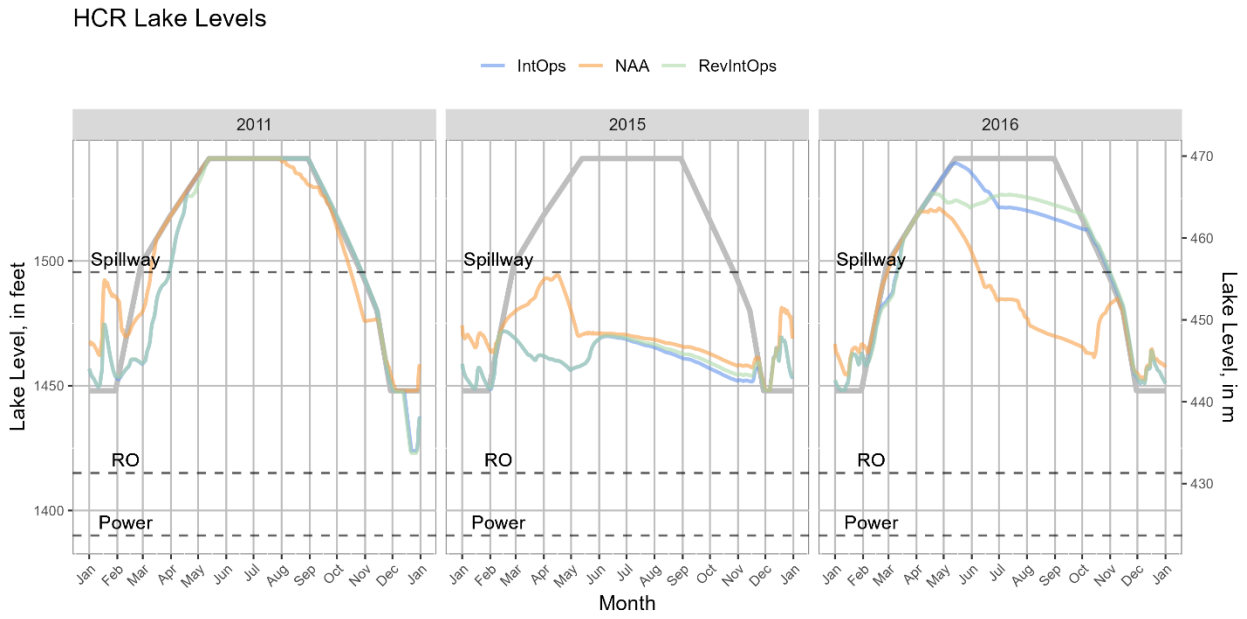


Figure 1-507 WV EIS RES-SIM Hills Creek Lake Levels in 2011, 2015, and 2016 Under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

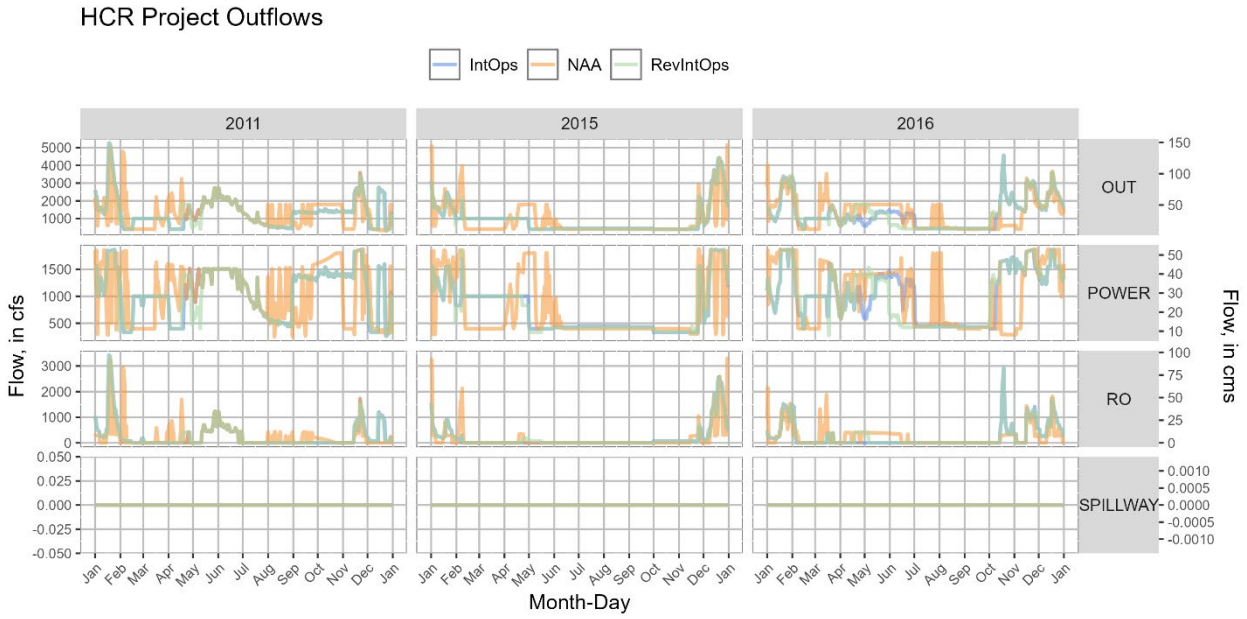


Figure 1-508. WV EIS RES-SIM Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

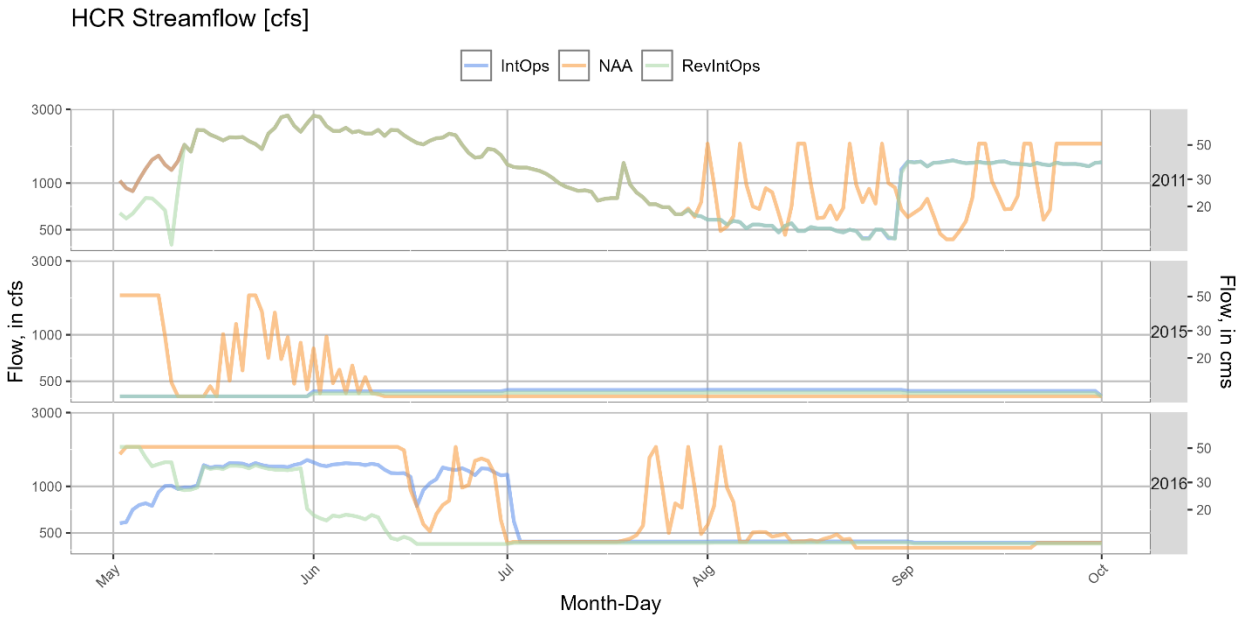


Figure 1-509. WV EIS RES-SIM Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

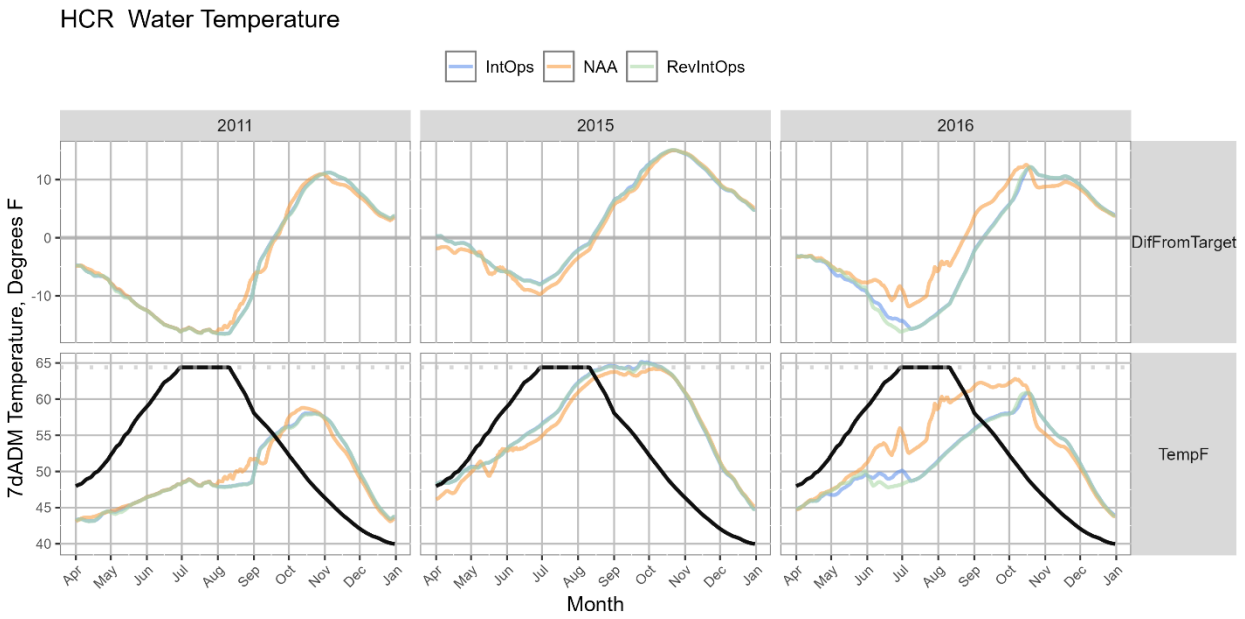


Figure 1-510. Comparison of Interim Operations (RevIntOps) for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black Line indicates simulated temperature target.

1.5.11.4.2 Lookout Point

RES-SIM Lake Levels and Outflows and CE-QUAL-W2 Temperature

Lake level and storage at Lookout Point in Interim Operations (RevIntOps) were nearly identical to Interim Operations (IntOps) (Figure 1-478, Figure 1-479, and Figure 1-480). Percentage of non-power outflow from Lookout Point Dam (Figure 1-514) and downstream simulated temperature (Figure 1-585) were very similar between RevIntOps and IntOps, resulting in less then 1 degree F difference on a monthly basis for the 3-year average (Figure 1-594). Further details are available in the Final EIS, Appendix D, NTOM description.

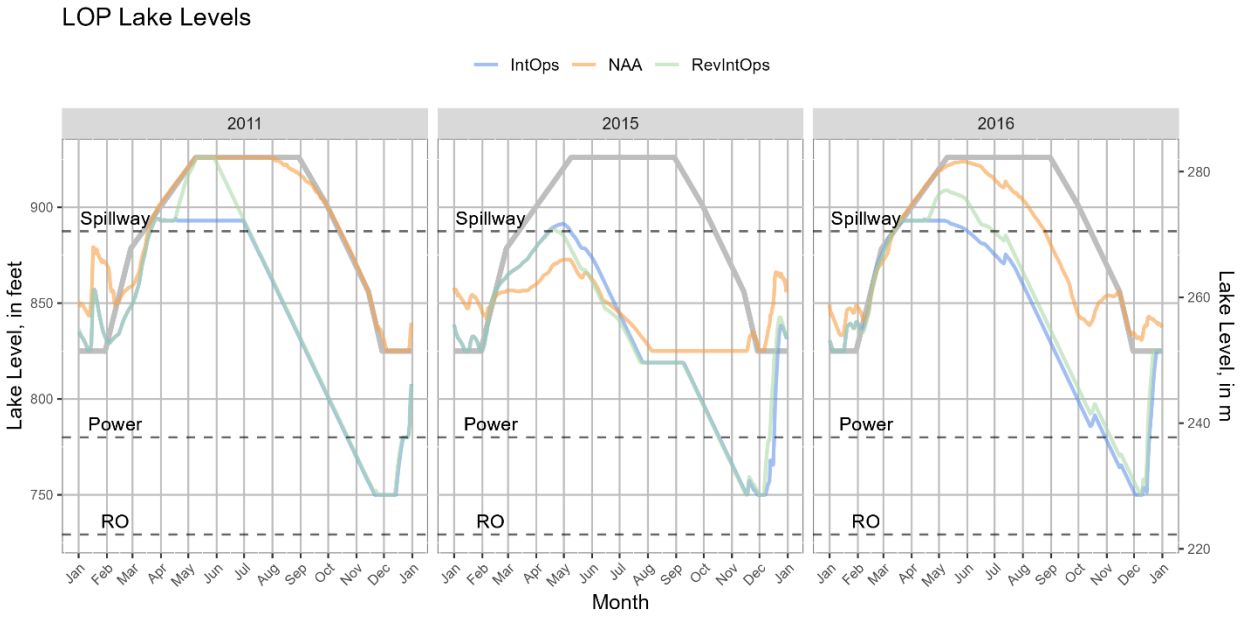


Figure 1-511 WV EIS RES-SIM Lookout Point Lake Levels in 2011, 2015, and 2016 Under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

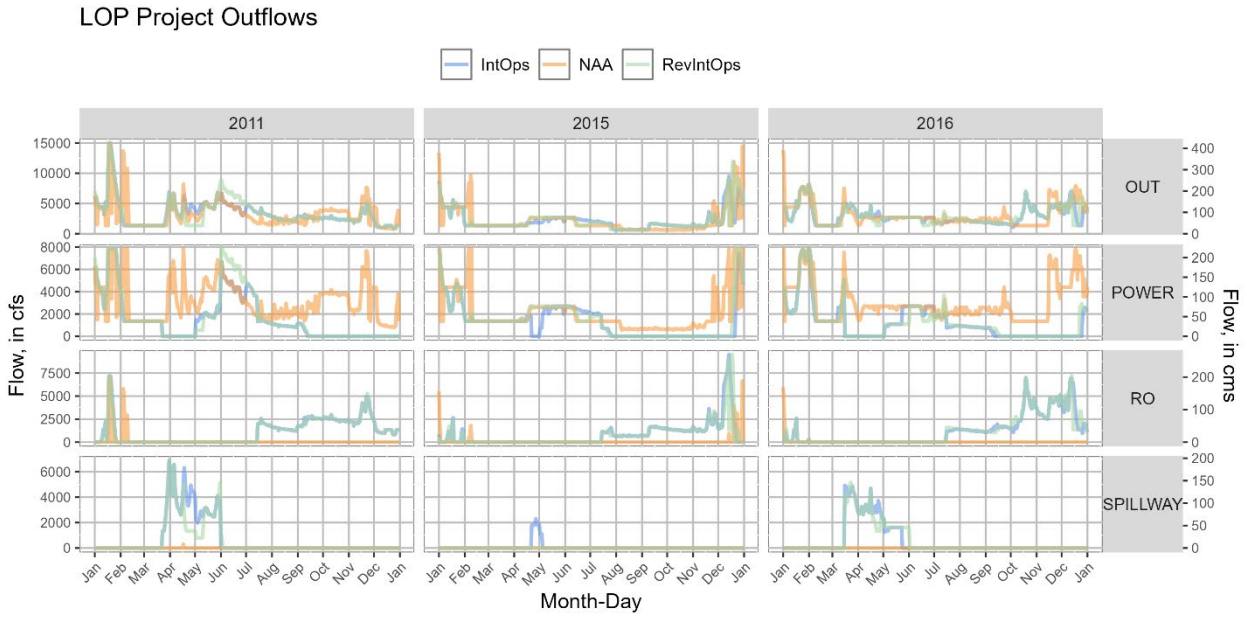


Figure 1-512. WV EIS RES-SIM Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 in Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

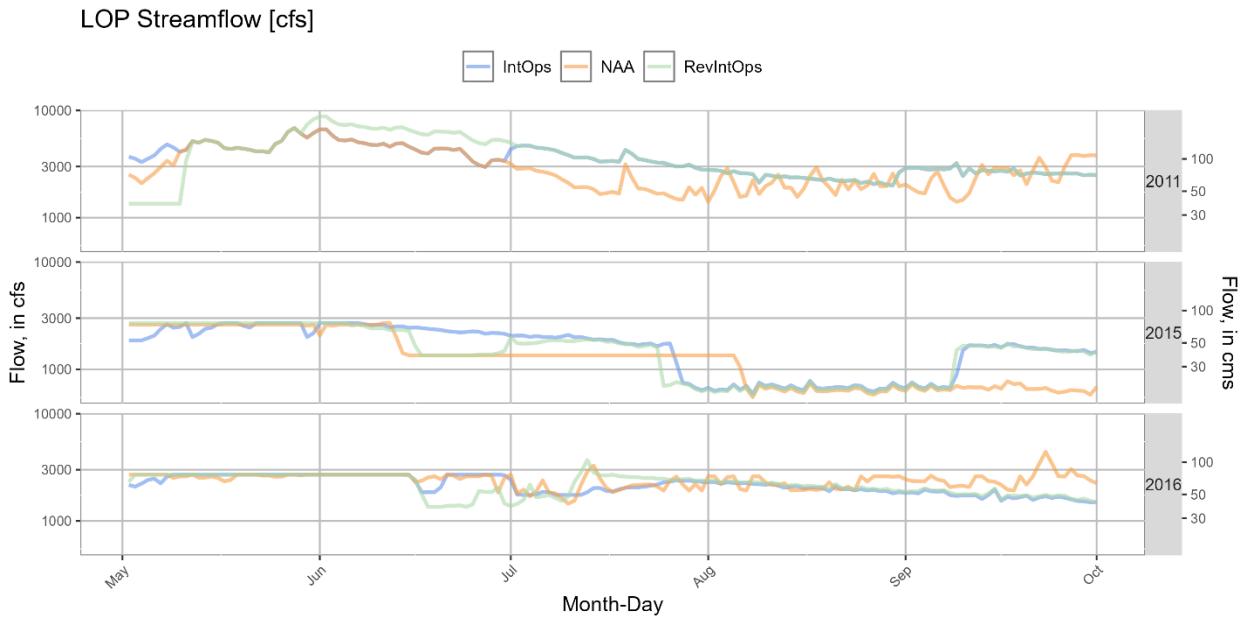


Figure 1-513. WV EIS RES-SIM Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

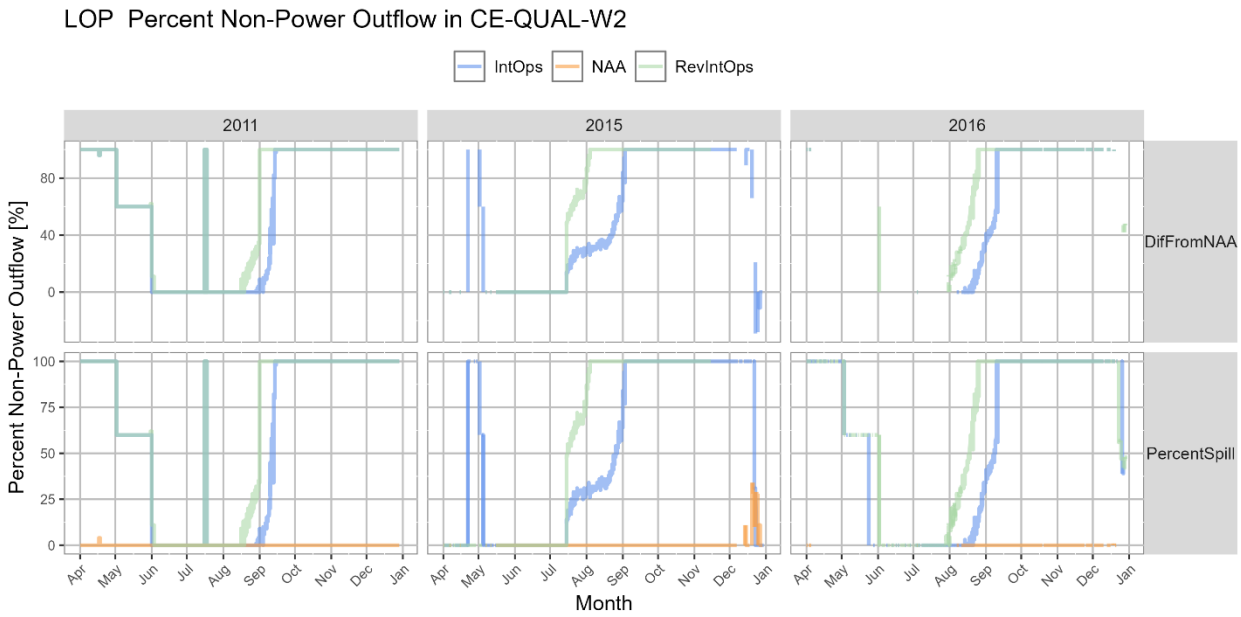


Figure 1-514. WV EIS Percent Spill Allocated in CE-QUAL-W2 Lookout Point Lake model for 2011, 2015, and 2016 under Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

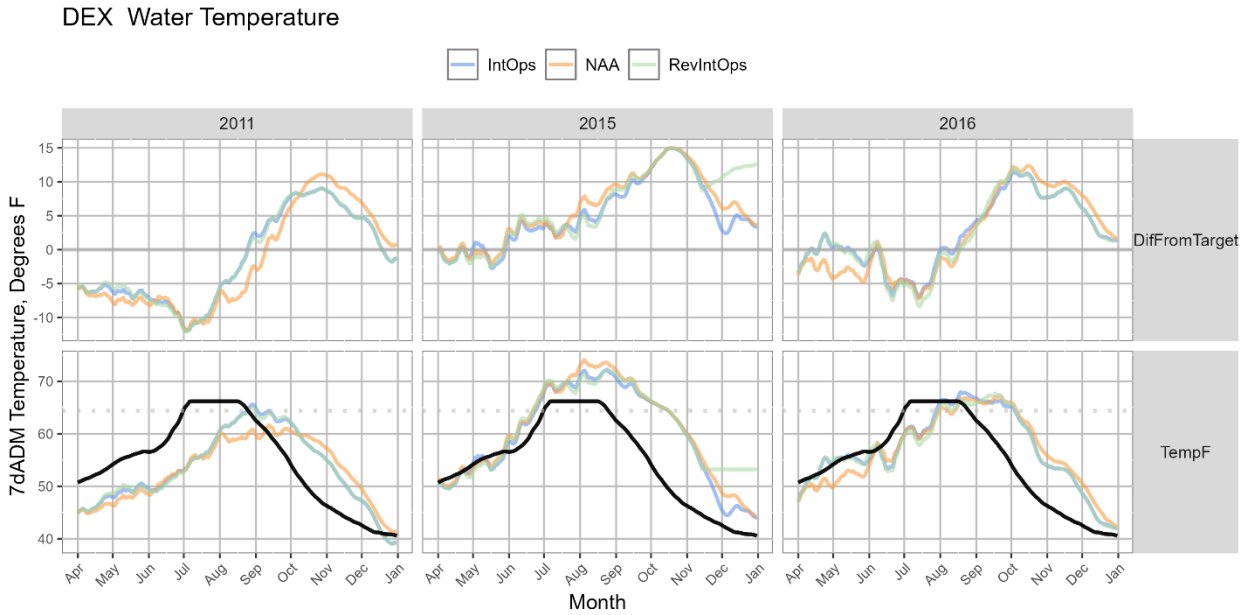


Figure 1-515. Comparison of Interim Operations (RevIntOps) for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028).

1.5.11.5 Mainstem Willamette River

Streamflow at Salem, Oregon in RevIntOps was nearly identical to NAA in 2011 and 2016. In 2015, RevIntOps streamflow was similar to NAA May-June and mid-August through October (Figure 1-486). While temperature simulations of river reaches downstream of the Willamette dams are not available for RevIntOps, results would likely be similar to those in IntOps, aside from minor potential differences in July-September of 2015. Water temperatures at Salem would also be affected by upstream dam operations, notably at Green Peter and Foster Dams, where summer and autumn downstream temperatures may be warmer compared to IntOps and NAA. However, the potential effect of South Santiam temperature may have a minimal effect downstream at Salem, where streamflow in RevIntOps would be greater than NAA and likely be less susceptible to downsstream heating. Overall water temperature differences between RevIntOps and NAA are likely to be less than 2 degrees F on a monthly basis, similar to those seen in RevIntOps (see Final EIS, Appendix D, NTOM for more details).

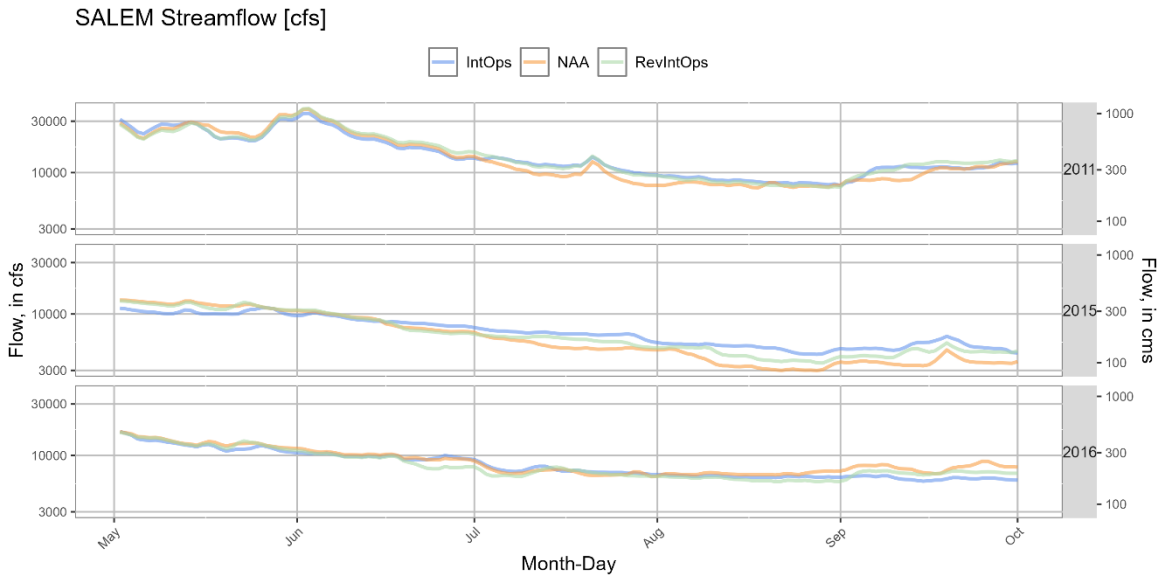


Figure 1-516. Streamflow Comparison Between Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA at Willamette River at SLMO.

1.6 SUPPORTING DATA FOR WATER QUALITY EFFECTS ANALYSIS

This section provides the figures and tables that represent the water temperature results for the WV EIS Chapter 3.5.3 Water Quality Effects Analysis. Refer to that chapter and section for explanations and interpretation of results for each alternative.

To assess impacts under each Alternative, the hourly water temperature below each dam was used to calculate the 7-day Average of the Daily Max (7dADM) water temperature. The 7dADM water temperature was then compared to the temperature targets at each location. Simulated water temperatures were evaluated and compared relative to NAA using the following metrics

based on the 3-year average of 2011, 2015, and 2016 (the calendar years available from CE-QUAL-W2 modeling):

- **Days Near Temperature Target:** Number of days in which the 7dADM water temperature was within 2 degrees F of the temperature target during **two** time frames: April-August and September-March, as well as the entire year. Temperature targets used in this analysis are those applied in the CE-QUAL-W2 model (discussed in Section 2.1.1), which are largely based on historical pre-dam conditions. In most cases, this provides an ideal reference point for the natural thermal regime. However, note that the temperature target at Cougar (CGRO) is the 2008 BiOp target (RA target) and is warmer than the simulations during deep drafting of Cougar Reservoir in some alternatives (2b, 3b, 5). See Figure 1-517 and Table 1-8 for annual values at each location, year, and alternative. See Figure 1-518 for differences from NAA at each location, year, and alternative.

Summer Extremes: Number of days in which the 7dADM water temperature is below 18 °C or 64.4 °F. The 18 °C thresholds correspond to the Oregon State biologically based numeric Water Quality Temperature Standard for salmon and trout rearing and migration (OAR 340-041-0028) and represents "Optimal" conditions for juveniles and adult Chinook salmon in Koch, et al., (2020). See Figure 1-519 and

Table 1-9 for values at each location, year, and alternative. See Figure 1-520 for differences from NAA at each location, year, and alternative.

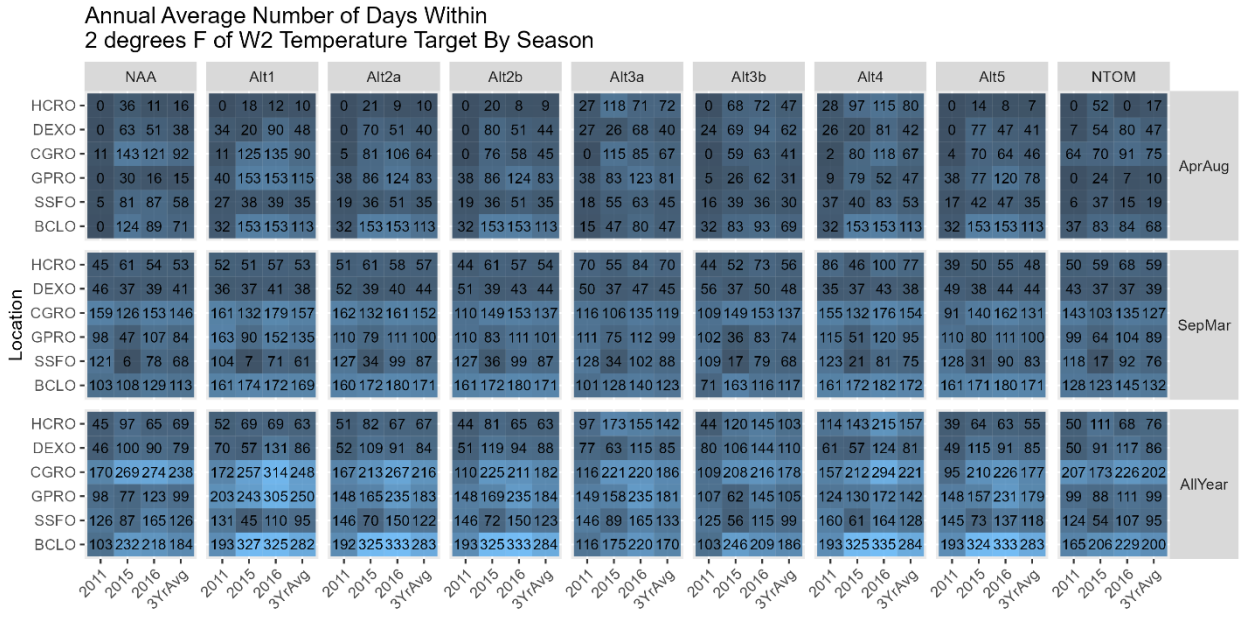


Figure 1-517. Annual number of days within 2°F of Temperature target April-August (top row of tables), September-March (middle row of tables), and all year (bottom row of tables). Explanation: "3YrAvg" = three-year average

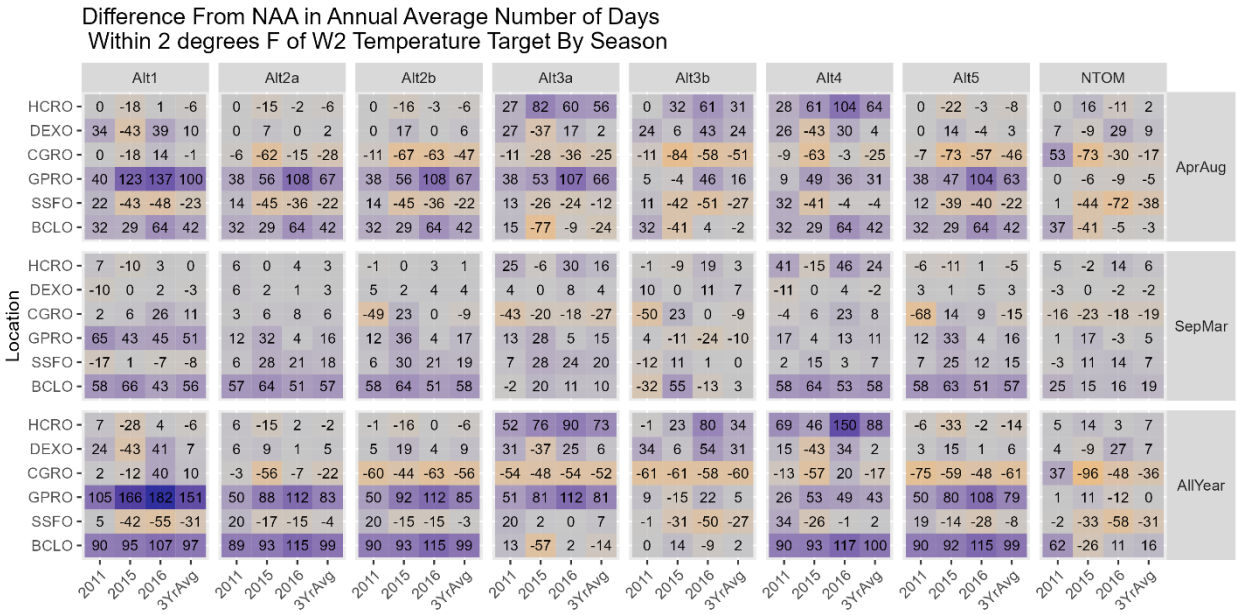


Figure 1-518. Difference, compared to NAA, in annual number of days within 2°F of Temperature target April-August (top row of tables), September-March (middle row of tables), and all year (bottom row of tables). Explanation: "3YrAvg" = three-year average

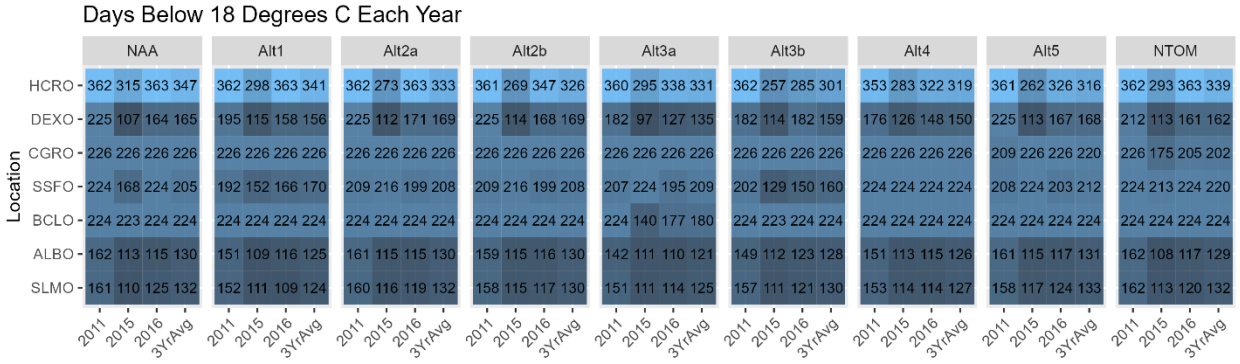


Figure 1-519. Days Below 18 Degrees C (64.4 Degrees F) in Each Year. Explanation: "3YrAvg" = three-year average.

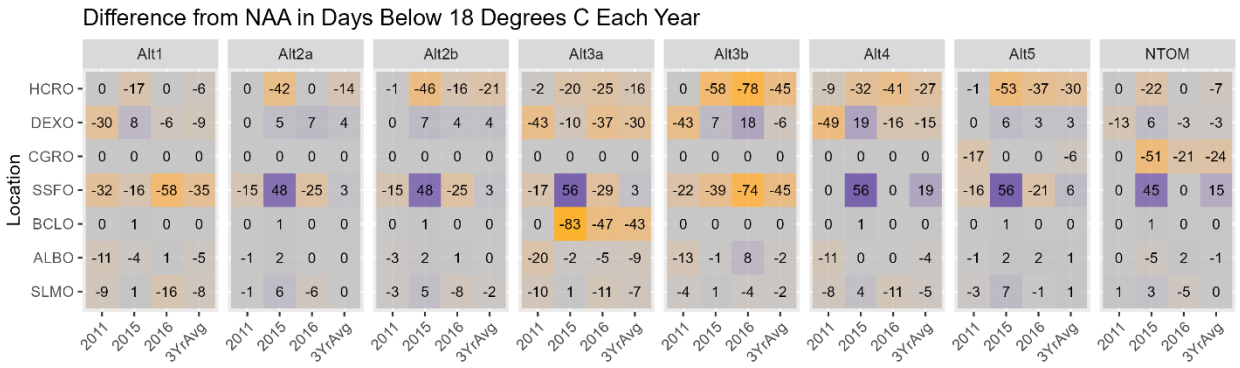


Figure 1-520. Difference, compared to NAA, in Days Below 18 Degrees C (64.4 Degrees F) in Each Year. Explanation: "3YrAvg" = three-year average.

Table 1-8. Average Annual Days Within 2 Degrees F of Temperature Target.

Location	NAA	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NTOM
HCRO	69	63	67	63	142	103	157	55	76
DEXO	79	86	84	88	85	110	81	85	86
CGRO	238	248	216	182	186	178	221	177	202
SSFO	126	95	122	123	133	99	128	118	95
GPRO	99	250	183	184	181	105	142	179	99
BCLO	184	282	283	284	170	186	284	283	200

Table 1-9. Average Days Below 18 Degrees C (64.4 Degrees F) per Year.

Location	NAA	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NTOM
HCRO	347	341	333	326	331	301	319	316	339
DEXO	165	156	169	169	135	159	150	168	162
CGRO	226	226	226	226	226	226	226	220	202
SSFO	205	170	208	208	209	160	224	212	220
BCLO	224	224	224	224	180	224	224	224	224
ALBO	130	125	130	130	121	128	126	131	129
SLMO	132	124	132	130	125	130	127	133	132

Simulated water temperatures were also used to calculate the estimated chinook egg emergence relative to NAA in 2011, 2015, and 2016 based on accumulated thermal units (ATUs; "degree-days"). While this metric was not used to evaluate thermal effects in the WV EIS, it is provided here for context. Early emergence has been known to lead to mortality due to the excessive flows, abundant predators, or insufficient resources experienced by juvenile salmon that hatch early (Jensen and Johnsen 1999; Einum and Flemming, 2000). The ATU calculation begins on the presumed day when eggs are in the gravel (Sep 01, Sep 20, Oct 1) and is

accumulated until the degree-day reaches 1750°F—day ATUs. For determining impacts under each WV EIS alternative, averages of the three spawn dates (Sep 01, Sep 20, and Oct 1) were used (Figure 1-521).

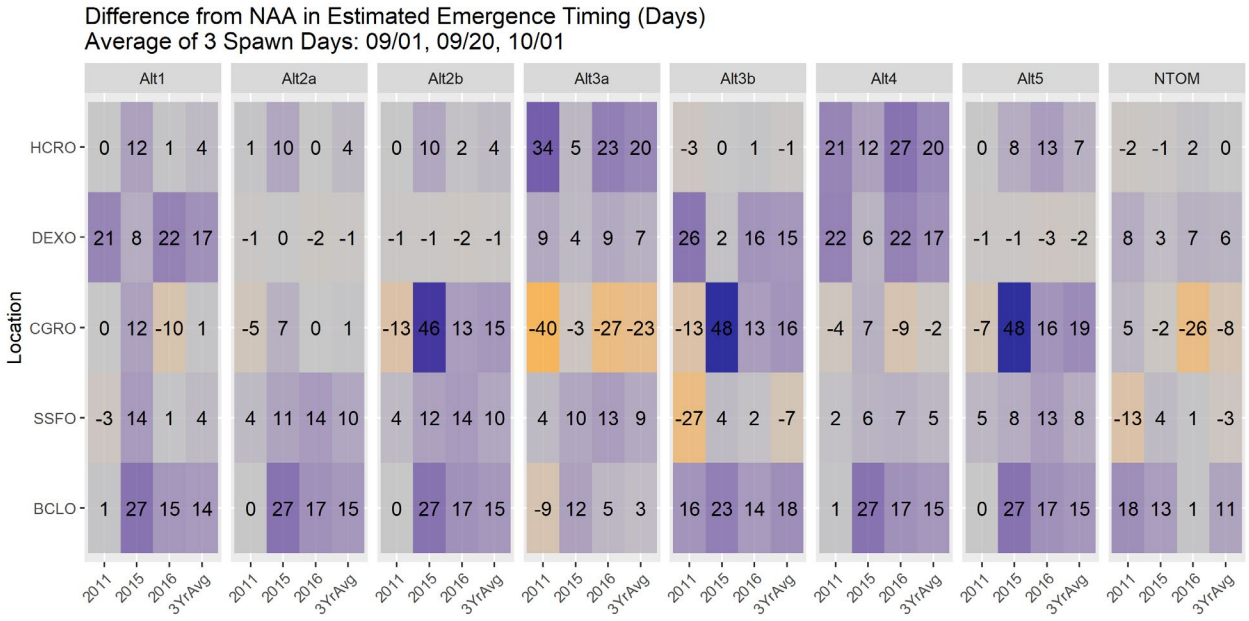


Figure 1-521. Difference in estimated chinook egg emergence timing relative to NAA (Alternative - NAA), in days.

1.6.1 No Action Alternative

Summary tables of NAA monthly mean water temperature is shown for each of the three simulated years in Figure 1-522.

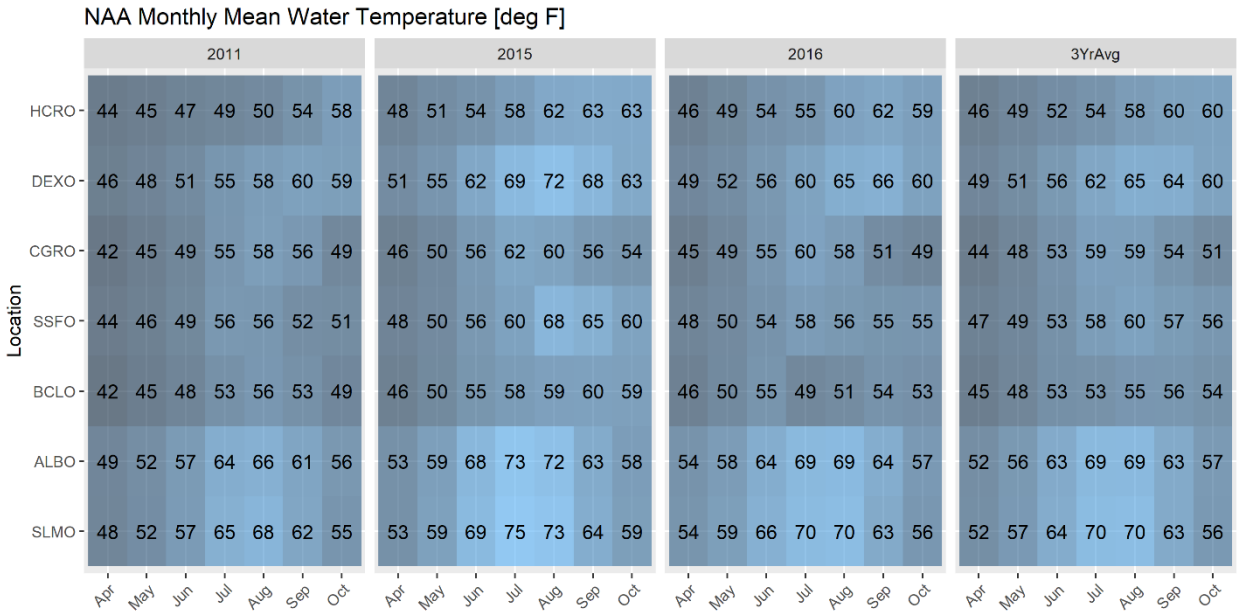


Figure 1-522. Simulated No Action Alternative Monthly Mean Water Temperature (deg F) in 2011, 2015, 2016, and average of these 3 years (3YrAvg).

1.6.1.1 North Santiam Dams

At Detroit Dam, the spillway gates are used to release warmer surface water in the spring and summer in the NAA. This helps to limit the amount of warmer water accumulated during summer and eventually released in the fall each year as the lake is drafted. Seven-day average of daily max water temperature in NAA downstream of Detroit and Big Cliff dams (BCLO) would generally be cooler than the temperature target for most of the year (April – October) in the 2011-year scenario (Figure 1-523). In the 2015-year scenario, water temperatures would follow the temperature target April – August, then exceed the target Sep-Dec. In the 2016-year scenario water temperatures would generally be cooler than the temperature target for most of the year (April – September), then exceed the target October-December.

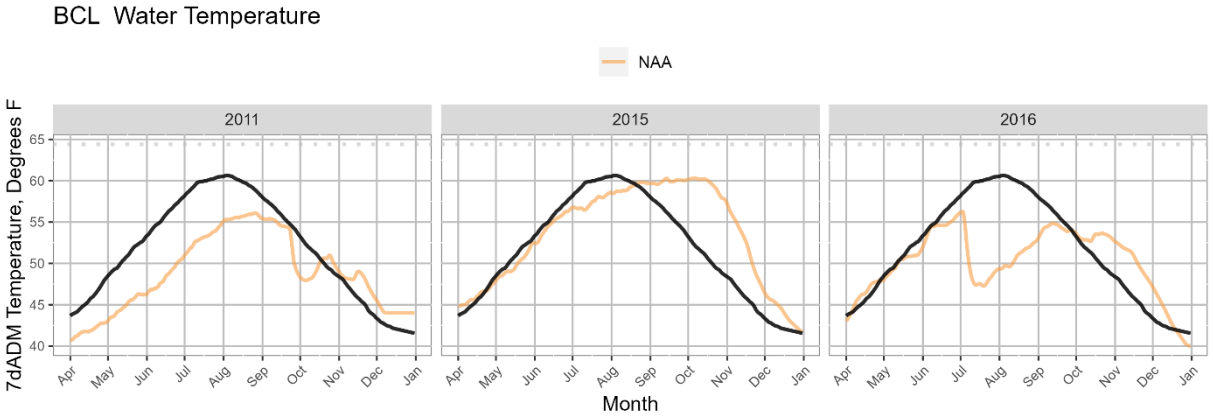


Figure 1-523. Comparison of NAA 7dADM temperature (Degrees F) for 2011,2015,2016 downstream of Big Cliff dam. Black line indicates temperature target.

1.6.1.2 South Santiam Dams

There are limited temperature control capabilities at Green Peter Dam in the NAA, so warm surface water accumulated during summer is eventually released in the fall in each year as the lake is drafted. At Foster Dam, there are spillway and weir operations that can help in releasing warmer, more seasonal surface water during the summer. Seven-day average of daily max water temperature in NAA downstream of Green Peter and Foster dams would generally be cooler than the temperature target April – September, then exceed the target October-December in the 2011 and 2016-year scenarios (Figure 1-524). In the 2015-year scenario, water temperatures would follow the temperature target April – July, then exceed the target Sep-Dec.

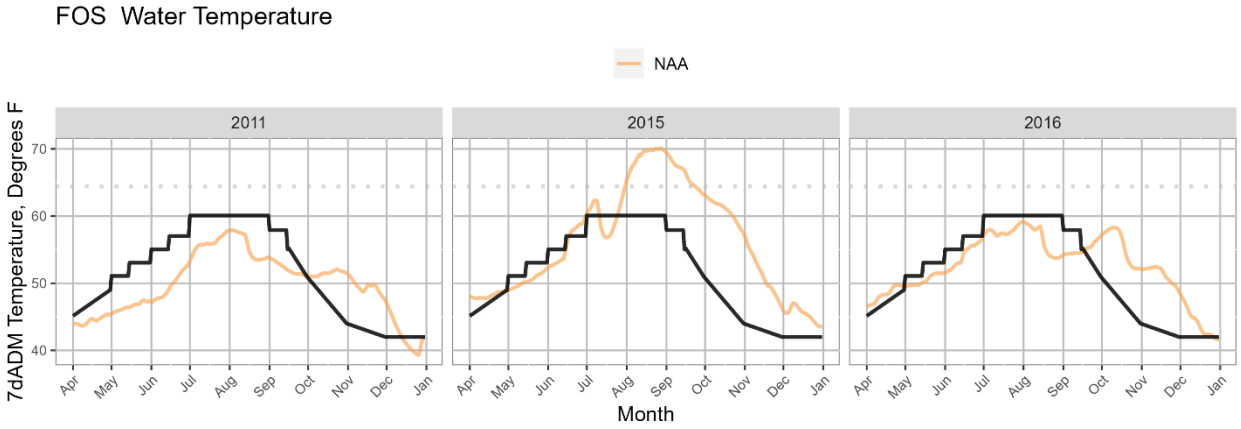


Figure 1-524. Comparison of NAA 7dADM temperature (Degrees F) for 2011,2015,2016 downstream of Foster dam. Black line indicates temperature target.

1.6.1.3 McKenzie Dams

Seven-day average of daily max water temperature in NAA downstream of Cougar dam would generally be cooler than the temperature target April – September, then match the target September-December in the 2011-year scenarios (Figure 1-525). In the 2015-year scenario, water temperatures would follow the temperature target April – September, then exceed the target October-December. In the 2016-year scenario, water temperatures would generally be at or below the temperature target April – October, then exceed the target November-December.

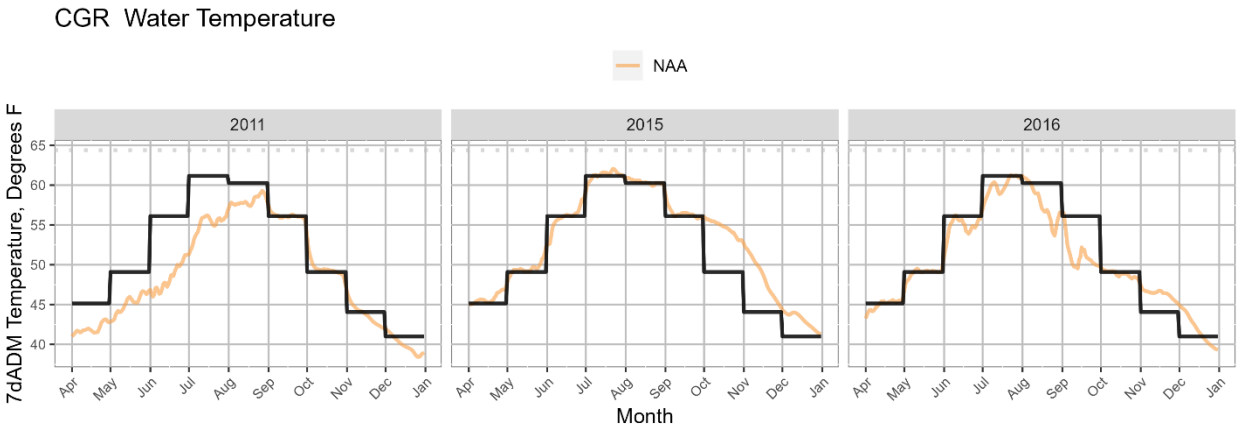


Figure 1-525. Comparison of NAA 7dADM temperature (Degrees F) for 2011,2015,2016 downstream of Cougar dam. Black line indicates temperature target.

1.6.1.4 Middle Fork Willamette Dams

There are limited temperature control capabilities at Hills Creek Dam in the NAA, so warm surface water accumulated during summer is eventually released in the fall each year as the lake is drafted. Seven-day average of daily max water temperature in NAA downstream of Hills Creek dam would generally be cooler than the temperature target April – September, then exceed the target October-December in the 2011-year scenario (Figure 1-526). In the 2015-year scenario, water temperatures would be cooler than the temperature target April – July, then exceed the target August - December. In the 2016-year scenario, water temperatures would be cooler than the temperature target April – July, then exceed the target August - December.

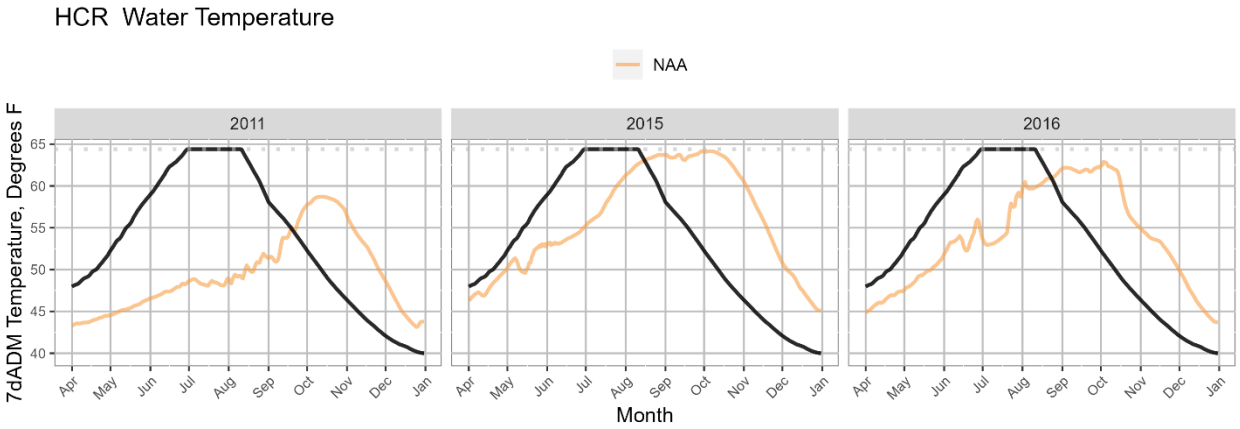


Figure 1-526. Comparison of NAA 7dADM temperature (Degrees F) for 2011,2015,2016 downstream of Hills Creek dam. Black line indicates temperature target.

There are limited temperature control capabilities at Lookout Point and Dexter Dams in the NAA, so warm surface water accumulated during summer is eventually released in the fall in each year as the lake is drafted. Seven-day average of daily max water temperature in NAA downstream of Dexter dam would generally be cooler than the temperature target April – August, then exceed the target about October-December in the 2011-year scenario (Figure

1-526). In the 2015-year scenario, water temperatures would exceed the temperature target June - December. In the 2016-year scenario, water temperatures would be cooler than the temperature target April – July, then exceed the target about August - December.

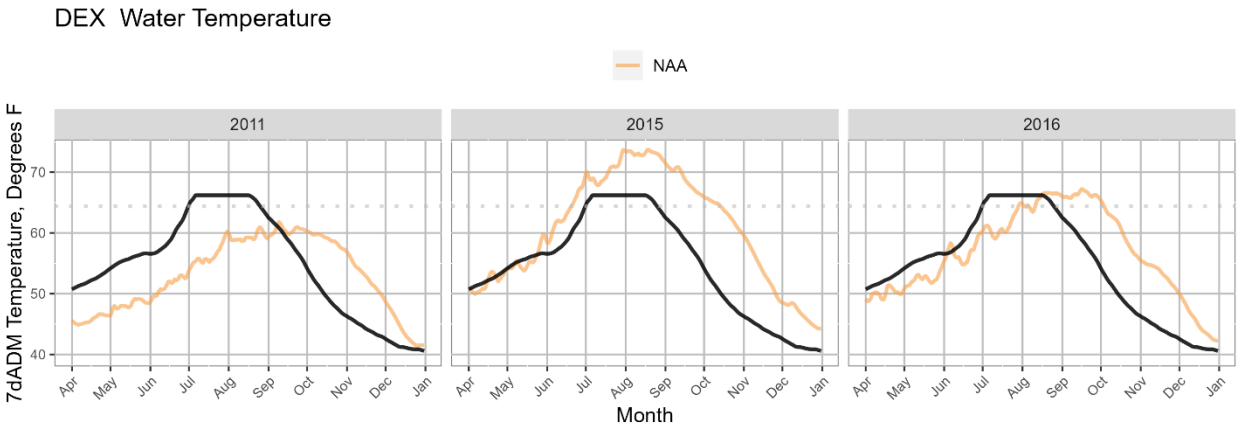


Figure 1-527. Comparison of NAA 7dADM temperature (Degrees F) for 2011,2015,2016 downstream of Dexter dam. Black line indicates temperature target.

1.6.2 Alternative 1 – Project Storage Alternative

Summary tables of Alternative 1 monthly mean water temperature and monthly mean difference between Alternative 1 and NAA for each of the three simulated years are shown in Figure 1-528 and Figure 1-529, respectively.

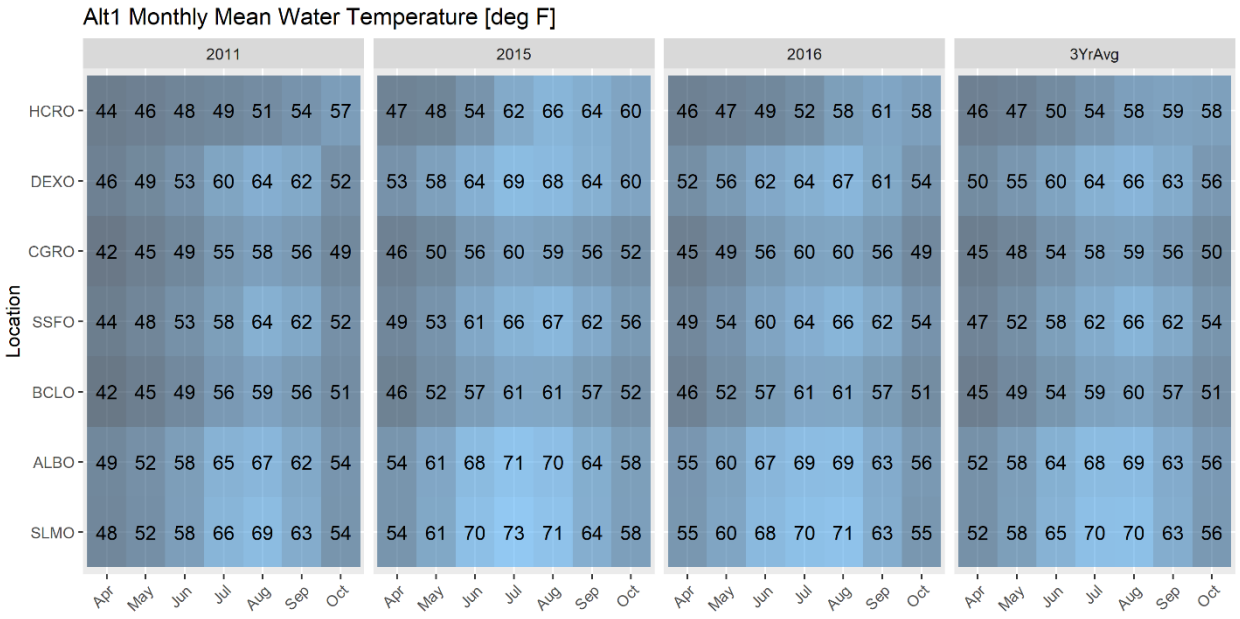


Figure 1-528. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 1.

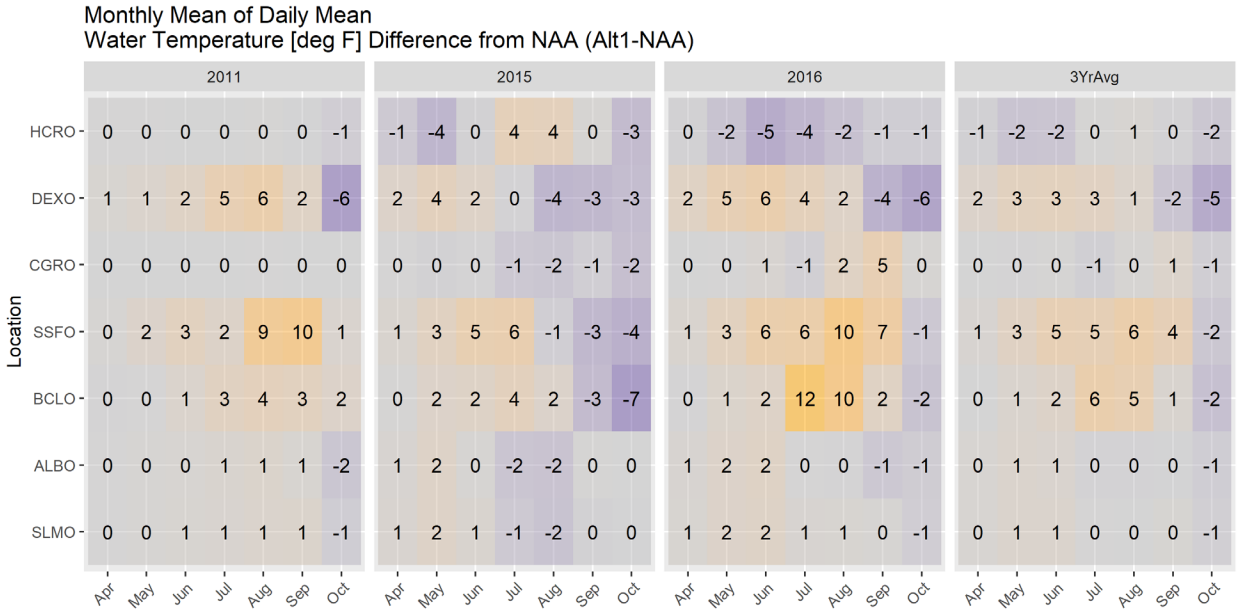


Figure 1-529. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 1.

1.6.2.1 North Santiam Dams

Alternative 1 as compared to the NAA (Figure 1-528; Figure 1-529*)* downstream of Detroit and Big Cliff dams (BCLO) would in the 2011-year scenario see water temperature increase up to 4 degrees starting in June through October (Figure 1-530). In the 2015-year scenario, water temperatures would increase 2 to 3 degrees from May to August and then decrease of 4 to 7 degrees in September to October. In the 2016-year scenario water temperatures would increase 2 to 12 degrees from May to September and then decrease by 2 degrees in October. For the Average of the three years water temperatures would increase 1 to 6 degrees from May to September and then decrease by 2 degrees in October.

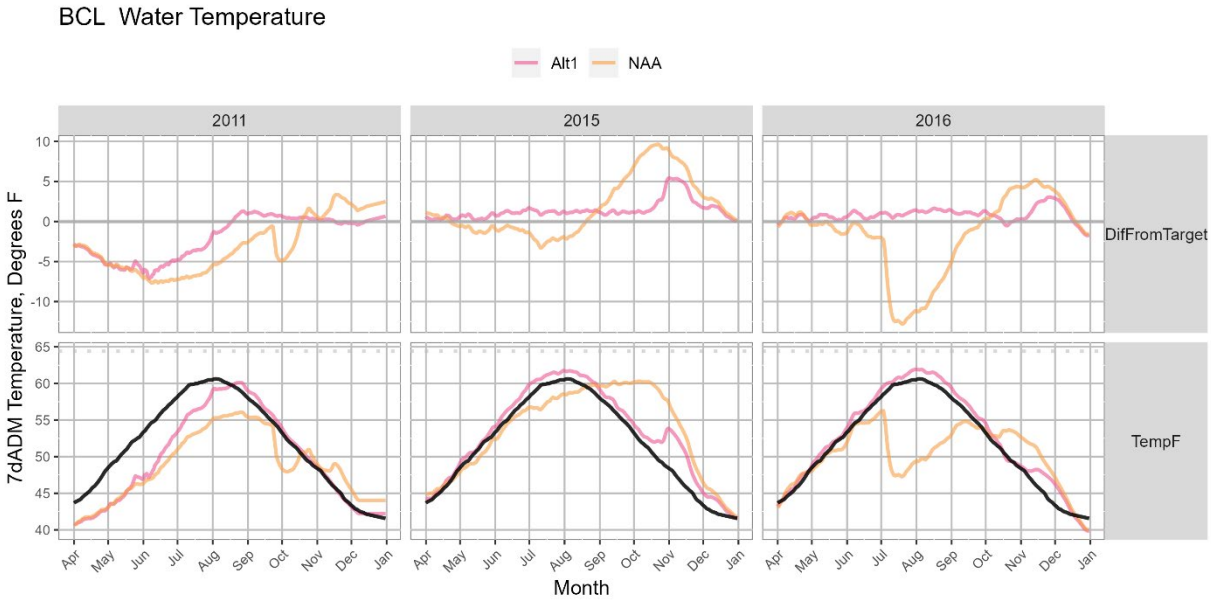


Figure 1-530. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. Black line indicates temperature target.

1.6.2.2 South Santiam Dams

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO; Figure 1-531; Figure 1-529) in the 2011-year scenario would see an increase starting in May through October up to 10 degrees. In the 2015-year scenario, water temperatures increase of 1 to 5 degrees from April to July and then decrease from 2 to 4 degrees from August to October. In the 2016-year scenario water temperatures increase up to 10 degrees from April to September and then decrease by 1 degree in October. For the Average of the three years (2011, 2015, 2016) water temperatures increase 1 to 6 degrees from April through September and then decrease by 2 degrees in October.

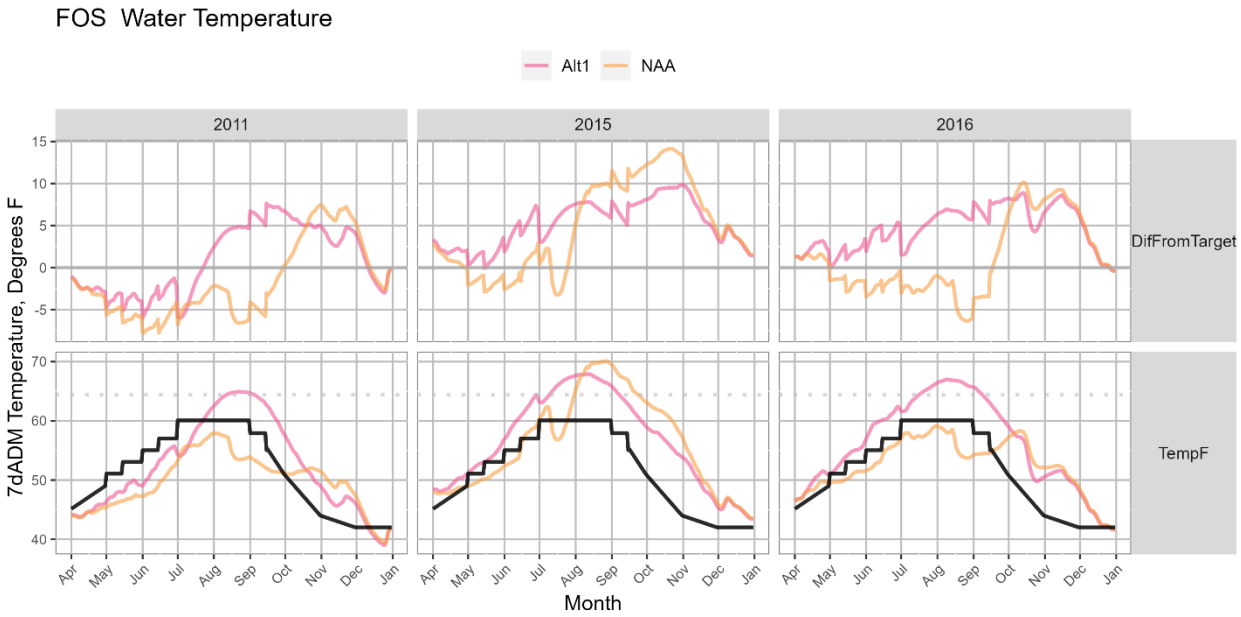


Figure 1-531. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam. Black line indicates temperature target.

1.6.2.3 McKenzie Dams

In the 2011-year scenario there would be no temperature difference at the South Fork McKenzie River near Rainbow site (CGRO; Figure 1-528; Figure 1-529; Figure 1-532) compared to the NAA. In the 2015-year scenario a decrease up to 2 degrees from July to October would occur under Alternative 1. In the 2016-year scenario a decrease is observed up to 1 degree in July and increase of 5 degrees in September is observed. For the Average of the three years (2011, 2015, 2016) a 1 degree temperature decrease is observed in July and October, an increase of 1 degree is observed in September.

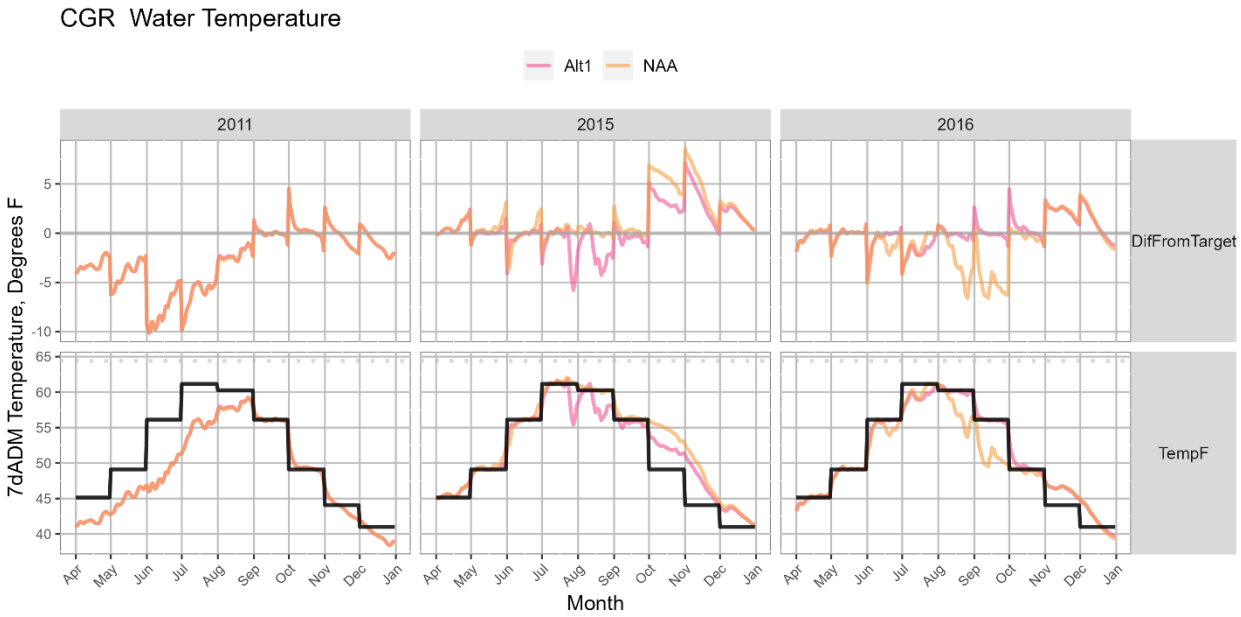


Figure 1-532. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black line indicates temperature target.

1.6.2.4 Middle Fork Willamette Dams

Alternative 1 includes a Water Temperature Control tower at Lookout Point to better regulate downstream temperatures to Dexter reservoir. Results are also compared to the NAA the Monthly Mean water temperatures (deg F) at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-528; Figure 1-529) In the 2011-year scenario, temperatures increase starting in May through September up to 6 degrees (Figure 1-534) and decrease by 6 degrees in October. In the 2015-year scenario: increase up to 4 degrees from April to June and then decrease by 4 degrees from July to October. In the 2016-year scenario an increase up to 6 degrees from April to August and then decrease by 6 degrees in October. For the Average of the three years (2011, 2015, 2016): increase up to 3 degrees from April to August and then decrease by 5 degrees in October.

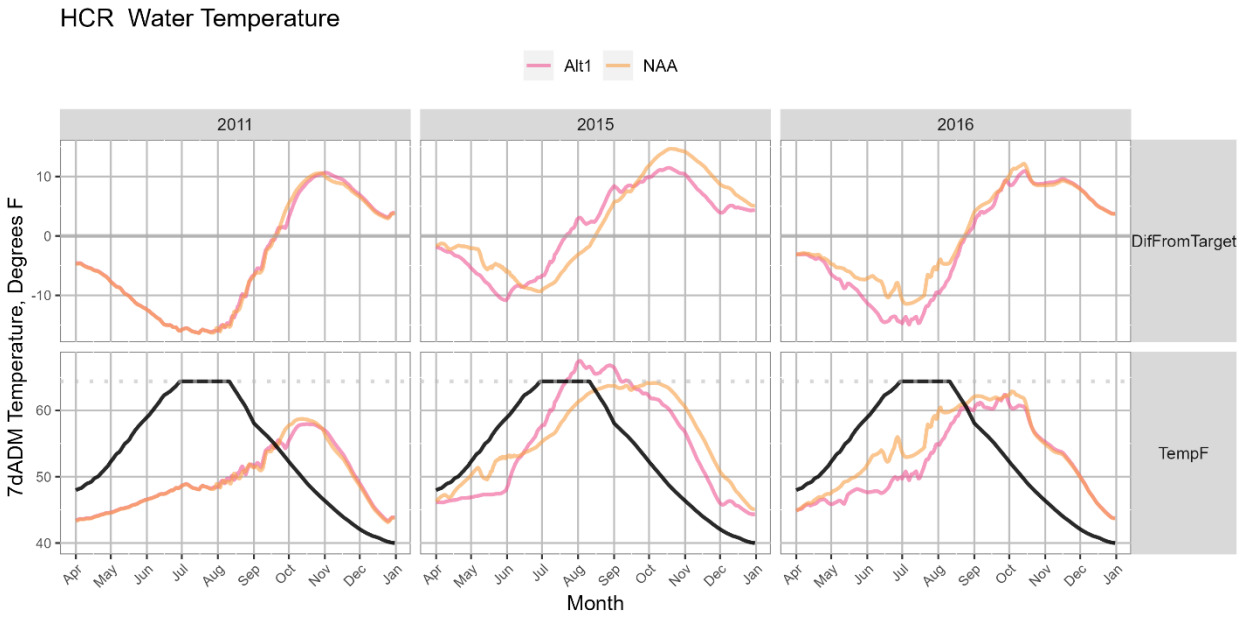


Figure 1-533. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black line indicates temperature target.

Daily Mean water temperatures (deg F) at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-528;Figure 1-529) in the 2011-year scenario would be similar to NAA from April until September and decrease by 1 degree in October. In the 2015-year scenario, Alternative 1 would produce a decrease by 3 degrees from April to June, increase by 3 degrees in July to September, decrease by 3 degrees in October. In the 2016-year scenario there would be no temperature change observed in April and then a decrease observed up to 5 degrees from May until October. For the three-year average (2011, 2015, 2016) a temperature decrease up to 2 degrees is observed in May, June, and October under Alternative 1.

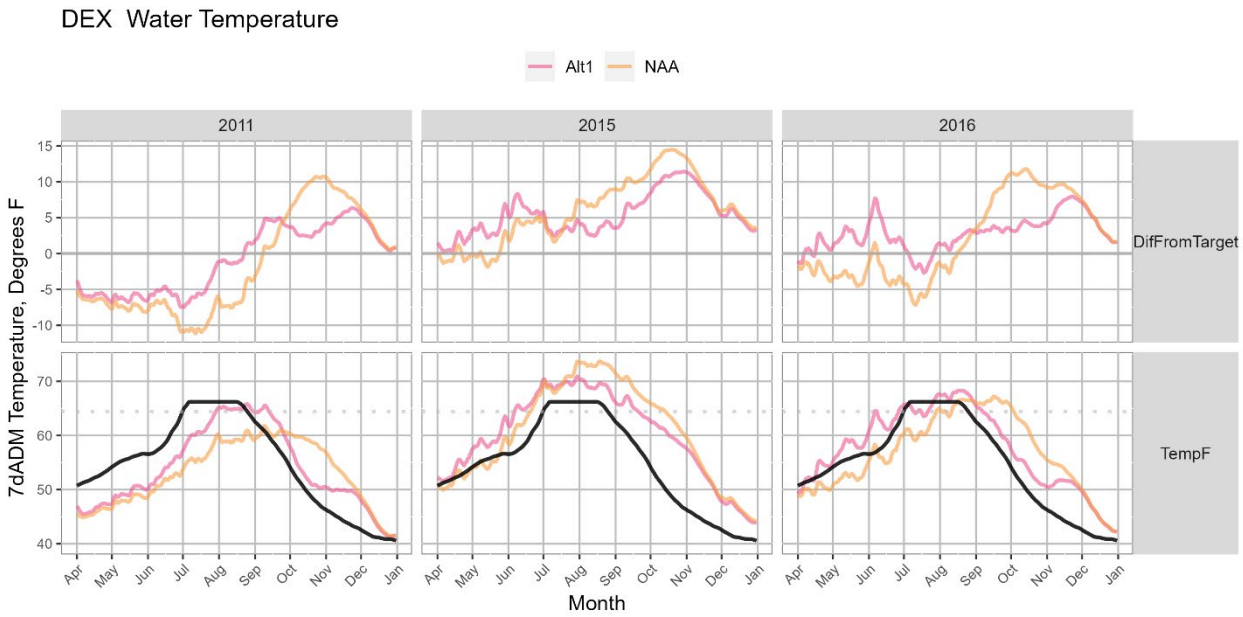


Figure 1-534. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target at Dexter Dam. Black line indicates temperature target.

1.6.2.5 Mainstem Willamette River

Mainstem Willamette River Alternative 1 results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-529). In the 2011-year scenario there would be no change in temperature in April and May; a 1 degree temperature increase from June until September and then a 1 degree decrease in October. In the 2015-year scenario, water temperature increases up to 2-degree from April until June and then decreases up to 3 degrees from July until September under Alternative 1. In the 2016-year scenario, water temperature increases up to 2 degrees from April until August and then 1 degree decreases in October. For the average of the three years (2011, 2015, 2016) a 2-degree temperature increase is observed in May and June with a 1 degree decrease in October.

Mainstem Willamette River Alternative 1 results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-529). In the 2011-year scenario a water temperature increase up to 1 degree is observed from July until September with a 2 degree decrease in October. In the 2015-year scenario, water temperature increases up to 2 degrees in April and May with a 1 degree decrease in July and August. In the 2016-year scenario, water temperature increases up to 2-degree from April until June followed by a 1-degree temperature decrease in September and October. For the average of the three years (2011, 2015, 2016) a water temperature increases up to 1-degree is observed from April until June with a 1-degree decrease in October.

1.6.3 Alternative 2a – Hybrid Alternative

Alternative 2a improvement measures for water temperature include:

- Deep fall drawdown to 35’ over the regulating outlet at Green Peter, use of RO in fall, use spillway for surface spill in spring and summer.
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.
- Water temperature control tower at Detroit reservoir
- Use the RO’s to discharge colder water during fall and winter drawdown operations at Green Peter reservoir.
- Use of the spillway for surface spill in the summer at Green Peter Reservoir
- Modifying existing outlets to allow releases at varying depths for temperature control specifically at Foster reservoir with a modification to the Facility Warm Water Supply (FWWS) pipe and fish weirs.

Summary tables of Alternative 2a monthly mean water temperature and monthly mean difference between Alternative 2a and NAA for each of the three simulated years are shown in and Figure 1-535 and Figure 1-536, respectively.

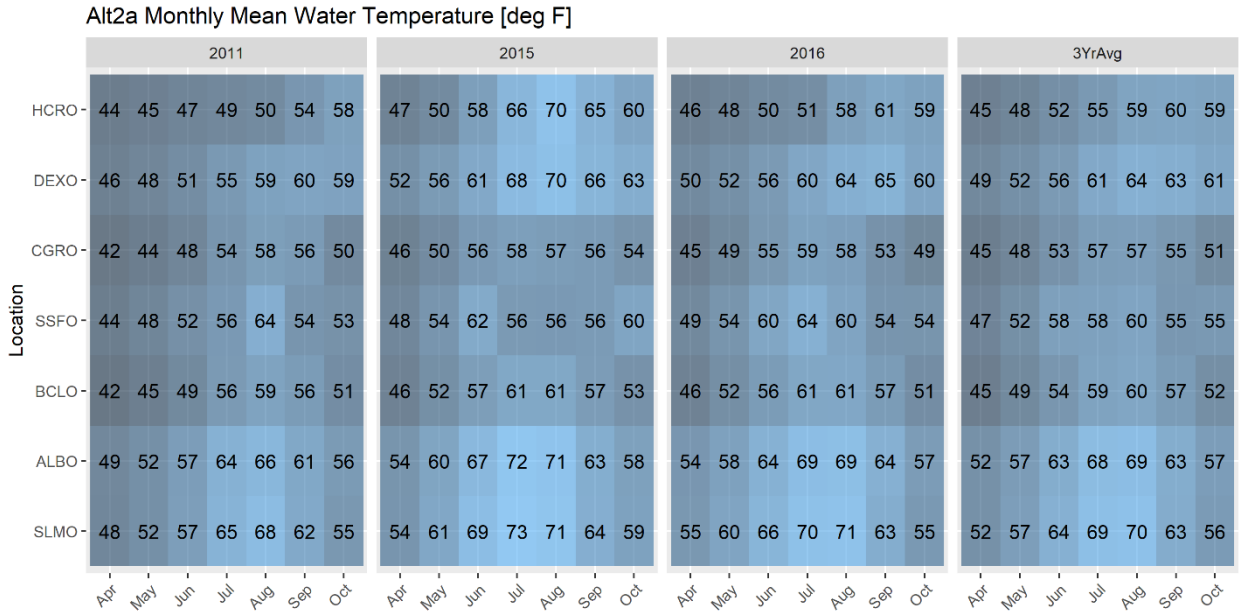


Figure 1-535. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) for Alternative 2a.

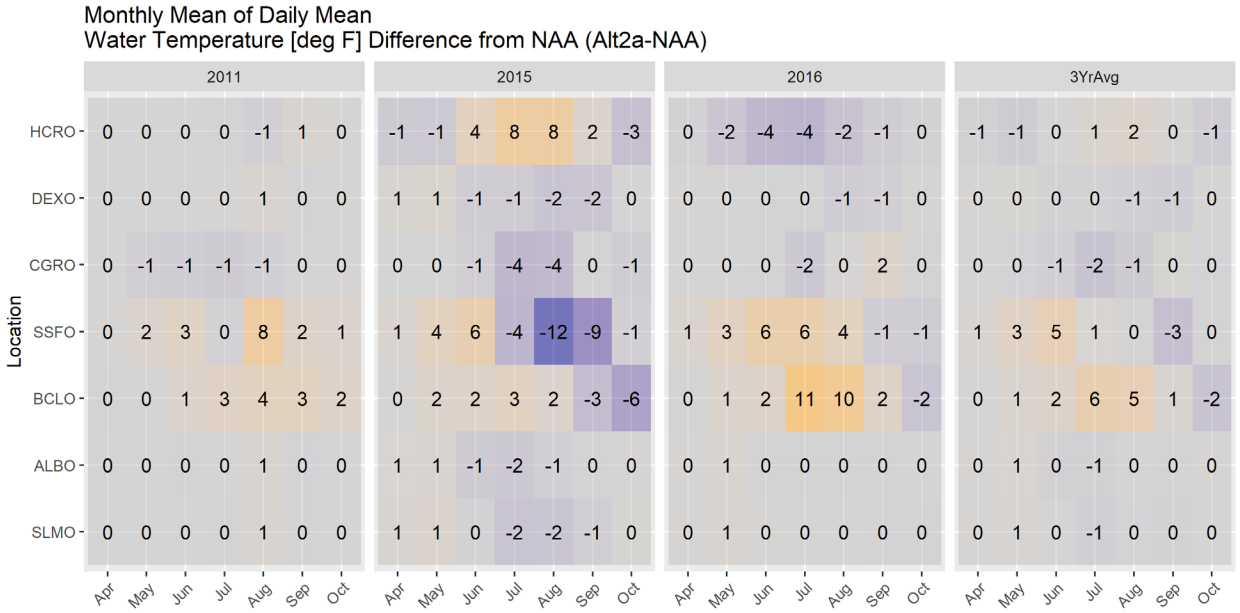


Figure 1-536. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 2a.

1.6.3.1 North Santiam Dams

Alternative 2a results as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO; Figure 1-535; Figure 1-536) in the 2011-year scenario would increase in water temperatures up to 4 degrees from June to October. In the 2015-year scenario water temperatures would increase up to 3 degrees from May until August and then a 4–6-degree decrease is observed in September and October. In the 2016-year scenario water temperatures increase up to 11 degrees from May to September and then a 2-degree decrease is observed in October. For the Average of the three years a water temperature increase up to 6 degrees is observed from May to September and then a 2 degree decrease is observed in October.

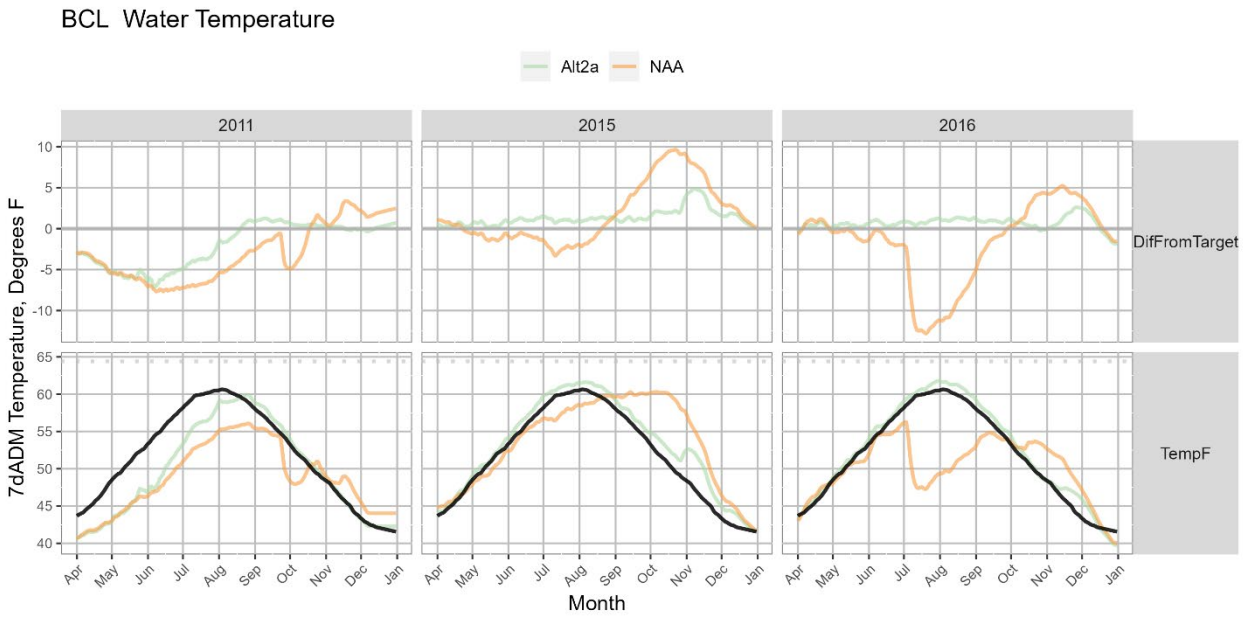


Figure 1-537. Comparison of Alternative 2a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target at Big Cliff dam.

1.6.3.2 South Santiam Dams

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO; Figure 1-535; Figure 1-479) in the 2011-year scenario would see an increase starting in May through October up to 10 degrees. In the 2015-year scenario an increase of 1 to 5 degrees from April to July and then decrease from 2 to 4 degrees from August to October. In the 2016-year scenario an increase up to 10 degrees from April to September and then decrease by 1 degree in October. For the Average of the three years (2011, 2015, 2016) an increase 1 to 6 degrees from April through September and then decrease by 2 degrees in October.

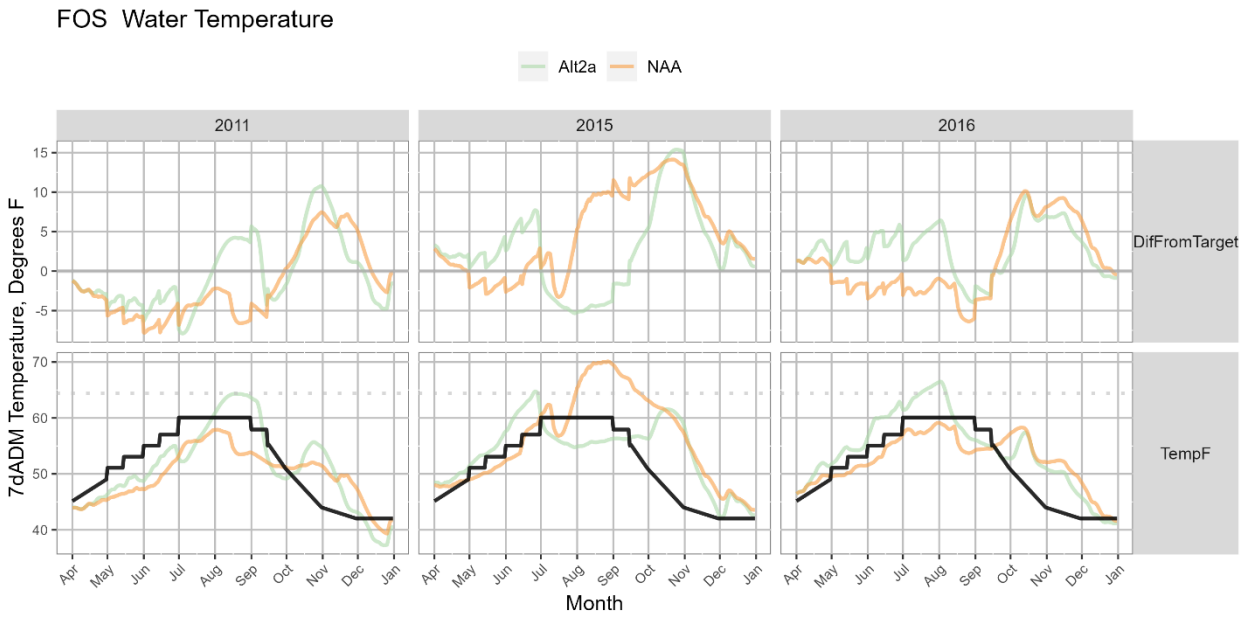


Figure 1-538. Comparison of Alternative 2a and NAA for 2011,2015,2016 with 7dADM temperatures (degrees F) and difference from the NAA downstream of Foster dam. Black line indicates temperature target.

1.6.3.3 McKenzie Dams

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-535;**Error! Reference source not found.**) in the 2011-year scenario there would be a decrease of 1-degree observed from May until August as compared to the NAA. In the 2015-year scenario a decrease up to 3-degrees is observed from June until August, as compared to the NAA. In the 2016-year scenario a decrease is observed up to 2 degrees in June and July, an increase is observed in September as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a decrease up to 2-degrees is observed from June until August as compared to the NAA.

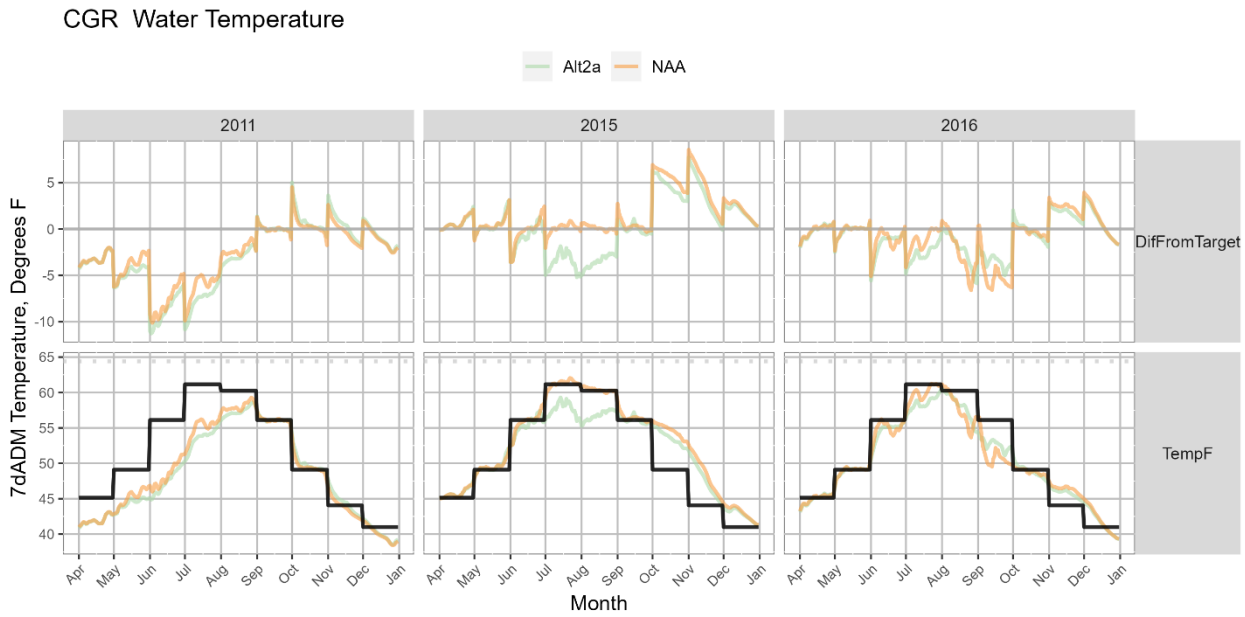


Figure 1-539. Comparison of Alternative 2a and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black line indicates temperature target.

1.6.3.4 Middle Fork Willamette Dams

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-535;Figure 1-540) in the 2011-year scenario would see an increase starting in May through September up to 6 degrees and decrease by 6 degrees in October. In the 2015-year scenario: increase up to 4 degrees from April to June and then decrease by 4 degrees from July to October. In the 2016-year scenario an increase up to 6 degrees from April to August and then decrease by 6 degrees in October. For the Average of the three years (2011, 2015, 2016): increase up to 3 degrees from April to August and then decrease by 5 degrees in October.

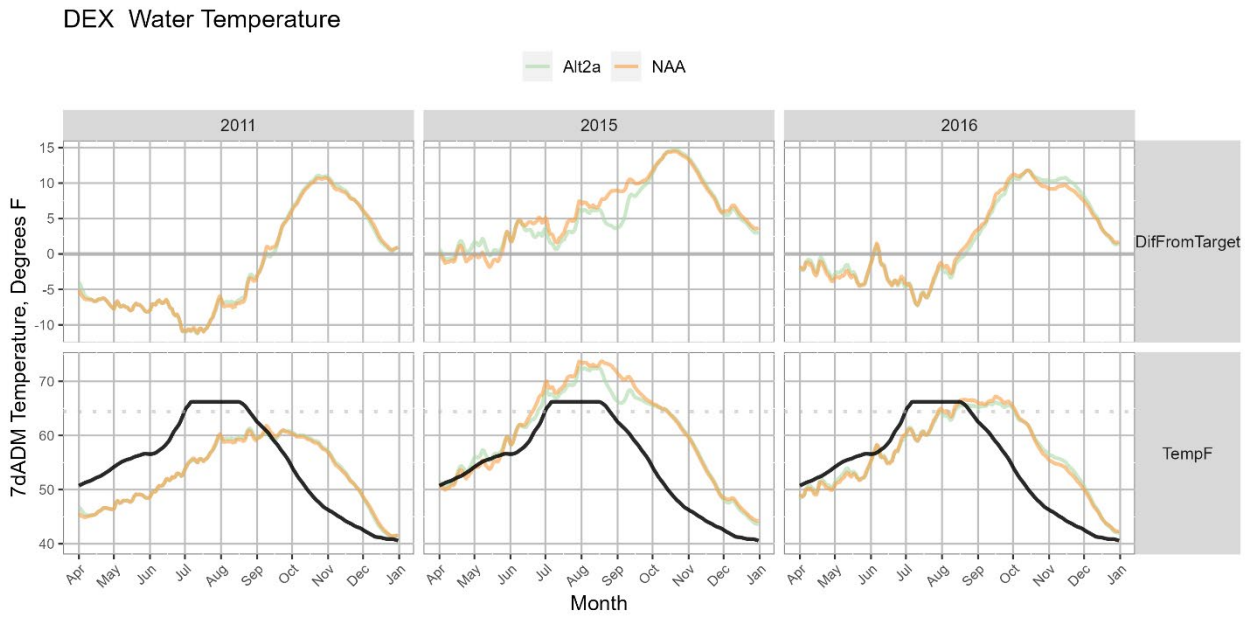


Figure 1-540. Comparison of Alternative 2a and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black line indicates temperature target.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures (deg F) at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-535; Figure 1-541) in the 2011-year scenario there would be no temperature difference from April until September and decrease by 1 degree in October as compared to the NAA. In the 2015-year scenario a decrease by 3 degrees from April to June, increase by 3 degrees in July to September, decrease by 3 degrees in October. In the 2016-year scenario there would be no temperature change observed in April and then a decrease observed up to 5 degrees from May until October. For the Average of the three years (2011, 2015, 2016) a temperature decrease up to 2 degrees is observed in May, June, and October.

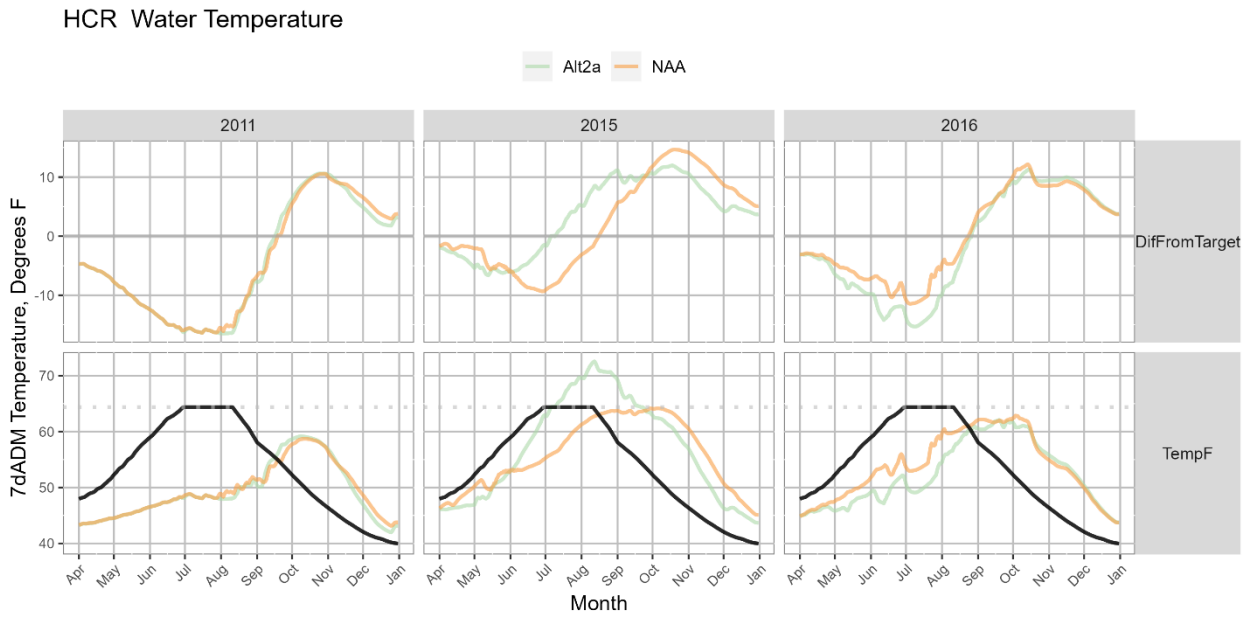


Figure 1-541. Comparison of Alternative 2a and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black line indicates temperature target.

1.6.3.5 Mainstem Willamette River

Mainstem Willamette River Alternative 2a results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-536). In the 2011-year scenario there would be a 1-degree water temperature increase in August. In the 2015-year scenario water temperatures increase up to 2-degree in April and May and then decrease up to 2 degrees from July until September. In the 2016-year scenario a water temperature increase of 1 degree is observed in May. For the Average of the three years (2011, 2015, 2016) water temperature increases 1-degree in May and then decreases by 1 degree in July and September.

Mainstem Willamette River Alternative 2a results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-536). In the 2011-year scenario a water temperature increase up to 1 degree is observed in August. In the 2015-year scenario a water temperature increase of 1 degree is observed in April and May and then 1 degree decrease in June and July. In the 2016-year scenario a water temperature increase of 1-degree is observed in May. For the Average of the three years (2011, 2015, 2016) a water temperature increase up to 1 degree is observed in May.

1.6.4 Alternative 2b – Hybrid Alternative

Alternative 2b improvement measures for water temperature include:

- Water temperature control tower at Detroit reservoir

- Use the RO's to discharge colder water during fall and winter drawdown operations at Green Peter reservoir.
- Use of the spillway for surface spill in the summer at Green Peter Reservoir
- Modifying existing outlets to allow releases at varying depths for temperature control specifically at Foster reservoir with a modification to the Facility Warm Water Supply (FWWS) pipe and fish weirs.

Summary tables of Alternative 2b monthly mean water temperature and monthly mean difference between Alternative 2b and NAA for each of the three simulated years are shown in and Figure 1-542 and Figure 1-543, respectively.

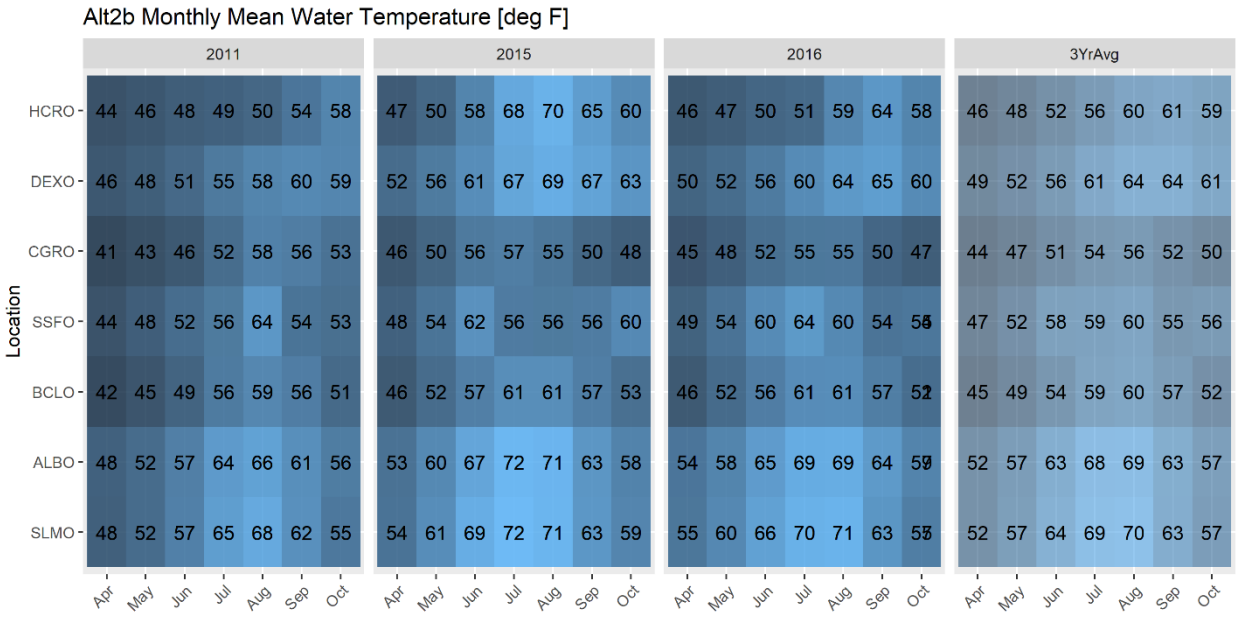


Figure 1-542. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 2b.

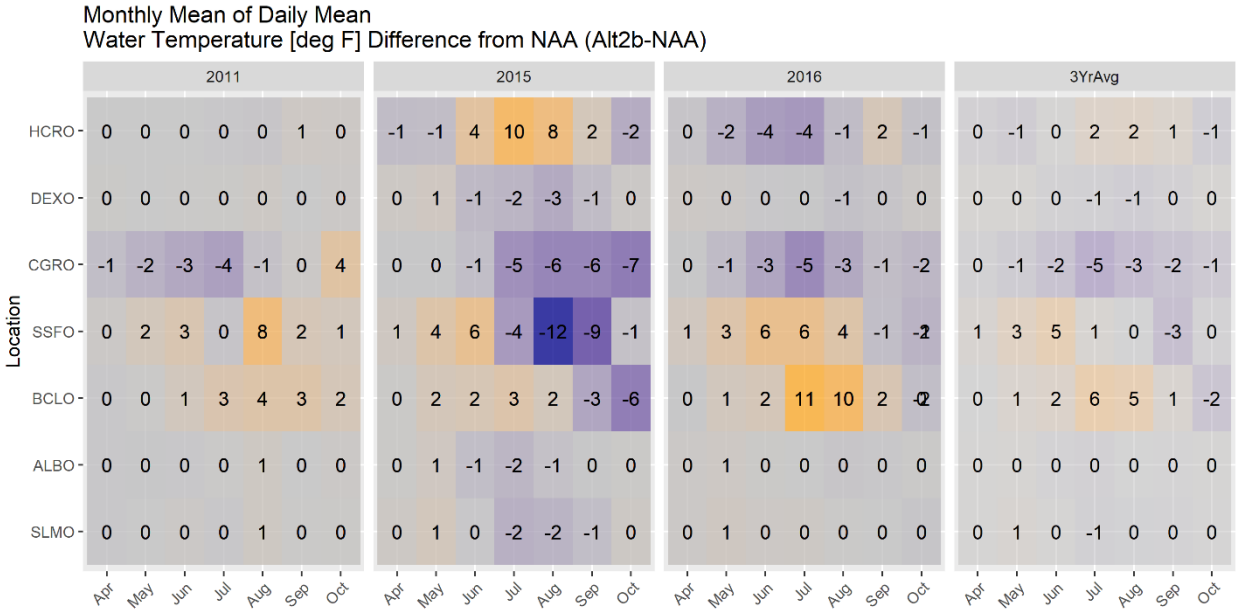


Figure 1-543. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 2b.

1.6.4.1 North Santiam Dams

Alternative 2b includes a Water Temperature Control tower at Detroit reservoir for water temperature management. Alternative 2b as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO in Figure 1-542, Figure 1-544) in the 2011-year scenario an increase up to 3-degrees is observed from June until October as compared to the NAA. In the 2015-year scenario an increase up to 3-degrees is observed from May until August and then decreases up to 6 degrees in September and October. In the 2016-year scenario an increase up to 11-degrees is observed from May until September as compared to the NAA. For the Average of the three years an increase up to 6-degrees is observed from May until September and then a decrease of 2-degrees in October as compared to the NAA.

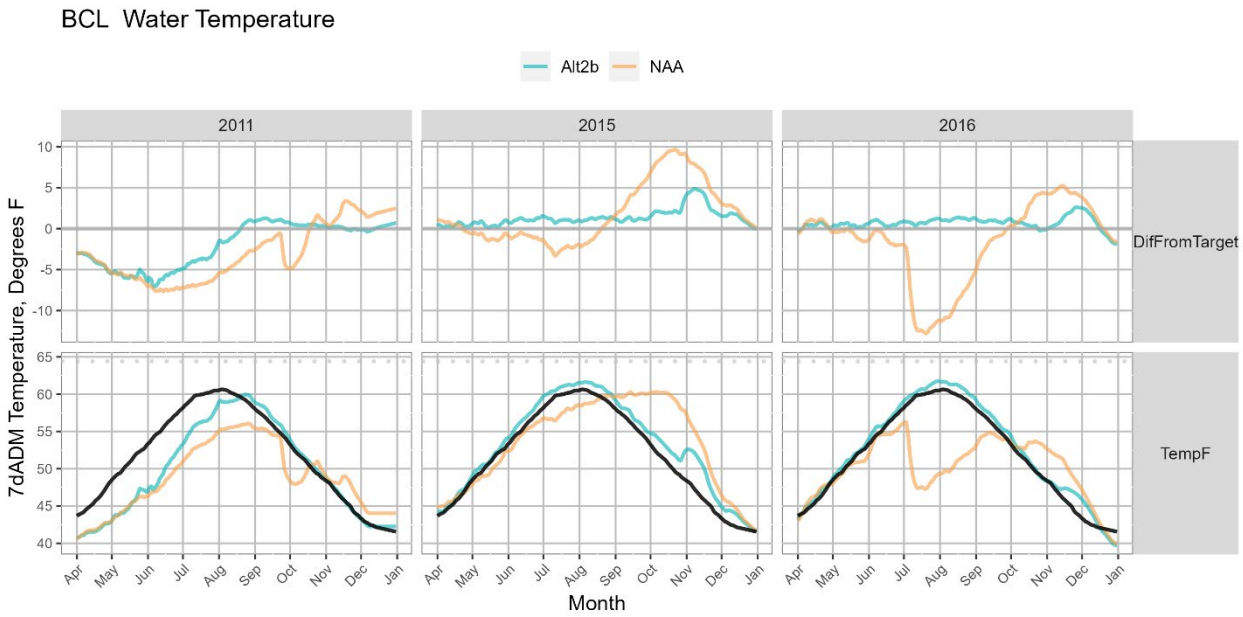


Figure 1-544. Comparison of Alternative 2b and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam.

1.6.4.2 South Santiam Dams

Alternative 2b includes the use of the RO's to discharge colder water during fall and winter drawdown operations at Green Peter reservoir. An additional measure includes the use of the spillway for surface spill in the summer at Green Peter reservoir. Also, a measure to modify existing outlets to allow releases at varying depths for temperature control specifically at Foster reservoir with a modification to the Facility Warm Water Supply (FWWS) pipe and fish weirs.

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO in Figure 1-543, Figure 1-545) in the 2011-year scenario would see an water temperature increase starting in May through October up to 8 degrees, although July observed a 1-degree temperature decrease. In the 2015-year scenario an increase in water temperatures of 1 to 6 degrees from April to June, a decrease in temperatures from 1 to 13 degrees is observed from July to October. In the 2016-year scenario an increase up to 6 degrees from April to August and then decrease by 2 degrees in September and October. For the Average of the three years (2011, 2015, 2016) an increase 1 to 5 degrees from April through June and then decrease up to 3 degrees from August until October.

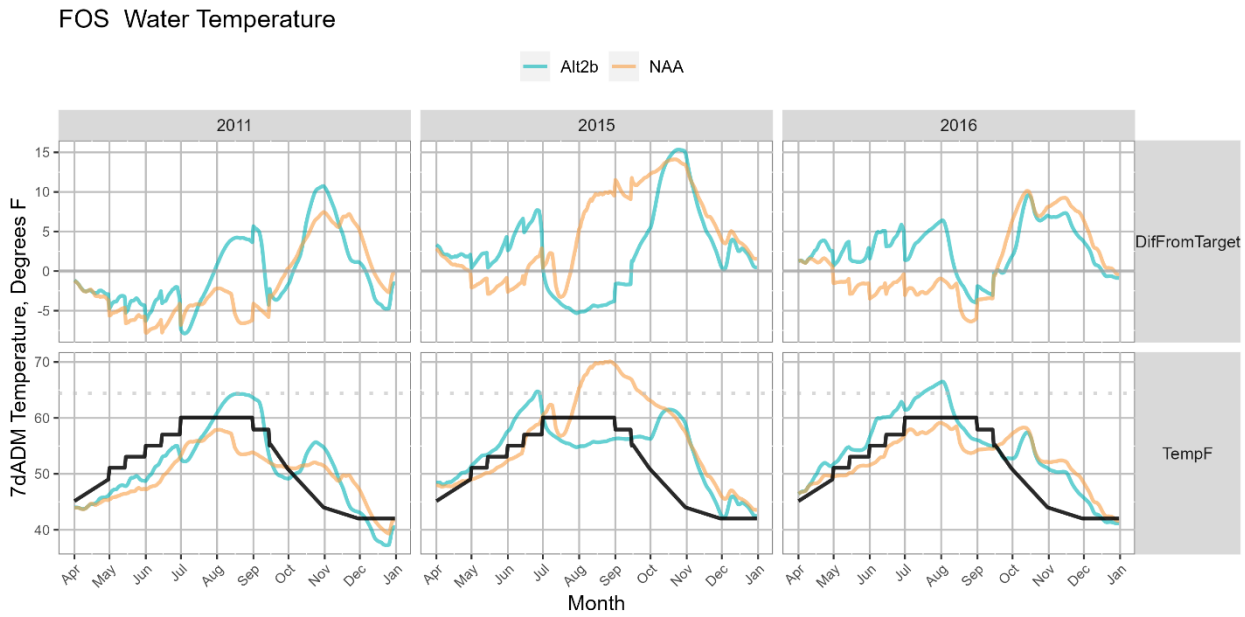


Figure 1-545. Comparison of Alternative 2b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam.

1.6.4.3 McKenzie Dams

There are no water temperature measures for Cougar or Blue River dams under Alternative 2b. Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-543; Figure 1-546) in the 2011-year scenario there would be a water temperature decrease up to 3-degrees from April through July and a 4-degree increase in October as compared to the NAA. In the 2015-year scenario a water temperature decrease up to 7-degrees is observed from June until October, as compared to the NAA. In the 2016-year scenario a temperature decrease is observed up to 5 degrees from May until October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a temperature decrease up to 4-degrees is observed from May until October as compared to the NAA. These water temperature decreases relative to NAA are a result of the deep drawdown, decreased residence time in Cougar Lake (reduced heating in the reservoir), and use of the diversion tunnel as the primary outlet.

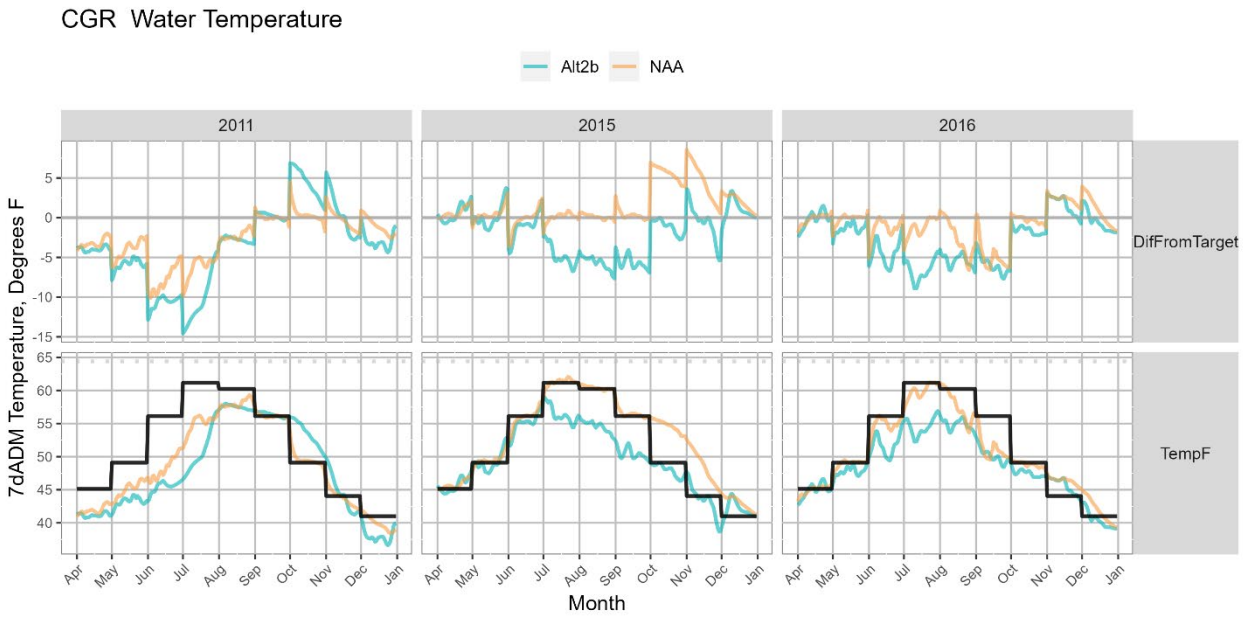


Figure 1-546. Comparison of Alternative 2b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black Line indicates temperature target.

1.6.4.4 Middle Fork Willamette Dams

Alternative 2b has no water temperature measures for the Middle Fork sub-basin. Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-547) in the 2011-year scenario there would be no temperature difference from April to October. In the 2015-year scenario observes a 1-degree increase in May, a water temperature decrease up to 3-degrees is observed from June until September. In the 2016-year scenario most months see no change in water temperatures except for August which decreases by 1 degree as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a water temperature decrease by 1 degree is observed from July through September.

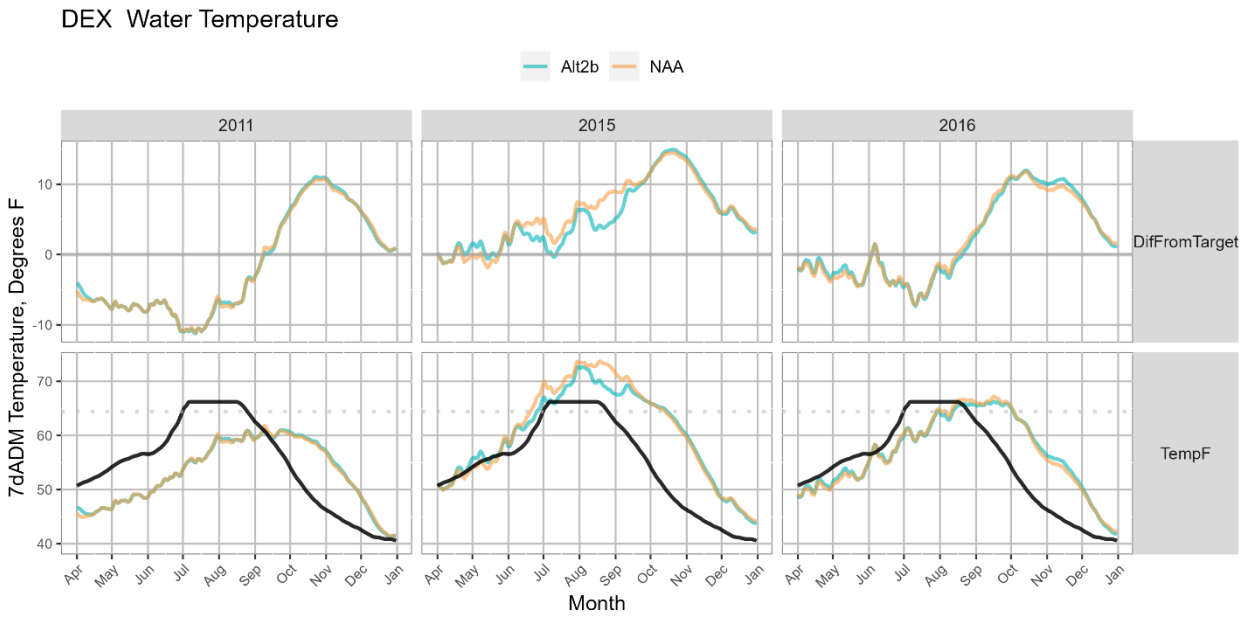


Figure 1-547. Comparison of Alternative 2b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black Line indicates temperature target.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures (deg F) at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-543; Figure 1-548) in the 2011-year scenario there would be no temperature difference from April to October as compared to the NAA. In the 2015-year scenario a decrease up to 2 degrees is observed in May and October, water temperature increases up to 9 degrees in June through September as compared to the NAA. In the 2016-year scenario water temperature decrease is observed up to 4 degrees from May until October, although September would increase by 1 degree. For the Average of the three years (2011, 2015, 2016) a water temperature decrease up to 1 degree is observed in May and October, a temperature increase up to 2-degrees occurs in July through September.

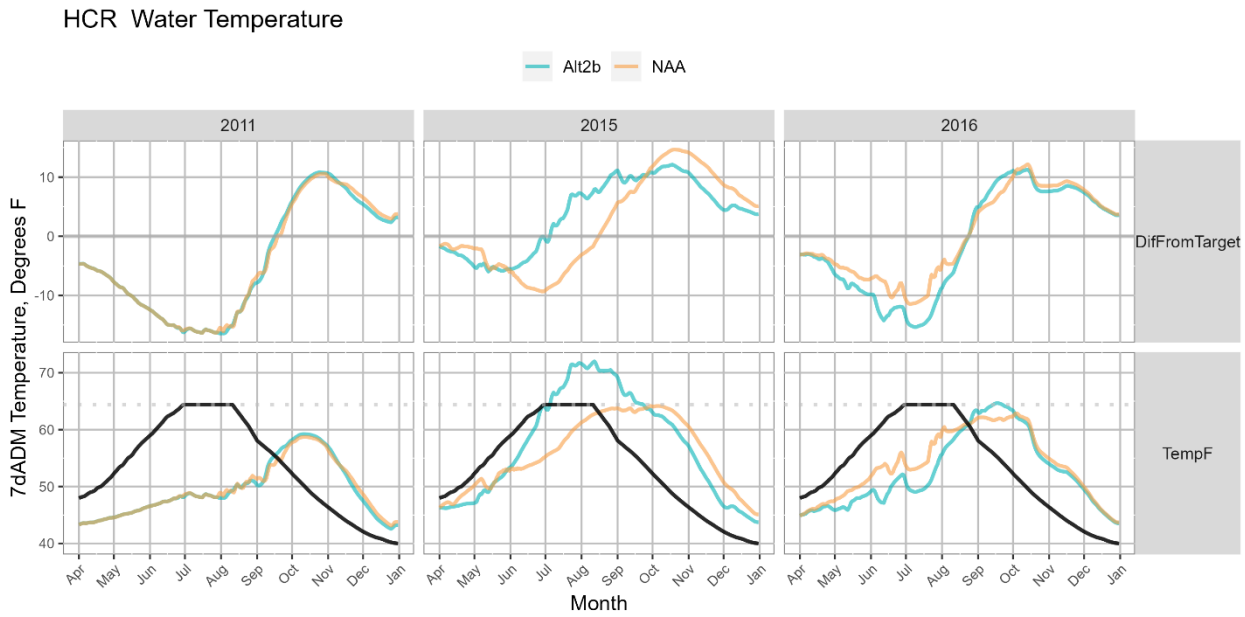


Figure 1-548. Comparison of Alternative 2b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black Line indicates temperature target.

1.6.4.5 Mainstem Willamette River

Mainstem Willamette River Alternative 2b results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-543). In the 2011-year scenario there would be a 1-degree water temperature increase in August. In the 2015-year scenario water temperatures decrease by 2-degree from July through September. In the 2016-year scenario a water temperature increase of 1 degree is observed in May. For the Average of the three years (2011, 2015, 2016) water temperature increases 1-degree in May and then decreases by 1 degree in July.

Mainstem Willamette River Alternative 2b results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-543). In the 2011-year scenario a water temperature increase up to 1 degree is observed in August. In the 2015-year scenario the water temperature decreases by 2-degrees from June through August. In the 2016-year scenario a water temperature increase of 1-degree is observed in May. For the Average of the three years (2011, 2015, 2016) no temperature change is observed.

1.6.5 Alternative 3a – Operations-Focused Fish Passage

Alternative 3a would utilize operation-based measures for fish passage survivability within the WVS dams and compared to the NAA. Operational improvements for water temperature measures include:

- Utilizing the RO's to discharge cold water during drawdown operations in the fall and winter to reduce water temperatures below Detroit, Green Peter, and Lookout Point dams
- Spring drawdown operations at Detroit, Lookout Point and Cougar
- Utilizing the spillway for surface spill in the summer at Detroit, Green Peter, Foster, Blue River, Hills Creek, and Lookout point dams
- Spreading spill would be conducted at Dexter and Lookout Point
- Modify existing outlets to allow releases at varying depths for temperature control by modifying the spillway to allow releases at varying depths for temperature control at Blue River and Hills Creek dams
- Lining of the lower RO tunnels to limit cavitation effects and to assist in temperature control at Detroit dam.

Summary tables of Alternative 3a monthly mean water temperature and monthly mean difference between Alternative 3a and NAA for each of the three simulated years are shown in and Figure 1-549 and Figure 1-550, respectively.

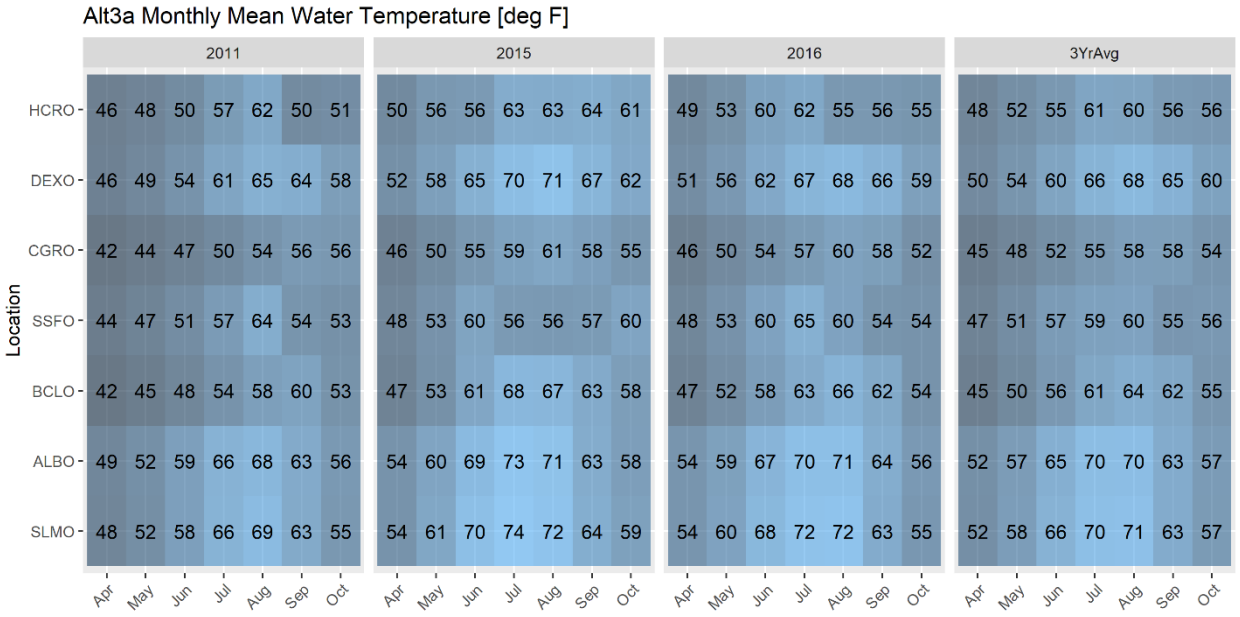


Figure 1-549. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 3a

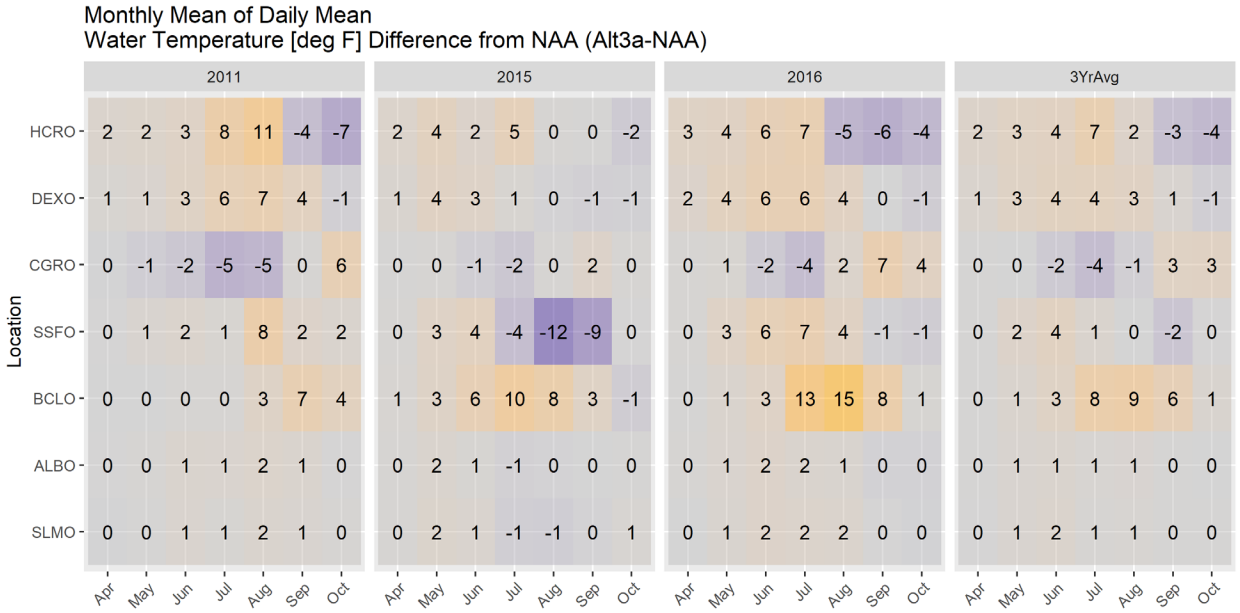


Figure 1-550. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 3a.

1.6.5.1 North Santiam Dams

Water temperature measures under Alternative 3a include Detroit reservoir utilizing the RO's to discharge colder water during drawdown operations in the fall and winter to reduce downstream water temperatures. The Detroit spillway would be utilized for surface spill in the summer which would assist in blending water temperatures below in Big Cliff. The lower RO's would be lined to limit cavitation effects and assist in releasing cooler water in the late fall at Detroit reservoir.

Alternative 3a as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO; Figure 1-550; Figure 1-551) the 2011-year scenario indicates an increase in water temperatures up to 7-degrees from August through October . Monthly Mean of Daily Max, Water Temperature difference from NAA (Alt3a-NAA). In the 2015-year scenario water temperatures increase up to 10 degrees from April until September, a 1-degree temperature decrease occurs in October. In the 2016-year scenario a water temperature increase up to 15-degrees is observed from May until October as compared to the NAA. For the average of the three years water temperatures increase up to 9-degrees from May until October.

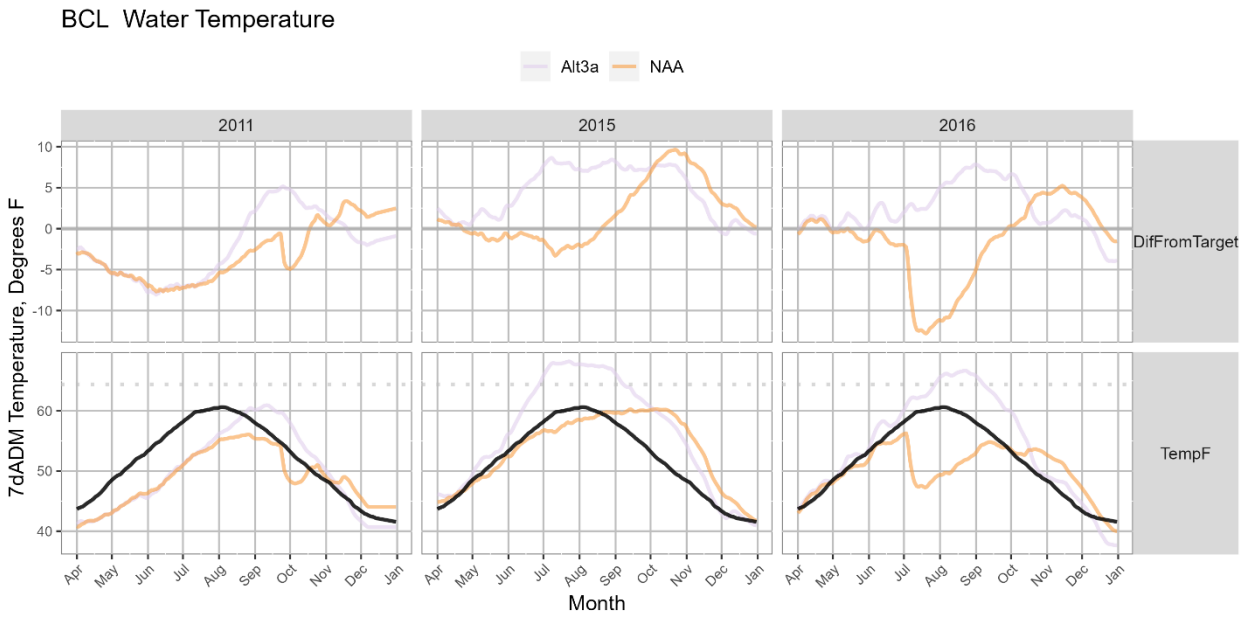


Figure 1-551. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. Black line indicates temperature target.

1.6.5.2 South Santiam Dams

Water temperature measures under Alternative 3a include Green Peter utilizing the RO's to discharge colder water during drawdown operations in the fall and winter to reduce downstream water temperatures and volitional downstream fish passage. The Green Peter and Foster dam spillways would be utilized in the summer for surface spill.

Alternative 3a results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO; Figure 1-550; Figure 1-552)the 2011-year scenario would see a water temperature increase starting in May through October up to 8 degrees, although July has no temperature change as compared to the NAA. In the 2015-year scenario water temperatures increase from 1 to 4 degrees in April through June, a decrease in temperatures from 4 to 13 degrees is observed from July to September. In the 2016-year scenario water temperatures increase up to 7 degrees from May to August and then decrease by 1 degree in September and October. For the Average of the three years (2011, 2015, 2016) an increase 1 to 4 degrees from May through June and then decrease up to 2 degrees from August and September.

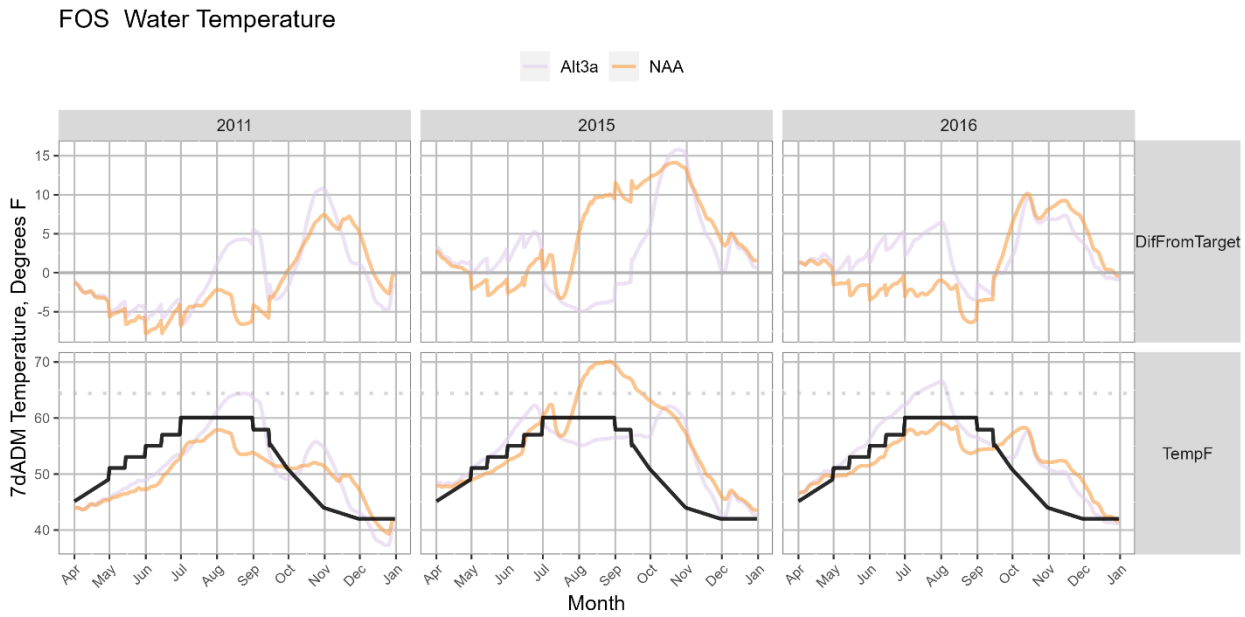


Figure 1-552. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam. Black line indicates temperature target.

1.6.5.3 McKenzie Dams

Water temperature measures under Alternative 3a include a modification to the spillway at Blue River reservoir to provide better water temperature management. The spillway would be used in the summer for surface spill. Not a direct water temperature measure but equally as important is Cougar reservoir implementing spring and fall drawdown operations for volitional downstream fish passage. And Blue River implementing a fall drawdown 15 ft below minimum conservation (1180 ft).

Temperature results for Alt 3a effects are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-550; Figure 1-553) in the 2011-year scenario there would be a water temperature decrease from 1 to 5-degrees from April through August, a 6-degree water temperature increase would occur in October as compared to the NAA. In the 2015-year scenario a water temperature increase of 1 to 2 degrees is observed in May, August, and September. A temperature decrease of 1-2 degrees is observed in June and July for the 2015-year scenario. In the 2016-year scenario a temperature increase is observed up to 6 degrees from April until July, a temperature decrease of up to 6 degrees occurs from August until October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a temperature increase up to 7-degrees is observed from April until August, a temperature decrease of 3-4 degrees occurs in September and October as compared to the NAA.

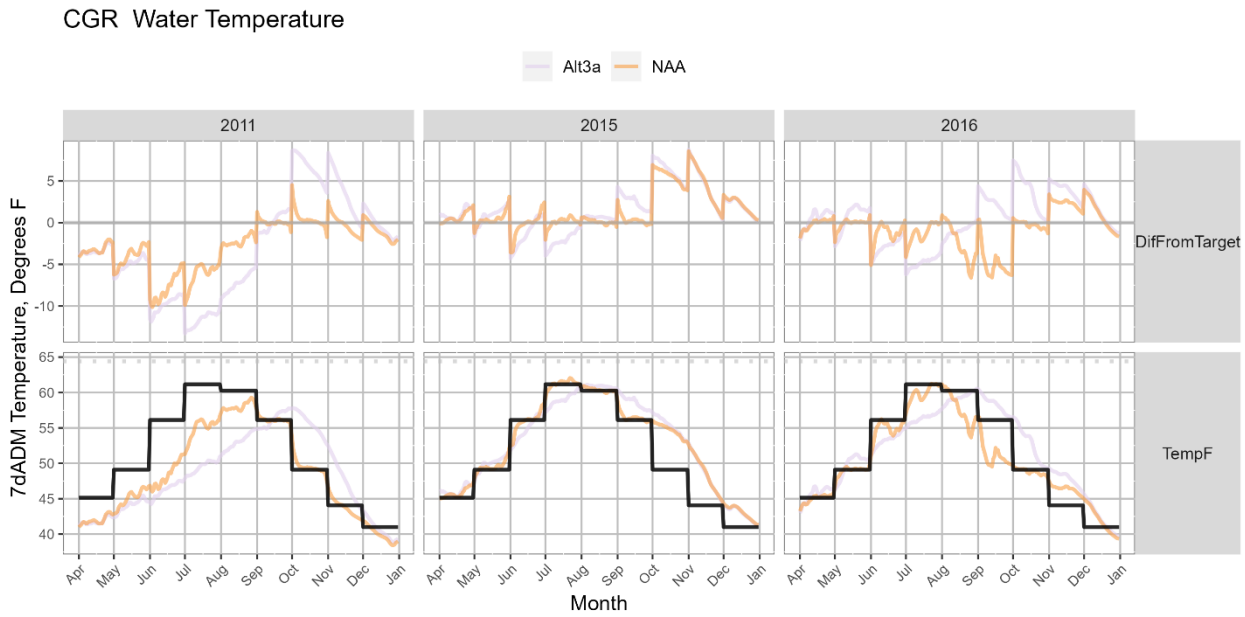


Figure 1-553. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black line indicates temperature target.

1.6.5.4 Middle Fork Willamette Dams

Water temperature measures under Alternative 3a include Hills Creek reservoir modification to the spillway and use the spillway for surface spill in the summer. Lookout point reservoir would utilize the RO's to discharge colder water during drawdown operations in fall and winter to reduce downstream water temperatures. The Lookout Point spillway would be utilized in the summer for surface spill. Dexter spillway would be utilized in order to spread surface spill.

Water temperature results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-550;Figure 1-554) in the 2011-year scenario water temperature increase from 1 to 6 degrees is observed from April to September. In the 2015-year scenario observes a 1-3 degree increase from April through July, then decrease of 1 degree in September. In the 2016-year scenario a 2 to 6 degree water temperature increase is observed from April through August and decrease by 1 degree in October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a water temperature increases from 1-4 degrees in April through September and decreases by 1 degree in October.

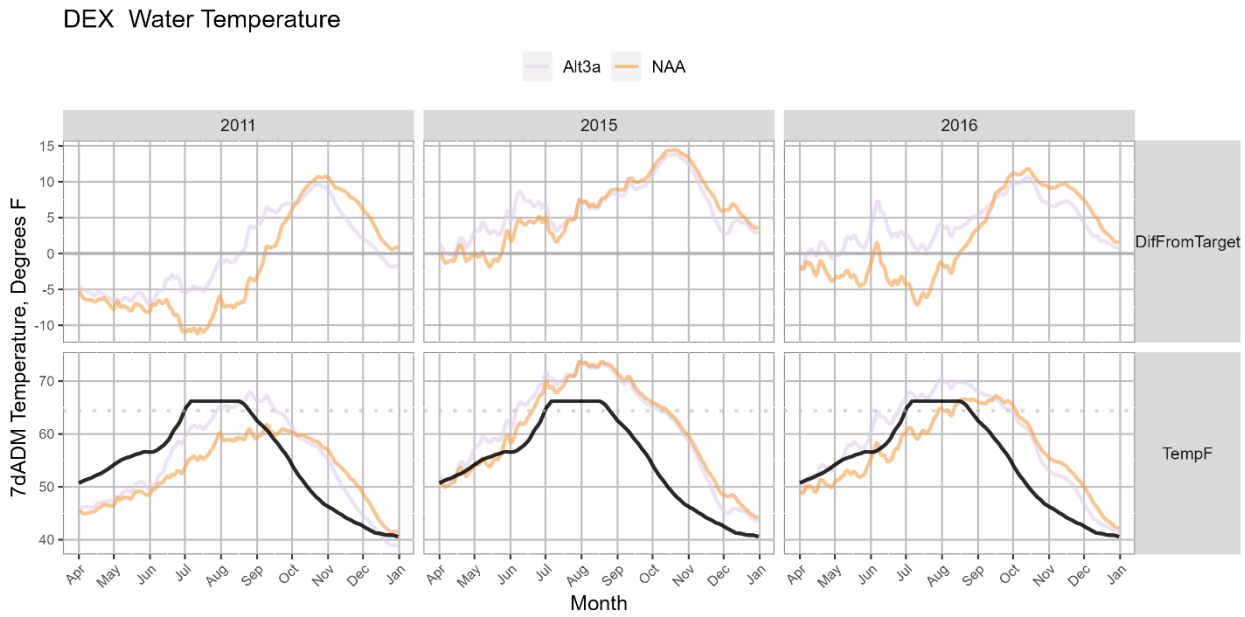


Figure 1-554. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black line indicates temperature target.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-550; Figure 1-554) in the 2011-year scenario water temperature increase from 2 to 11 degrees is observed from April to August, a decrease from 4 to 6 degrees occurs in September and October. In the 2015-year scenario observes a 1-6 degree increase from April through July, then decrease of 1 degree in October as compared to the NAA. In the 2016-year scenario water temperature increase 3-6 degrees from April through July and decrease up to 6 degrees from August to October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a water temperature increase 2 to 7 degrees from April through August and then decrease up to 4 degrees in September and October.

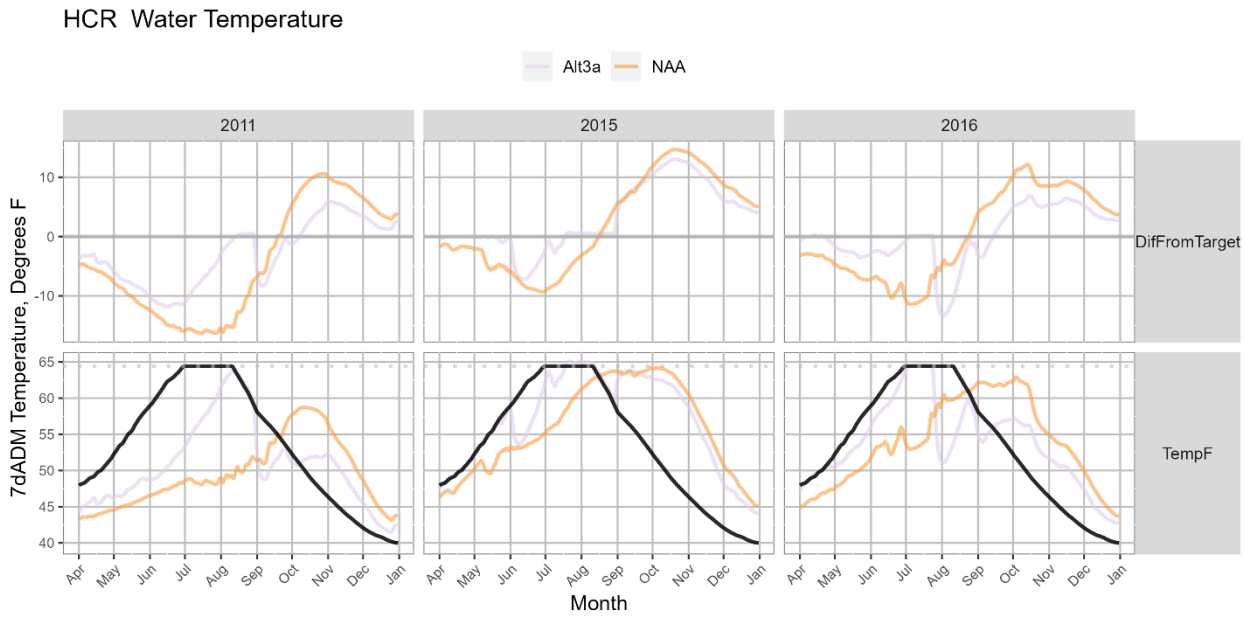


Figure 1-555. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek Dam. Black line indicates temperature target.

1.6.5.5 Mainstem Willamette River

Mainstem Willamette River Alternative 3a results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-550). In the 2011-year scenario, water temperature increases by 1 degree from June through September as compared to the NAA. In the 2015-year scenario temperature increases 1 to 2 degrees in April through June and then decreases by 1 degree in July and August as compared to the NAA. In the 2016-year scenario water temperatures increase up to 2-degrees from May until August as compared to the NAA. For the average of the three years (2011,2015, 2016) water temperature increases up to 2 degrees from May until July as compared to the NAA.

Mainstem Willamette River Alternative 3a results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-550). In the 2011-year scenario water temperatures increase up to 2 degrees from June through September as compared to the NAA. In the 2015-year scenario water temperatures increase up to 2-degrees in May and June as compared to the NAA. In the 2016-year scenario water temperatures increase up to 2-degrees from May until August as compared to the NAA. For the average of the three years (2011,2015, 2016) water temperatures increase up to 2-degrees from May until August as compared to the NAA.

1.6.6 Alternative 3b – Operations-Focused Fish Passage Alternative (using diversion tunnel at Cougar)

Alternative 3b measures include operational improvements for water temperature:

- Utilizing the RO's to discharge cold water during drawdown operations in the fall and winter to reduce water temperatures below Detroit, Green Peter, and Lookout Point dams
- Spring drawdown operations at Hills Creek, Green Peter, and Cougar (to the diversion tunnel)
- Utilizing the spillway for surface spill in the summer at Detroit, Green Peter, Foster, Blue River, Hills Creek, and Lookout point dams
- Modifying the spillway to allow releases at varying depths for temperature control at Blue River and Hills Creek dams
- Lining of the lower RO tunnels to limit cavitation effects and to assist in temperature control at Detroit dam
- Modifying the Cougar dam diversion tunnel for water temperature control and complying with dam safety

Summary tables of Alternative 3b monthly mean water temperature and monthly mean difference between Alternative 3b and NAA for each of the three simulated years are shown in and Figure 1-556 and Figure 1-557, respectively.

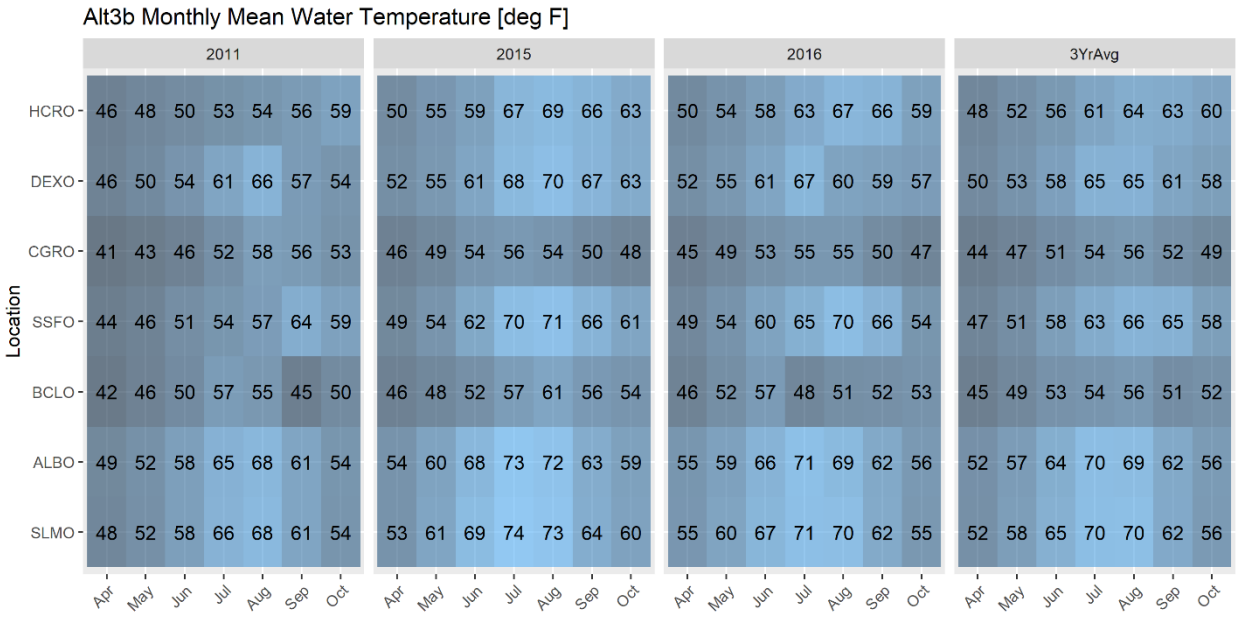


Figure 1-556. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 3b.

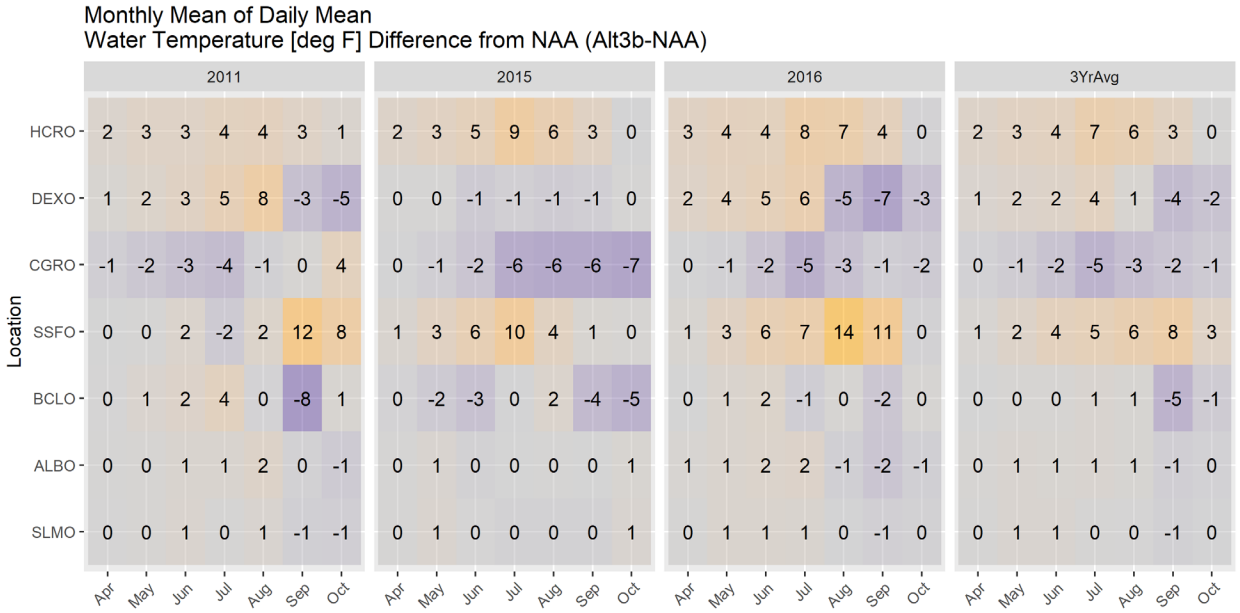


Figure 1-557. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 3b.

1.6.6.1 North Santiam Dams

Water temperature measures under Alternative 3b include Detroit reservoir utilizing the RO's to discharge colder water during drawdown operations in the fall and winter to reduce downstream water temperatures. The Detroit spillway would be utilized for surface spill in the summer which would assist in blending water temperatures below in Big Cliff. The lower RO's would be lined to limit cavitation effects and assist in releasing cooler water in the late fall at Detroit reservoir.

Alternative 3b as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO; Figure 1-557; Figure 1-558) the 2011-year scenario indicates an increase in water temperatures up to 4-degrees from May through July, an 8 degree temperature decrease is observed in September as compared to the NAA . Monthly Mean of Daily Max, Water Temperature difference from NAA (Alt3b-NAA). In the 2015-year scenario water temperatures decrease up to 5 degrees from May until October, although a 1-degree temperature increase is observed in August. In the 2016-year scenario a water temperature increase up to 2-degrees is observed in May and June, a temperature decrease of 1 to 2 degrees occurs in July and September. For the average of the three years water temperatures increase by 1-degrees in July, and then decrease up to 5 degrees in September and October as compared to the NAA.

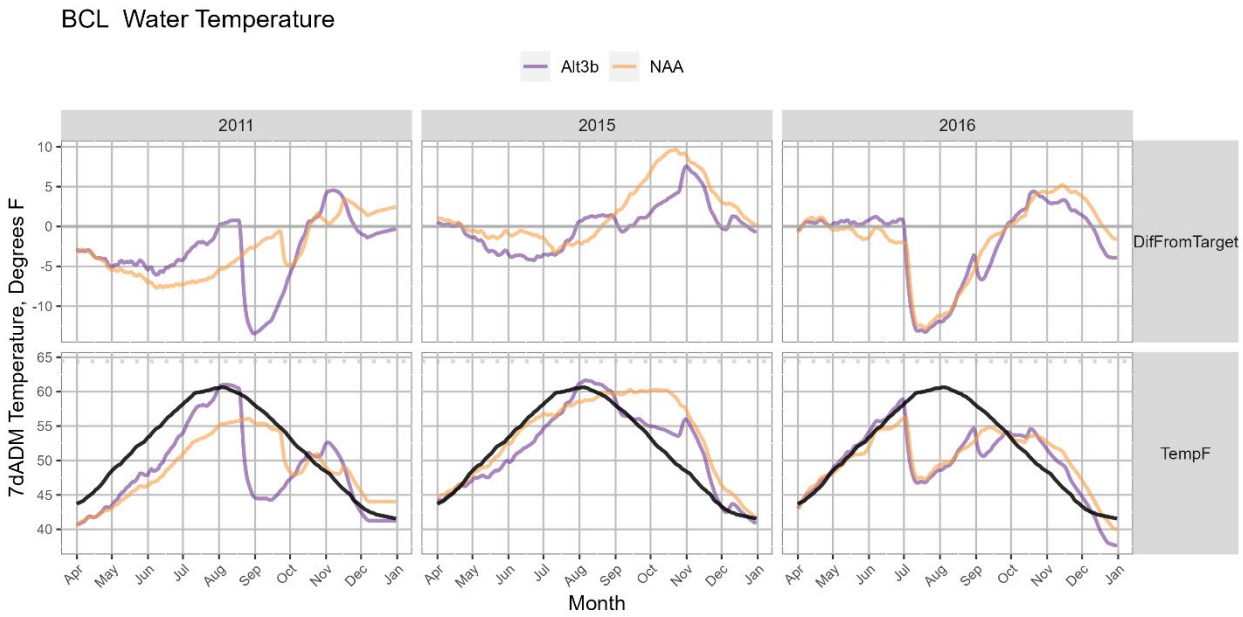


Figure 1-558. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff Dam. Black line indicates temperature target.

1.6.6.2 South Santiam Dams

Water temperature measures under Alternative 3b include Green Peter utilizing the RO's to discharge colder water during drawdown operations in the fall and winter to reduce downstream water temperatures and volitional downstream fish passage. The Green Peter and Foster dam spillways would be utilized in the summer for surface spill.

Alternative 3b results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO; Figure 1-557; Figure 1-559) the 2011-year scenario would see a water temperature increase starting in June through October up to 12 degrees, although July would have a 2-degree temperature decrease as compared to the NAA. In the 2015-year scenario water temperatures increase from 1 to 10 degrees in April through September as compared to the NAA. In the 2016-year scenario water temperatures increase up to 15 degrees from April through September as compared to the NAA. For the Average of the three years (2011, 2015, 2016) an increase 1 to 8 degrees from April through October as compared to the NAA.

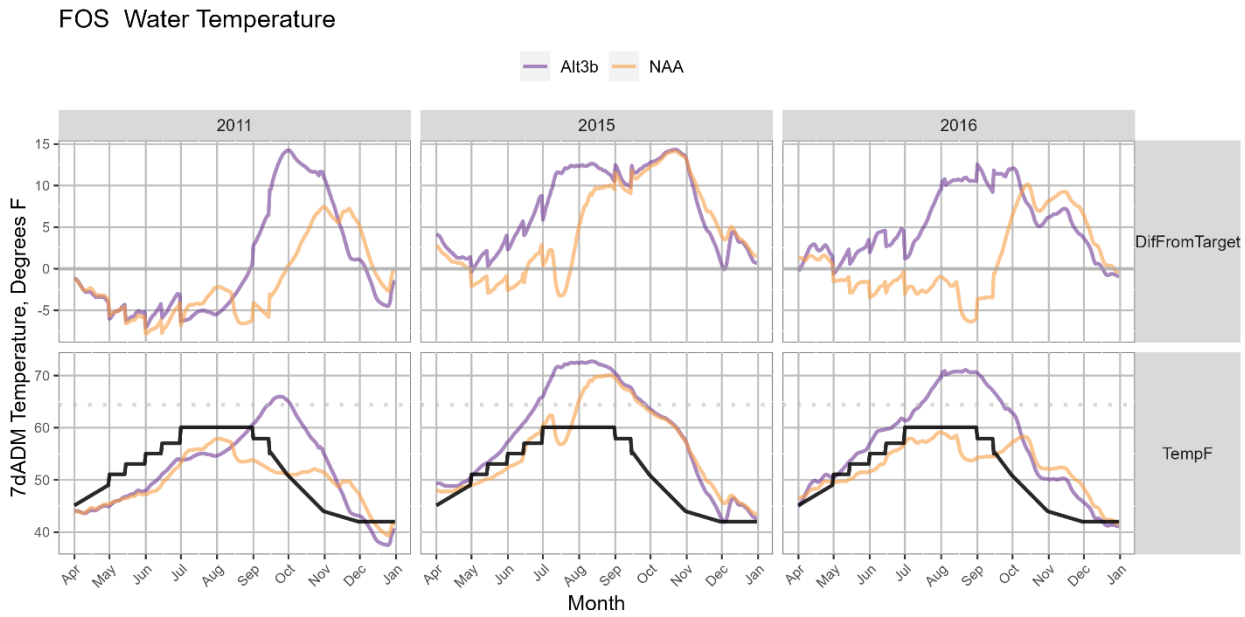


Figure 1-559. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster Dam. Black line indicates temperature target.

1.6.6.3 McKenzie Dams

Water temperature measures under Alternative 3b include modifying the diversion tunnel at Cougar reservoir to provide better temperature control. Measures for Blue River include a modification to the spillway to provide better water temperature management. The Blue River spillway would be used in the summer for surface spill.

Temperature results for Alt 3b effects are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-557; Figure 1-560) in the 2011-year scenario there would be a water temperature decrease from 1 to 3-degrees from April through July, a 4-degree water temperature increase would occur in October as compared to the NAA. In the 2015-year scenario a water temperature decrease of 1 to 7 degrees is observed in May through October as compared to the NAA. In the 2016-year scenario a temperature decrease is observed up to 5 degrees from June through October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a temperature decrease up to 5-degrees is observed from May through October as compared to the NAA.

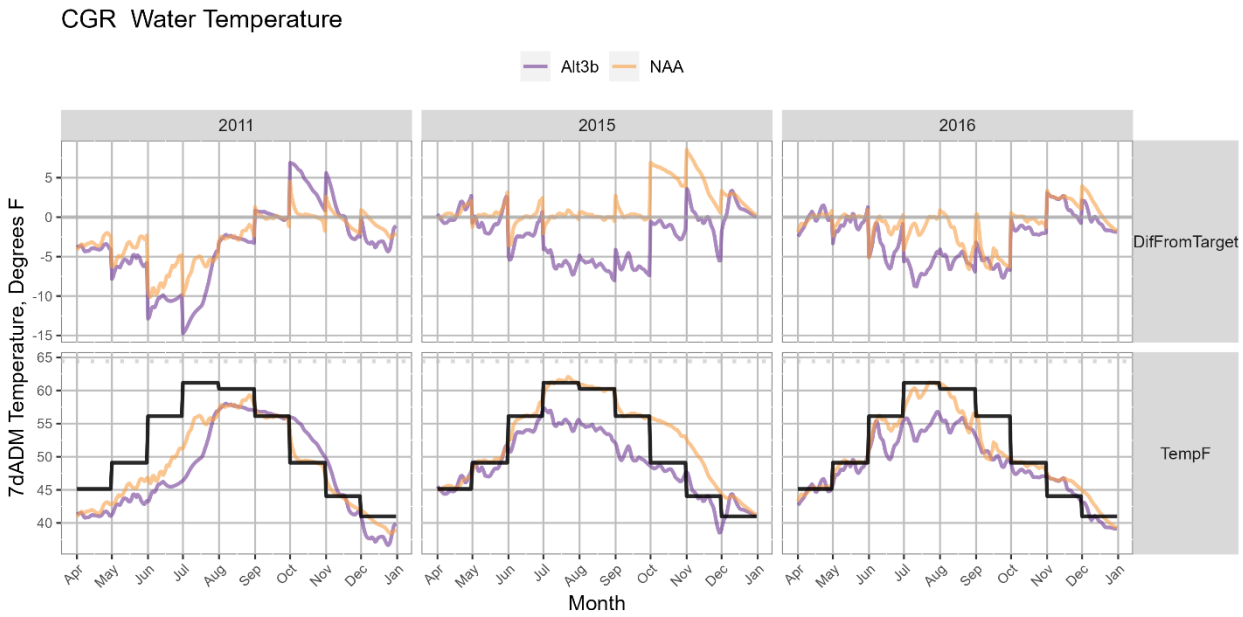


Figure 1-560. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster Dam. Black line indicates temperature target.

1.6.6.4 Middle Fork Willamette Dams

Water temperature measures under Alternative 3b include Hills Creek reservoir modification to the spillway and use the spillway for surface spill in the summer. Lookout point reservoir would utilize the RO's to discharge colder water during drawdown operations in fall and winter to reduce downstream water temperatures. The Lookout Point spillway would be utilized in the summer for surface spill. Dexter spillway would be utilized in order to spread surface spill.

Water temperature results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-557; Figure 1-561) in the 2011-year scenario water temperature increase from 1 to 8 degrees is observed from April to August. In the 2015-year scenario observes a 1 degree decrease from June through September as compared to the NAA. In the 2016-year scenario a 2 to 6-degree water temperature increase is observed from April through July and decrease up to 7-degrees from August until October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a water temperature increases from 1-4 degrees in April through August and decreases up to 3-degrees in September and October.

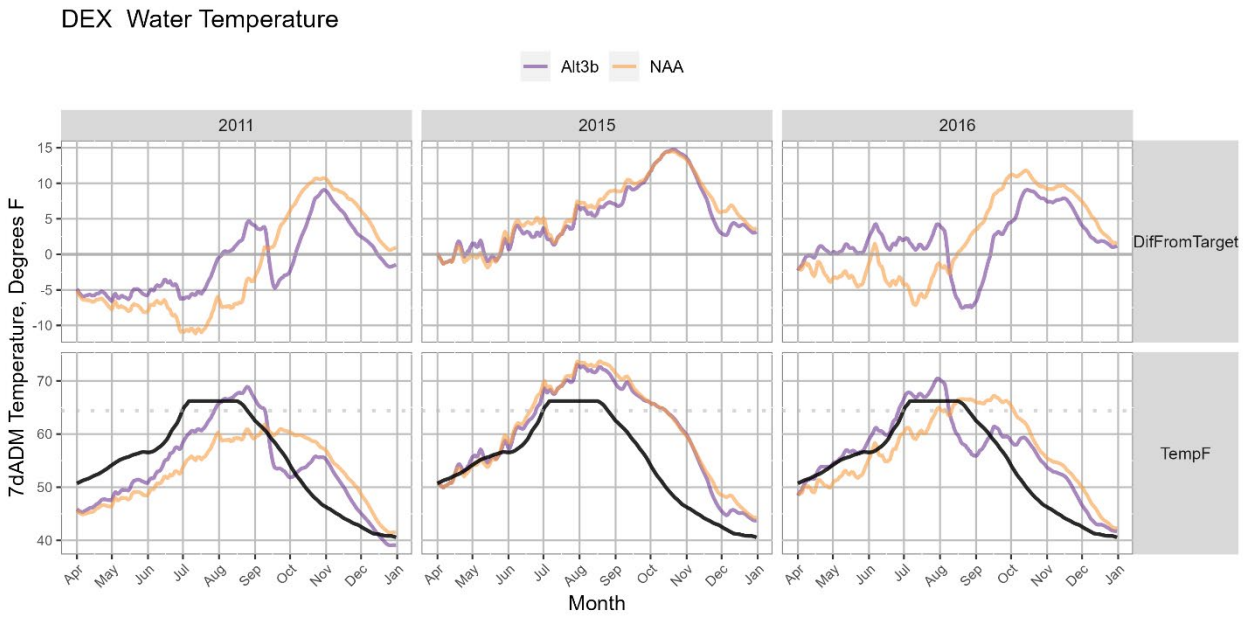


Figure 1-561. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter Dam. Black line indicates temperature target.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures (deg F) at the Middle Fork Willamette River above Salt Creek gaging site (HCRO Figure 1-557;Figure 1-562) in the 2011-year scenario water temperature increase from 1 to 5 degrees is observed from April to October (Fig XX). In the 2015-year scenario observes a 2-9 degree increase from April through September as compared to the NAA. In the 2016-year scenario water temperature increases 3-8 degrees from April through September as compared to the NAA. For the Average of the three years (2011, 2015, 2016) water temperatures increase 2 to 7 degrees from April through September as compared to the NAA.

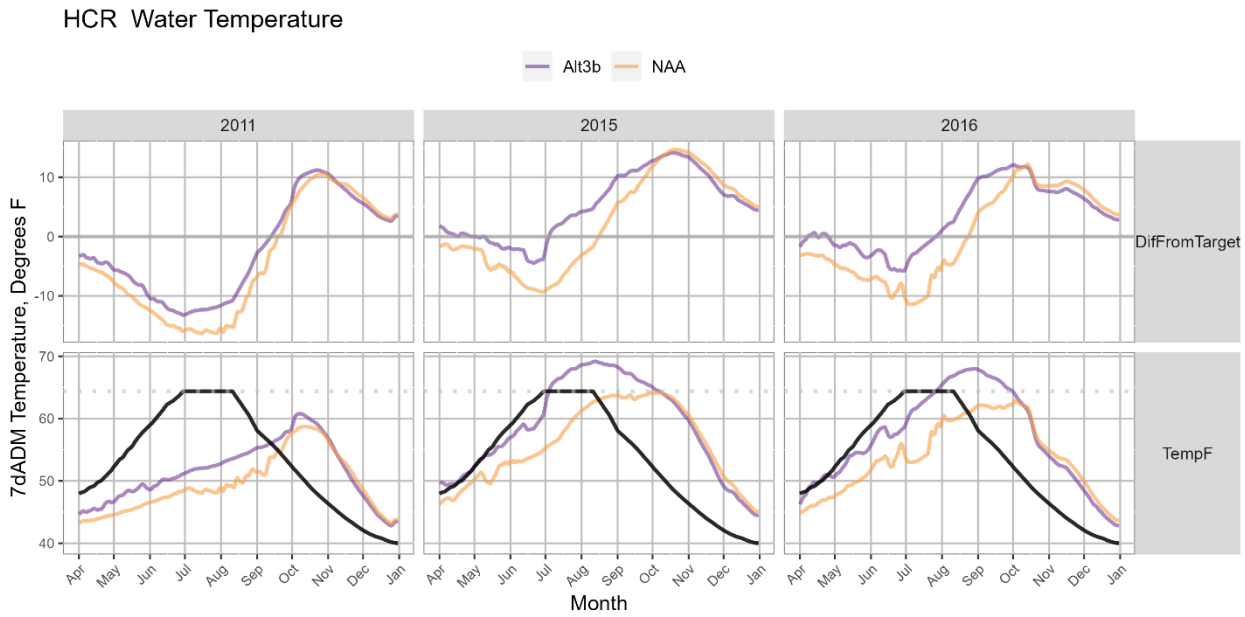


Figure 1-562. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek Dam. Black line indicates temperature target.

1.6.6.5 Mainstem Willamette River

Mainstem Willamette River Alternative 3b results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-557) 2011-year scenario water temperature increases by 1 degree from May through August and decreases by 1 degree in September and October as compared to the NAA. In the 2015-year scenario temperature increases by 1 degree in May and October and decreases by 1 degree in July and September as compared to the NAA. In the 2016-year scenario water temperatures increase up to 2-degrees from May until July and then decreases by 1 degree in September as compared to the NAA. For the average of the three years (2011,2015, 2016) water temperature increases by 1 degree in May and June and then decreases by 1 degree in September as compared to the NAA.

Mainstem Willamette River Alternative 3b results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-557) in the 2011-year scenario water temperatures increase up to 2 degrees from June through August and then decreases by 1 degree in October as compared to the NAA. In the 2015-year scenario water temperatures increase by 1-degrees in May and October as compared to the NAA. In the 2016-year scenario water temperatures increase up to 2 degrees from April through July and then decreases up to 2 degrees from August until October as compared to the NAA. For the average of the three years (2011,2015, 2016) water temperatures increase by 1-degrees from May until July and then decrease by 1-degree in September as compared to the NAA.

1.6.7 Alternative 4 – Structures-Based Fish Passage Alternative

Alternative 4 structural improvements for water temperature measures include:

- Water temperature control towers at Detroit, Hills Creek, and Lookout Point dams
- Modify existing outlets to allow releases at varying depths for temperature control at Foster reservoir by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs
- Utilizing the RO's to discharge cold water during drawdown operations in the fall and winter to reduce water temperatures below Green Peter dam
- Utilizing the spillway for surface spill in the summer at Green Peter dam.

Summary tables of Alternative 4 monthly mean water temperature and monthly mean difference between Alternative 4 and NAA for each of the three simulated years are shown in and Figure 1-563 and Figure 1-564, respectively.

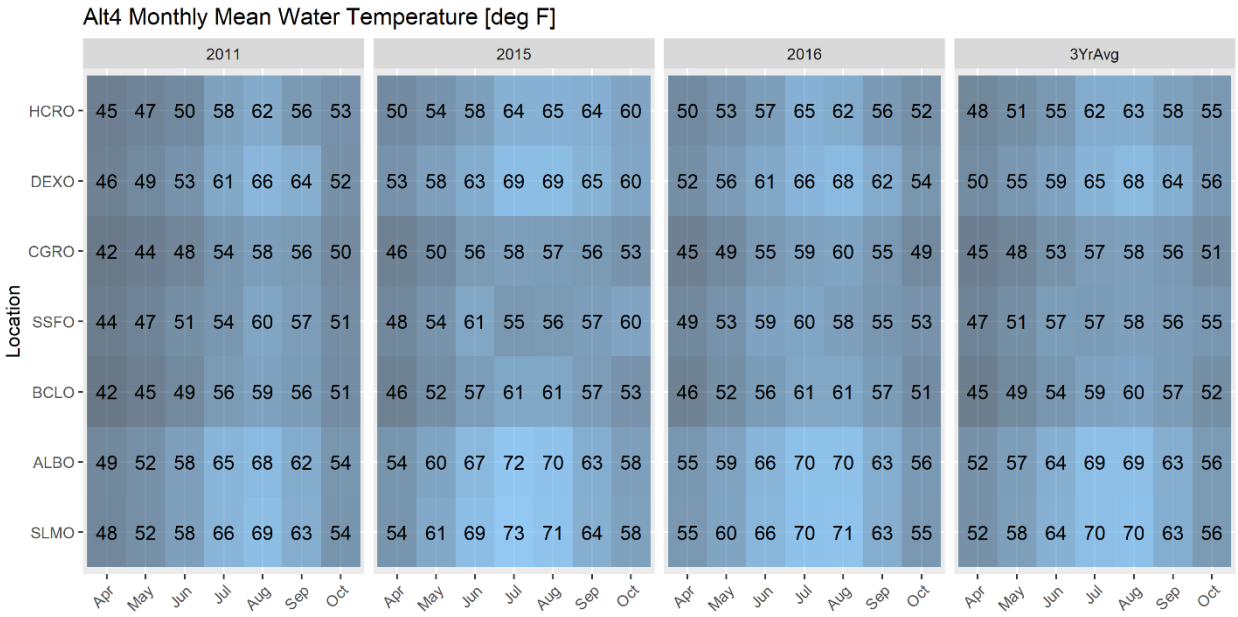


Figure 1-563. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 4.

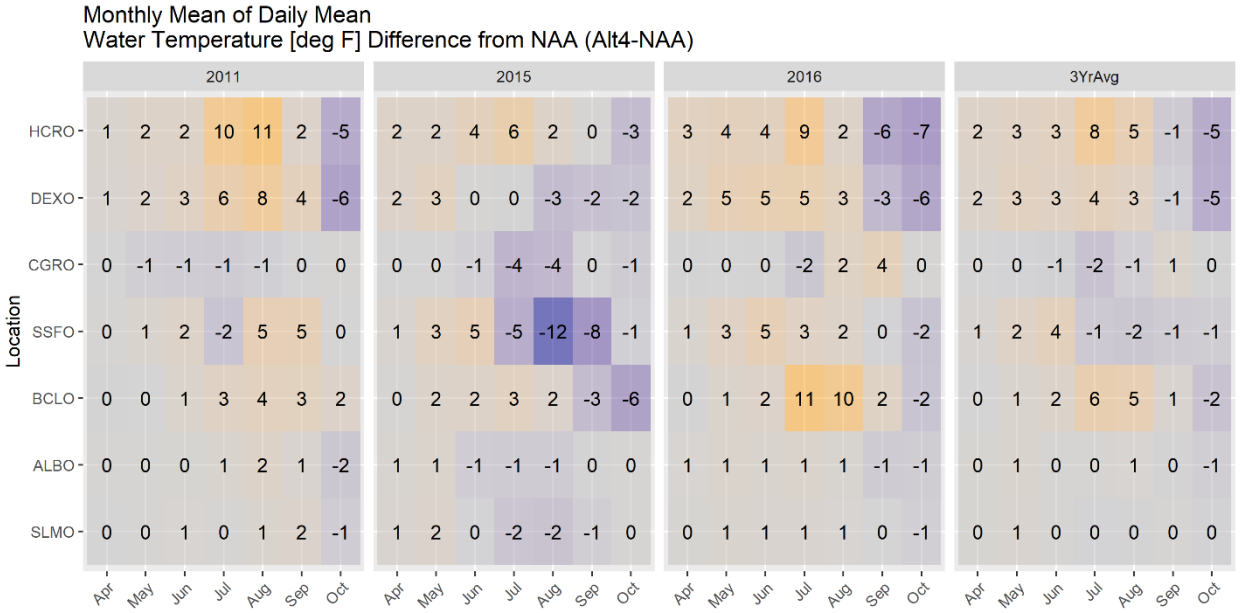


Figure 1-564. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 4.

1.6.7.1 North Santiam Dams

Alternative 4 measures at Detroit reservoir include a water temperature control tower. Alternative 4 results as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO; Figure 1-564; Figure 1-565) in the 2011-year scenario see water temperature increase up to 3 degrees starting in June through October. In the 2015-year scenario water temperatures would increase 2 to 3 degrees from May to August and then decrease up to 6 degrees in September and October. In the 2016-year scenario water temperatures would increase up to 11 degrees from May to September and then decrease by 2 degrees in October. For the average of the three years (2011,2015,2016) water temperatures would increase up to 6 degrees from May until September and then decrease by 2 degrees in October.

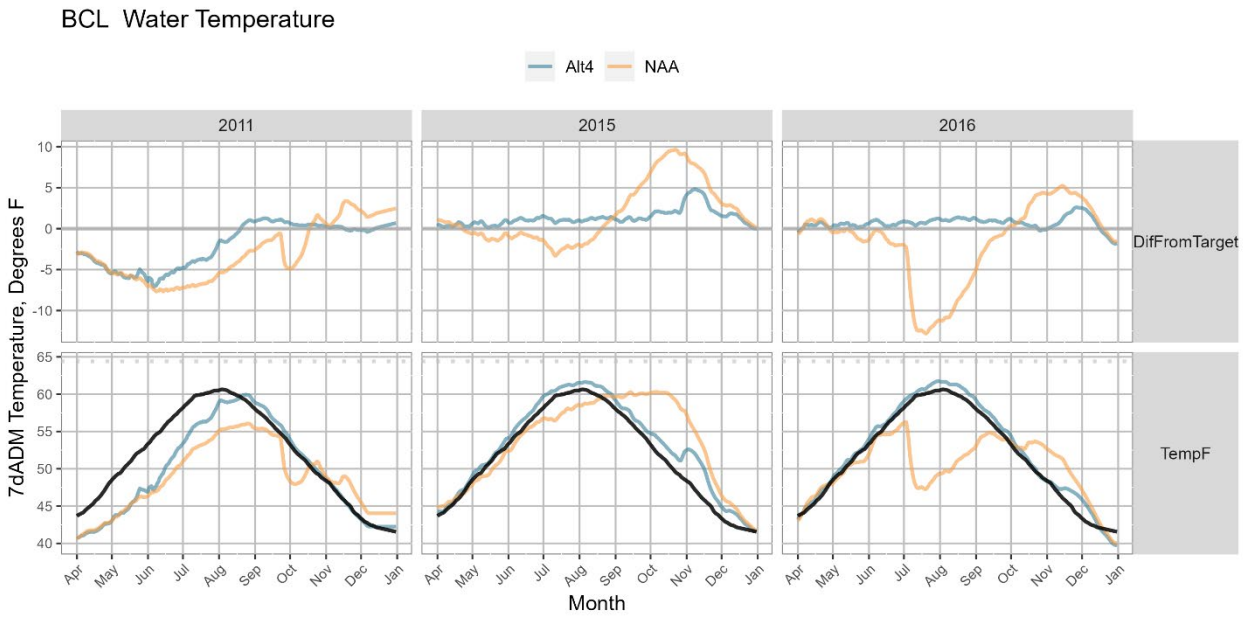


Figure 1-565. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff Dam. Black line indicates temperature target.

1.6.7.2 South Santiam Dams

Alternative 4 measures at Green Peter reservoir include utilizing the RO's to discharge colder water during drawdown operation in the fall and winter to reduce downstream water temperatures. The Green Peter spillway is used for surface spill in the summer. At Foster reservoir the existing outlets would be modified to allow releases at varying depths for temperature control at the Facility Warm Water Supply (FWWS) pipe and fish weirs.

Alternative 4 results as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO; Figure 1-564; Figure 1-566) in the 2011-year scenario water temperatures would increase up to 5 degrees from May until September, although a 2-degree decrease occurs in July. In the 2015-year scenario water temperatures would increase up to 5 degrees from April to June and then decrease up to 13 degrees from July through October. In the 2016-year scenario water temperatures would increase up to 5 degrees from April to August and then decrease by 2 degrees in October. For the average of the three years water temperatures would increase up to 4 degrees from April until June and decrease up to 2 degrees from July through October.

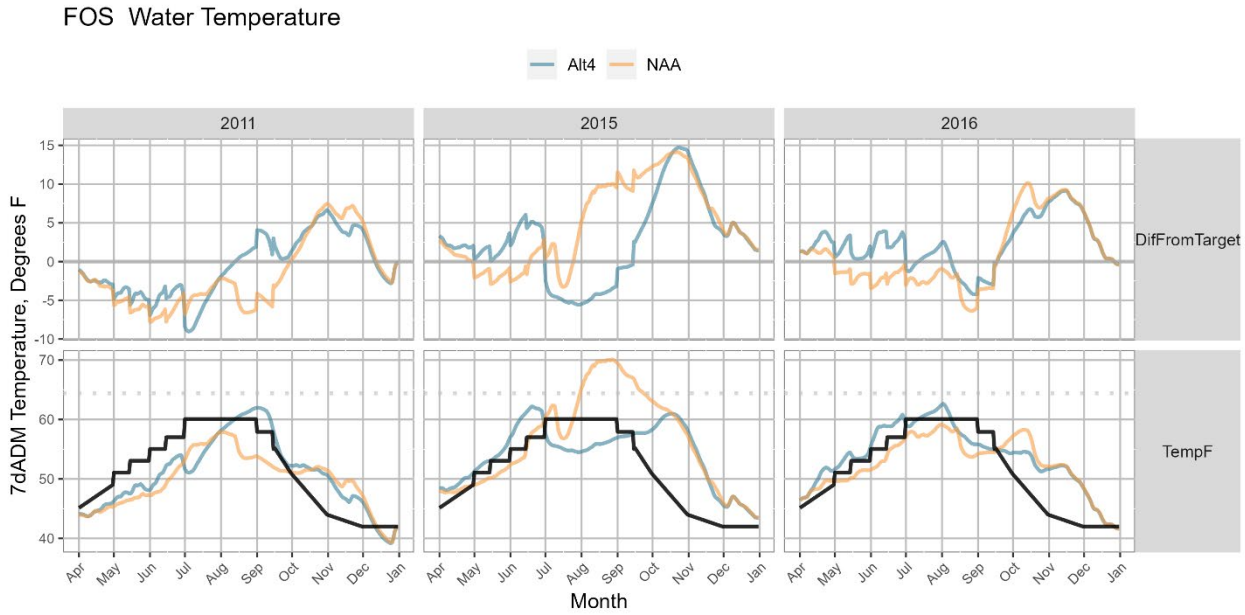


Figure 1-566. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster Dam. Black line indicates temperature target.

1.6.7.3 McKenzie Dams

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-564; Figure 1-567) in the 2011-year scenario water temperature would decrease by 1 degree from May until August. In the 2015-year scenario there would be a decrease of up to 3 degrees from July to October. In the 2016-year scenario a decrease is observed up to 2 degrees in July and an increase of 4 degrees is observed in August and September. For the Average of the three years (2011, 2015, 2016) water temperature decreases up to 2 degrees from June until August and then increases by 1 degree in September.

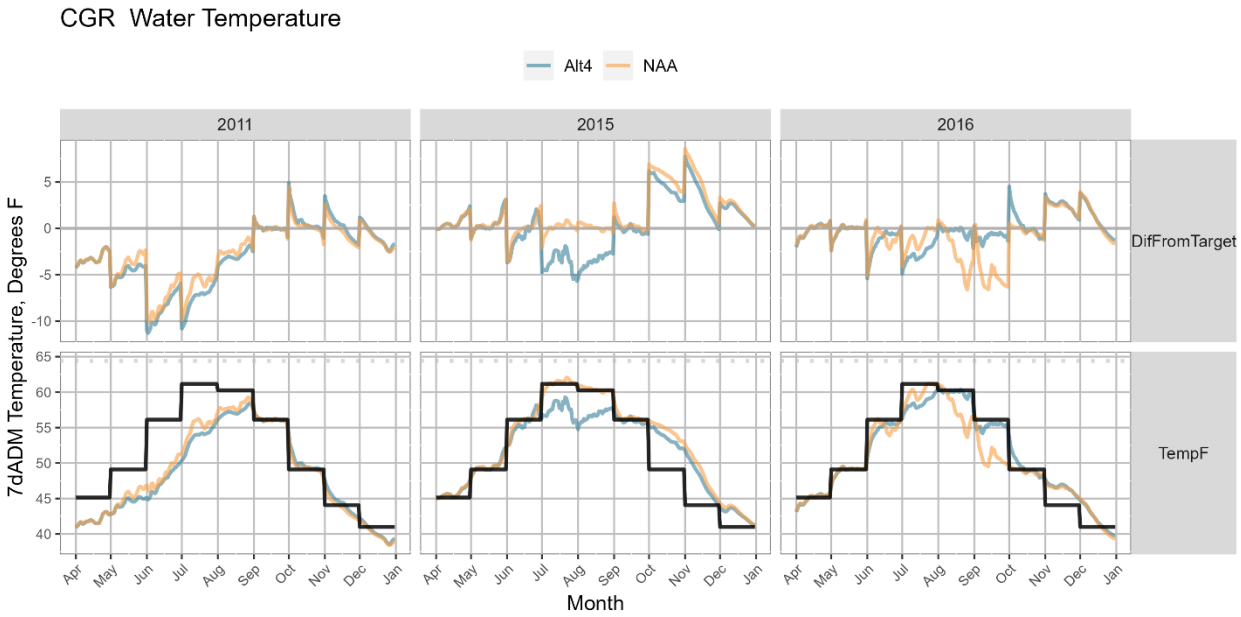


Figure 1-567. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar Dam. Black line indicates temperature target.

1.6.7.4 Middle Fork Willamette Dams

Alternative 4 measures at Hills Creek and Lookout Point dams include water temperature control towers to better regulate downstream water temperatures. There are no Alternative 4 temperature measures for Dexter or Fall Creek reservoirs.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-564;Figure 1-568) in the 2011-year scenario water temperature would increase starting in April through September up to 8 degrees and decrease by 6 degrees in October. In the 2015-year scenario water temperature would increase up to 3 degrees in April and May and then decrease up to 3 degrees from August to October. In the 2016-year scenario water temperatures would increase up to 5 degrees from April to August and then decrease up to 6 degrees in September and October. For the average of the three years water temperatures would increase up to 4 degrees from April through August and then decrease up to 5 degrees in September and October.

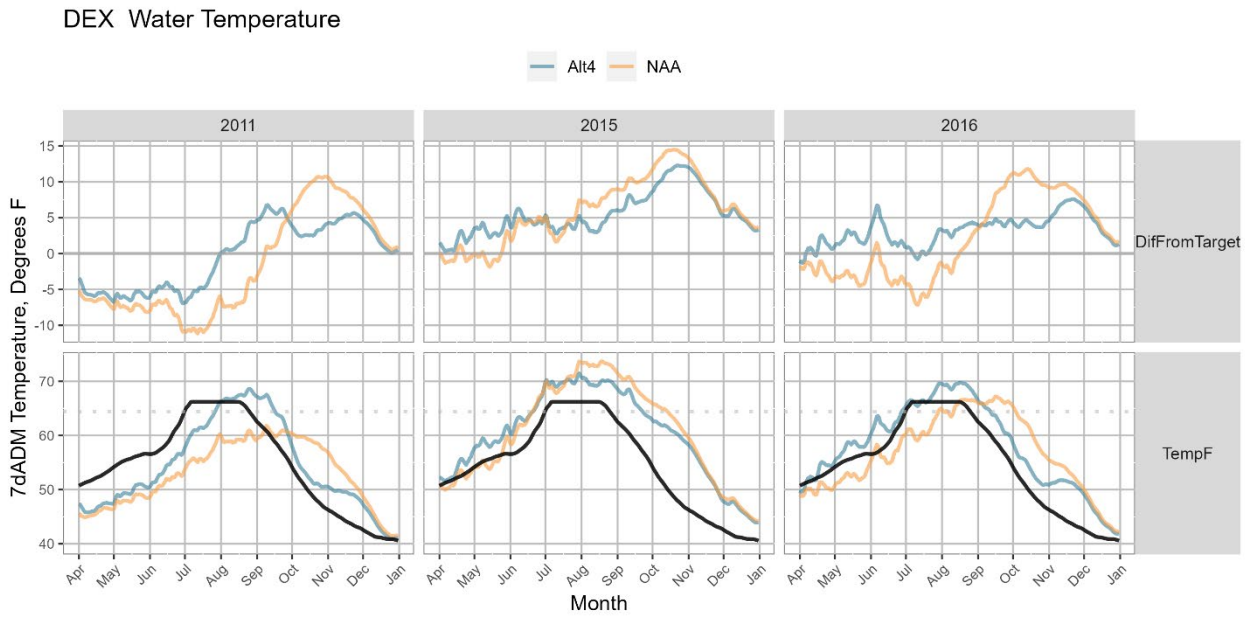


Figure 1-568. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter Dam. Black line indicates temperature target.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-564; Figure 1-569) in the 2011-year scenario water temperatures would increase up to 12 degrees from April through September and then decrease by 5 degrees in October. In the 2015-year scenario water temperatures would increase up to 6 degrees from April through August and then decrease by 3 degrees in October. In the 2016-year scenario water temperatures would increase up to 9 degrees from April through August and then decrease by 7 degrees in September and October. For the average of the three years (2011,2015,2016) water temperatures would increase up to 8 degrees from April through August and then decrease up to 5 degrees in September and October.

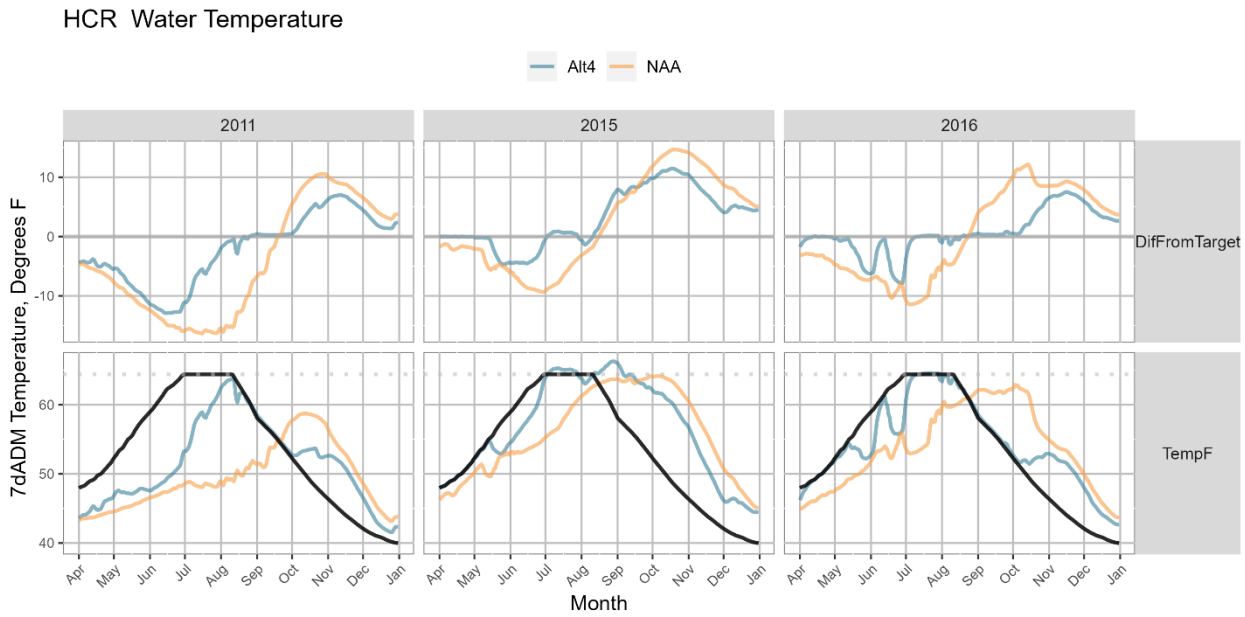


Figure 1-569. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek Dam. Black line indicates temperature target.

1.6.7.5 Mainstem Willamette River

Mainstem Willamette River Alternative 4 results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-564) 2011-year scenario water temperature increases by 1 degree in June and August to September and decreases by 1 degree in October as compared to the NAA. In the 2015-year scenario temperature increases up to 2 degrees from April to May and decreases up to 2 degrees in July and September as compared to the NAA. In the 2016-year scenario water temperatures increase by 1-degrees from May until July and then decreases by 1 degree in October as compared to the NAA. For the average of the three years (2011,2015, 2016) water temperature increases by 1 degree in May as compared to the NAA.

Mainstem Willamette River Alternative 4 results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-564) in the 2011-year scenario water temperatures increase up to 2 degrees from July through September and then decreases by 2 degrees in October as compared to the NAA. In the 2015-year scenario water temperatures increase by 1-degrees in April and May and then decreases by 1 degree in July and August as compared to the NAA. In the 2016-year scenario water temperatures increase up to 2-degrees from April through August and then decreases by 1 degree from September through October as compared to the NAA. For the average of the three years (2011,2015, 2016) water temperatures increase by 1-degrees in April through May and August and then decrease by 1-degree in October as compared to the NAA.

1.6.8 Alternative 5 – Preferred Alternative Qualitative Assessments

Alternative 5 improvement measures for water temperature include:

- Water temperature control tower at Detroit reservoir
- Use the RO's to discharge colder water during fall and winter drawdown operations at Green Peter reservoir
- Use of the spillway for surface spill in the summer at Green Peter Reservoir
- Modifying existing outlets to allow releases at varying depths for temperature control specifically at Foster reservoir with a modification to the Facility Warm Water Supply (FWWS) pipe and fish weirs.

Summary tables of Alternative 5 monthly mean water temperature and monthly mean difference between Alternative 5 and NAA for each of the three simulated years are shown in and Figure 1-570 and Figure 1-571, respectively.

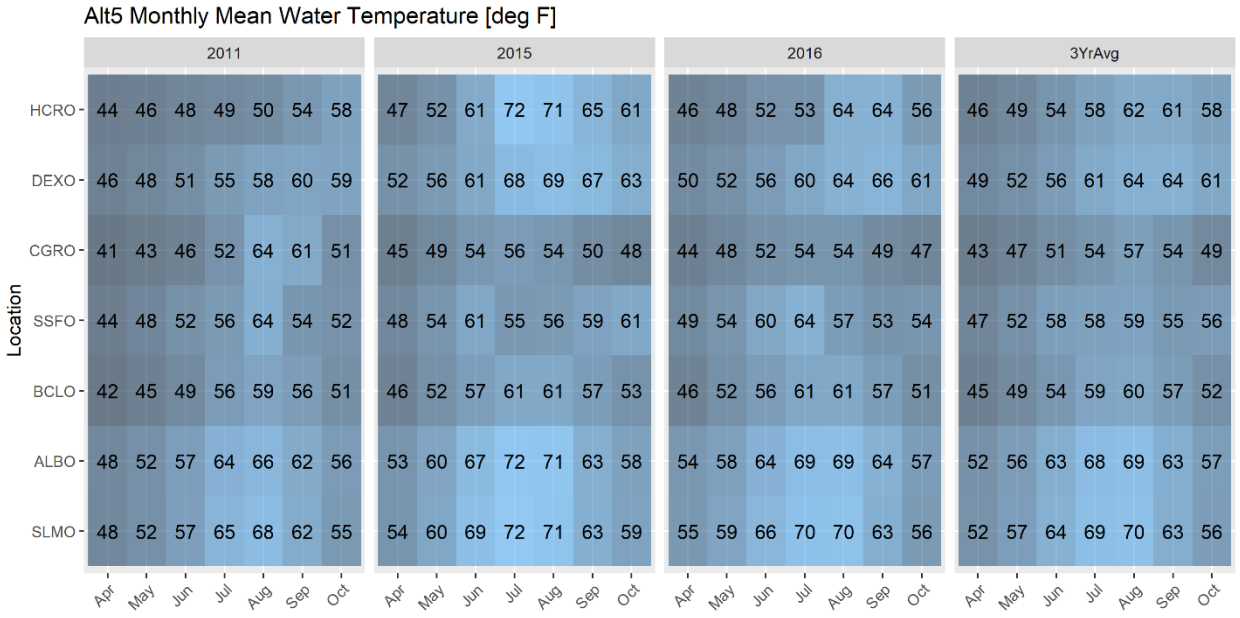


Figure 1-570. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 5.

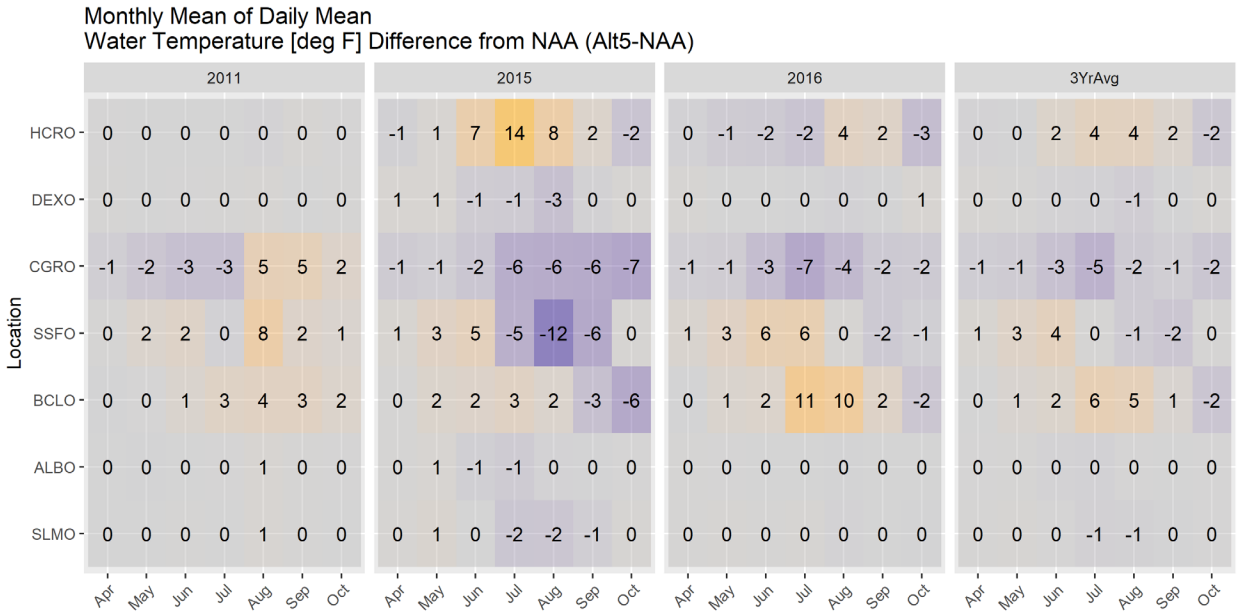


Figure 1-571. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 5.

1.6.8.1 North Santiam Dams

Alternative 5 includes a Water Temperature Control tower at Detroit reservoir for water temperature management. Alternative 5 as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO in Figure 1-571, Figure 1-572) in the 2011-year scenario an increase up to 3-degrees is observed from June until October as compared to the NAA. In the 2015-year scenario an increase up to 3-degrees is observed from May until August and then decreases up to 6 degrees in September and October. In the 2016-year scenario an increase up to 11-degrees is observed from May until September as compared to the NAA. For the Average of the three years an increase up to 6-degrees is observed from May until September and then a decrease of 2-degrees in October as compared to the NAA.

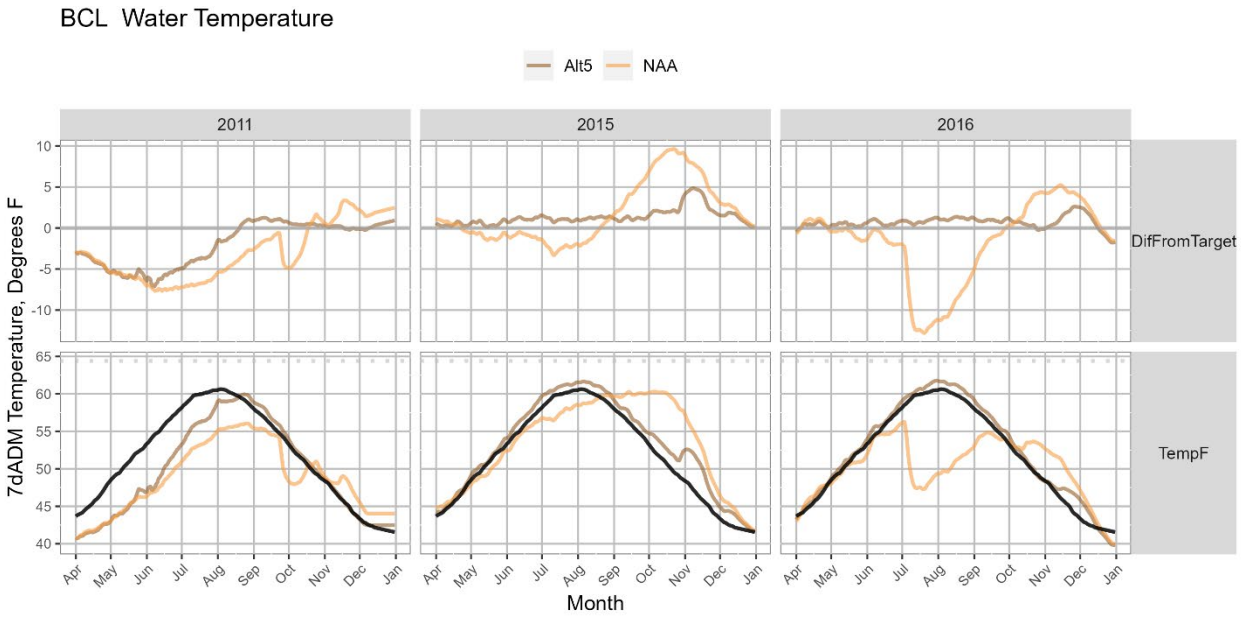


Figure 1-572. Comparison of Alternative 5 and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023).

1.6.8.2 South Santiam Dams

Alternative 5 includes the use of the RO's to discharge colder water during fall and winter drawdown operations at Green Peter reservoir. An additional measure includes the use of the spillway for surface spill in the summer at Green Peter reservoir (Figure 1-573). Also, a measure to modify existing outlets to allow releases at varying depths for temperature control specifically at Foster reservoir with a modification to the Facility Warm Water Supply (FWWS) pipe and fish weirs.

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO in Figure 1-571, Figure 1-574) in the 2011-year scenario would see an water temperature increase starting in May through October up to 8 degrees, although July observed a 1-degree temperature decrease. In the 2015-year scenario an increase in water temperatures of 1 to 6 degrees from April to June, a decrease in temperatures from 1 to 13 degrees is observed from July to October. In the 2016-year scenario an increase up to 6 degrees from April to August and then decrease by 2 degrees in September and October. For the Average of the three years (2011, 2015, 2016) an increase 1 to 5 degrees from April through June and then decrease up to 3 degrees from August until October.

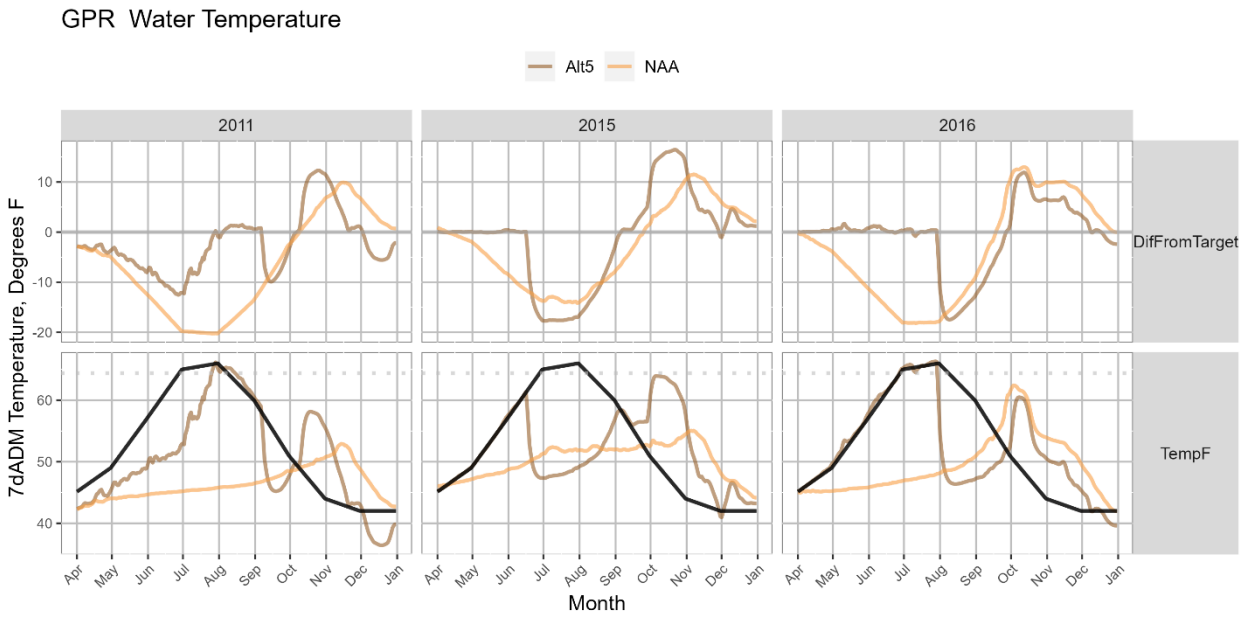


Figure 1-573. Comparison of Alternative 5 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Green Peter dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively.

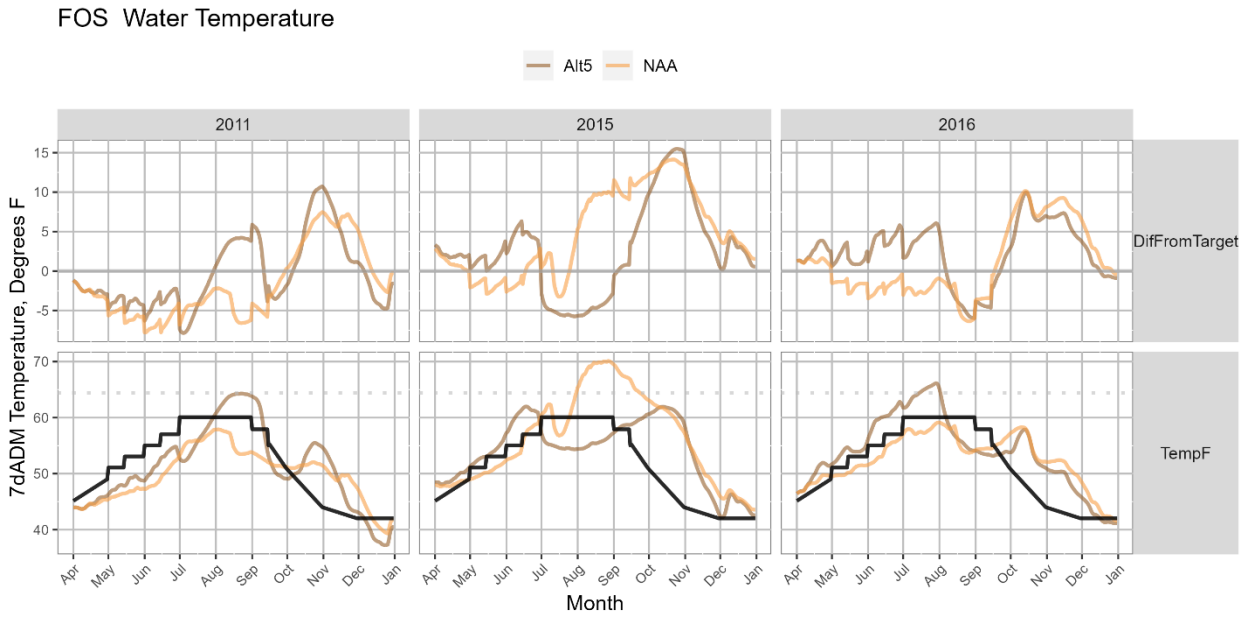


Figure 1-574. Comparison of Alternative 5 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively.

1.6.8.3 McKenzie Dams

There are no water temperature measures for Cougar or Blue River dams under Alternative 5. Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-571, Figure 1-575). The Cougar 2011 model contained an error in which outflow was specified through the WTC4 outlet rather than the RO from julian day 202 to 280 while the lake level was above the RO intake. This resulted in warmer release temperature than Alternative 2b. Due to the late discovery of this error, it is recommended to use Alternative 2b instead of Alternative 5 for 2011 at Cougar. In the 2015-year scenario a water temperature decrease up to 7 degrees is observed from June until October, as compared to the NAA. In the 2016-year scenario a temperature decrease is observed up to 5 degrees from May until October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a temperature decrease up to 4 degrees is observed from May until October as compared to the NAA. These water temperature decreases relative to NAA are a result of the deep drawdown, decreased residence time in Cougar Lake (reduced heating in the reservoir), and use of the diversion tunnel as the primary outlet.

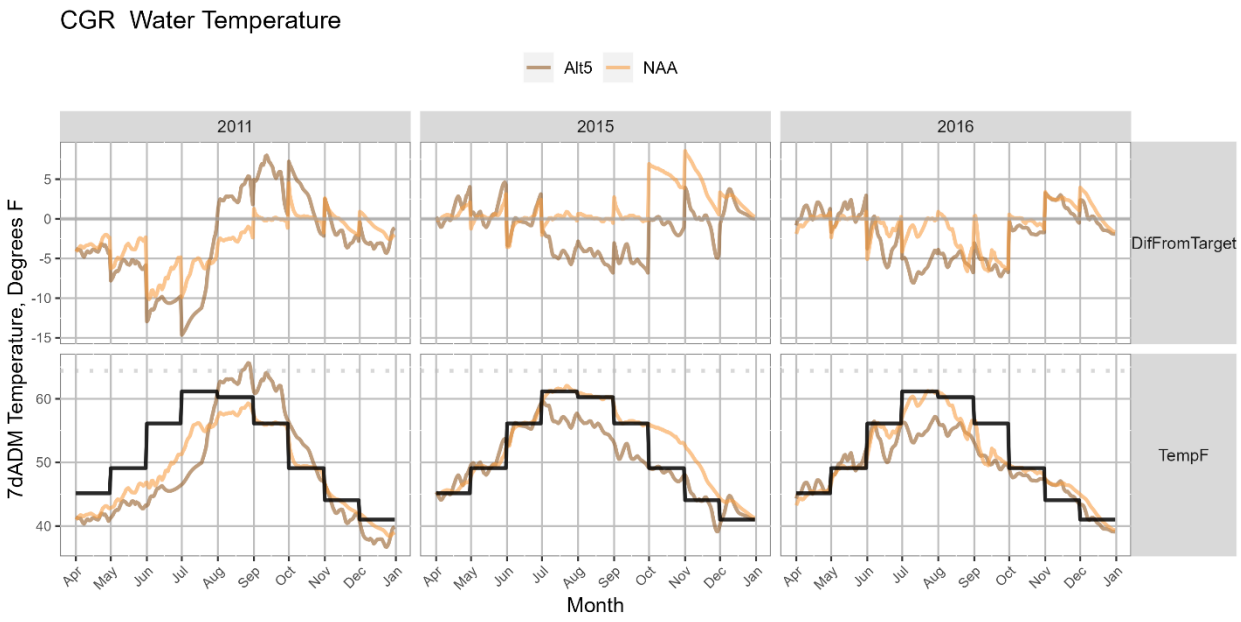


Figure 1-575. Comparison of Alternative 5 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively.

1.6.8.4 Middle Fork Willamette Dams

Alternative 5 has no water temperature measures for the Middle Fork sub-basin. Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-571, Figure 1-576) in the 2011-year

scenario there would be no temperature difference from April to October. In the 2015-year scenario observes a 1-degree increase in May, a water temperature decrease up to 3-degrees is observed from June until September. In the 2016-year scenario most months see no change in water temperatures except for August which decreases by 1 degree as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a water temperature decrease by 1 degree is observed from July through September.

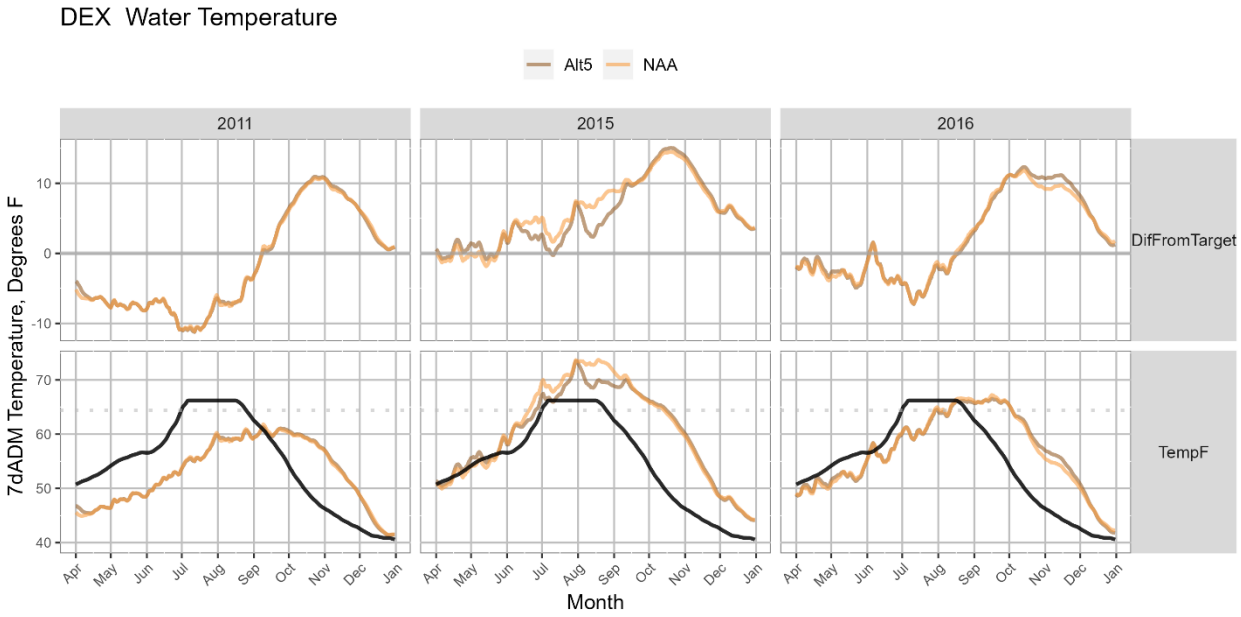


Figure 1-576. Comparison of Alternative 5 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures (deg F) at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-571, Figure 1-577) in the 2011-year scenario there would be no temperature difference from April to October as compared to the NAA. In the 2015-year scenario a decrease up to 2 degrees is observed in May and October, water temperature increases up to 9 degrees in June through September as compared to the NAA. In the 2016-year scenario water temperature decrease is observed up to 4 degrees from May until October, although September would increase by 1 degree. For the Average of the three years (2011, 2015, 2016) a water temperature decrease up to 1 degrees is observed in May and October, a temperature increase up to 2 degrees occurs in July through September.

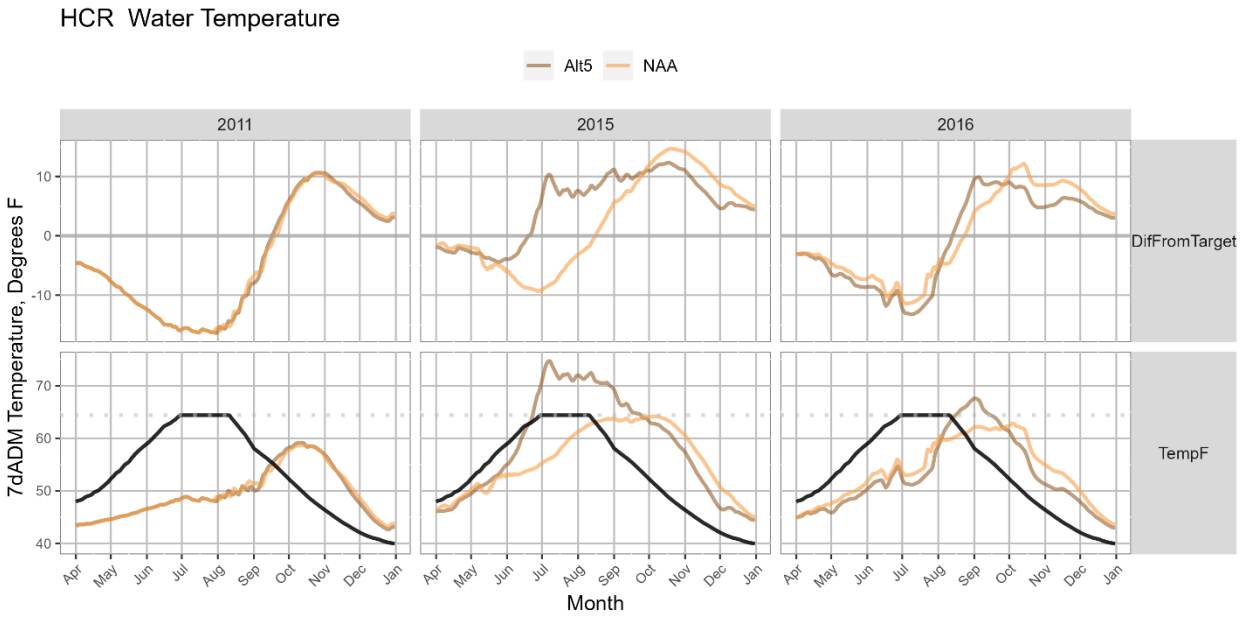


Figure 1-577. Comparison of Alternative 5 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black line and grey dotted lines represent the temperature target and the Oregon State Temperature Standard (State of Oregon, 2023), respectively.

1.6.8.5 Mainstem Willamette River

Mainstem Willamette River Alternative 5 results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-571). In the 2011-year scenario there would be a 1-degree water temperature increase in August. In the 2015-year scenario water temperatures decrease by 2-degree from July through September. In the 2016-year scenario a water temperature increase of 1 degree is observed in May. For the Average of the three years (2011, 2015, 2016) water temperature increases 1-degree in May and then decreases by 1 degree in July.

Mainstem Willamette River Alternative 5 results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-571). In the 2011-year scenario a water temperature increase up to 1 degree is observed in August. In the 2015-year scenario the water temperature decreases by 2 degrees from June through August. In the 2016-year scenario a water temperature increase of 1 degree is observed in May. For the Average of the three years (2011, 2015, 2016) no temperature change is observed.

THE DEIS HAS BEEN MODIFIED TO REVISE THE FOLLOWING INFORMATION IN THE FEIS

1.6.9 Interim Operations (Near Term Operations Measure (NTOM))

NTOM improvement measures for water temperature include:

- No spill cap to best achieve downstream water temperature targets at Detroit (NAA included a 60% cap)
- Early and deeper draft of Green Peter and Lookout Point reservoir for fish passage use of RO's resulting in mixed temperature changes dependent on timing of draft and water year-type.
- Use of spillway for surface spill in the spring at Green Peter and Lookout Point reservoirs

Summary tables of NTOM monthly mean water temperature and monthly mean difference between NTOM and NAA for each of the three simulated years are shown in and Figure 1-578 and Figure 1-579, respectively. The figures and tables in this section represent the NTOM DEIS HEC-RESSIM and CE-QUAL-W2 modeling and analysis and were not updated for the FEIS.

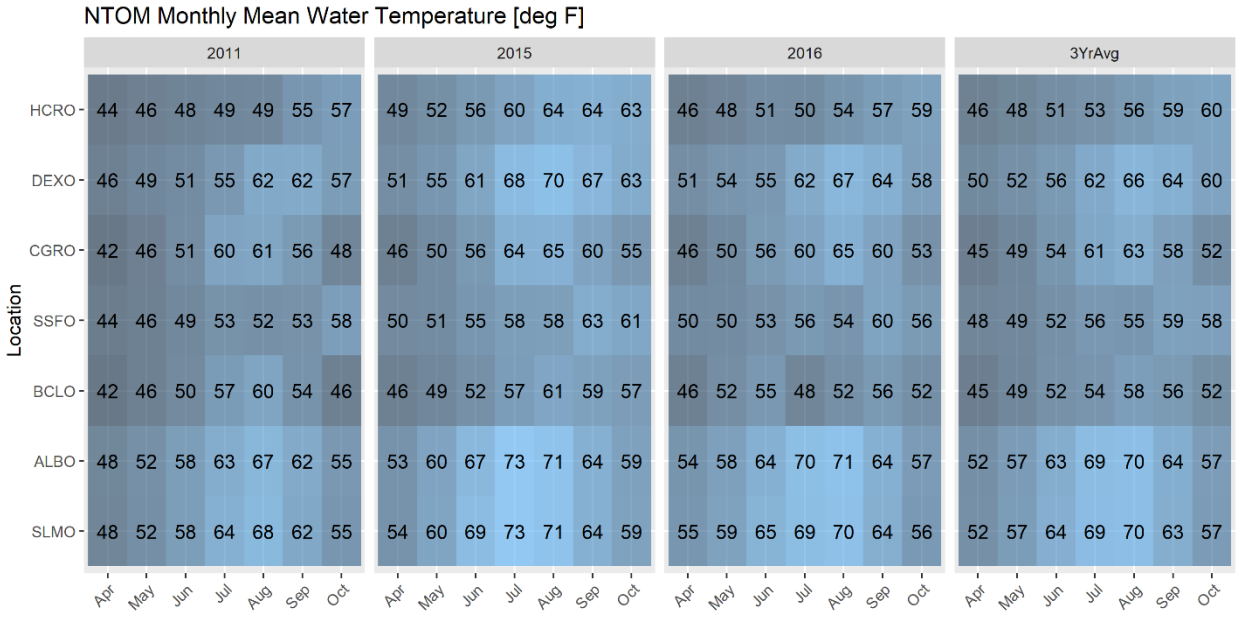


Figure 1-578. Monthly Mean of Water Temperatures (Fahrenheit) for NTOM.

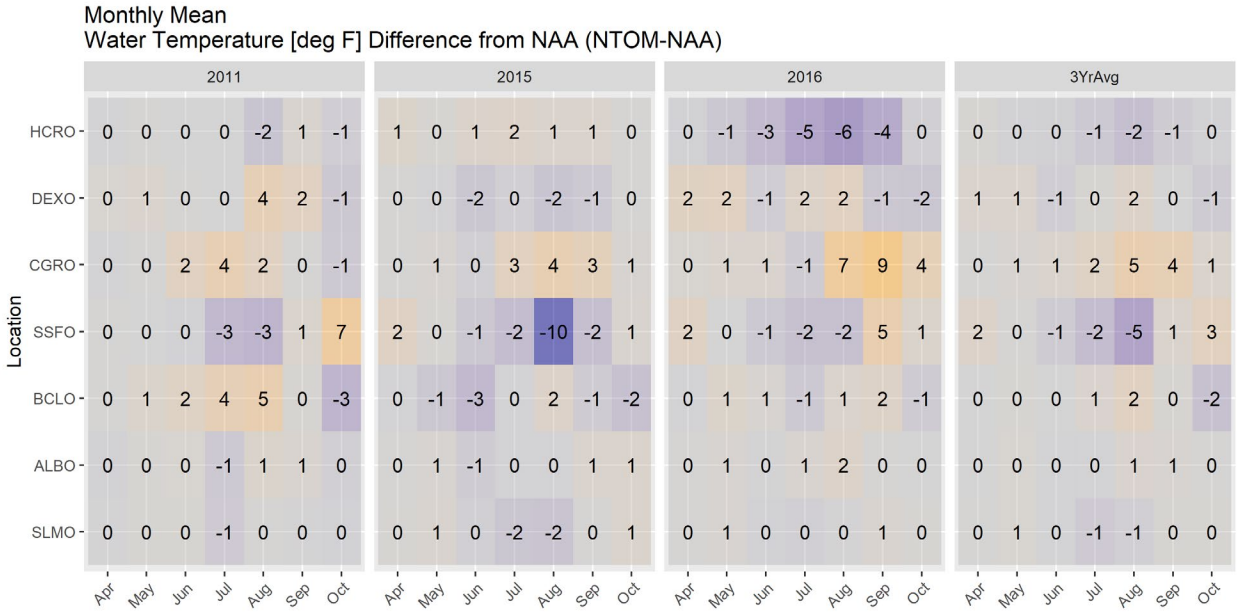


Figure 1-579. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to NTOM.

1.6.9.1 North Santiam Dams

NTOM includes increased spillway and RO use compared to NAA for fish passage and water temperature management. NTOM is compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO in Figure 1-579, Figure 1-580) in the 2011-year scenario an increase up to 5-degrees F is observed from June until October as compared to the NAA. In the 2015-year scenario a decrease of as much as 3 degrees F (June) and an increase up to 2-degrees F (August) was shown in NTOM DEIS temperature modeling results. However, updated NTOM (FEIS) ResSim modeling resulted in more time in which warmer surface water would be released through the power outlet during July – September. While no CE-QUAL-W2 temperature modeling was available for updated NTOM FEIS ResSim results, it is likely that these updated operations would result in similar release temperatures as NAA until July, when NTOM (FEIS) would result in warmer releases, then be followed by cooler releases about October-November as compared to NAA. This would likely result in a negligible difference in Days Near Temperature Target or Days Above 64.4 °F metrics between DEIS and FEIS NTOM.

The 2016-year scenario was generally within a few degrees of NAA throughout the year. All three calendar years displayed cooler temperatures in NTOM compared to NAA in October. It is likely that negligible differences in temperature estimates would result from DEIS to FEIS NTOM results in 2011 and 2016 at Detroit Lake, due to the similarities in ResSim operations in those years. For the average of the three years an increase up to 2-degrees F is likely from July to August followed by a decrease of about 2-degrees F in October as compared to the NAA.

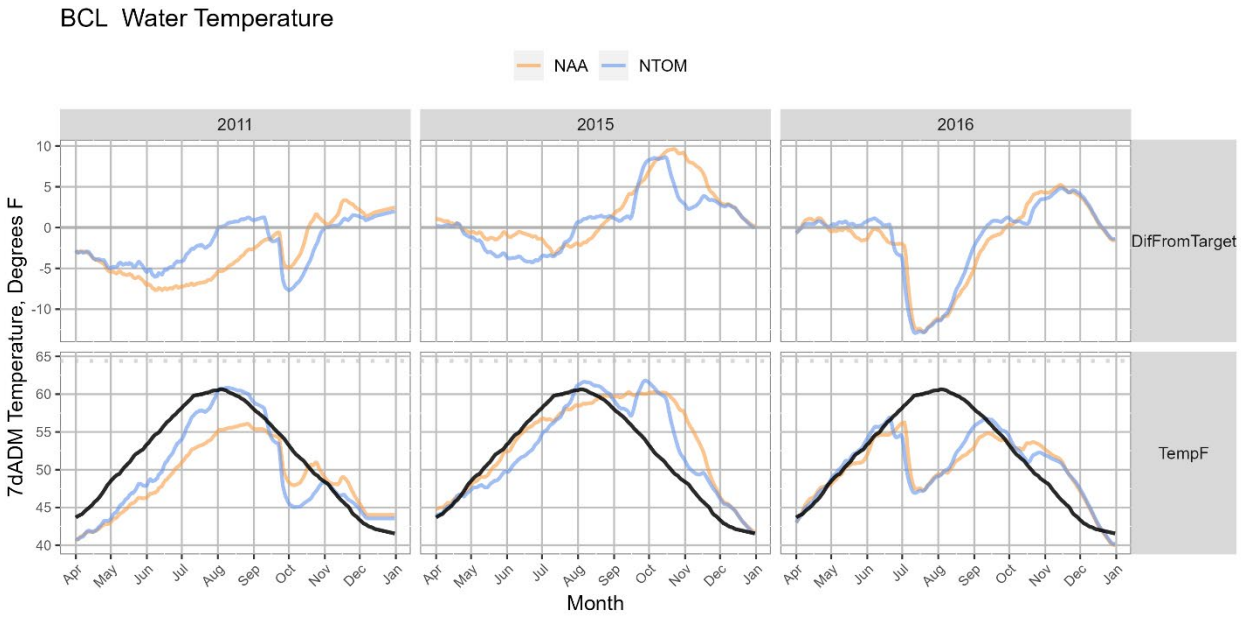


Figure 1-580. Comparison of NTOM and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Big Cliff dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028).

1.6.9.2 South Santiam Dams

NTOM includes the use of the spillway for surface spill in the spring followed by a deep drawdown in late summer to use the ROs fall and winter. Additionally, spillway and fish weir usage was expanded in NTOM for downstream fish passage and temperature control at Foster Dam.

NTOM is compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Santiam gaging site below Green Peter Dam (GPRO in Figure 1-581) and on the South Santiam below Foster Dam in Figure 1-582. Downstream of Green Peter, temperature would generally be warmer in April (when spillway use was possible), similar to baseline in June-August, and warmer in October (as the epilimnion is drafted), and cooler after November or whenever the lower target elevation is achieved (WVS BA Temp appendix, Section 1.6.3). Downstream of Foster dam, water temperature model results indicate the modified operations for both fish passage and temperature management at Green Peter and Foster would result in warmer conditions in April (due to Green Peter spill), cooler in June-August (due to greater Green Peter outflow), warmer in October (as Green Peter warm surface water is drafted), and cooler temperature after November or whenever the lower target elevation is achieved (WVS BA Temp appendix section 1.6.4)

During spring, Green Peter spill resulted in warmer temperature downstream below Green Peter and Foster Dams in 2015 and 2016 (Figure 1-581, Figure 1-582). Updated NTOM (FEIS) ResSim modeling resulted in minor differences compared to NTOM (DEIS) results, especially in

spring of 2015 (Figure 1-446) where the lake did not fill above the spillway. This effect on release temperature would likely be cooler April 2015 release temperature compared to NTOM DEIS and potentially warmer release temperature mid-August through October in 2015. When averaged over the 3 years, 2011, 2015, and 2016, this effect would likely result in a negligible difference in the Days Near Temperature Target or Days Above 64.4 °F metrics between DEIS and FEIS NTOM. On a monthly basis, NTOM was 2 degrees F warmer than NAA in April below Foster in 2015 and 2016 (SSFO in Figure 1-579). Due to the cooler conditions and relatively higher lake levels in 2011, warmer epilimnetic water was not yet available to be released via the spillway in that year and no discernable change in temperature downstream was observed during April of that year. It is likely that negligible differences in temperature estimates would result from DEIS to FEIS NTOM results in 2011 and 2016 at Green Peter Lake, due to the similarities in ResSim operations in those years.

During the deep draft at Green Peter Dam in July-August, higher release rates from the deeper power intakes resulted in cooler temperature downstream below Foster compared to NAA (monthly values ranging from 2 to 10 degrees F cooler; Figure 1-579). This effect was followed immediately by warmer release rates (up to 7 degrees F on a monthly average basis compared to NAA) as the epilimnion was drafted to the power and RO intakes until this warmer water was exhausted; coinciding with the pool level achieving the target elevation of 780 ft in late October-November. At this point in the year, release temperature below Green Peter and Foster Dams was relatively cooler than NAA due to the smaller Green Peter reservoir volume and shorter residence time.

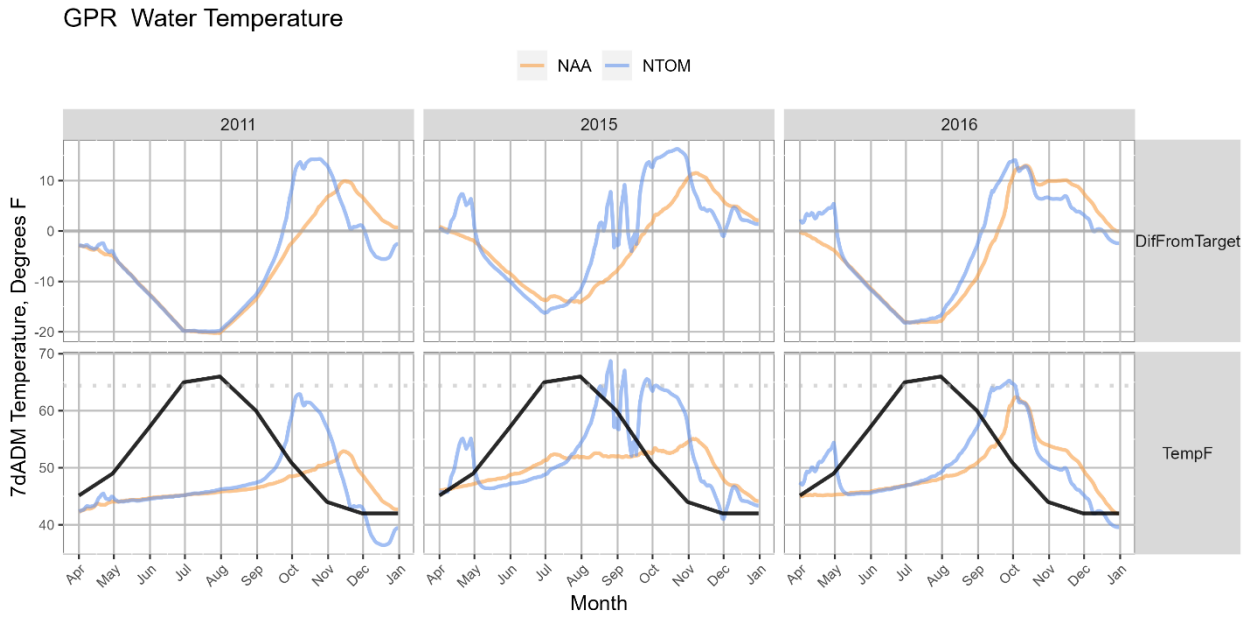


Figure 1-581. Comparison of NTOM for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Green Peter dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028).

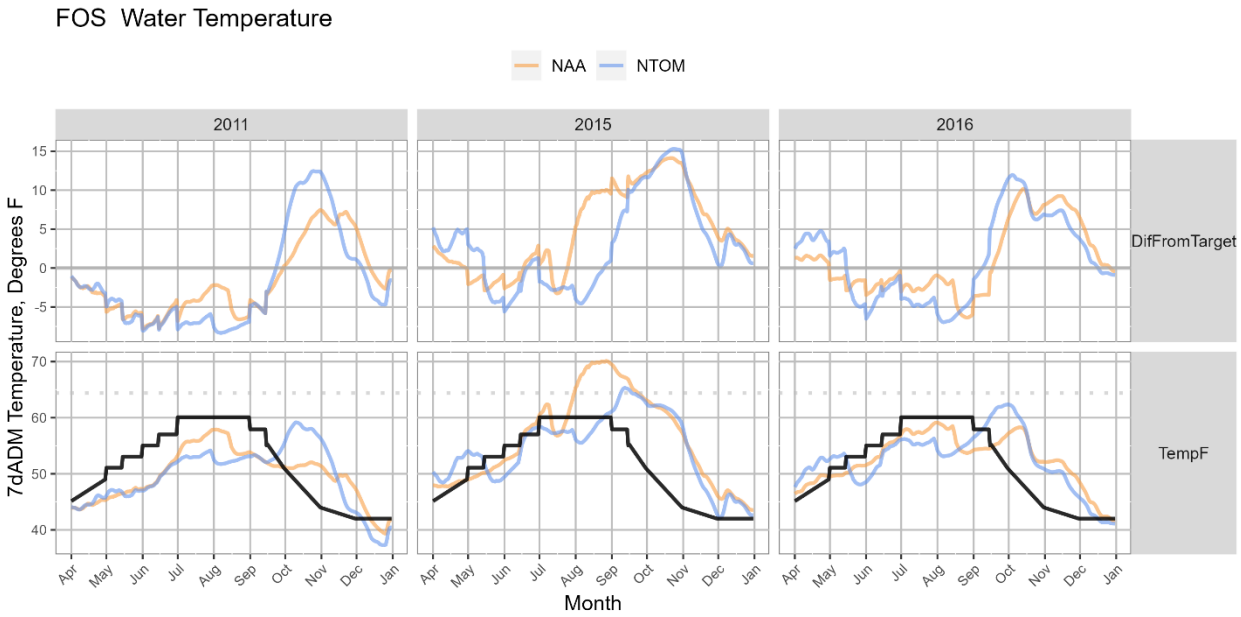


Figure 1-582. Comparison of NTOM for 2011, 2015, 2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Foster dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028).

1.6.9.3 McKenzie Dams

There are no water temperature measures for Cougar or Blue River dams under NTOM. Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-579; Figure 1-583). In 2011, the lake was refilled into the usable range for the water temperature control tower June-November and resulted in release temperatures warmer than NAA in early summer, but below or near the temperature target throughout the year. However, in the drier 2015 and 2016 years, inflows were not high enough to support refill and resulted in relatively warm surface releases (5-12 degrees F warmer than NAA July-October) from the RO. Autumn temperatures in November-December were negligibly different from NAA below Cougar.

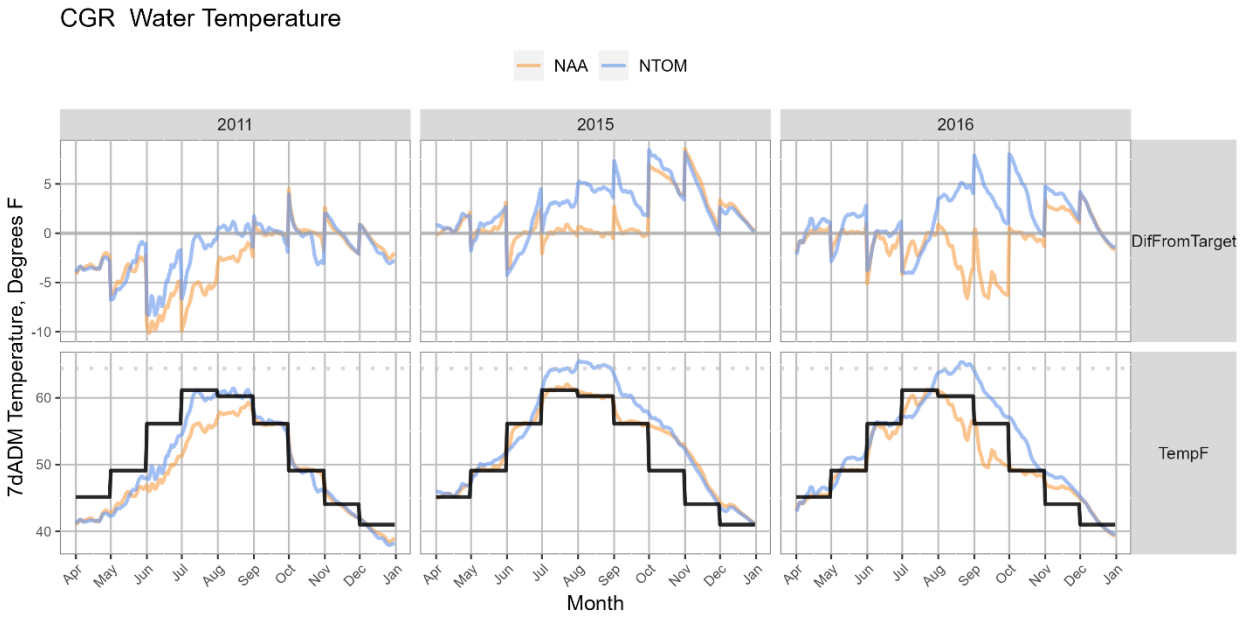


Figure 1-583. Comparison of NTOM for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Cougar dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028).

1.6.9.4 Middle Fork Willamette Dams

NTOM has no water temperature measures for the Middle Fork sub-basin. As compared to the NAA the Monthly Mean of Daily Mean water temperatures (deg F) at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-579; Figure 1-584) in the 2011-year scenario there would be no temperature difference from April to October as compared to the NAA. In the 2015-year scenario a decrease up to 2 degrees is observed in May and October, water temperature increases up to 9 degrees in June through September as compared to the NAA. In the 2016-year scenario water temperature decrease is observed up to 4 degrees from May until October, although September would increase by 1 degree. For the Average of the three years (2011, 2015, 2016) a water temperature decrease up to 1 degree is observed in May and October, a temperature increase up to 2-degrees occurs in July through September.

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-579; Figure 1-585) in the 2011-year scenario there would be no temperature difference from April to October. In the 2015-year scenario observes a 1-degree increase in May, a water temperature decrease up to 3-degrees is observed from June until September. In the 2016-year scenario most months see no change in water temperatures except for August which decreases by 1 degree as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a water temperature decrease by 1 degree is observed from July through September.

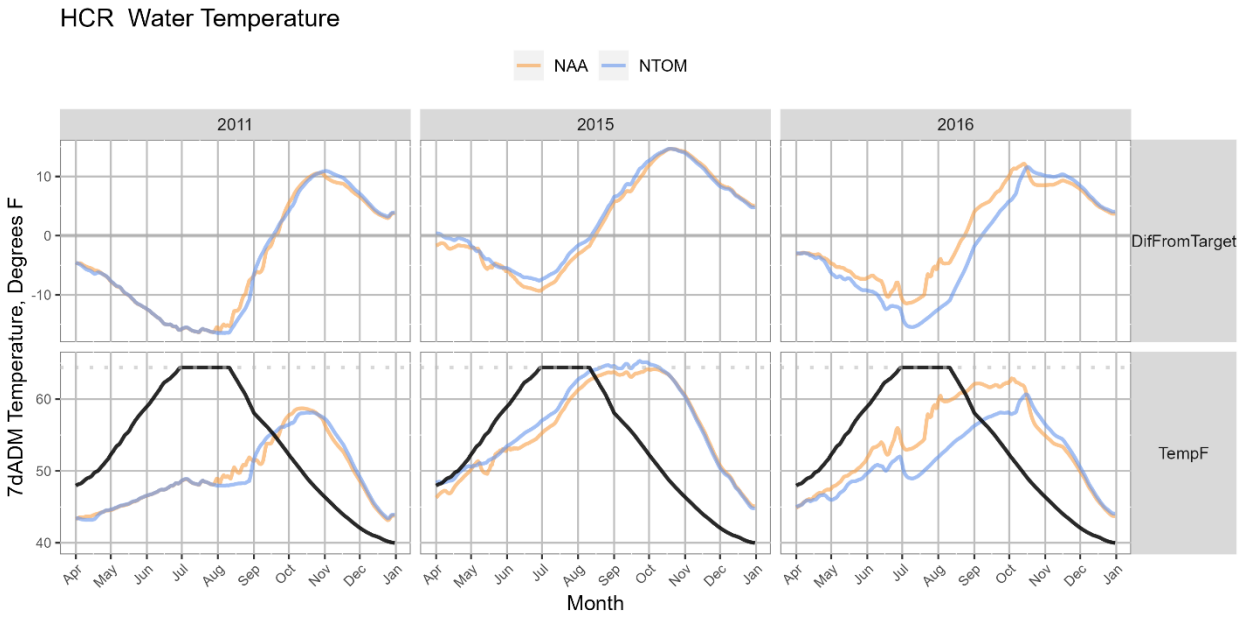


Figure 1-584. Comparison of NTOM for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Hills Creek dam. Black Line indicates simulated temperature target.

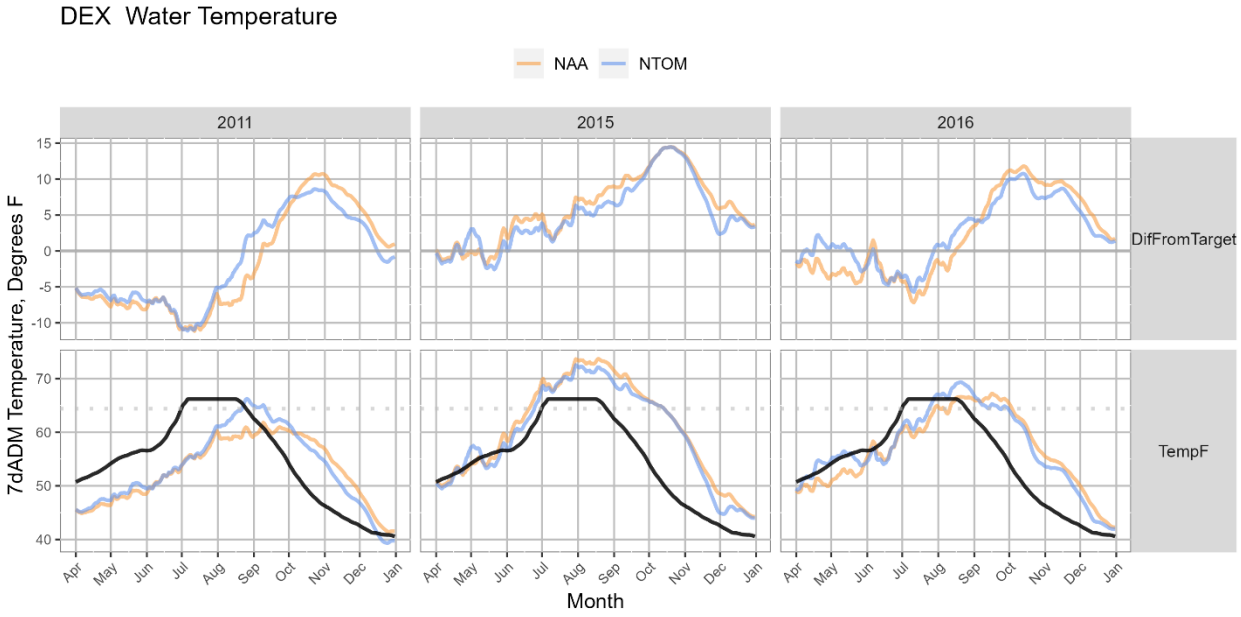


Figure 1-585. Comparison of NTOM for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the temperature target downstream of Dexter dam. Black Line indicates simulated temperature target; grey dotted line indicates the EPA water quality standard (OAR 340-041-0028).

1.6.9.5 Mainstem Willamette River

Mainstem Willamette River NTOM results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-579). Temperature changes in NTOM from NAA at Salem did not exceed 1 degree F except for July-August of 2015, which resulted in a 2 degree F decrease from NAA.

Mainstem Willamette River NTOM results are compared to the NAA using the Monthly Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-579). Temperature changes in NTOM from NAA at Albany did not exceed 1 degree F except for August of 2016, which resulted in a 2 degree F increase from NAA.

1.6.10 Supplemental EIS

This section provides the figures and tables that represent the water temperature results for the WV EIS Chapter 3.5.3 Water Quality Effects Analysis of the SEIS. Refer to that chapter and section for explanations and interpretation of results for each alternative. Metrics utilized in the FEIS and shown in Section 1.6 (Days Near Temperature Target and Number of days in which the 7dADM water temperature is below 18 °C or 64.4 °F are shown in Figure 1-586, Figure 1-588). The 18 °C thresholds correspond to the Oregon State biologically based numeric Water Quality Temperature Standard for salmon and trout rearing and migration (OAR 340-041-0028) and represents “Optimal” conditions for juveniles and adult Chinook salmon in Koch, et al., (2020). See Figure 1-519 and

Table 1-9 for values at each location, year, and alternative. See Figure 1-520 for differences from NAA at each location, year, and alternative.

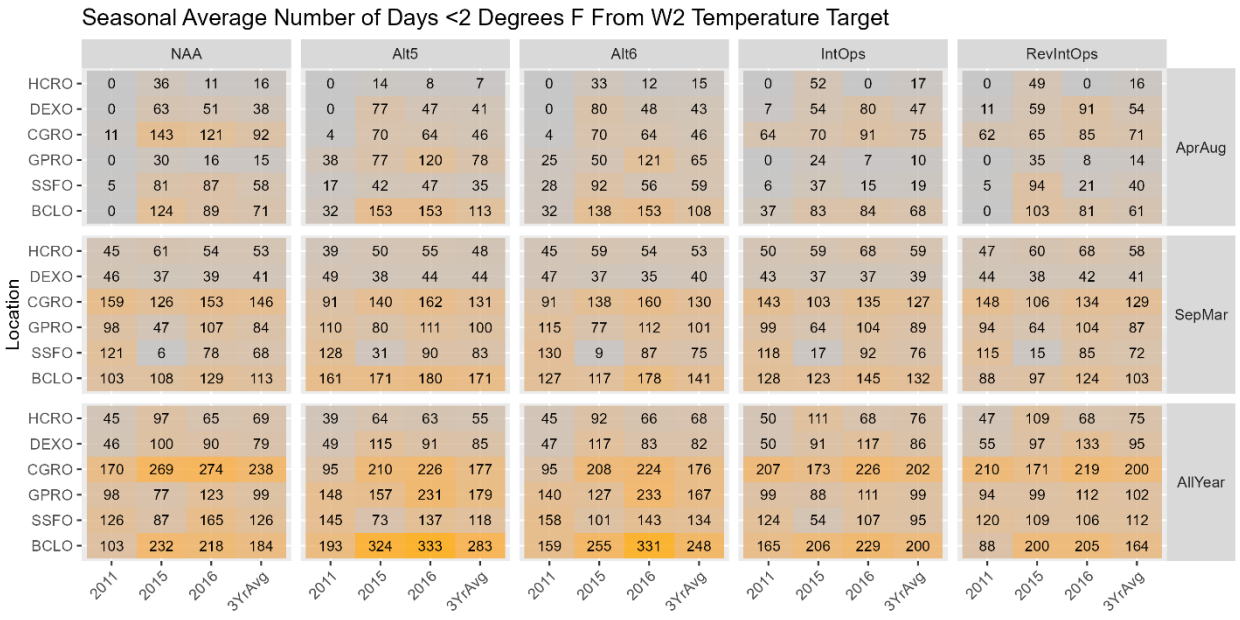


Figure 1-586. Annual number of days within 2°F of Temperature target April-August (top row of tables), September-March (middle row of tables), and all year (bottom row of tables). Explanation: "3YrAvg" = three-year average

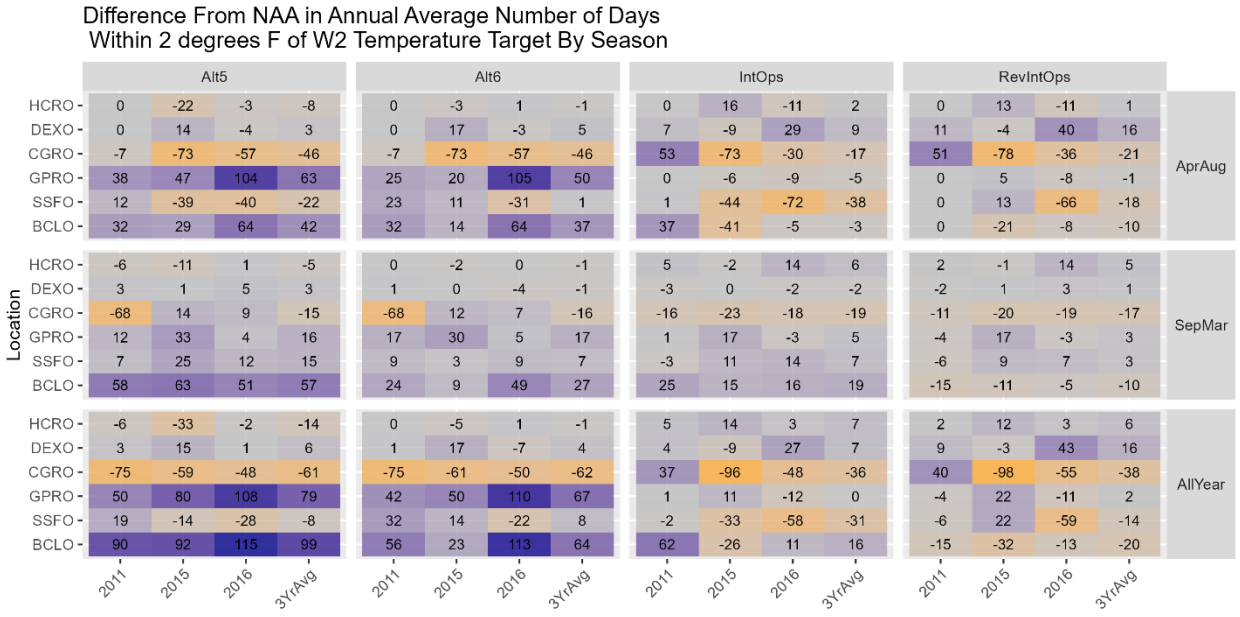


Figure 1-587. Difference, compared to NAA, in annual number of days within 2°F of Temperature target April-August (top row of tables), September-March (middle row of tables), and all year (bottom row of tables). Explanation: "3YrAvg" = three-year average

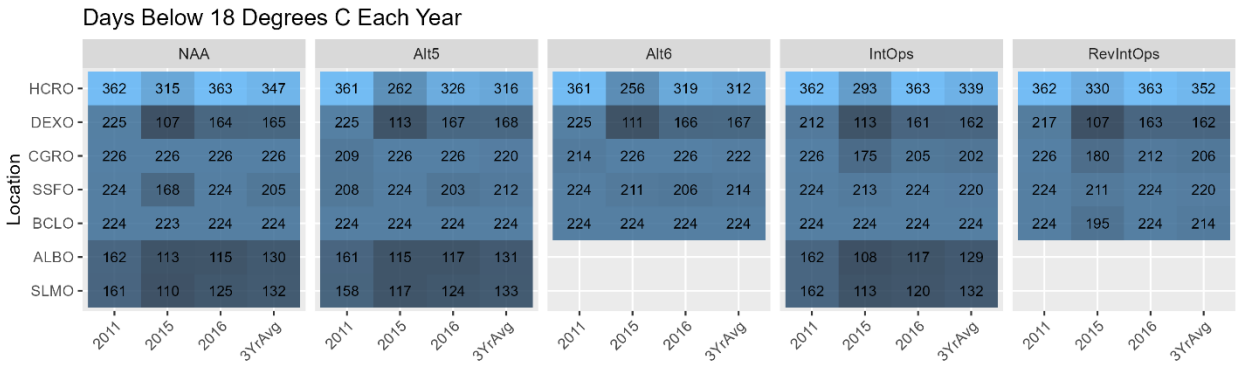


Figure 1-588. Days Below 18 Degrees C (64.4 Degrees F) in Each Year. Explanation: "3YrAvg" = three-year average.

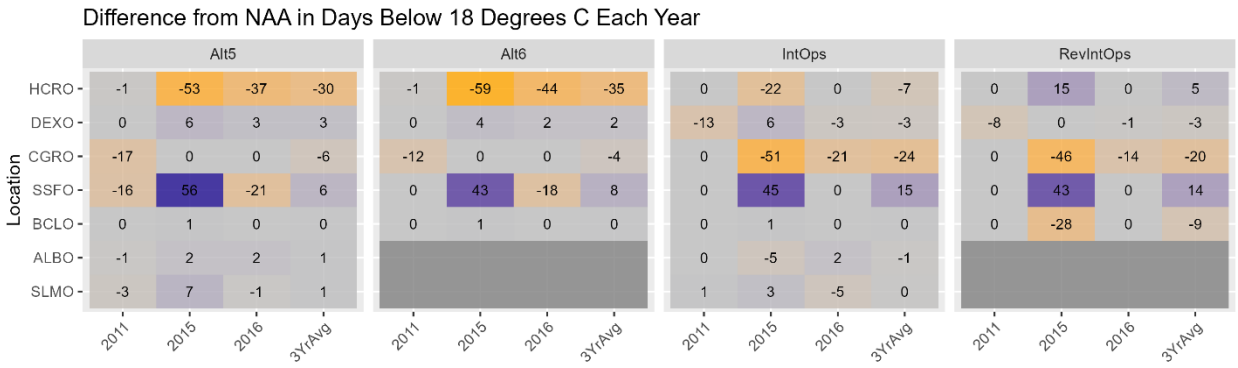


Figure 1-589. Difference, compared to NAA, in Days Below 18 Degrees C (64.4 Degrees F) in Each Year. Explanation: "3YrAvg" = three-year average.

Table 1-10. Average Annual Days Within 2 Degrees F of Temperature Target.

Location	NAA	Alt5	Alt6	IntOps	RevIntOps
HCRO	69	55	68	76	75
DEXO	79	85	82	86	95
CGRO	238	177	176	202	200
GPRO	99	179	167	99	102
SSFO	126	118	134	95	112
BCLO	184	283	248	200	164

Table 1-11. Average Days Below 18 Degrees C (64.4 Degrees F) per Year.

Location	NAA	Alt5	Alt6	IntOps	RevIntOps
HCRO	347	316	312	339	352
DEXO	165	168	167	162	162
CGRO	226	220	222	202	206
SSFO	205	212	214	220	220
BCLO	224	224	224	224	214
ALBO	130	131		129	
SLMO	132	133		132	

1.6.10.1 Alternative 6 - No Hydropower

Summary tables of Alternative 6 monthly mean water temperature and monthly mean difference between Alternative 6 and NAA for each of the three simulated years are shown in and Figure 1-591 and Figure 1-592, respectively.

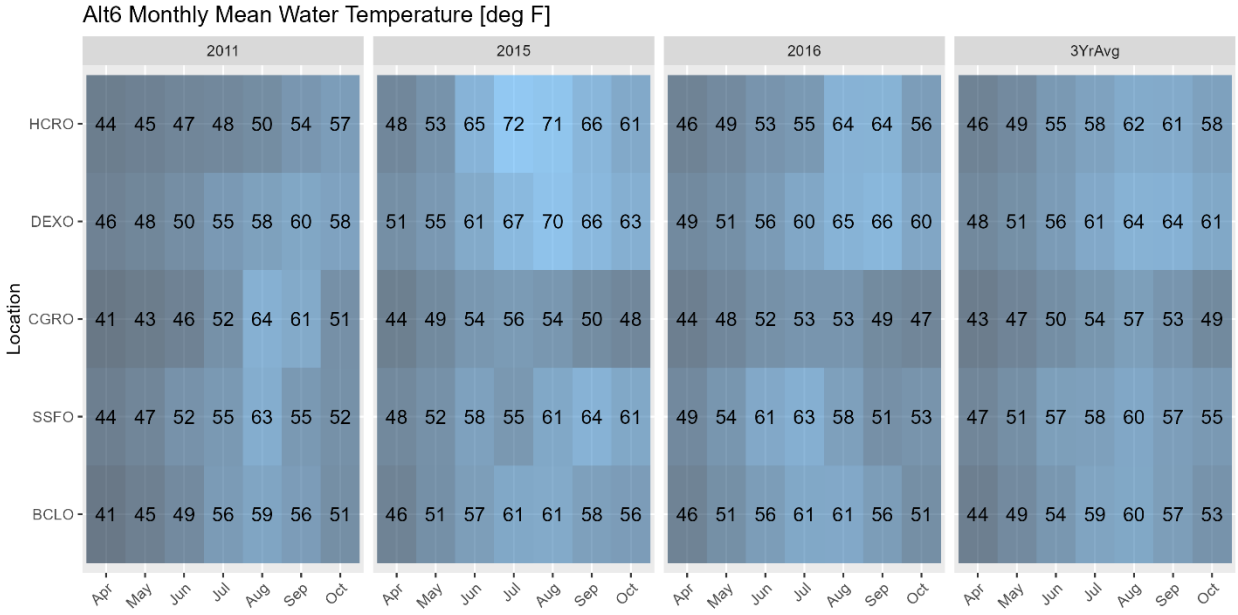


Figure 1-590. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 6.

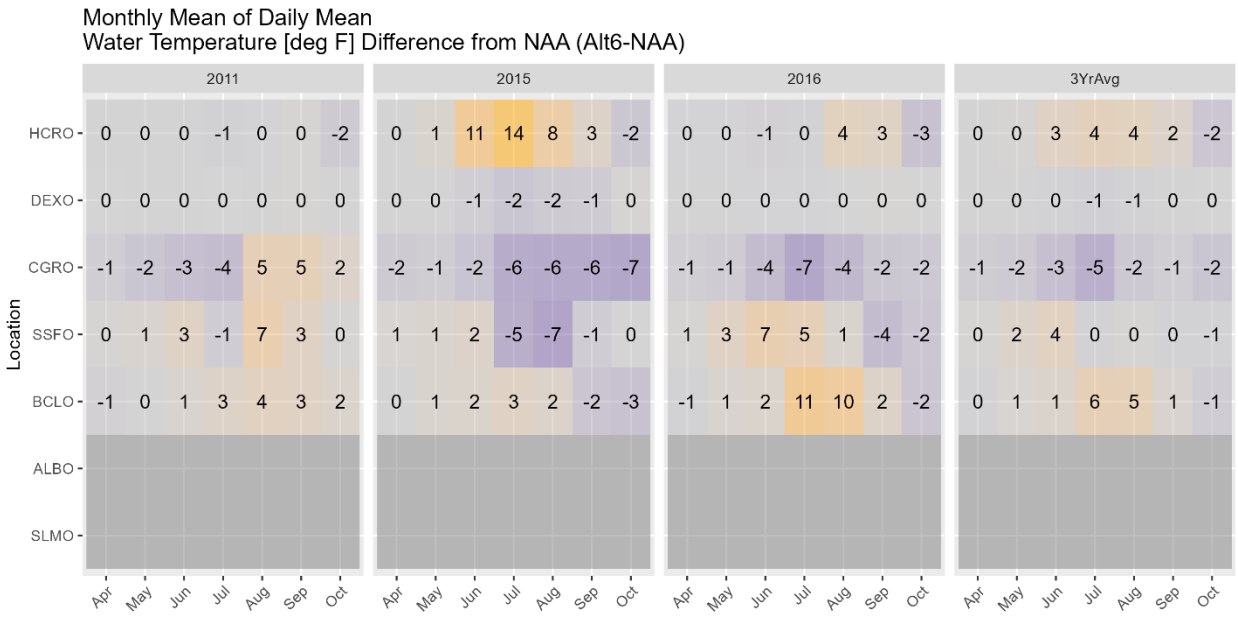


Figure 1-591. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 6.

1.6.10.2 Interim Operations (RevIntOps)

Interim Operations are based on Interim Operations (also referred to as Near Term Operations Measure (NTOM) in Final EIS, Appendix D) with updates to include deep fall/winter drawdown at Detroit Dam and Reservoir and use of the 2008 Biological Opinion minimum flow targets basin wide. Summary tables of Interim Operations monthly mean water temperature and monthly mean difference between Interim Operations (RevIntOps) and NAA for each of the three simulated years are shown in Figure 1-593 and Figure 1-594, respectively.

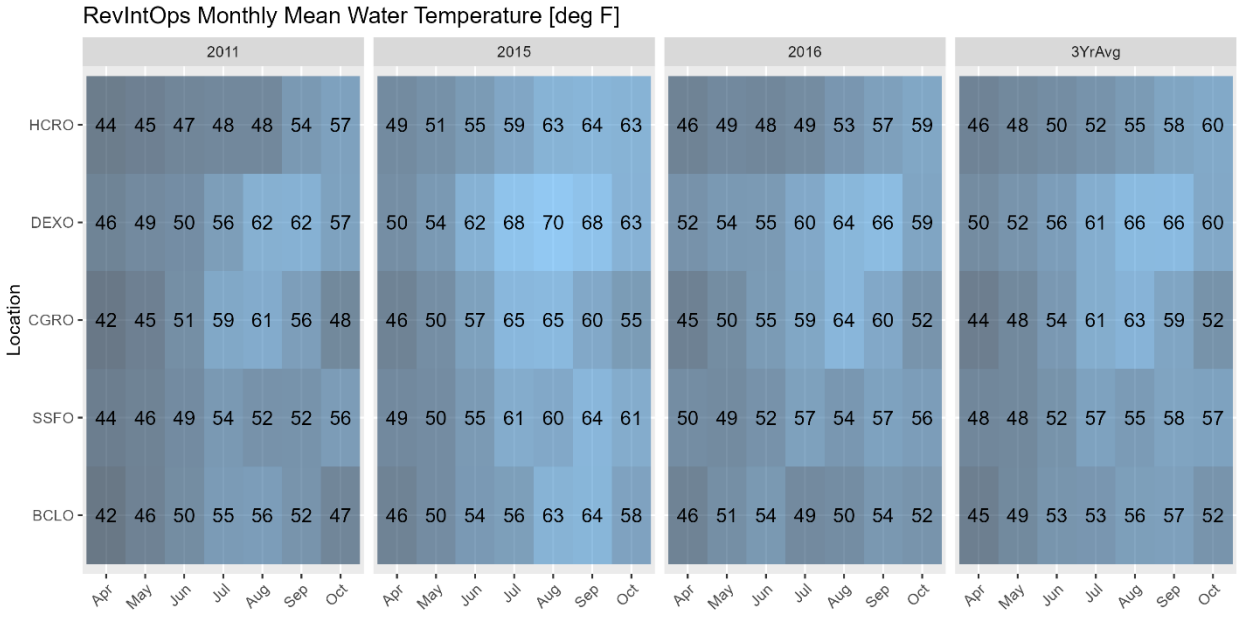


Figure 1-592. Monthly Mean of Water Temperatures (Fahrenheit) for Interim Operations (RevIntOps).

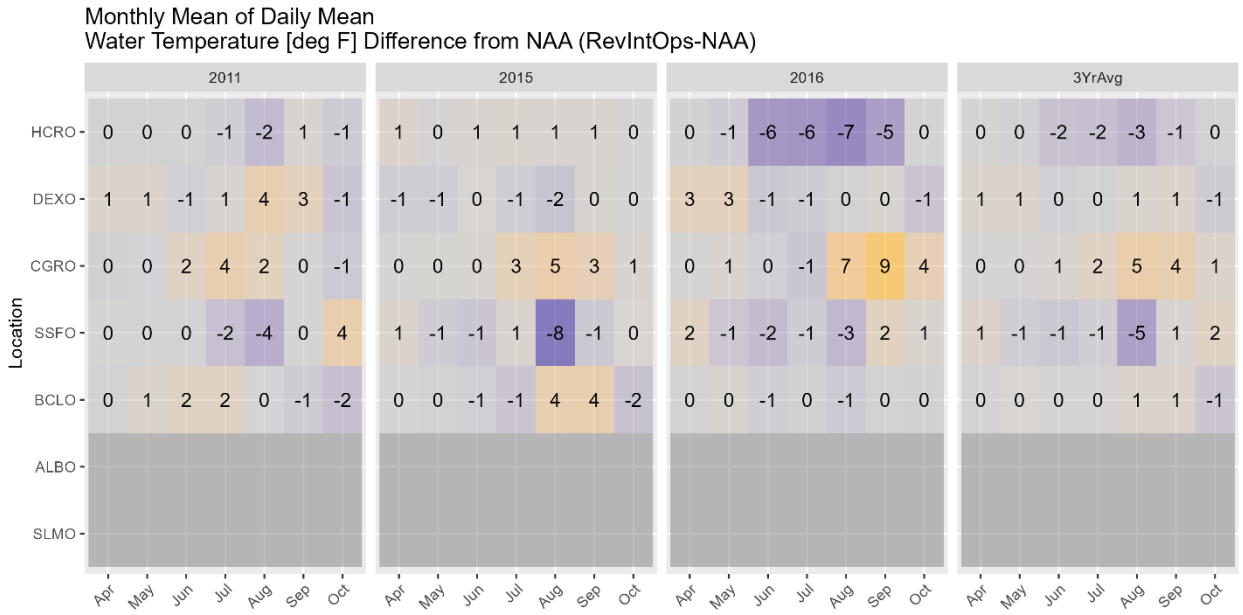


Figure 1-593. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Interim Operations (RevIntOps).

1.7 SUPPLEMENTAL MATERIAL

1.7.1 Comparison of NAA with Measurements

Simulating dam operations and water temperatures for the WV EIS involved the application of rules and assumptions that simplified the complex human-based water management decisions (i.e., minimum flow negotiations, flood operations), special operations (i.e., power/maintenance outages, fish passage, temperature management), and environmental factors (i.e., evaporation) that occur day-to-day and are encompassed in the measured values at each stream gage. Therefore, it is expected that the comparison of measurements with NAA results would not match identically but provide context for the potential range that could occur in each of the 3 years simulated in the CE-QUAL-W2 temperature models.

The CE-QUAL-W2 water temperature models received outflow and lake elevation input data from the HEC-ResSim model. The comparison between NAA and measured conditions should not be considered "calibration" and is not ideal due to the differences in operations (outflow, lake level) and evaporation rates assumed in the HEC-ResSim model. HEC-ResSim spans an 84-year period of record is not calibrated specifically to the years shown (2011, 2015, and 2016), so differences in any specific year can be expected as actual human operations during each individual year differed from what a model has applied consistently across all years. This

comparison between NAA and measured values is intended to display how NAA is not the same as the observed/measured conditions that occurred in those actual years, but instead a modeled application of the operational rules that were in place in April 2019 and imposed across the 84-year period of record.

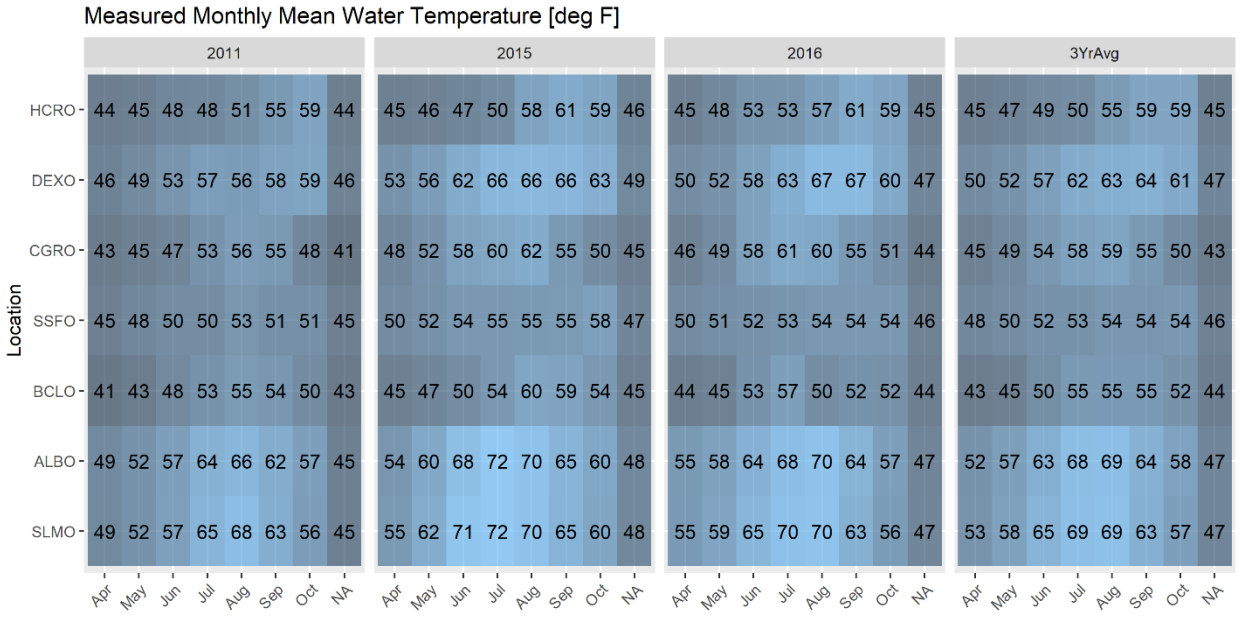


Figure 1-594. Monthly Mean of Measured Water Temperatures (Fahrenheit).

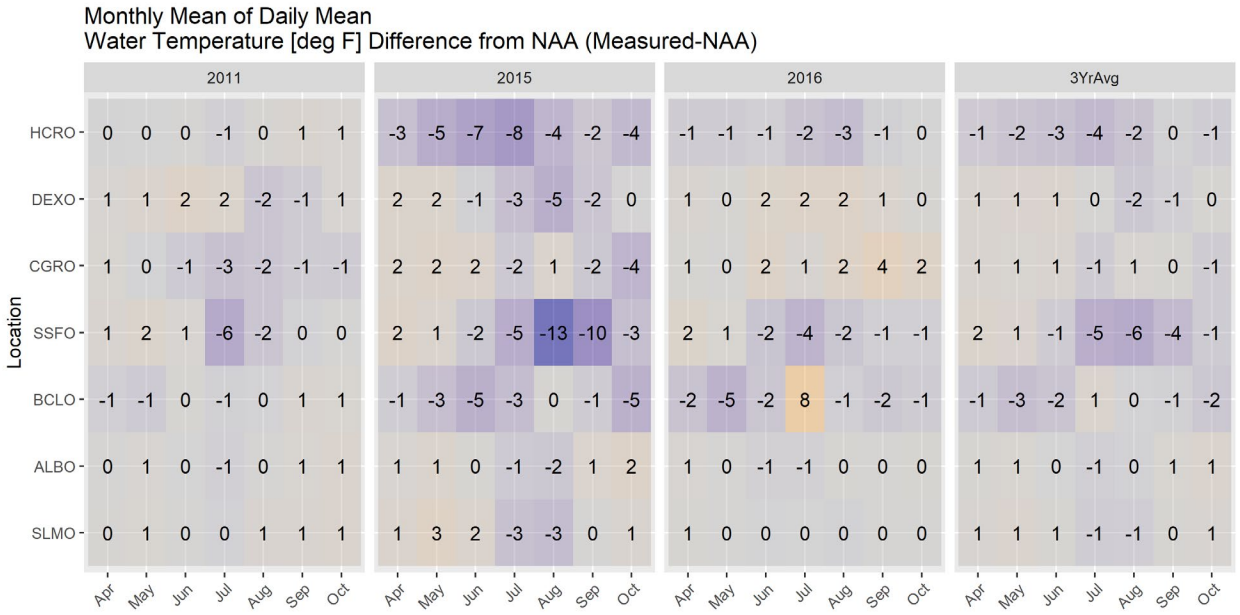


Figure 1-595. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from Measurements to NAA.

1.7.1.1 North Santiam Dam

Monthly Mean of Daily Mean Measured water temperatures were compared to the NAA at the North Santiam at Niagara gaging site (BCLO; Figure 1-596; Figure 1-598). The 2011-year measurements were generally within 1 degree of NAA. The 2015-year measurements were 3 to 5 degrees cooler than NAA from May to July and then up to 5 degrees cooler than NAA in September and October. The 2016-year measurements were 3 to 5 degrees cooler than NAA from April to June and then up to 8 degrees warmer than NAA in July, and finally up to 2 degrees cooler than NAA in September and October. For the average of the three years (2011,2015,2016) water temperatures measurements were generally up to 3 degrees cooler in May-June and up to 2 degrees cooler in October as compared to NAA. These differences can be linked to different dam operations imposed in NAA in comparison to measurements (Figure 1-597).

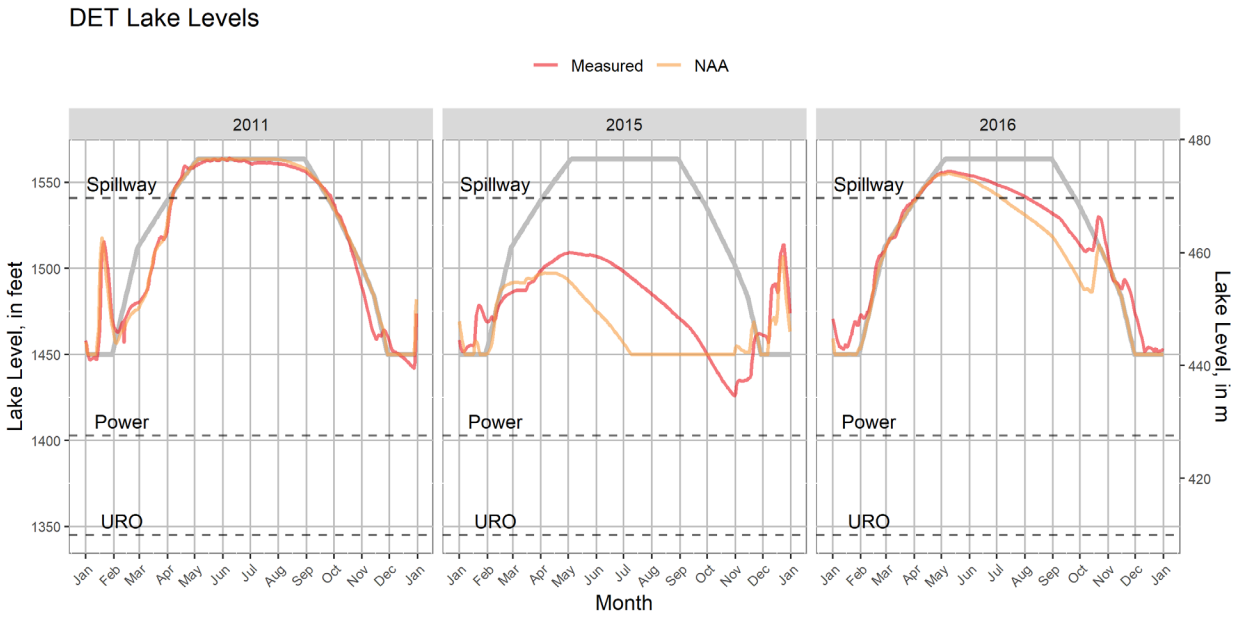


Figure 1-596. Detroit Lake Level Comparison of Measurements and NAA in 2011, 2015, and 2016. Grey Line Represents the Rule Curve.

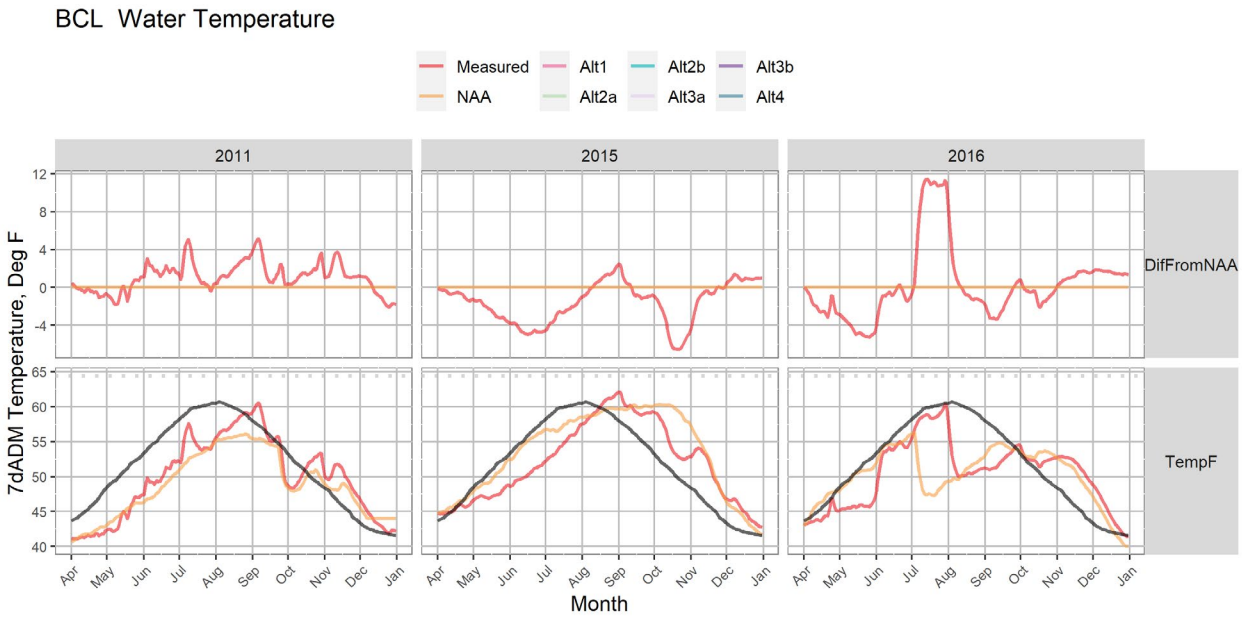


Figure 1-597. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference From NAA Downstream of Big Cliff Dam. Black Line Indicates Temperature Target.

1.7.1.2 South Santiam Dams

Monthly Mean of Daily Mean Measured water temperatures were compared to NAA at the South Santiam below Foster gaging site (SSFO; Figure 1-596; Figure 1-601). The 2011-year measurements were generally within 2 degrees of NAA, aside from the month of July when measurements were up to 5 degrees cooler. The 2015-year measurements were 2 to 13 degrees cooler than NAA from June to October. The 2016-year measurements were 2 to 4 degrees cooler than NAA from June to August. For the average of the three years (2011,2015,2016) water temperatures measurements were generally up to 4 to 6 degrees cooler in July-September compared to NAA. These differences can be linked to different dam operations imposed in NAA in comparison to measurements (Figure 1-599, Figure 1-600).

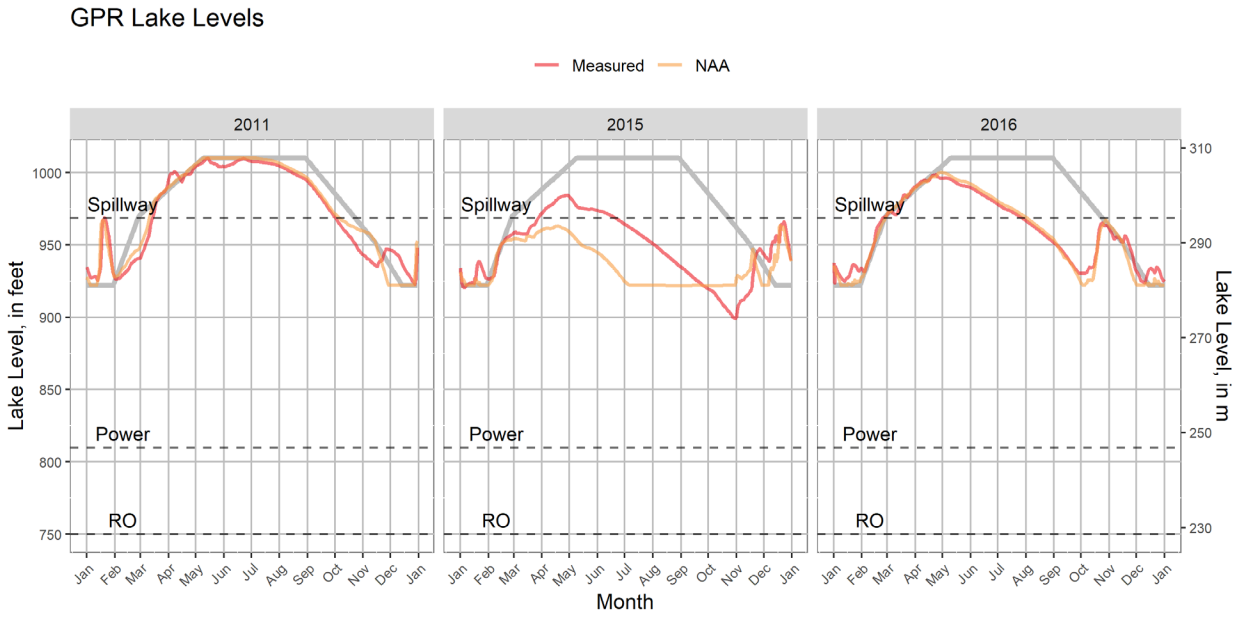


Figure 1-598. Green Peter Lake Level Comparison of Measurements and NAA in 2011, 2015, and 2016. Grey Line Represents the Rule Curve.

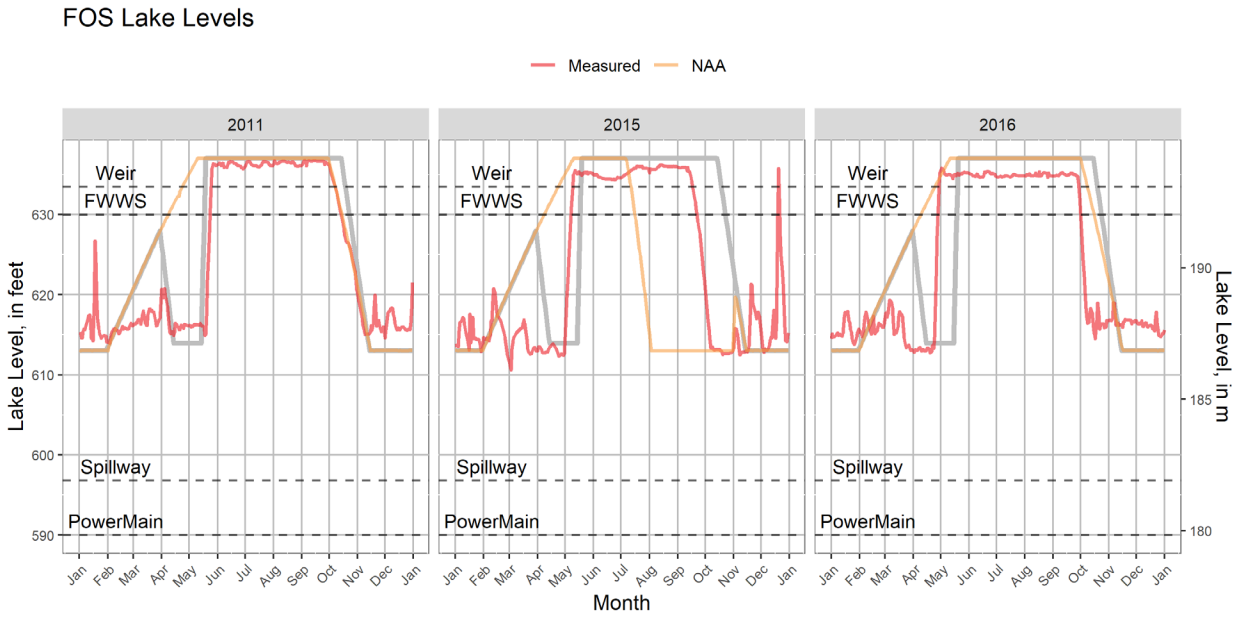


Figure 1-599. Foster Lake Level Comparison of Measurements and NAA in 2011, 2015, and 2016. Grey Line Represents the Rule Curve.

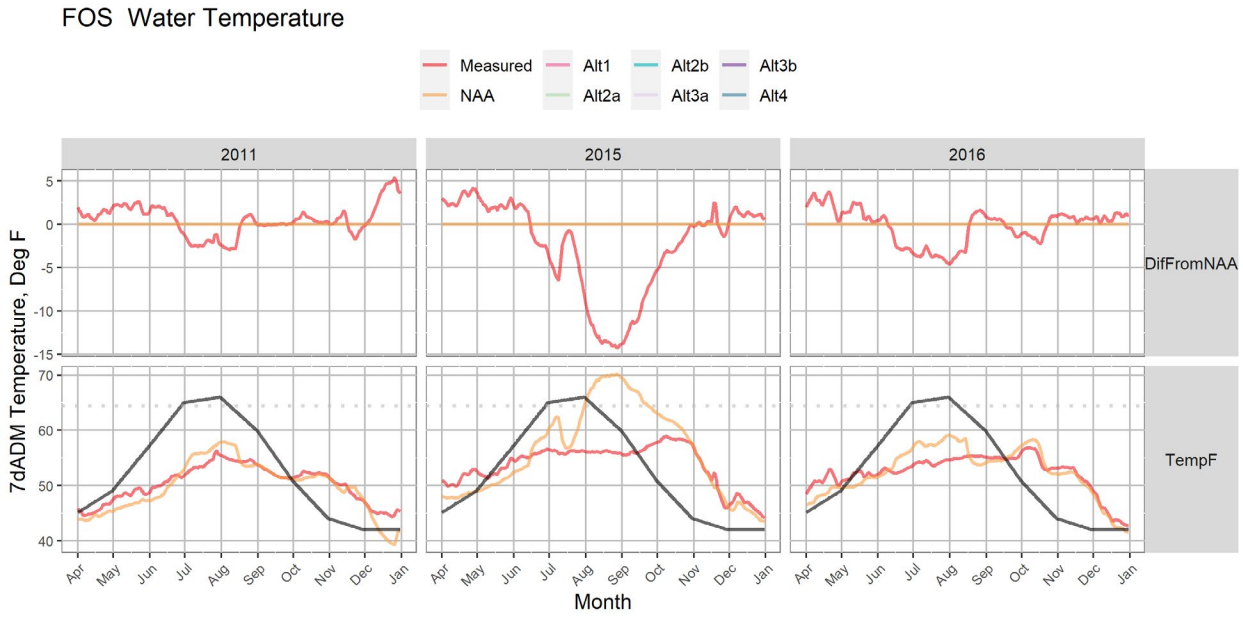


Figure 1-600. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference from NAA Downstream of Foster Dam. Black Line Indicates Temperature Target.

1.7.1.3 McKenzie Dams

Monthly Mean of Daily Mean Measured water temperatures were compared to the NAA at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-596; Figure 1-603). The 2011-year measurements were generally within 1 degrees of NAA, aside from the month of June-July when measurements were up to 3 degrees cooler. The 2015-year measurements were generally within 2 degrees from NAA aside from October when measurements were 4 degrees cooler than NAA. The 2016-year measurements were generally within 2 degrees from NAA aside from September when measurements were 4 degrees warmer than NAA. These differences can be linked to different dam operations imposed in NAA in comparison to measurements (Figure 1-602).

For the average of the three years (2011, 2015, 2016) water temperatures measurements were within 1 degrees of NAA.

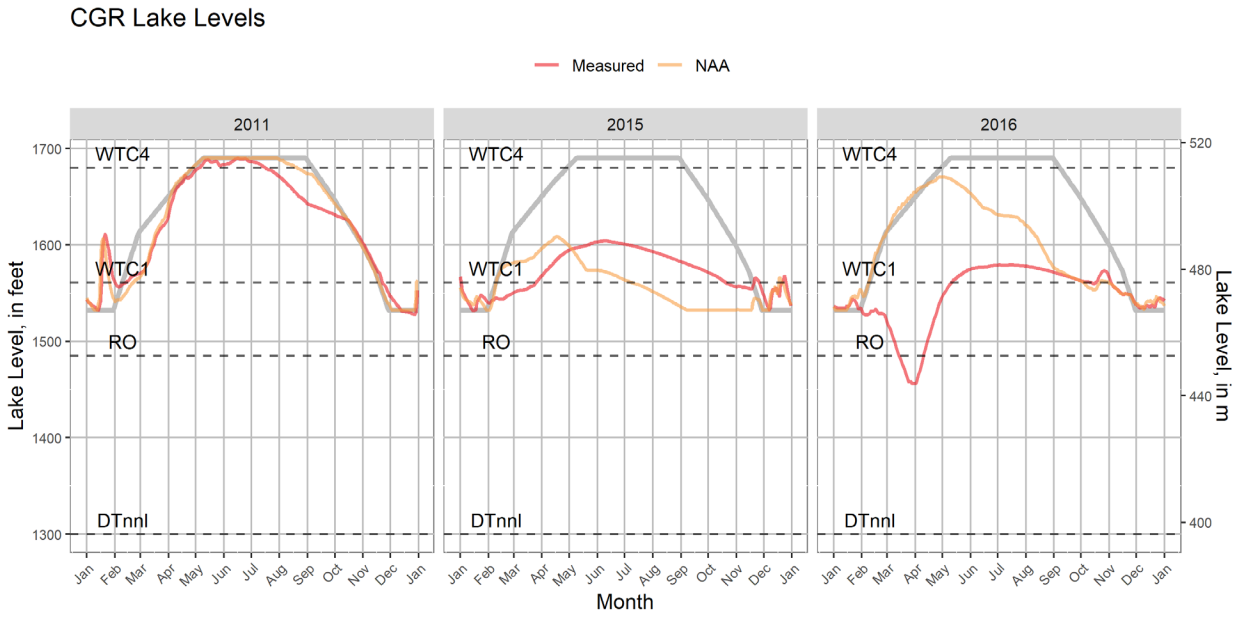


Figure 1-601. Cougar Lake Level Comparison of Measurements, NAA in 2011, 2015, and 2016.

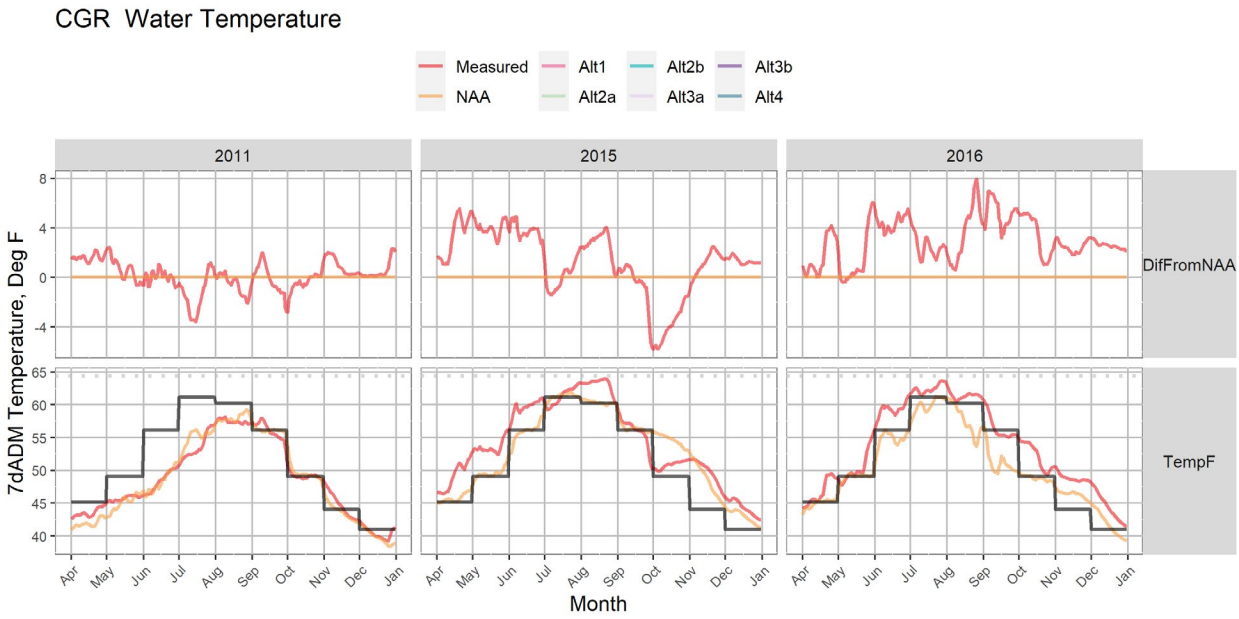


Figure 1-602. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference from NAA Downstream of Cougar Dam. Black Line Indicates Temperature Target.

1.7.1.4 Middle Fork Willamette Dams

Monthly Mean of Daily Mean Measured water temperatures were compared to NAA at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-596; Figure 1-605). The 2011 and 2016 year measurements were generally within 2 degrees of NAA. The 2015-year measurements were generally within 2 degrees of NAA except July-August when

measurements were 3 to 5 degrees cooler than NAA. For the average of the three years (2011,2015,2016) water temperatures measurements were generally within 2 degrees of NAA. These differences can be linked to different dam operations imposed in NAA in comparison to measurements.

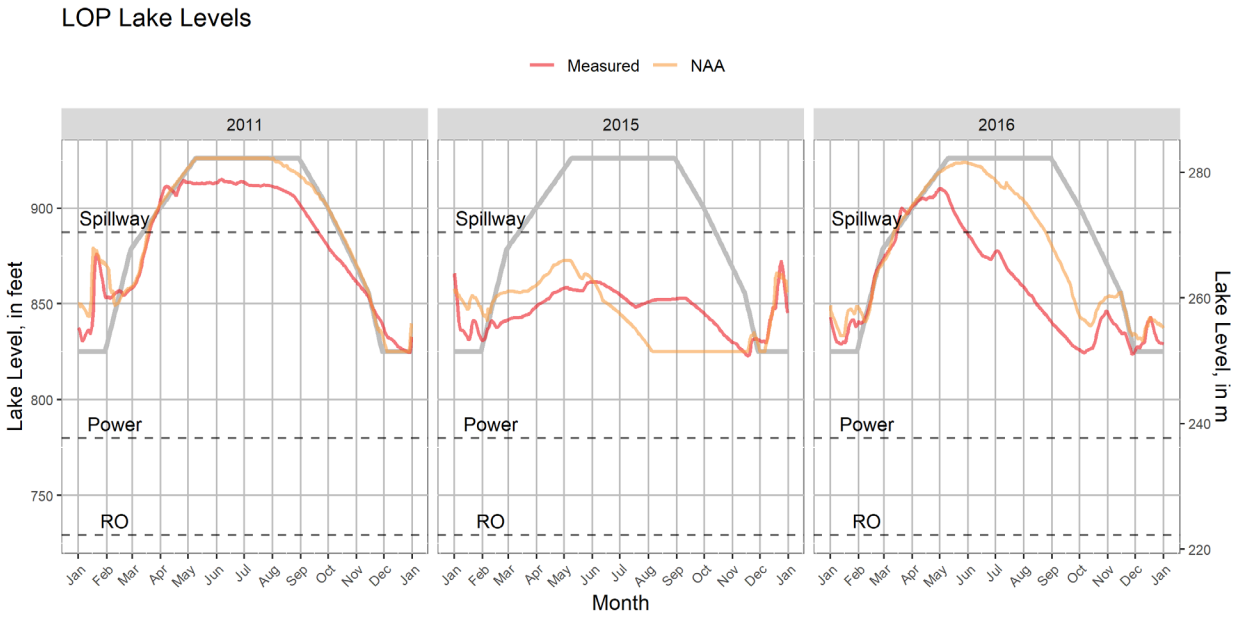


Figure 1-603. Lookout Point Lake Level Comparison of Measurements and NAA in 2011, 2015, and 2016.

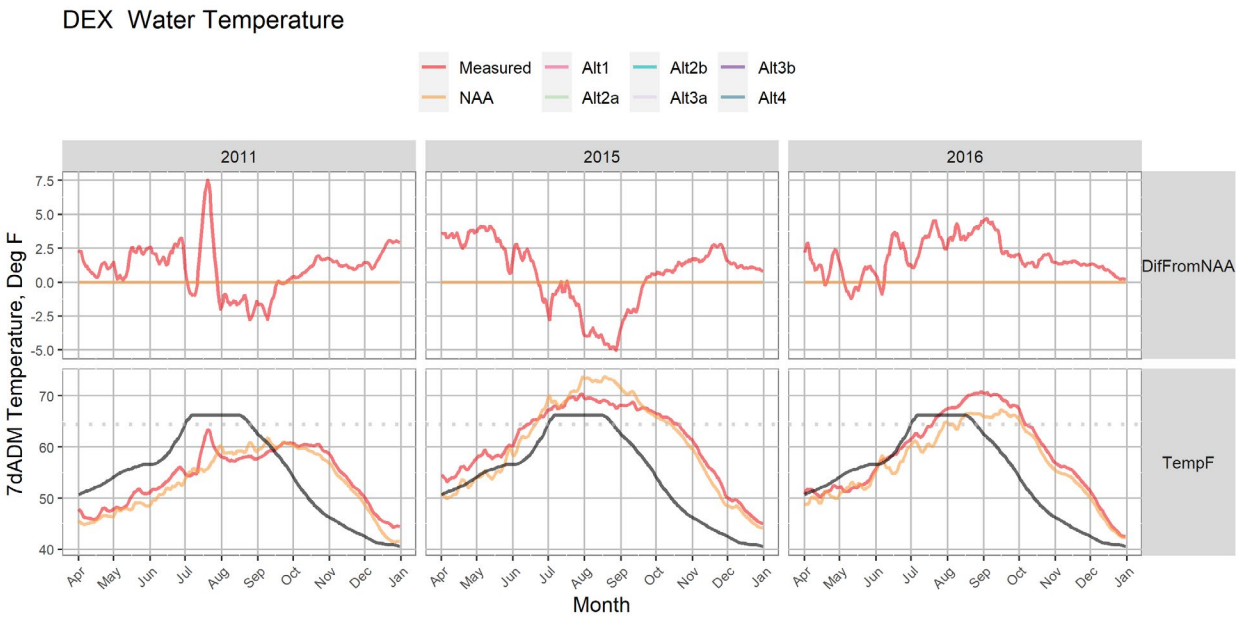


Figure 1-604. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference from NAA Downstream of Dexter Dam. Black Line Indicates Temperature Target.

Monthly Mean of Daily Mean Measured water temperatures were compared to NAA at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-596; Figure 1-606). The 2011-year measurements were generally within 1 degrees of NAA. The 2015-year measurements were 2 to 8 degrees cooler than NAA from April to October. The 2016-year measurements were generally within 1 degree from NAA except July-August, when measurements were 2 to 3 degrees cooler than NAA. For the average of the three years (2011,2015,2016) water temperatures measurements were within 1 degree of NAA outside of May-August when measurements were up to 4 degrees cooler compared to NAA. These differences can be linked to different dam operations imposed in NAA in comparison to measurements.

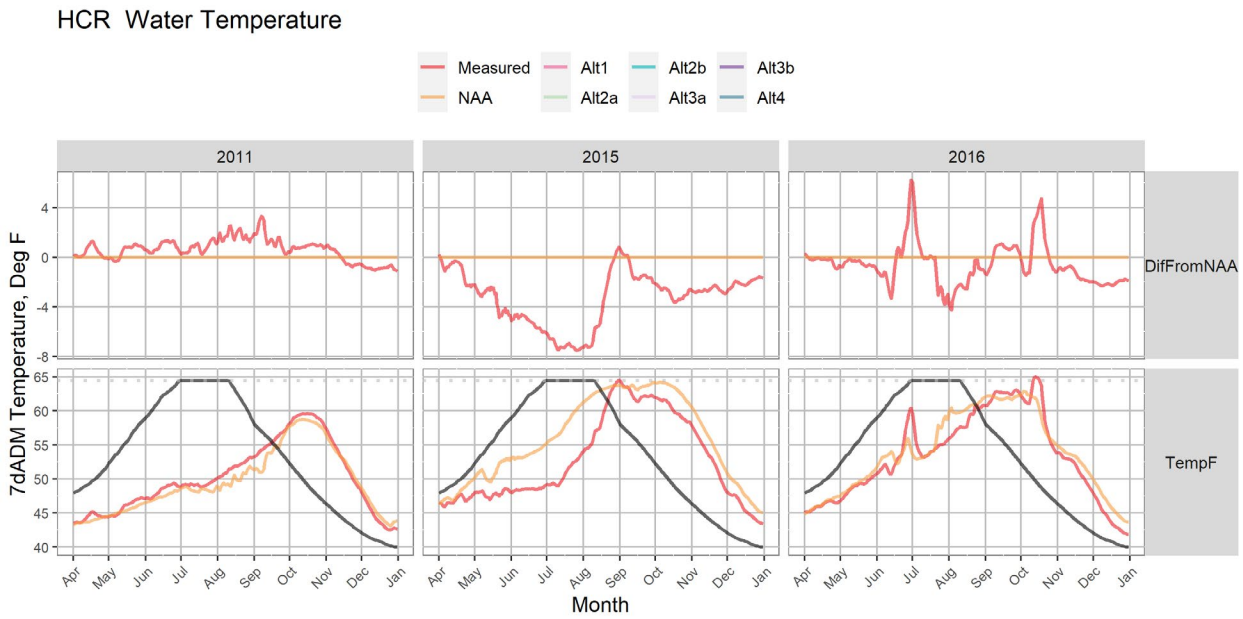


Figure 1-605. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference from NAA Downstream of Hills Creek Dam. Black Line Indicates Temperature Target.

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CHAPTER 2 - TOTAL DISSOLVED GAS (TDG)

2.1 BACKGROUND

This section describes the TDG model development and application for the WV EIS. Empirical models were developed based on measured TDG and operations data within recent timeframes with respect to the writing of this document. The TDG models were then used to provide TDG estimates for the WV EIS for the Period of Record (1936 – 2019).

2.1.1 TDG Model Development

Total Dissolved Gas (TDG) production was empirically estimated as a function of spill rate at Detroit / Big Cliff dams, Green Peter / Foster dams, Lookout Point / Dexter dams and Cougar dam through separate numerical models (referred to as a group of models as "WILTDG" v1) Each WILTDG model is based on measured TDG and operations data ranging from 2011 to 2020 (Table 2-1).

Spill can occur via a spillway (SW) or regulating outlet (RO) and typically results in TDG supersaturation (equation 1, from Wells, 2020). Downstream TDG was calculated using the mixing equation with flow and TDG from each outlet. Powerhouse (PH) TDG was assumed to equal upstream TDG levels or a constant value at approximately 100% TDG. TDG calculated using daily average flows was compared to the daily average observed TDG to account for travel time and dispersion. TDG was estimated as a function of spill rate via the spillway (SW) or regulating outlets (RO) at Detroit / Big Cliff dams. The form of this equation is as follows (Equation 2, from Wells, 2020):

$$\%\boldsymbol{TDG} = \boldsymbol{a} + \boldsymbol{be}^{\boldsymbol{cQ_s}} \qquad \text{Eq. 1}$$

Where:

a, **b**, and **c** are empirical coefficients

$\mathbf{Q_s}$ = total spill, in cfs (except Big Cliff)

The spill rate (Q_s, Equation 2) for Big Cliff Dam tailwater is represented using the flow-weighted specific spillbay discharge (Equation 2) borrowed from SYSTDG methods used on the lower Snake and Columbia River projects (USACE, 2020). Total spill rate alone could not explain the variable TDG production rates which were noted during the initial model calibration. At Big Cliff, individual spillbay flow rates were calculated by proportioning the total spill based on the reported opening of each spillbay.

$$\boldsymbol{Q_s} = \frac{\sum_{i=1}^{nb} \boldsymbol{Q_i^C}}{\sum_{i=1}^{nb} \boldsymbol{Q_i^{(C-1)}}} \qquad \text{Eq. 2}$$

Where:

$\boldsymbol{Q_i}$ = discharge through spillbay i (use measured discharge or spill pattern lookup values)

nb = the number of project spillbays

C = Project and spill pattern specific constant

Estimated TDG caused by spill from 1, 2, and 3 spillway gates is compared with Detroit Spill only (Spillway and RO) in Figure 2-6. This analysis assumes a minimum spillway gate flow of 1050 cfs. Reductions in TDG occur with additional spillway gates, however, this effect diminishes as total flow increases. The average TDG reduction realized by spreading spill across spillway gates can be summarized with respect to total spill as follows: 2000 to 3000 cfs (2 gates): 14%, 3000 to 6000 cfs (3 gates): 10%, greater than 6000 cfs (3 gates): 1%. While it is feasible to use all three spillway gates at BCL, the WV EIS limited spill to 2 gates to incorporate current regular operating procedures (when turbines are in use) allowing the 3rd spillway at Big Cliff to be opened automatically when unplanned turbine outages occur to avoid drying up the North Santiam River downstream.

TDG models were developed at other WV dams using similar methodology as that used at DET-BCL with parameters shown in Table 2-1 and Table 2-2. The empirical coefficients and upstream TDG were estimated using trial and error and basing fit on visual error analysis with an emphasis on representing higher values of TDG based on professional judgment. The models were calibrated by adjusting the coefficients in Equations 1 and 2 and setting a minimum value for TDG production, as needed (Table 2-2). The goal of calibration was to minimize error statistics (Table 2-3) and follow the patterns of observed TDG and spill relationships (Figure 2-1 to Figure 2-25). For Cougar, there is no TDG data that has been observed for the diversion tunnel operation, so all TDG estimation for alternatives with diversion tunnel flow were assumed to be equivalent to powerhouse outflow (TDG = 102%).

Table 2-1. Representation of project outlets and configuration

Project	Abbreviation	Outlets	Spillway use criteria	Downstream Project	Tailrace gauge	Data range
Detroit	DET	SW, RO, PH	Forebay > 1541 ft	BCL	--	--
Big Cliff	BCL	3 spillbays, PH	--	--	BCLO	2011 - 2020
Green Peter	GPR	SW, RO, PH	5/28 to 6/19/2020	FOS	--	--
Foster	FOS	SW, PH	--	--	SSFO	2015 - 2020
Hills Creek	HCR	RO, PH	--	--	HCRO	2012
Lookout Point	LOP	SW, RO, PH	Forebay > 888 ft	DEX	--	--
Dexter	DEX	SW, PH	--	--	DEXO	2015 - 2020
Cougar	CGR	RO, PH	--	--	CGRO	2015 - 2020

Additionally, model error was compared to tailwater elevations but no further model parameterization was deemed necessary. Higher TDG values were weighted above lower TDG values when matching patterns. Given the complexity of multiple outlets and multiple projects in series, the model was able to adequately reproduce the pattern and magnitude of observed TDG. The models are appropriate to be used to predict changes in operations, given spill rates are within range used to calibrate the model and there are no structural changes.

Table 2-2. Empirical coefficients for TDG production. If the a, b, c coefficient set results in TDG production less than 100%, then a floor was set.

Outlet	a	b	c	C, eq. 2 (nbays)	Minimum TDG (%)
DET SW	117	0	-0.005	--	--
DET RO	135	-50	-0.001	--	115
BCL SW	130	-80	-0.0015	2	100
GPR SW	130	-10	-0.001	--	103
GPR RO	130	-70	-0.0005	--	103
FOS SW	122	-70	-0.0005	--	110
CGR RO	120	-19	-0.001	--	102
LOP SW	120	-20	-0.0002	--	--
LOP RO	105	-5	-0.001	--	100
DEX SW	119	-17	-0.0003	--	--
HCR RO	123	-57	-0.0012	--	102

Table 2-3. WILTDG Error statistics

Gauge	Number of daily average values	mean error	absolute mean error	root mean square error
BCLO	3215	-0.4	2.4	3.8
SSFO	1943	1.7	2.3	3.0
HCRO	38	-0.6	3.4	4.4
DEXO	1909	-0.2	1.5	2.0
CGRO	2035	1.6	2.4	3.1

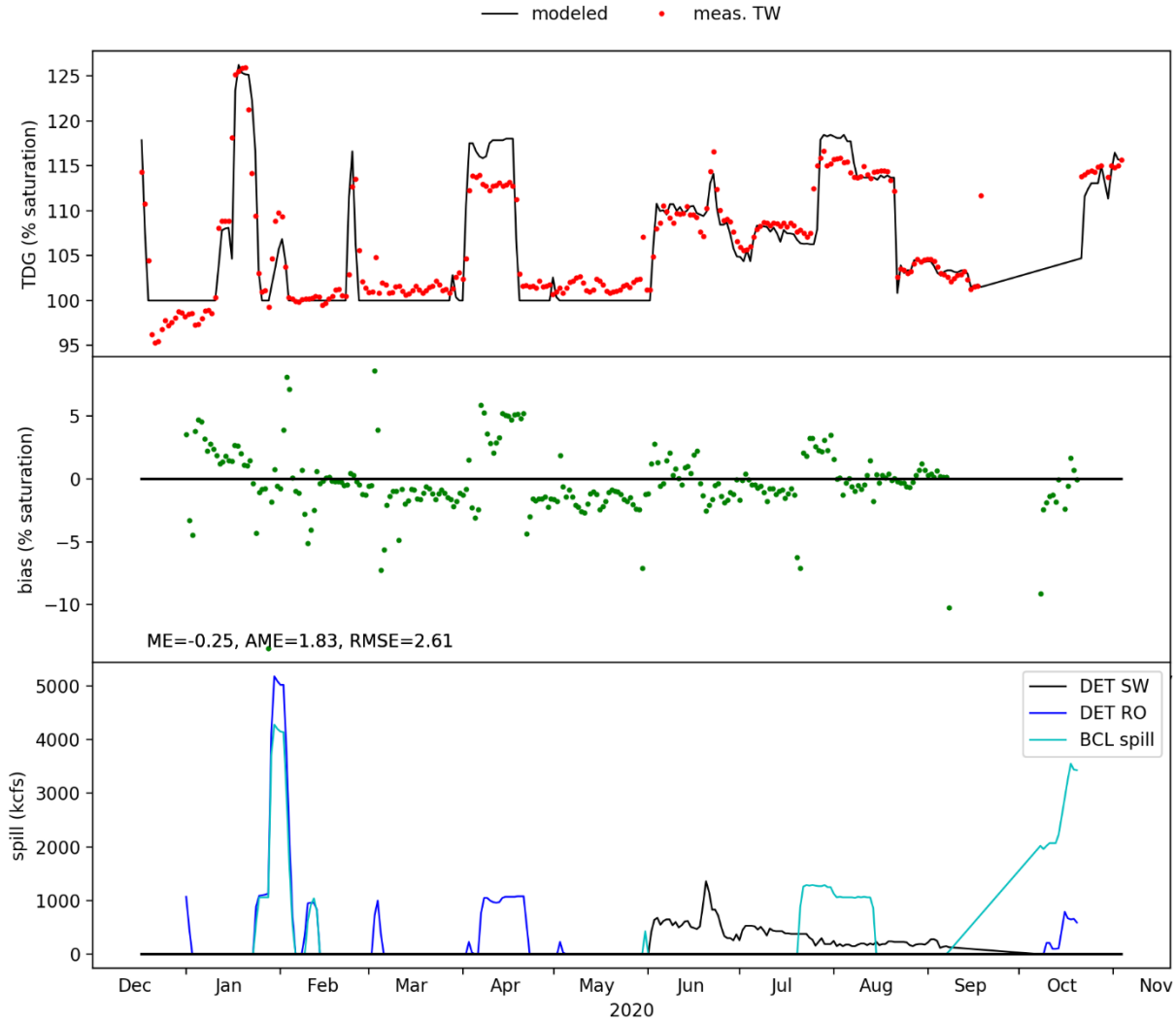


Figure 2-1. Example Time series of North Santiam model results at BCLO.

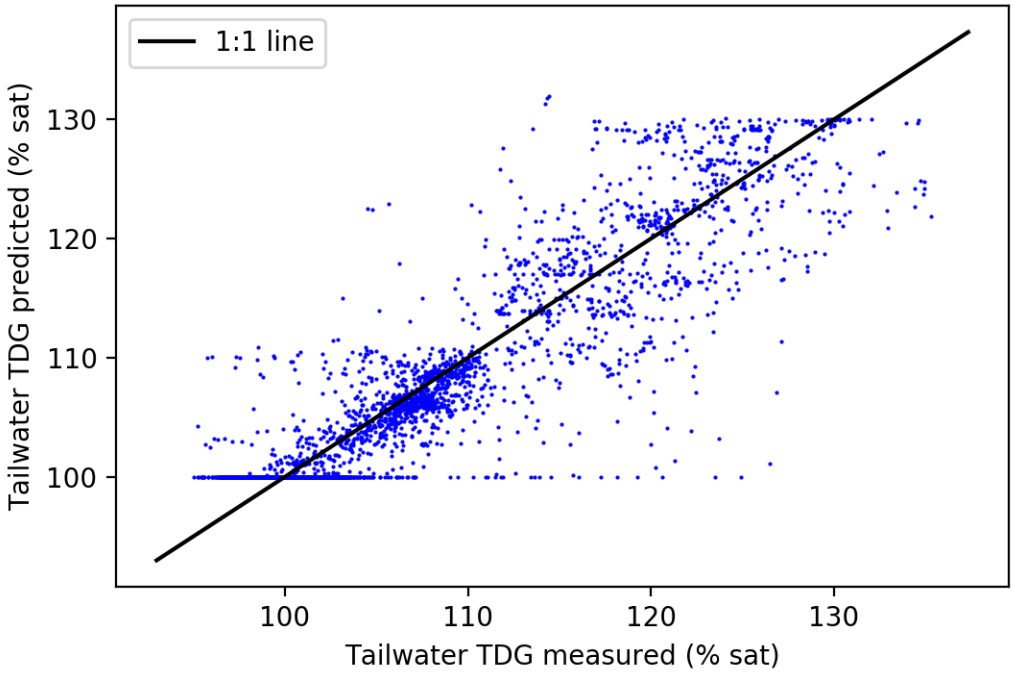


Figure 2-2. Model estimation of TDG compared to measurements at BCLO.

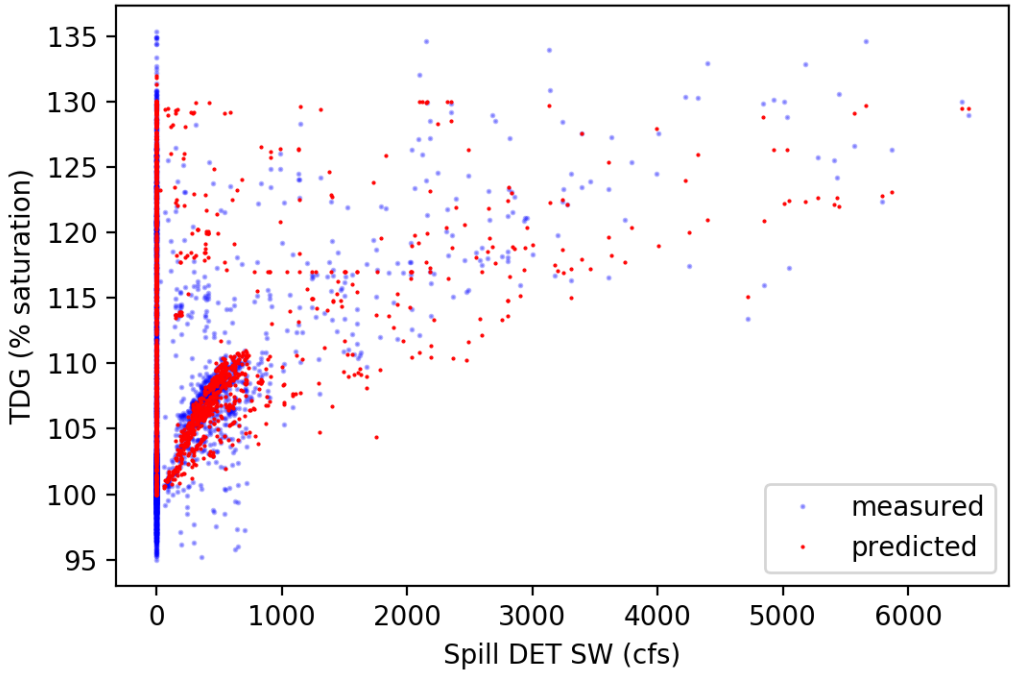


Figure 2-3. Model estimation and measurements of TDG compared to spill at Detroit spillway.

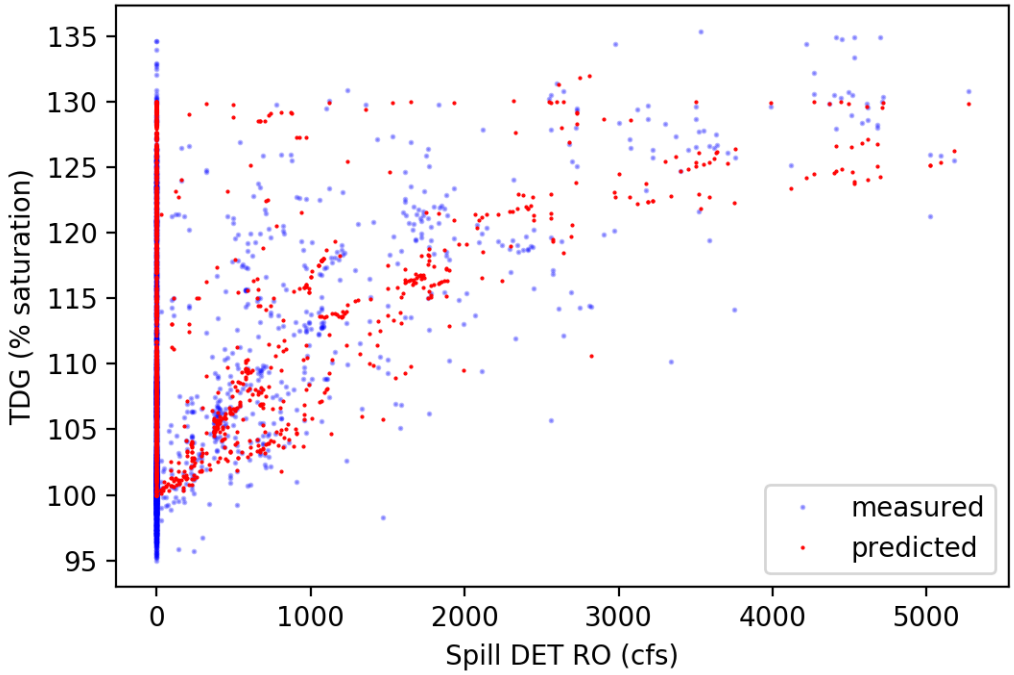


Figure 2-4. Model estimation and measurements of TDG compared to spill at Detroit regulating outlet.

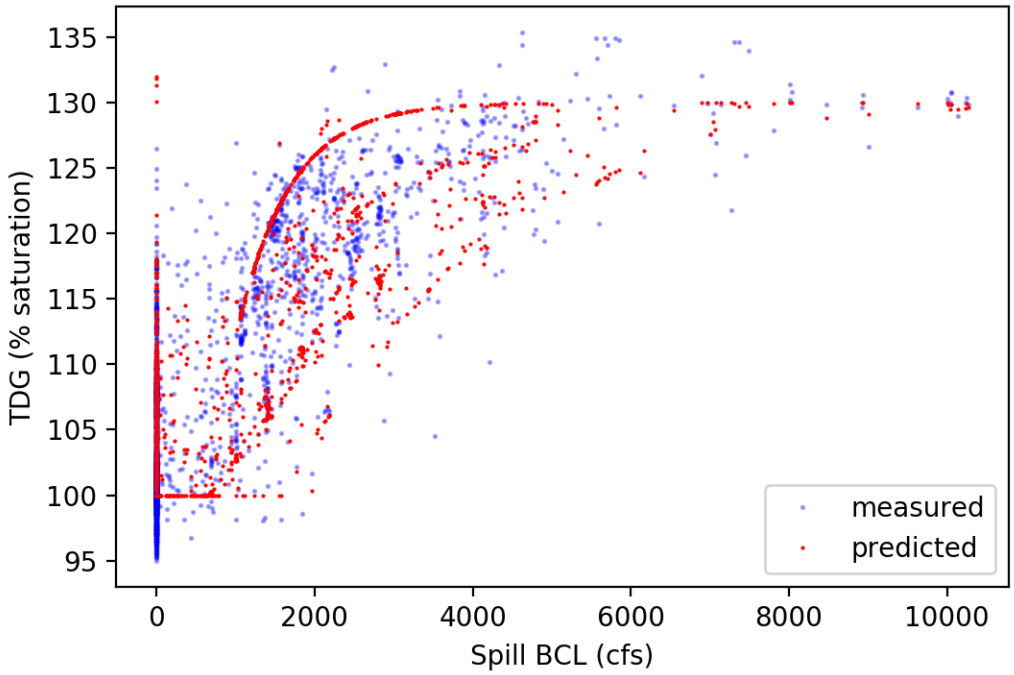


Figure 2-5. Model estimation and measurements of TDG compared to spill at Big Cliff spillway.

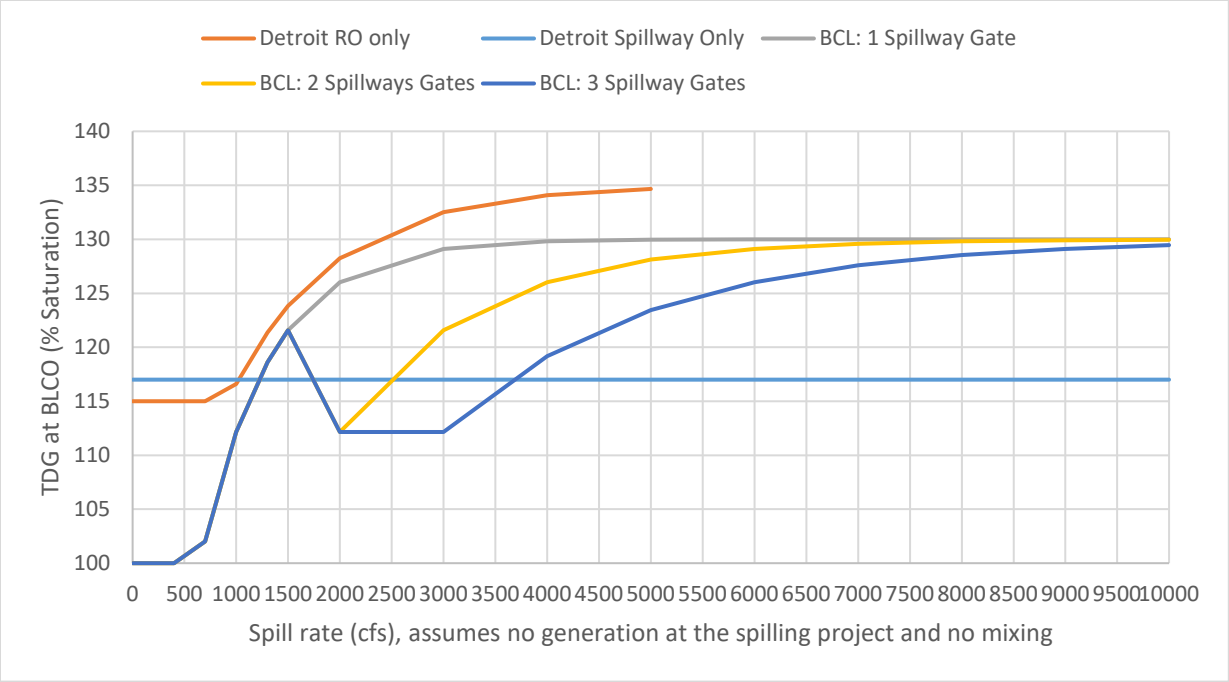


Figure 2-6. Model predictions of TDG downstream of Big Cliff Dam. Assumes that there is only one spill source and there is no mixing with generation flow.

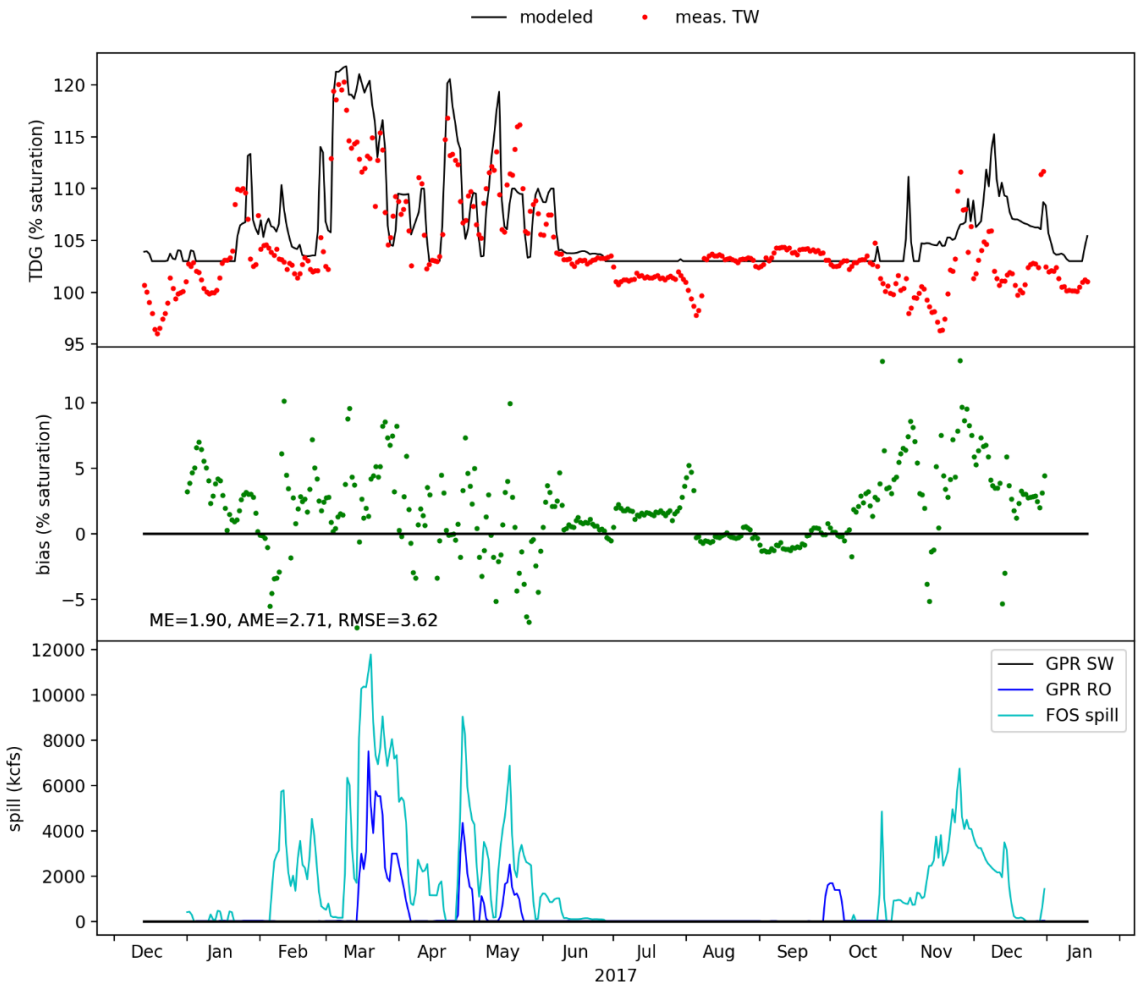


Figure 2-7. Example time series of South Santiam model results at SSFO.

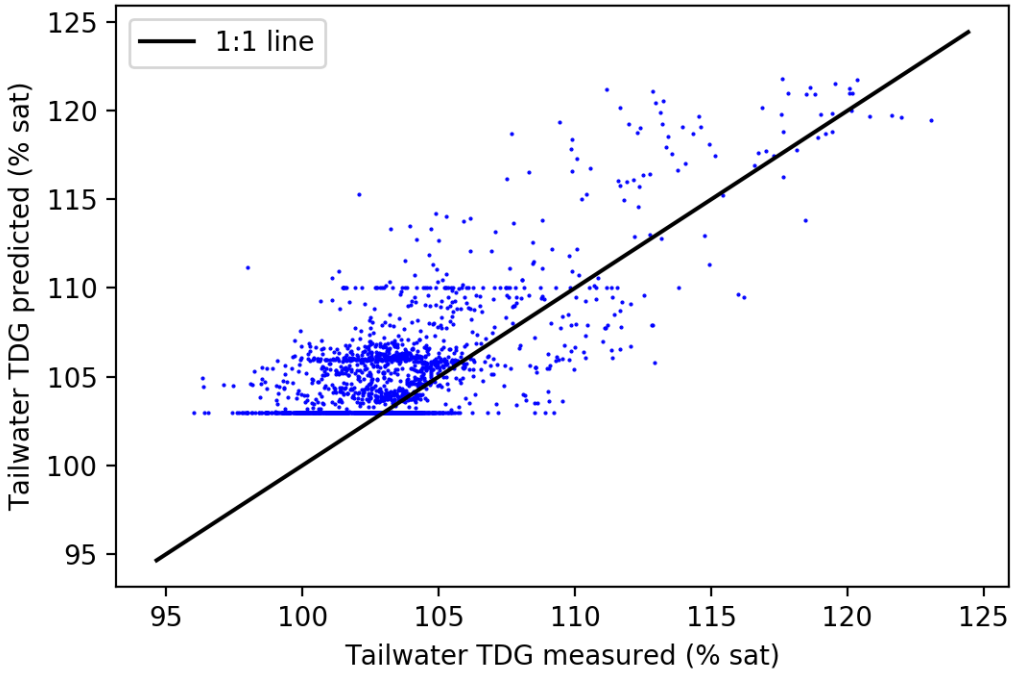


Figure 2-8. Model estimation of TDG compared to measurements at SSFO.

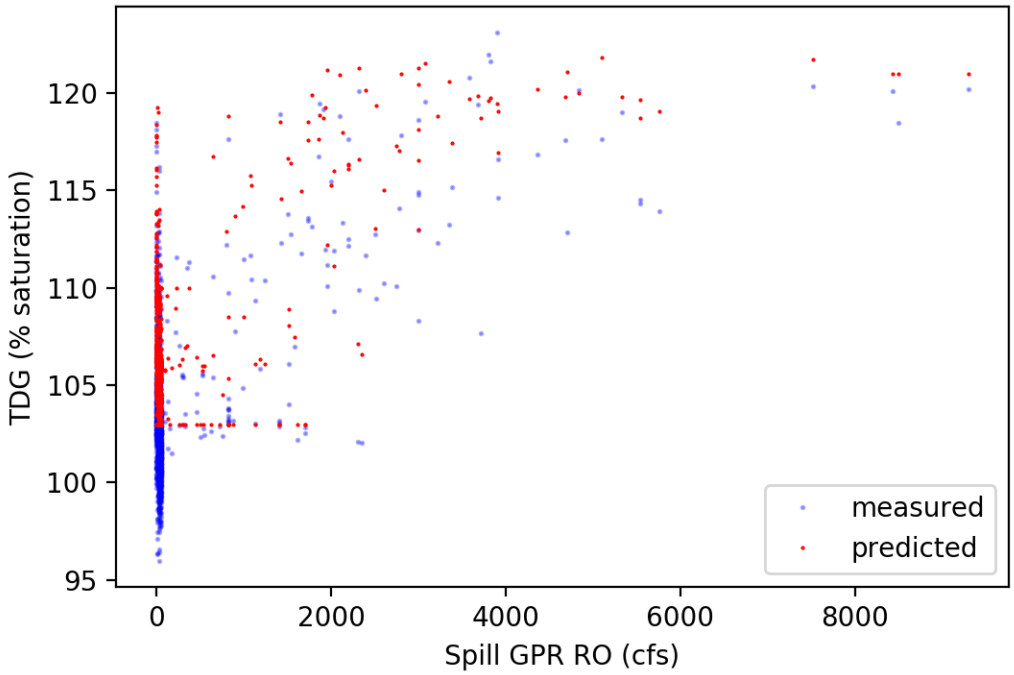


Figure 2-9. Model estimation and measurements of TDG compared to spill at Green Peter regulating outlet.

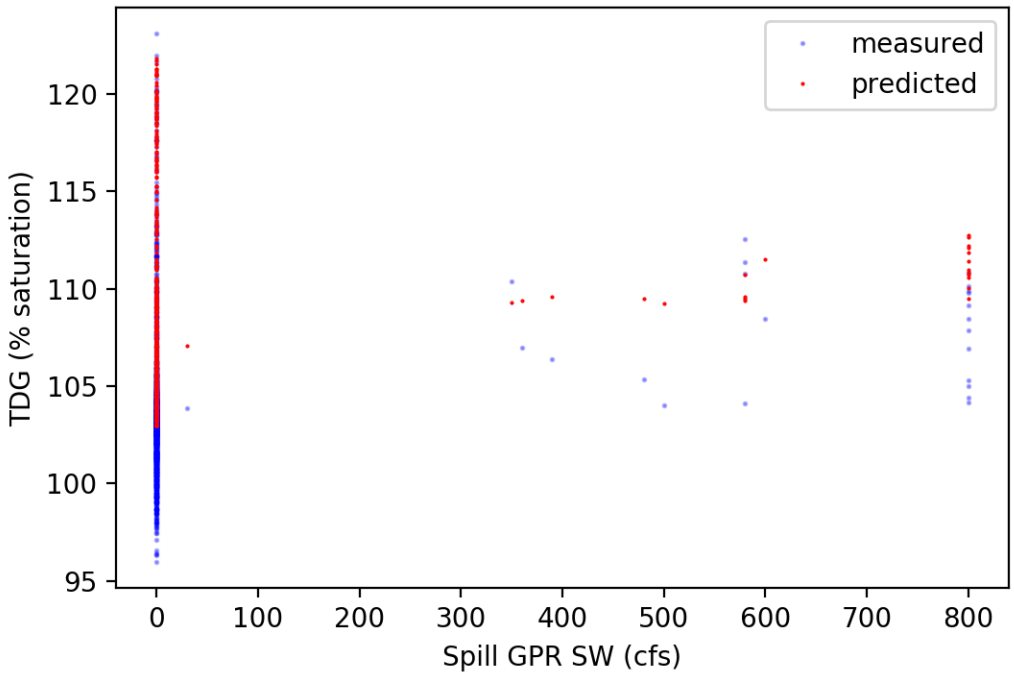


Figure 2-10. Model estimation and measurements of TDG compared to spill at Green Peter spillway.

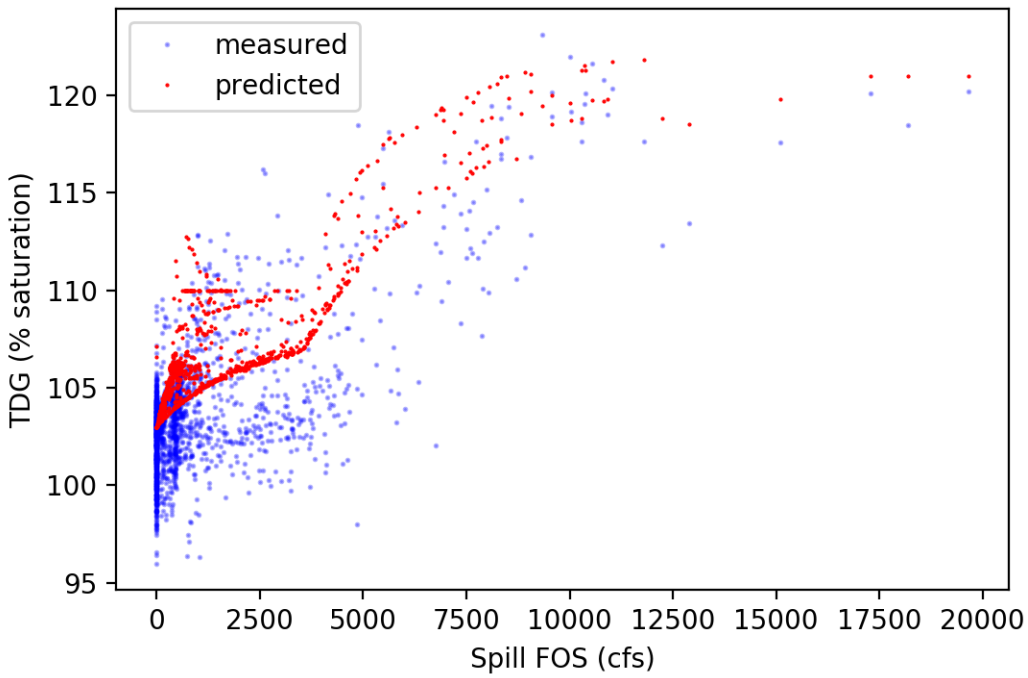


Figure 2-11. Model estimation and measurements of TDG compared to spill at Foster spillway.

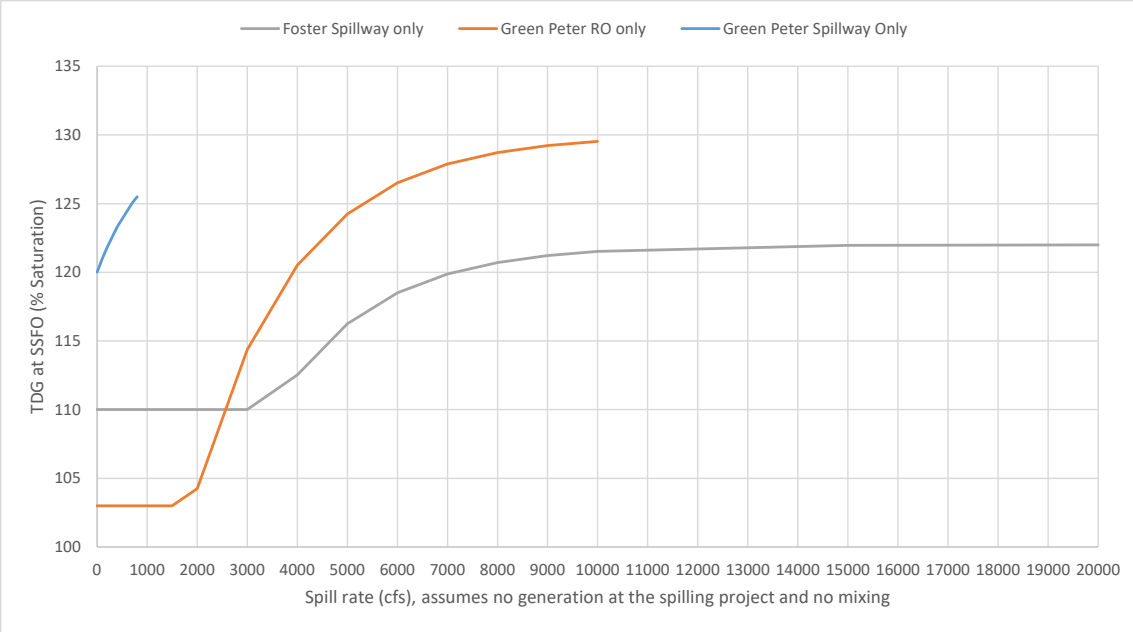


Figure 2-12. Model predictions of TDG at Green Peter and Foster Dams. Only one spill source and no mixing with generation flow assumed at Green Peter Dam due to absence of spillway data.

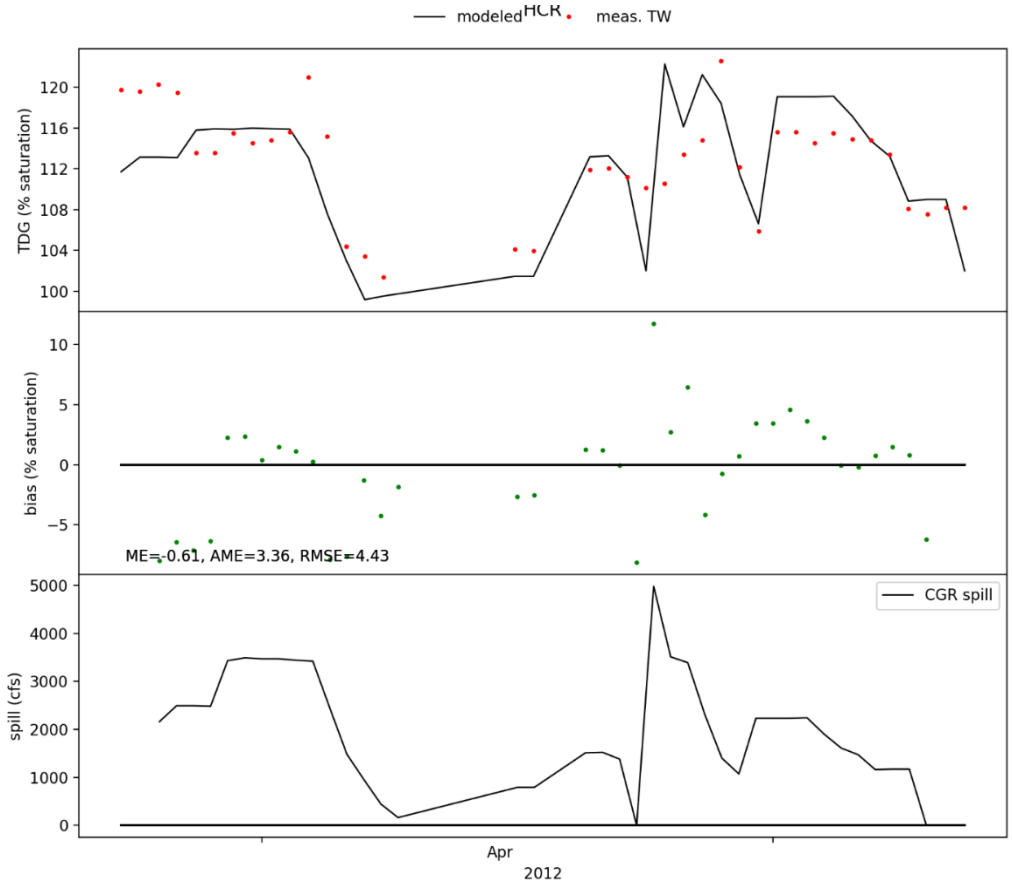


Figure 2-13 Example time series of Middle Fork Willamette model results at HCRO.

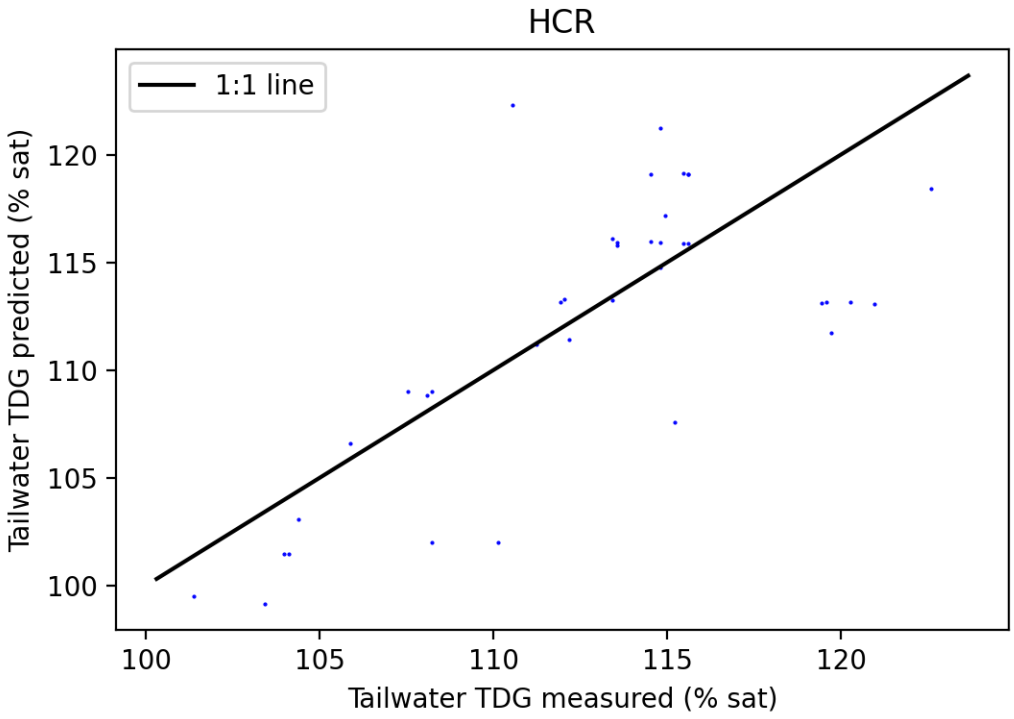


Figure 2-14 Model estimation of TDG compared to measurements at HCRO.

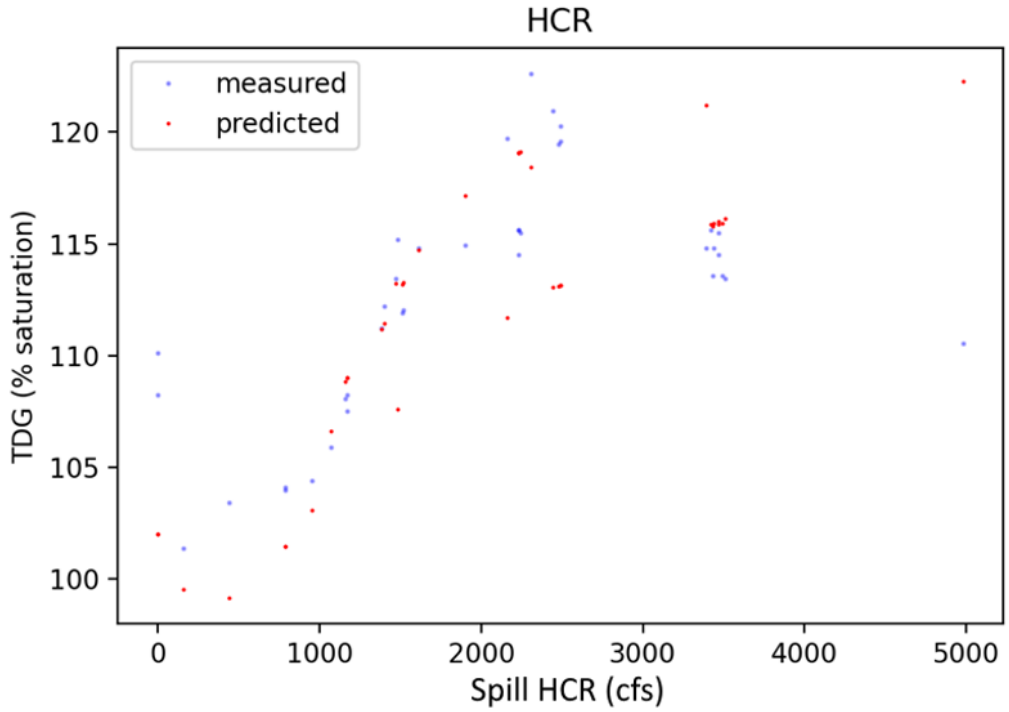


Figure 2-15. Model estimation and measurements of TDG compared to spill at Hills Creek regulating outlet.

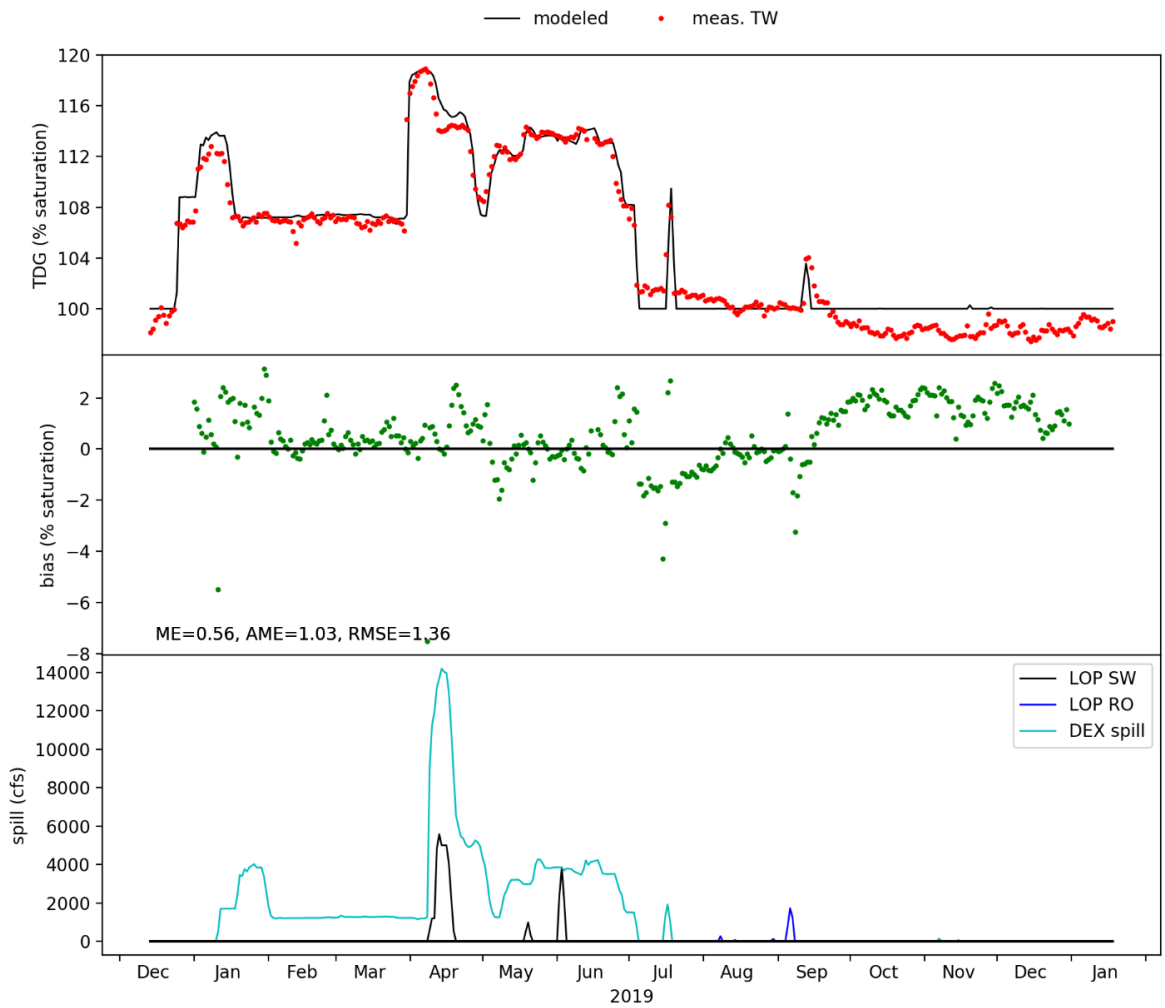


Figure 2-16. Example time series of Middle Fork Willamette model results at DEXO.

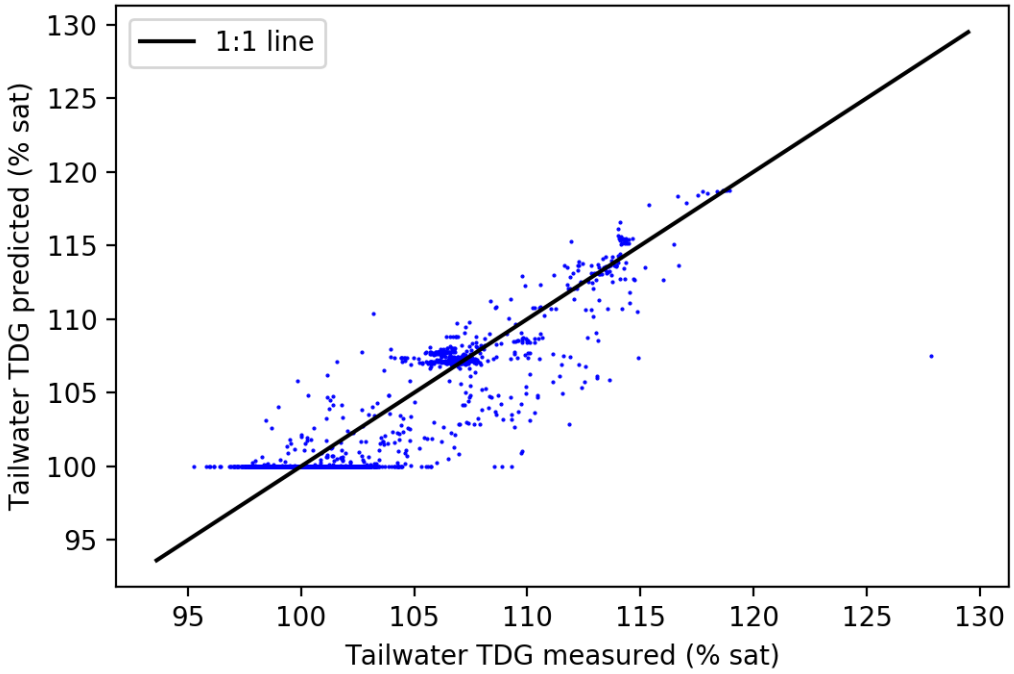


Figure 2-17. Model estimation of TDG compared to measurements at DEXO.

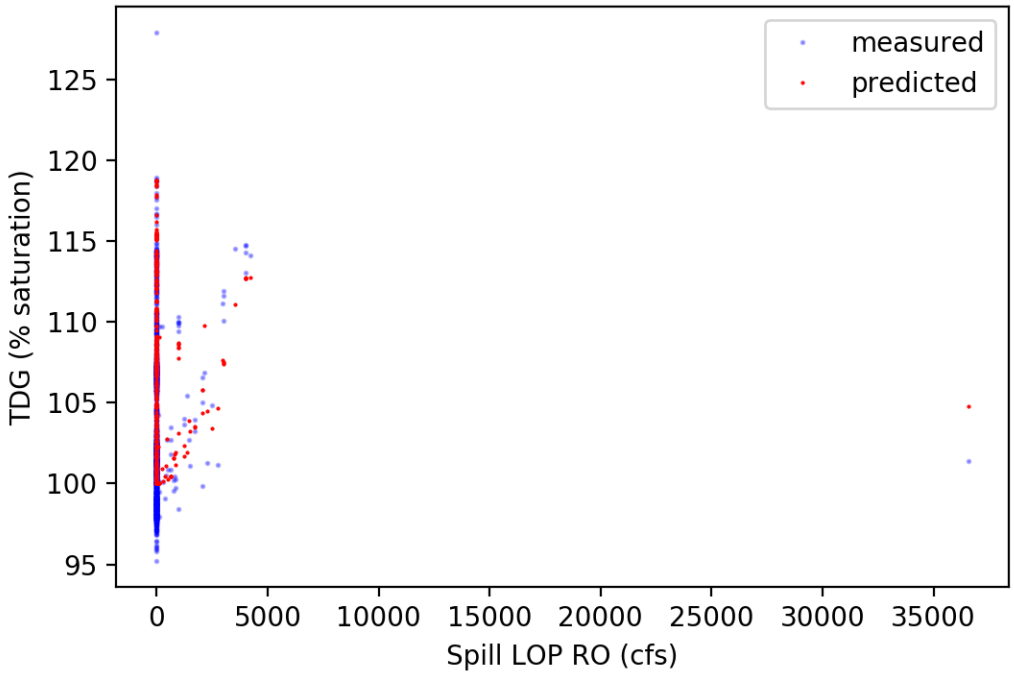


Figure 2-18. Model estimation and measurements of TDG compared to spill at Lookout Point regulating outlet.

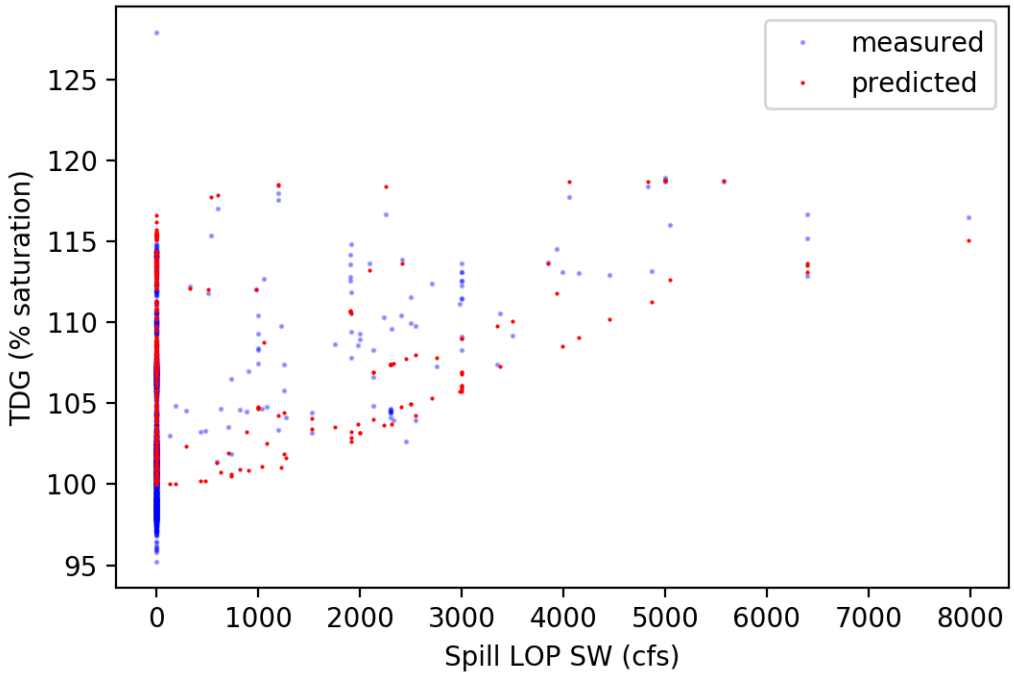


Figure 2-19. Model estimation and measurements of TDG compared to spill at Lookout Point spillway.

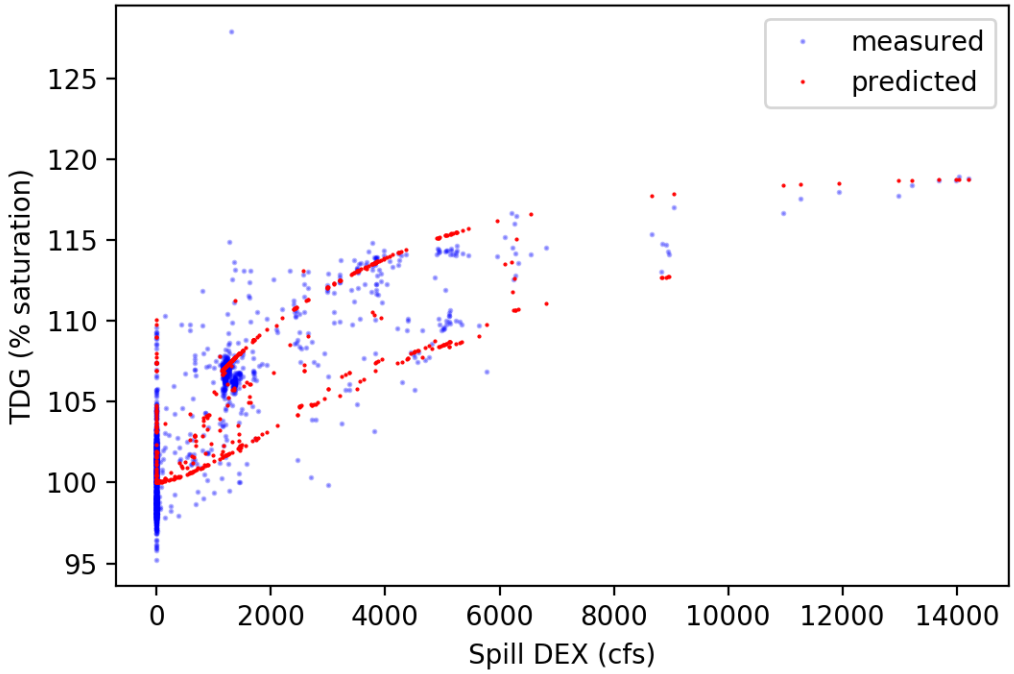


Figure 2-20. Model estimation and measurements of TDG compared to spill at Dexter spillway.

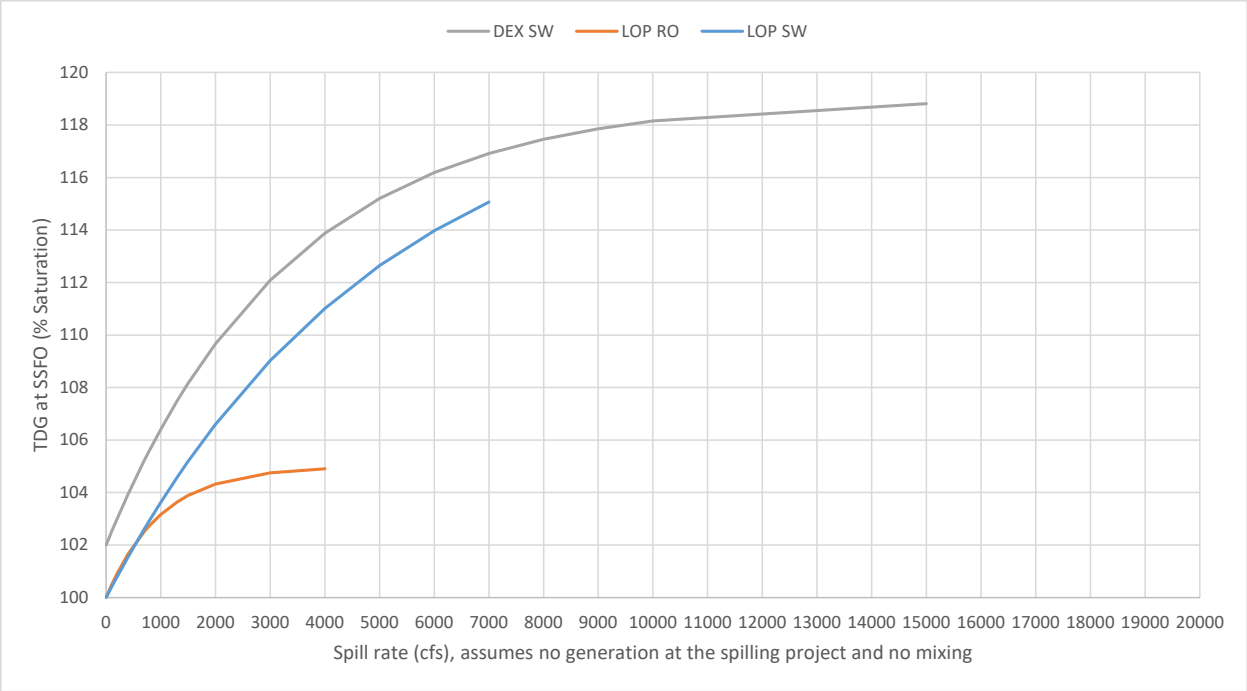


Figure 2-21. Model predictions of TDG below Lookout Point-Dexter Dams. Only one spill source and no mixing with generation flow assumed at Lookout Point Dam due to absence of spillway data.

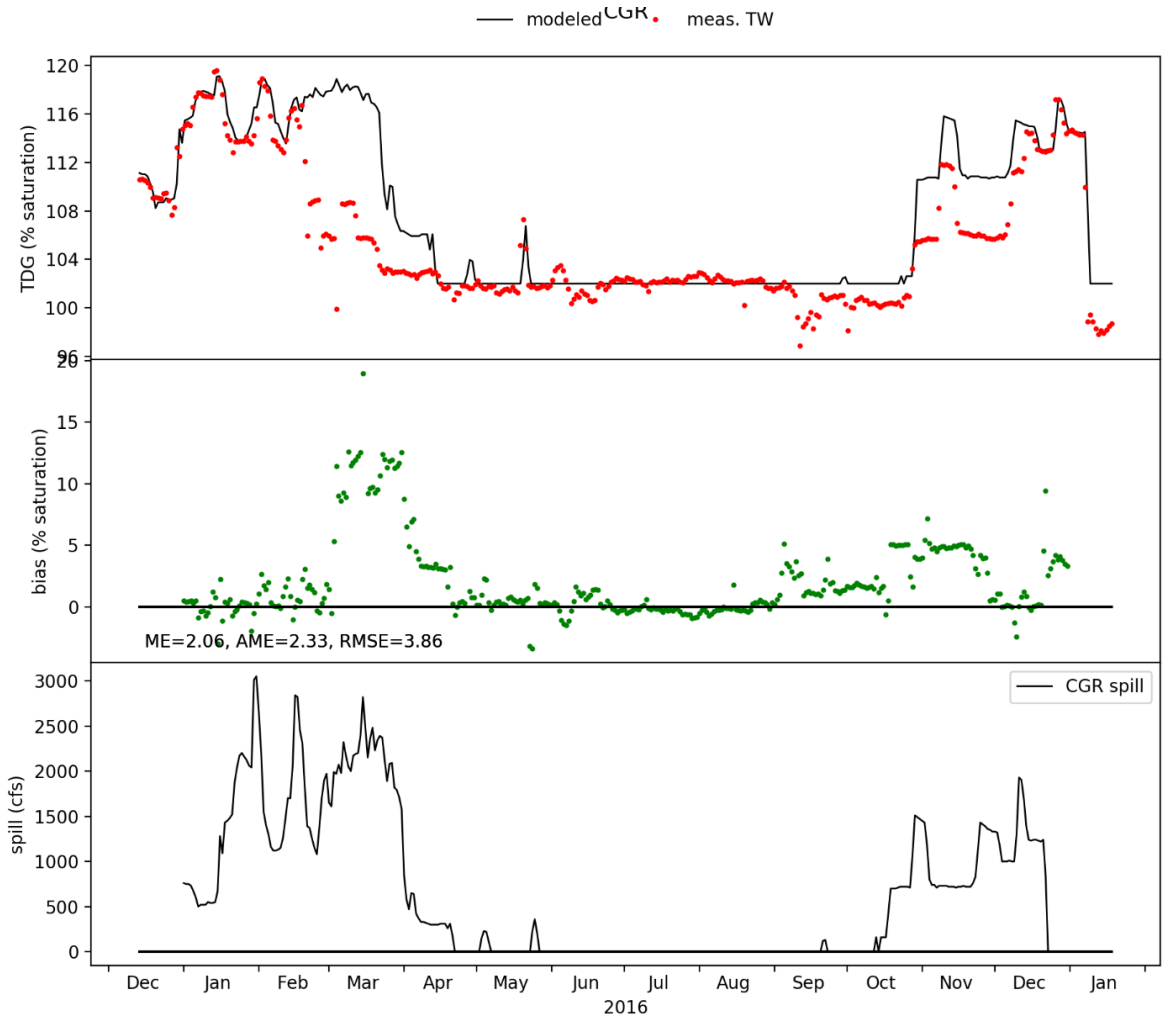


Figure 2-22. Example time series of South Fork McKenzie model results at CGRO.

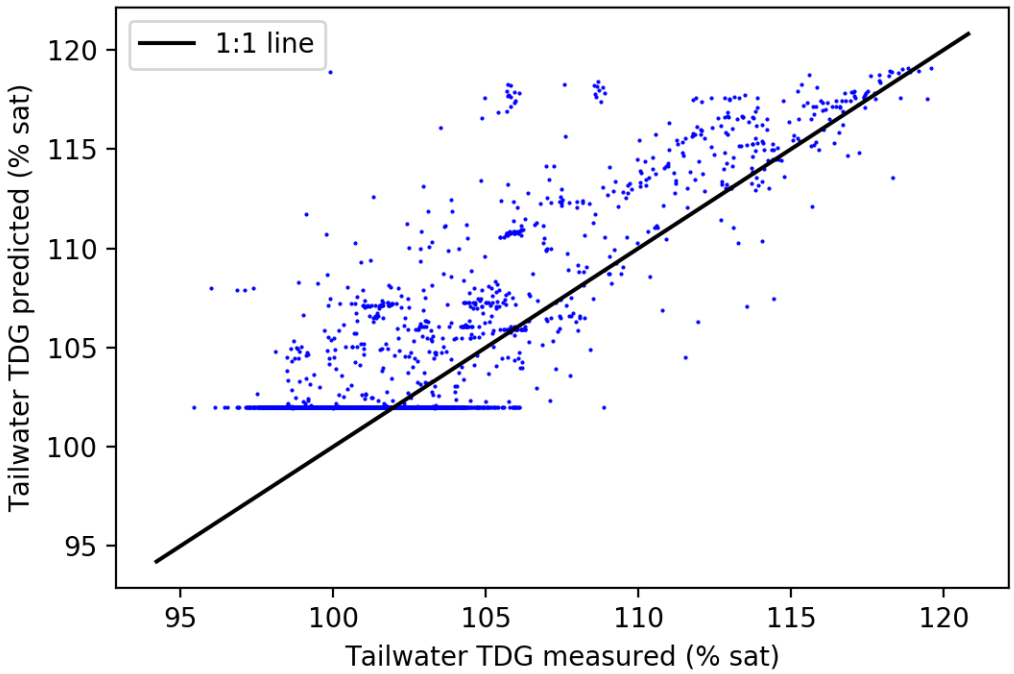


Figure 2-23. Model estimation of TDG compared to measurements at CGRO.

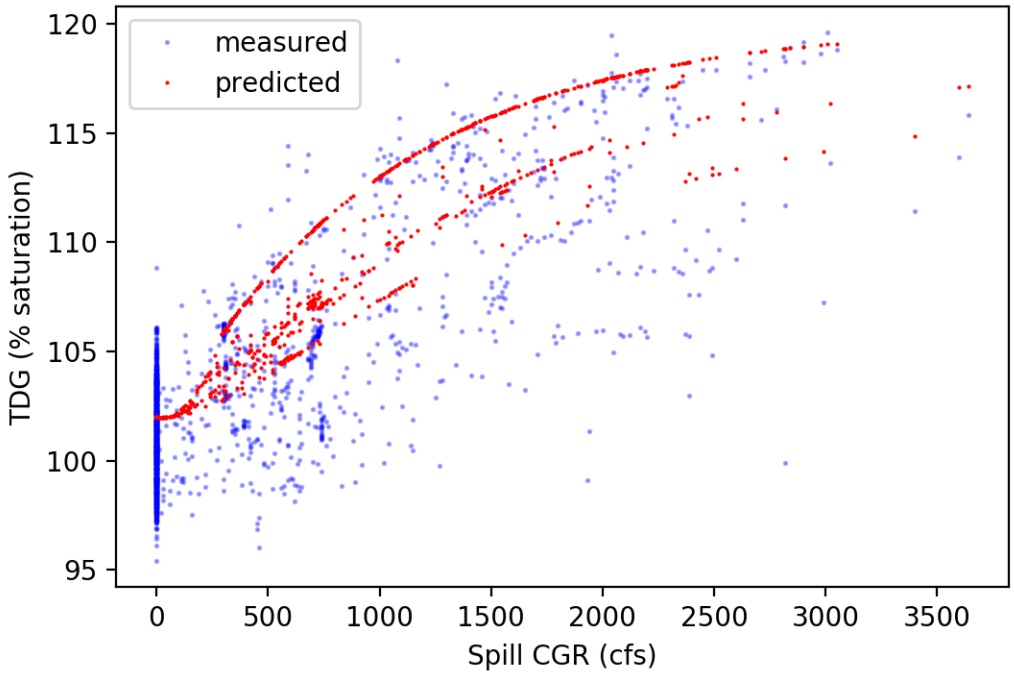


Figure 2-24. Model estimation and measurements of TDG compared to spill at Cougar regulating outlet.

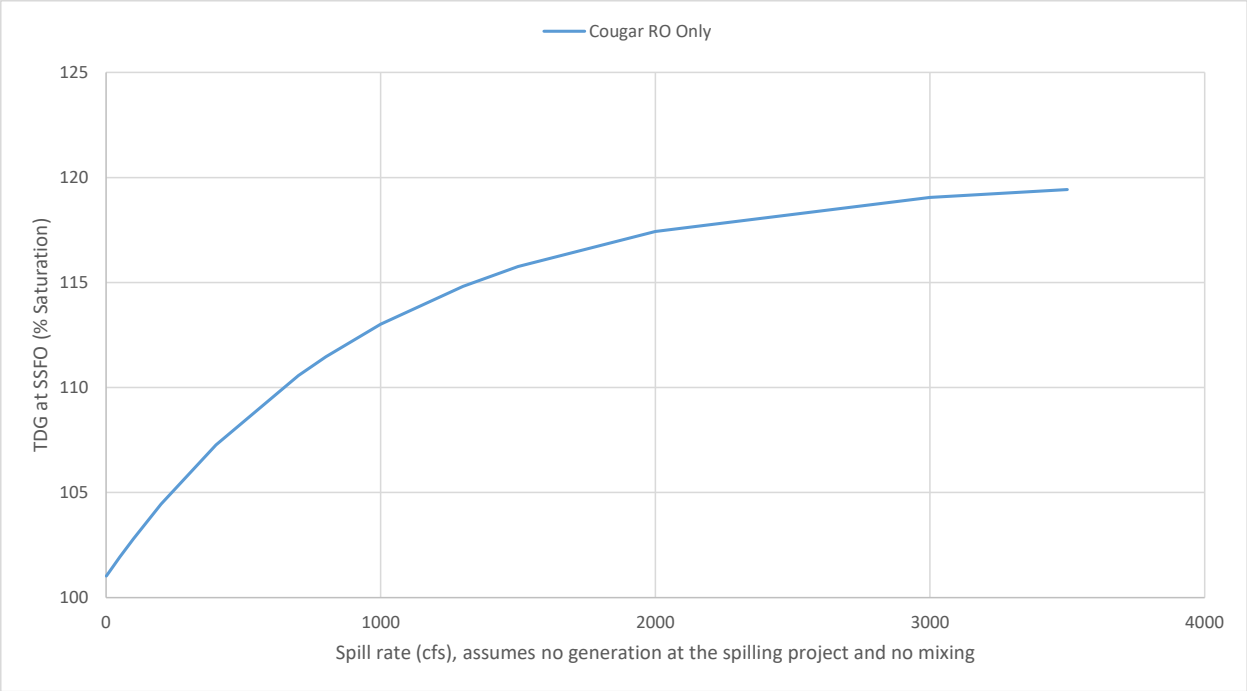


Figure 2-25. Model predictions of TDG below Cougar Dam. Only one spill source and no mixing with generation flow assumed below Cougar Dam.

Imposed Turbine Outages

Turbine outages caused by lack of energy demand, maintenance, or emergency safety measures can lead to spillway or regulating outlet usage and TDG exceedances of 110% below Willamette Valley Project Dams. Turbine outages were not included in HEC-ResSim simulations, so a method to introduce those outages into the TDG estimation was included here. To assess an average turbine outage rate per year for each WVP project, the observed turbine outages during 2009-2020 were used in combination with upcoming planned maintenance (Table 2-4). Estimated annual turbine outage rates as a percentage were applied to dam releases provided by the HEC-ResSim model in each alternative (e.g., NAA, Alternative 1) on random days during the year to recreate "forced" (i.e., unplanned) turbine outages. An additional 3% outage rate per year at all projects was imposed to recreate "planned" outages (e.g., maintenance) on random days during the winter months (December, January, February), aligning with planned outage periods described in the 2008 BiOp (NOAA, 2008) and Willamette Fish Operations Plan (USACE, 2017). For each day in which a turbine outage was imposed in each HEC-ResSim simulation (84-year simulation spanning 1936 – 2019), project power outflow was re-allocated to the appropriate spill outlet (spillway or RO, depending on lake level) outflow. A comparison of TDG over the entire period of record show a relatively close fit to the historic observations (Figure 2-26), especially at higher TDG levels (95th% TDG in Figure 2-27). The annual number of days in which spill and TDG exceedances (greater than 110%) occurred were similar in NAA and the observed record (Figure 2-28). A comparison of NAA and observed operations/TDG below each major TDG-producing WVP projects during separate wet winters are shown in Figure 2-29, Figure 2-30, Figure 2-31, and Figure 2-32. While the simulated high spill described here does

not always align with the observed record, the number of spill events that were imposed using the random turbine outages method described here led to general agreement of the TDG exceedance trends in the historical record while allowing a projection of turbine outages into the period of record and in each alternative.

Table 2-4. Projected Annual Turbine Outage (percentage of days per year) Applied to HEC-ResSim WVP Outflow Data in WV EIS Alternatives for Estimating TDG.

Project	Estimated Annual Turbine Outage (Percentage Days)
DET	7%
BCL	3%
GPR	2%
FOS	2%
LOP	2%
DEX	6%
CGR	8%
HCR	3%

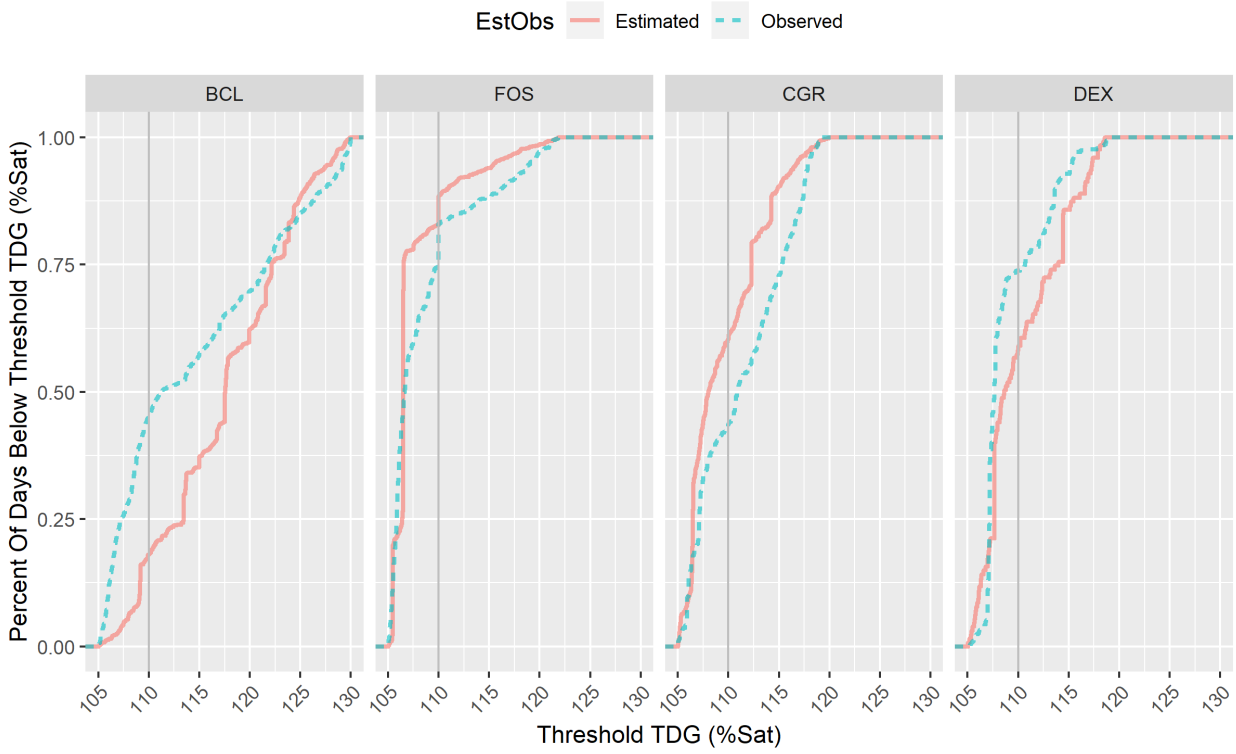


Figure 2-26. Percentage of Days Below a Given Threshold TDG (non-exceedance cumulative distribution function) as Estimated below Big Cliff (BCL), Foster (FOS), Cougar (CGR), and Dexter (DEX) Dams.

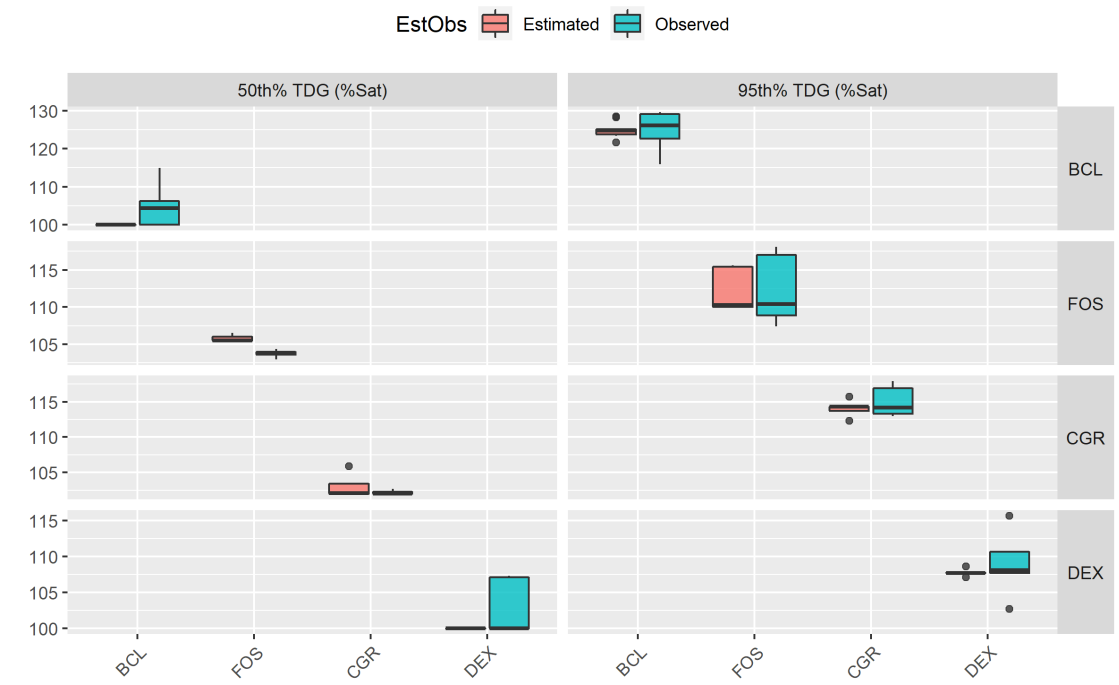


Figure 2-27. 50th and 95th percentile non-exceedance of estimated TDG under NAA (Estimated) compared to observed historical data (Observed) below Big Cliff (BCL), Foster (FOS), Cougar (CGR), and Dexter (DEX) Dams.

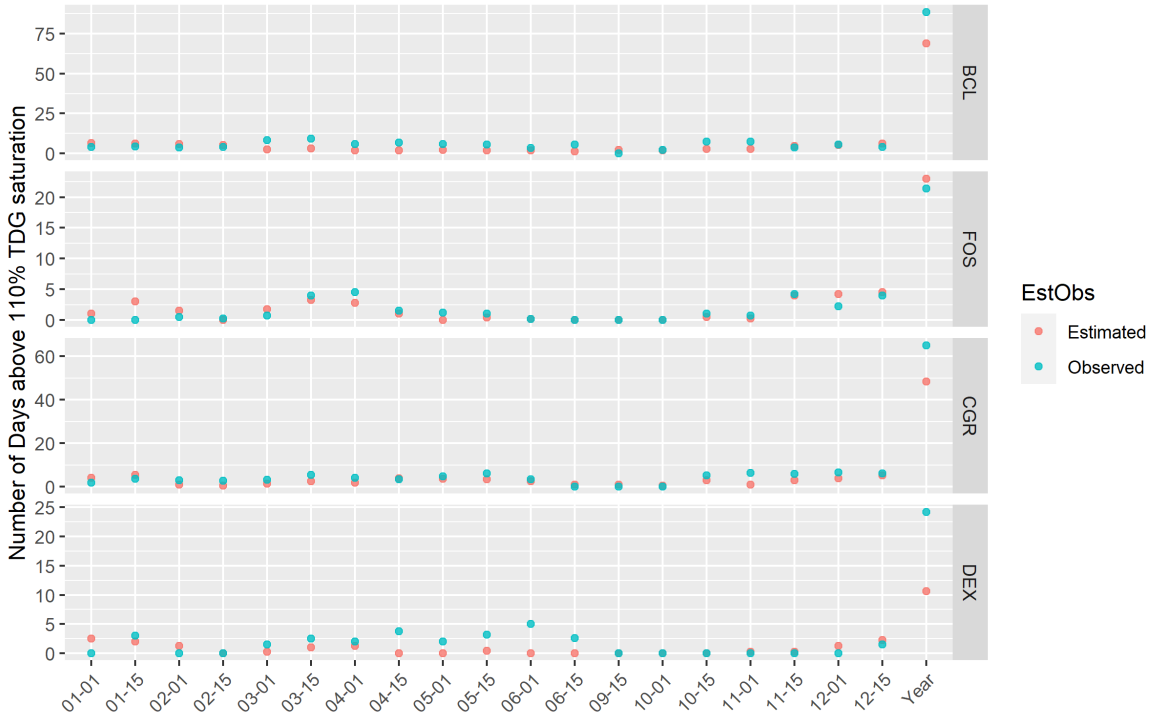


Figure 2-28. Number of days above 110% TDG in each bi-monthly period as estimated under NAA (Estimated) compared to observed historical data (Observed) below Big Cliff (BCL), Foster (FOS), Cougar (CGR), and Dexter (DEX) Dams.



Figure 2-29. Simulated operations and TDG at Detroit (DET) and Big Cliff (BCL) During three relatively large spring-time flow events comparing NAA (Estimated) to observed historical data (Observed). Abbreviations: spillRO; Regulating Outlet spill flow, spillSW; Spillway outlet flow, spilltotal; Total outflow.

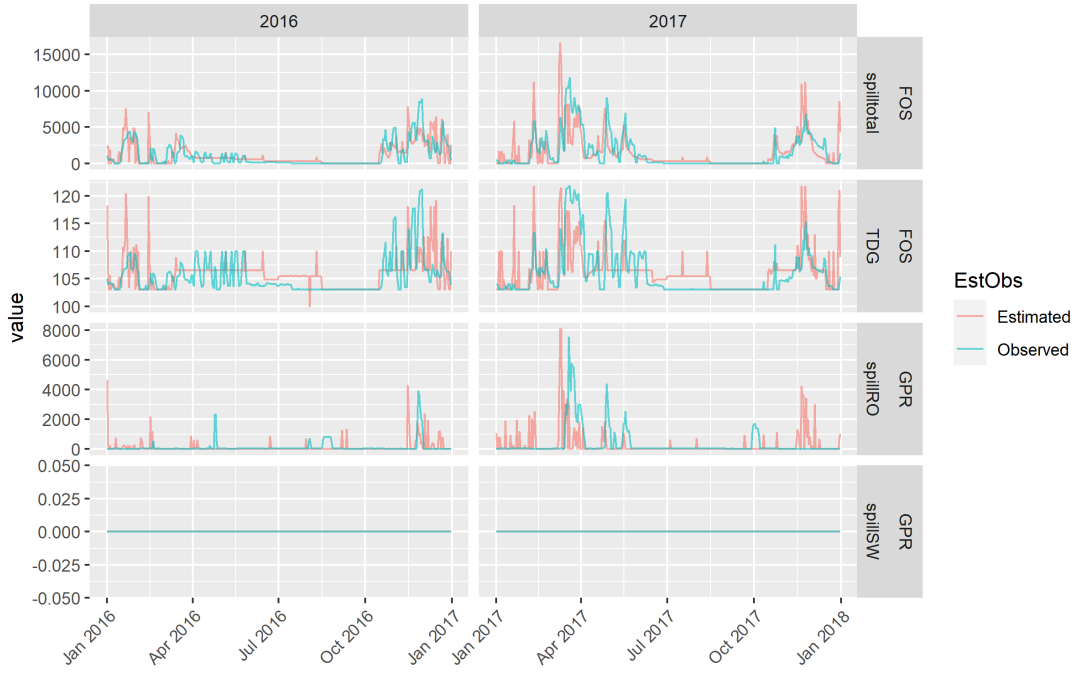


Figure 2-30. Simulated operations and TDG at Green Peter (GPR) and Foster (FOS) During Two relatively large spring-time flow events comparing NAA (Estimated) to observed historical data (Observed). Abbreviations: spillRO; Regulating Outlet spill flow, spillSW; Spillway outlet flow, spilltotal; Total outflow.

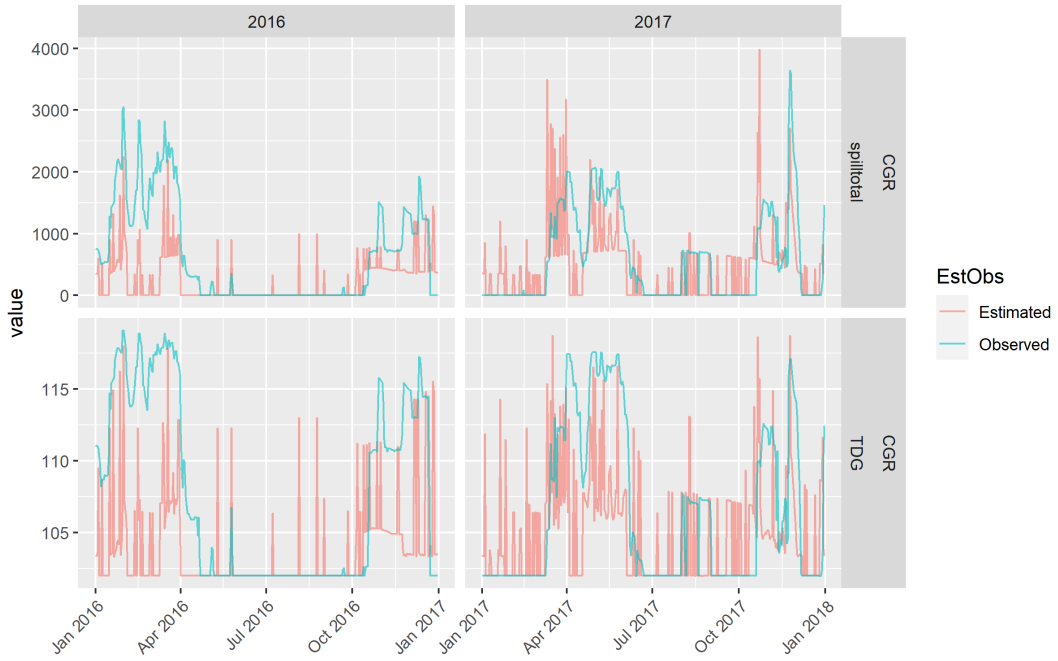


Figure 2-31. Simulated operations and TDG at Cougar (CGR) During Two relatively large spring-time flow events comparing NAA (Estimated) to observed historical data (Observed). Abbreviations: spillRO; Regulating Outlet spill flow, spillSW; Spillway outlet flow, spilltotal; Total outflow.



Figure 2-32. Simulated operations and TDG at Lookout Point (LOP) and Dexter (DEX) During two relatively large spring-time flow events comparing NAA (Estimated) to observed historical data (Observed). Abbreviations: spillRO; Regulating Outlet spill flow, spillSW; Spillway outlet flow, spilltotal; Total outflow.

2.1.2 Structural TDG Abatement Modeling Assumptions

Measure 174: Structural Improvements to reduce tailwater TDG where needed.

This measure describes structural modifications of current outlets, spillways or stilling basins to reduce tailwater TDG at Detroit, Big Cliff, Green Peter, Foster, Cougar, Lookout Point and Dexter Dams in the WVP. Previous work summarizing the monitoring efforts to compare structural and operational solutions for reducing TDG below Columbia River dams has shown varying degrees of success across different projects depending on flowrate per spillbay, number of spillbays, and spillway gate geometry/elevation/construction (USACE, 1996). A comparison of observed TDG reductions across studies is shown in Table 2-5. The following solutions have been evaluated in previous studies (USACE, 1996; USACE, 2002; USACE, 2009):

- **Spillway deflectors**, also called flip lips, have been installed at many Snake/Columbia River projects and are the most common structural solution for TDG abatement in the Columbia River. Spillway deflectors serve to redirect the spill jet from a plunging flow that transports air bubbles deep into the stilling basin to a horizontal jet that maintains entrained air much closer to the water surface (Figure 2-33). These deflectors are designed so that as the spillway discharge volumes increase (such as in a high river flow condition), the spillway discharges will eventually become high enough to override the spillway deflectors and begin the deep plunging action necessary for adequate energy dissipation. When projects operate outside of the spillway deflector design range, the spillway deflectors are less effective and may cause even higher TDG concentrations due to increased plunging depths in the stilling basin.

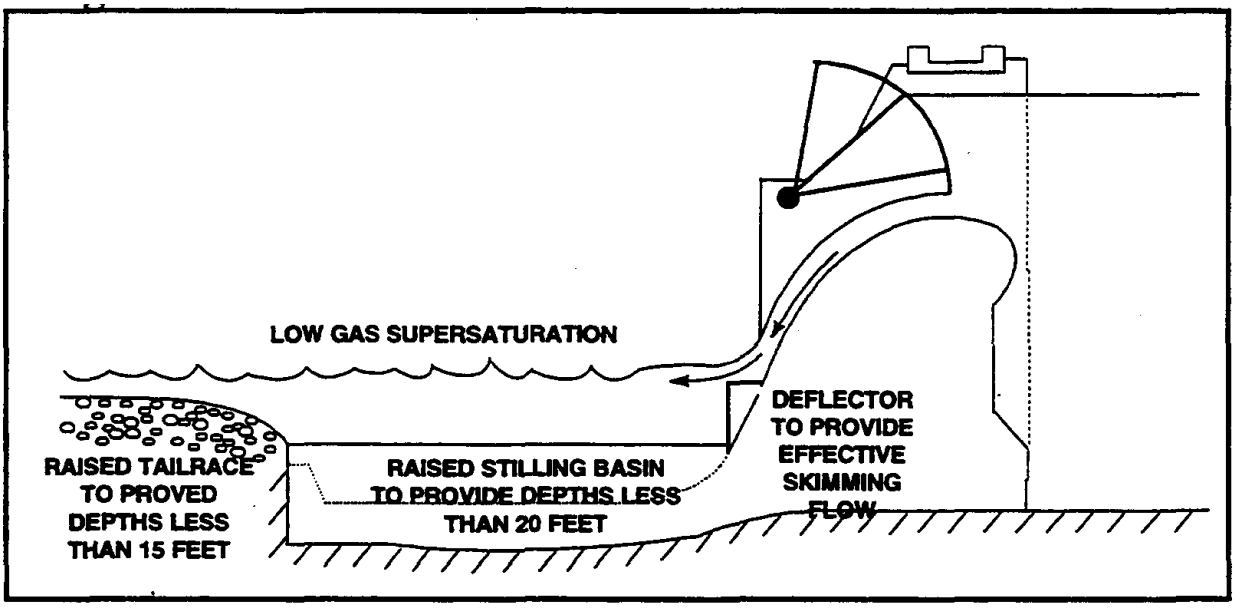


Figure 2-33. Conceptual Diagram of Potential Structural TDG Gas Abatement Structures (Figure 3.06.1 in USACE, 1996).

- **Raised tailrace or raised stilling basin** consists of added rock fill near the dam, contained by concrete cap to help reduce the plunging effect. This could result in a longer zone of turbulence and potentially increased erosion downstream of the dam. This may reduce the dam's structural integrity. Fish mortality from such structures is unknown.
- **Flip Bucket or Roller Bucket spillways** are intended to reduce the plunge depth. During low voluntary spillway discharges, the hydraulic jump will form in the flip bucket. During higher discharges the flip bucket will sweep out, and the discharge will plunge into the stilling basin below the flip bucket, which may produce high gas concentrations. A roller bucket looks somewhat like a flip bucket except that a roller bucket is submerged. Instead of dissipating energy by sweeping out during higher discharges, the roller bucket forms two horizontal rollers to dissipate energy.
- **Boulder augmentation or debris jams** could help create more natural riffles downstream of USACE projects and help degas supersaturated water. Little is known regarding the design and construction of riffles and debris jams and how effective these man-made structures may be for TDG abatement.
- **Spill patterns** that distribute spillbay flows uniformly across the entire spillway could help reduce downstream TDG. Dam safety protocols in the Willamette Valley Project limit the possibility of implementation during some higher flow conditions.
- **Constructed pipe extensions** on the downstream side of ROs to submerge releases in the stilling basin could reduce jet impact on the tailwater surface.

Table 2-5. Summary of literature regarding observed TDG reduction associated with TDG abatement strategies.

Site	Details of TDG abatement structure	Approximate TDG % reduction downstream	Source and Notes
Rock Island Dam	Spillbay 29 flow deflector installed in 2000	4.5%	Carroll et al., 2001
Rock Island Dam	Spillbay 16 flow deflector installed in 2001	<6.0% (no values above 110%)	Carroll et al., 2002
Wanapum Dam	Deflectors installed at all spill bays in 2000	3-4% at flows < 60kcfs 1-2% at flow >100kcfs	USACE, 2001
Wanapum Dam	Deflectors installed at all spill bays in 2000	At Beverly Bridge: 9% at spill of 120kcfs 6% at spill of 150kcfs	Juul (2003) compared 2000-2001 to 1996-1997 data
Ice Harbor Dam	10 spillway flow deflectors installed in 1998	20% overall; peak reduction from 170 to 125 TDG	Schneider and Wilhelms, 2016
John Day Dam	18 spillway flow deflectors installed in 1999	Peak reduction from 170% to 125% TDG	DGAS Phase 2 (USACE, 2002)
Chief Joseph	Spillway flow deflectors installed 2006-2008	15% at flows >38kcfs	Schneider, 2012

The Dissolved Gas Abatement Study (DGAS) for the USACE Columbia River Dams determined that a combination of Spillway deflectors and/or a raised tailrace/stilling basin has the best opportunity to reduce TDG through structural solutions on the Columbia-Snake system (USACE, 1996). Following those findings, additional spillway deflectors were installed at the USACE Lower Snake and Columbia River Dams. The observed reductions to TDG in the studies shown in Table 2-5 are based on Columbia/Snake River flow, which can be roughly 10 times larger than the Willamette.

A reduction factor TDG estimation for alternatives that incorporated Measure 174 was considered given the following information:

- While there is a large difference in hydrology, dam configuration, and spillway gate sizes between the Columbia and Willamette Dams, the potential TDG reductions due to structural improvements generally ranged between 3% to 9%; higher TDG reductions within the normal range of spill.
- Reductions in TDG realized through WILTDG modeling of spreading spill across multiple spillway gates at Big Cliff Dam were about 10% (assuming 3000-6000 cfs range; see Figure 2-6).

Given this information (and lack of 3-dimensional computational fluid dynamics and dissolved gas modeling), a reduction factor of 5% was imposed for TDG estimates at BCL, FOS, CGR, and DEX exceeding 110 % in WV EIS Measure 174.

2.2 TDG RESULTS AND EFFECTS ANALYSIS

Available data from Detroit/Big Cliff, Green Peter/Foster, Lookout Point/Dexter, Hills Creek, and Cougar Dams was utilized to simulate TDG with the WILTDG model. This model was adapted from the Columbia River System TDG model, WILTDG, an empirical (data-driven) model depending primarily on spill outflow (non-turbine releases) and power outflow (turbine releases) at each dam. The period of record used by the HEC-ResSim modeling was applied to WILTDG at the locations listed above for each alternative. For a complete listing of the measures included in each alternative, see Chapter 3.

The WILTDG model output includes estimated TDG based on project operations and the annual number of days above 110% (Appendix D). TDG results are compared to the State of Oregon water quality standards in the Oregon Administrative Record (OAR) 340-041-0031: "Except when stream flow exceeds the ten-year, seven-day average flood, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection may not exceed 110% of saturation".

Dam releases from non-turbine outlets (defined as "spill" in this EIS) are known to produce elevated TDG. The average number of days with spill per year are compared in each Alternative and dam (Figure 2-34) and help to explain locations and alternatives with relatively higher TDG. Generally, TDG is generated initially at the high-head dam when spill occurs (e.g., Detroit Dam) and can increase downstream if spill occurs at the downstream re-regulating dam (e.g., Big Cliff Dam). TDG estimates from WILTDG were then tabulated as the average number of days exceeding 110% TDG per year over all simulations (84 year period of record, 8 dams, 9 alternatives in Figure 2-35 and Table 2-6. The annual number of days above 110% TDG is compared to the NAA for each alternative and summarized in Figure 2-36. *Note: Impacts at GPR, HCR, LOP are underestimates; extensive TDG data from spillgate operations at these projects did not exist at the time of the EIS development. The number of days (*Figure 2-34*) with spill may be a more appropriate metric for effects at these locations.*

Due to timing of WV EIS alternative modeling prior to court-mandated injunction measures, TDG abatement modifications in Alternatives 1 and 4 represent an under-estimate of the expected TDG when incorporated into reasonably foreseeable actions over the planning horizon of the WV EIS. Correct estimates of TDG downstream of Big Cliff Dam would likely be 5% TDG points higher in Alternatives 1 and 4 than stated in this modeling effort. See the Cumulative Effects Section of this EIS for more information.

Revisions to NTOM HEC-ResSim modeling from DEIS to FEIS resulted in minor changes limited to extreme dry years in the North and South Santiam sub-basins, when TDG is generally lower, due to lower spill flow. While minor differences of short duration may occur as a result of the updated ResSim results, higher minimum flow rules during spring (increased spill and TDG) and

minor reductions to lake levels that allow for spillway operations related to temperature operations (reduced spill flow and TDG) in dry years), these differences likely sum to a negligible change when averaging over many years. WILTDG analysis was not available for the FEIS due to the likelihood that further modeling analysis would lead to negligible or minor differences regarding effects between DEIS and FEIS results. The figures and tables in this section represent the NTOM DEIS HEC-RESSIM as WILTDG modeling and analysis were not updated for the NTOM FEIS.

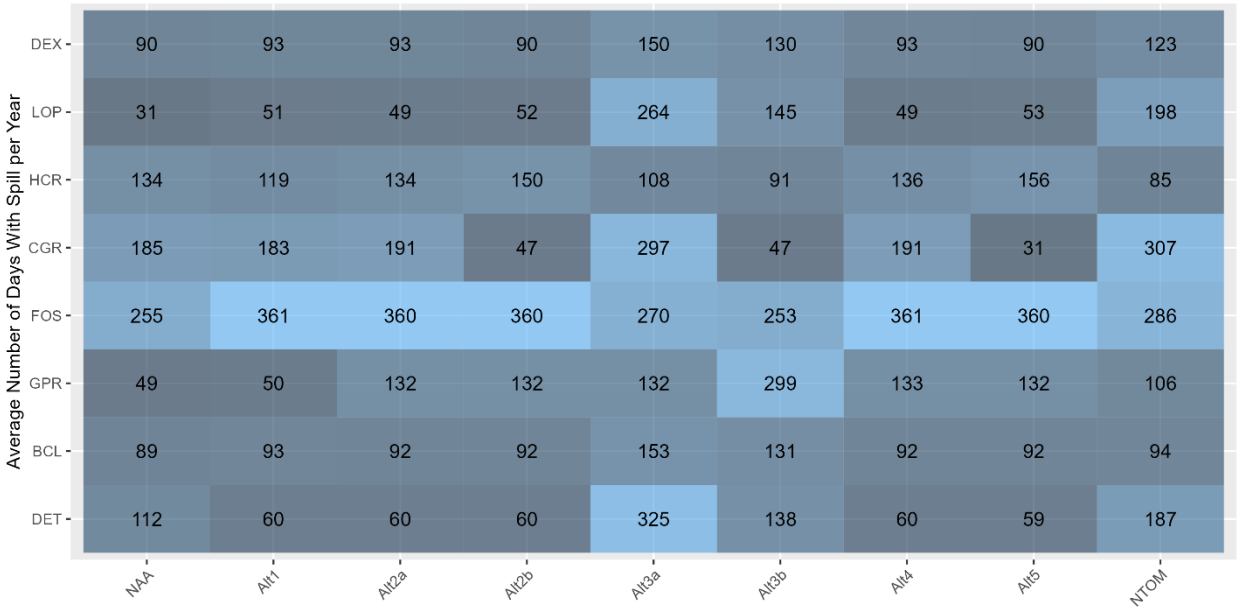


Figure 2-34. Average Number of Days with Spill per Year Under Each Alternative

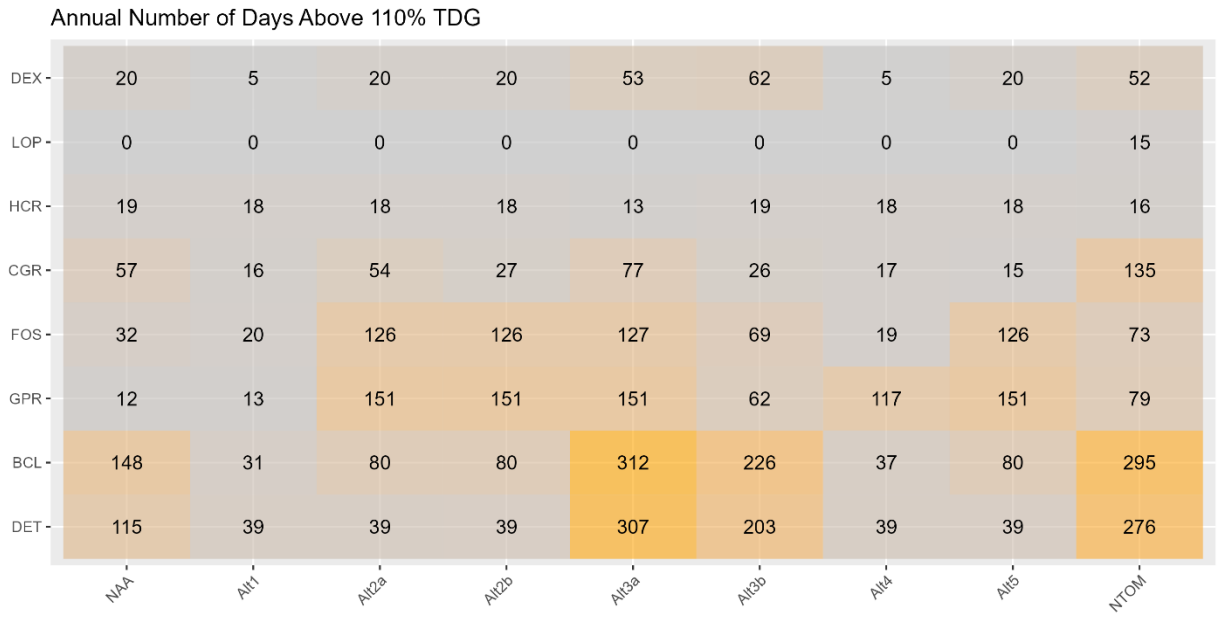


Figure 2-35. Average Number of Days above 110% TDG (numerical values shown) in Dam Tailraces Under Each Alternative. Note: Impacts at GPR, HCR, LOP are underestimates; extensive TDG data from spillgate operations at these projects did not exist at the time of the EIS development.

Table 2-6. Average Number of Days With TDG Above 110 %.

Location	NAA	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NTOM
DEX	20	5	20	20	53	62	5	20	52
LOP	0	0	0	0	0	0	0	0	15
HCR	19	18	18	18	13	19	18	18	16
CGR	57	16	54	27	77	26	17	15	135
FOS	32	20	126	126	127	69	19	126	73
GPR	12	13	151	151	151	62	117	151	79
BCL	148	31	80	80	312	226	37	80	295
DET	115	39	39	39	307	203	39	39	276

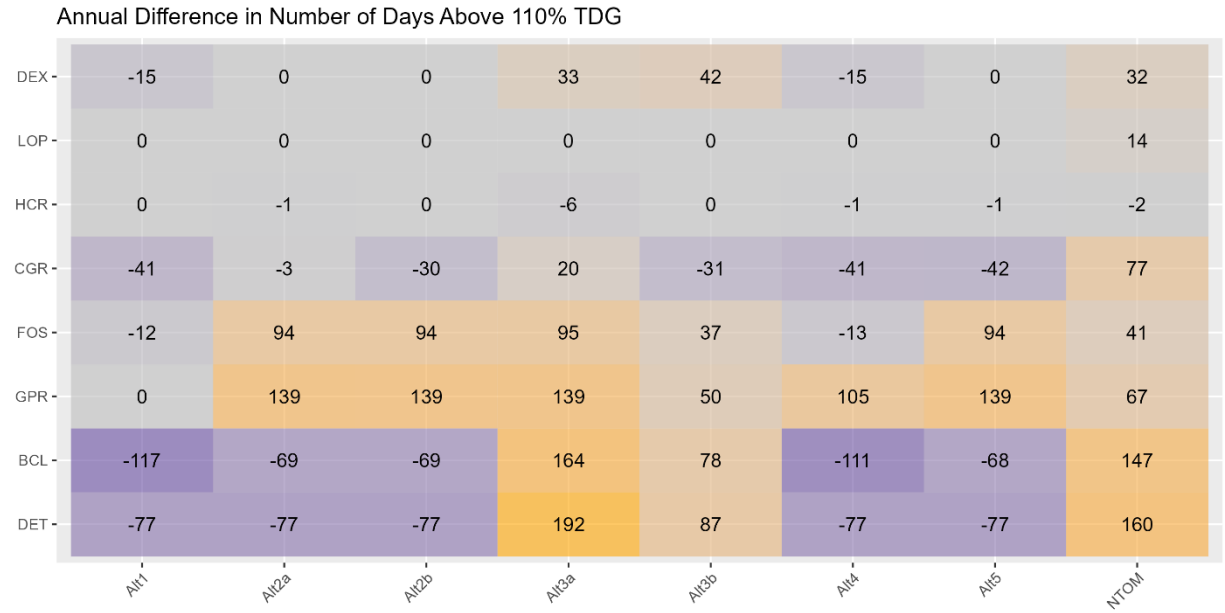


Figure 2-36. Annual Difference in Number of Days Above 110% TDG Compared to the No Action Alternative. Note: Impacts at GPR, HCR, LOP are underestimates; extensive TDG data from spillgate operations at these projects did not exist at the time of the EIS development.

2.2.1 No Action Alternative

A comparison of NAA with measurements is shown in Imposed Turbine Outages. Further information on NAA is available in Measure Assumptions.

2.2.1.1 North Santiam Dams

With current operations the same as stated in Section 3.5 Water Quality Affected Environment, exceedances of the 110% TDG water quality standard would continue to occur frequently downstream of Big Cliff (up to 148 days per year) and below Detroit Dam (up to 115 days per year; Figure 2-35). The Average Number of Days of Spill per Year would remain 127 at Detroit and 84 at Big Cliff (Figure 2-34).

2.2.1.2 South Santiam Dams

Under the No Action Alternative operations would remain as described in the Section 3.5 Water Quality Affected Environment. Although no TDG measurements exist immediately downstream of Green Peter, it is estimated that the 110% TDG level would be exceeded 12 days per year on average based on the frequency of spill under NAA. Foster would be above 110% TDG for 32 days on average (Figure 2-35). The Average Number of Days of Spill per year would remain 47 days at Green Peter and 209 days at Foster (Figure 2-34).

2.2.1.3 McKenzie Dams

Cougar reservoir would remain as described in the Section 3.5 Water Quality Affected Environment with an average of 57 days above 110% TDG levels (Figure 2-35). The Average Number of Days of Spill per year at Cougar would remain 162 days (Figure 2-34).

2.2.1.4 Middle Fork Willamette Dams

Hills Creek TDG would continue to exceed the 110% TDG water quality standard for an average of 19 days per year under NAA. Although no TDG measurements exist immediately downstream of Lookout Point, it is estimated that the 110% TDG level would not be exceeded. TDG immediately below Dexter would continue above 110% for an average of 20 days per year (Figure 2-35). The Average Number of Days of Spill per year would continue at Hills Creek with 120 days, Lookout Point would continue to be 31 days and Dexter would continue to be 87 days (Figure 2-34).

2.2.2 Alternative 1 – Project Storage Alternative

Alternative 1 includes structural improvement measures to reduce TDG at Detroit, Big Cliff, Green Peter, Foster, Lookout Point, Dexter, and Cougar dams. Measure 174 in Alternative 1 applied to LOP-DEX, CGR, GPR-FOS, and DET-BCL and resulted in an estimated 5% reduction in TDG values above 110% at the control point immediately below the lowest dam in each sub-basin (Figure 2-37, Figure 2-38).

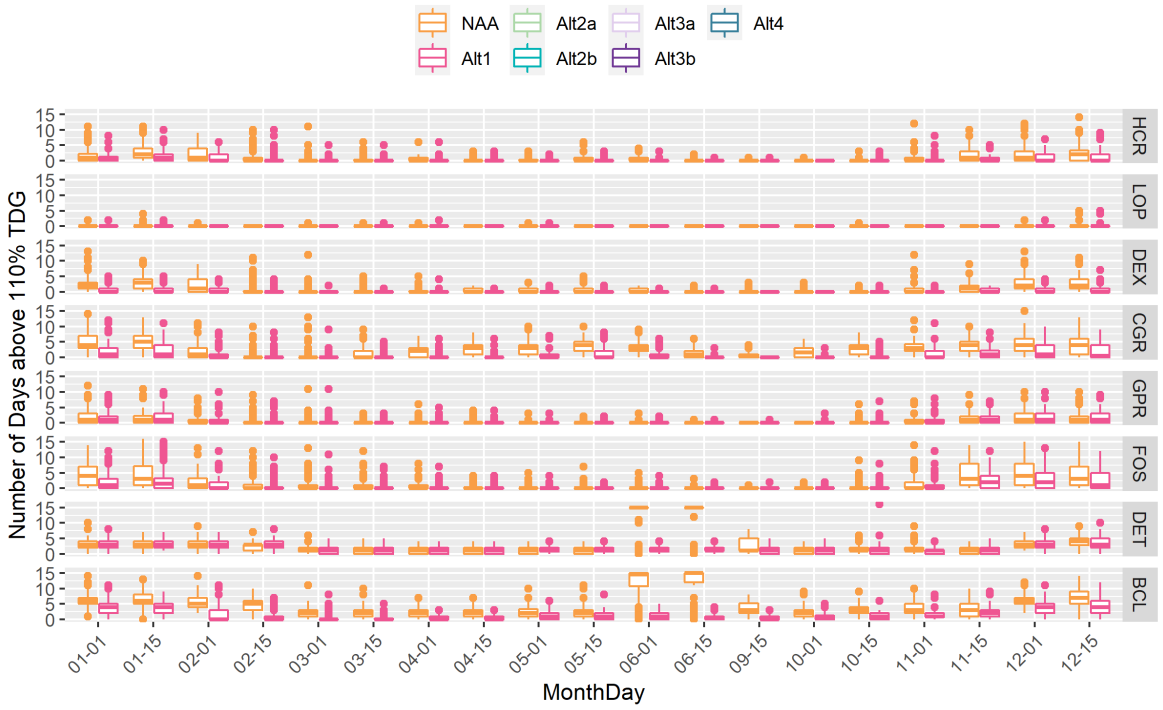


Figure 2-37. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 1 and NAA.

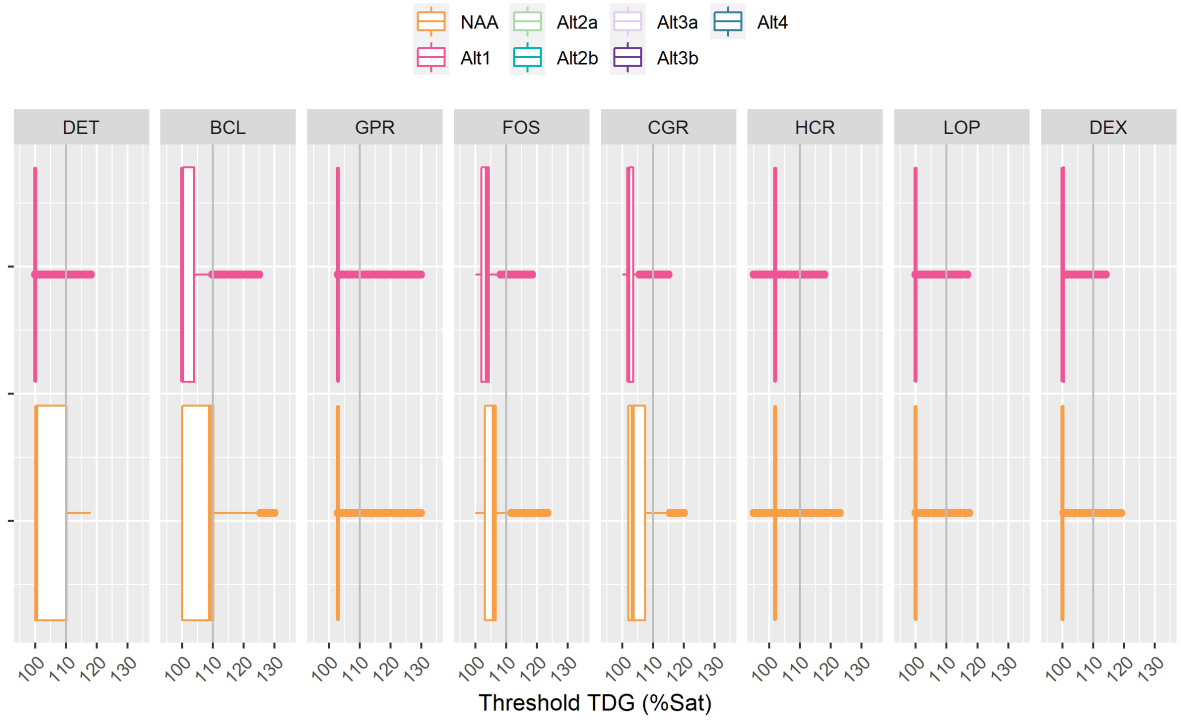


Figure 2-38. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 1 and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.2.1 North Santiam Dams

Under Alternative 1, the average number of days above 110% TDG levels at Big Cliff is 31 and Detroit is 39 (Figure 2-35). This equates to a reduction in TDG below Big Cliff of 117 annually. Annual differences in number of days above 110% of TDG exceedances and below Detroit is reduced to 77 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Detroit is 62 days and Big Cliff is 88 days (Figure 2-34).

2.2.2.2 South Santiam Dams

Under Alternative 1, Green Peter reservoir results in 13 average number of days above 110% TDG levels, whereas Foster would be 20 average number of days above 110% (Figure 2-35). Green Peter has a reduction of 0 days of TDG exceedances and Foster is reduced by 12 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 48 days and Foster is 285 days (Figure 2-34).

2.2.2.3 Mckenzie Dams

Under Alternative 1, the average number of days above 110% TDG levels would be 16 at Cougar reservoir (Figure 2-35). Cougar reservoir has a reduction of 41 days of TDG exceedances as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 160 days under Alternative 1 (Figure 2-34). Blue River is expected to have similar operations as stated in the Affected Environment and NAA. As the RO's are routinely utilized and not turbines TDG levels would not be expected to change.

2.2.2.4 Middle Fork Willamette Dams

Under Alternative 1, the Average number of days above 110% TDG levels at Hills Creek is 9 average days, Lookout Point is 0, and Dexter is 5 average days (Figure 2-35). Hills Creek has a reduction of 9 days of TDG exceedances, Lookout Point has 0 days reduction, and Dexter is reduced by 15 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Hills Creek is 93 days, Lookout Point is 51 days and Dexter is 89 days (Figure 2-34). Fall Creek is expected to have similar operations as stated in the Affected Environment and NAA, as such there would not be expected TDG levels to change.

2.2.3 Alternative 2a – Hybrid Alternative

There are no measures to reduce TDG at the WVS dams in Alternative 2a. Boxplots in each half-month period and annual boxplots comparing Alternative 2a and NAA are shown in Figure 2-39 and Figure 2-40 respectively.

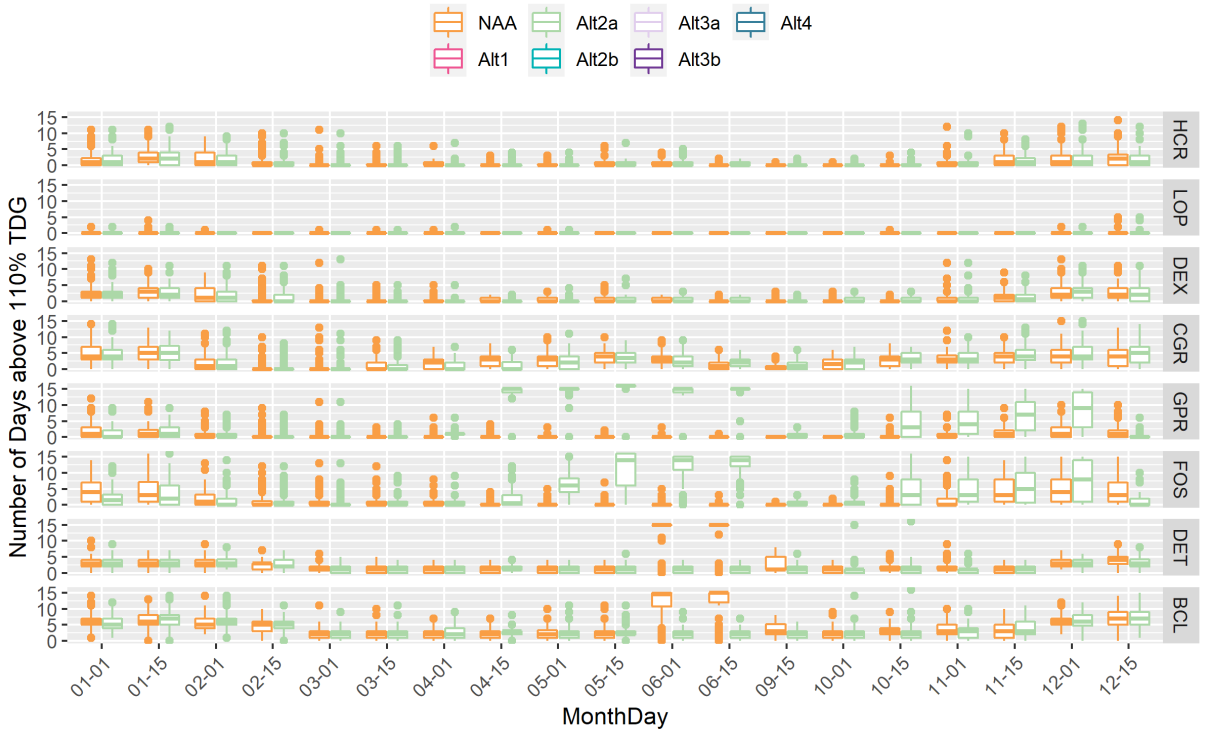


Figure 2-39. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 2a and NA

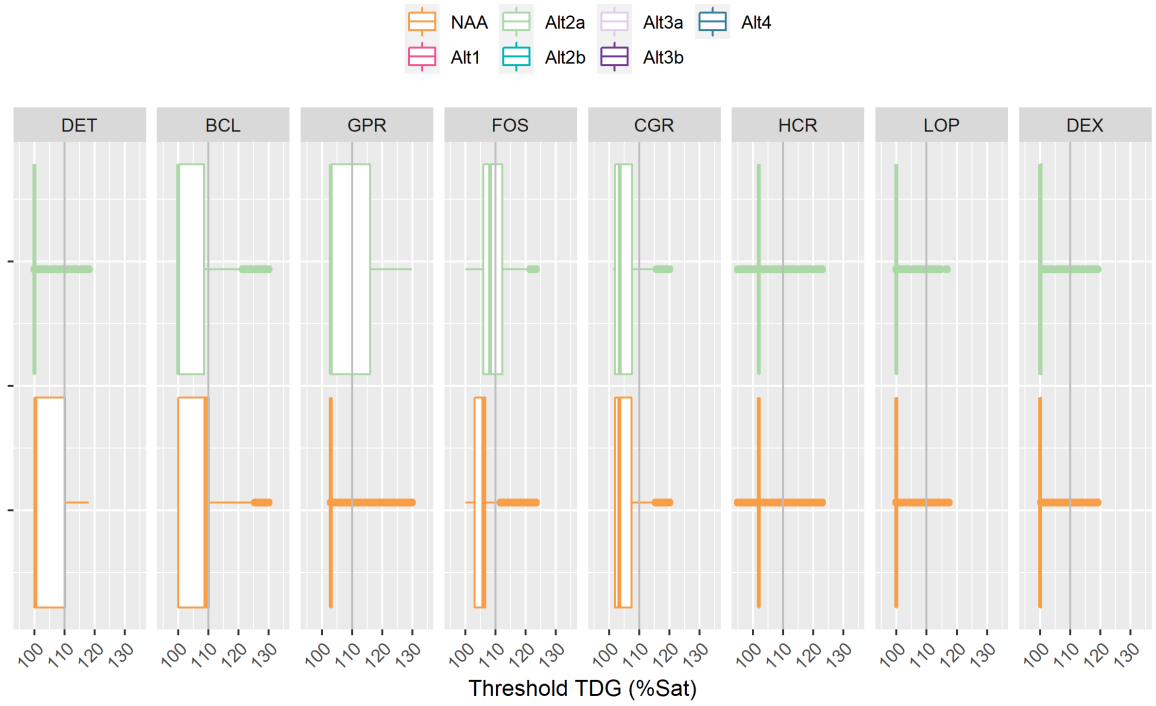


Figure 2-40. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 2a and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.3.1 North Santiam Dams

Under Alternative 2a, Detroit reservoir is observed to have 39 average number of days above 110% TDG levels and Big Cliff is 80 average number of days (Figure 2-35). Detroit reservoir is reduced by 77 days and Big Cliff has a reduction in 69 Annual difference in number of days above 110% of TDG exceedances as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Detroit is 62 days and Big Cliff is 87 days (Figure 2-34).

2.2.3.2 South Santiam Dams

Under Alternative 2a, the average number of days above 110% TDG levels at Green Peter is 151 days and Foster is 126 days (Figure 2-35). Green Peter has an increase of 139 days of TDG exceedances and Foster is increased by 94 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 190 days and Foster is 284 days (Figure 2-34).

2.2.3.3 Mckenzie Dams

There are no TDG management measures for Cougar or Blue River Reservoirs. Under Alternative 2a, the average number of days above 110% TDG levels at Cougar is 54 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is decreased by 3 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 168 days (Figure 2-34).

In Table 3.2-3 Hydrologic Processes states “slightly lower flow in spring of dry years as reservoir fills. Higher summer flow in dry years.” TDG exceedance may occur if water is released through the non-turbine outlets of dams, spill, and maintenance operations.

2.2.3.4 Middle Fork Willamette Dams

Under Alternative 2a, Lookout Point has reduction of 0 days and on average 0 days of TDG exceedance for the year (Figure 2-35). Dexter dam is reduced by 0 days and exceeds TDG by 20days by average number of days (Figure 2-36). Hills Creek dam has a reduction of 1 day of Annual Difference in Number of Days above 110% and on average number of days exceeds TDG by 18 days as compared to the No Action Alternative. The Average Number of Days of Spill per year at Hills Creek is 121 days, Lookout Point is 48 days, and Dexter is 91 days (Figure 2-34).

2.2.4 Alternative 2b – Hybrid Alternative

Alternative 2b has no measures to reduce TDG although modelling results are included. Boxplots in each half-month period and annual boxplots comparing Alternative 2b and NAA are shown in Figure 2-41 and Figure 2-42 respectively.

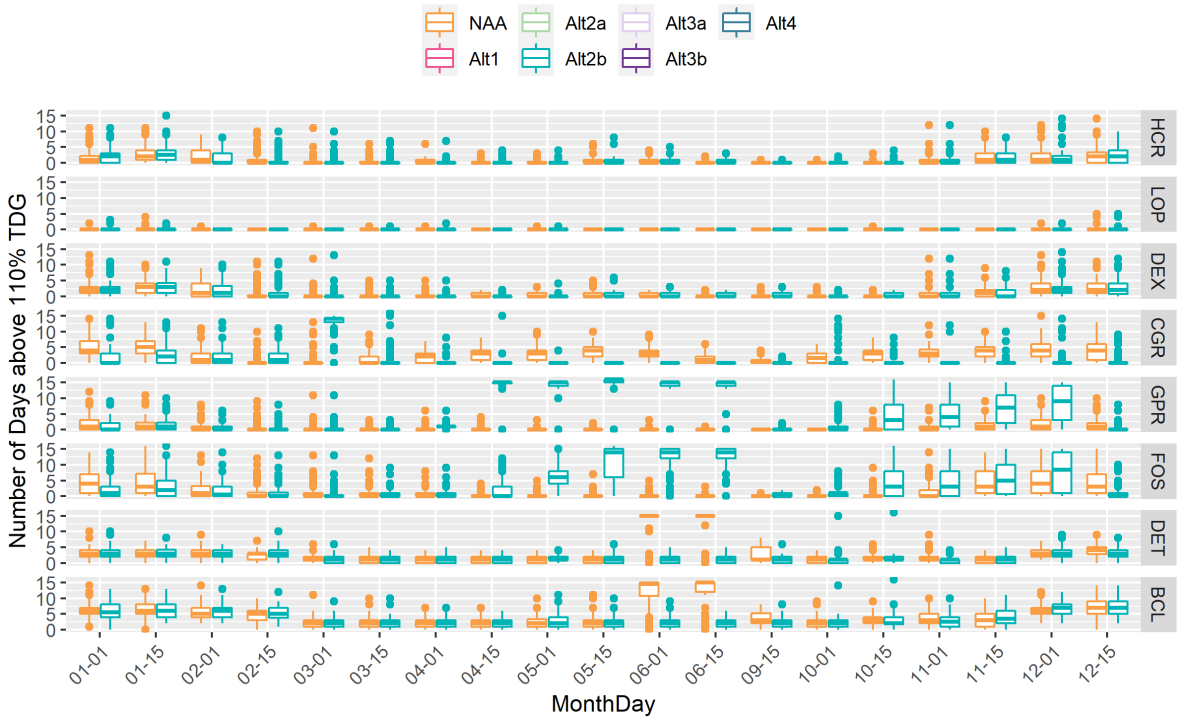


Figure 2-41. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 2b and NAA.

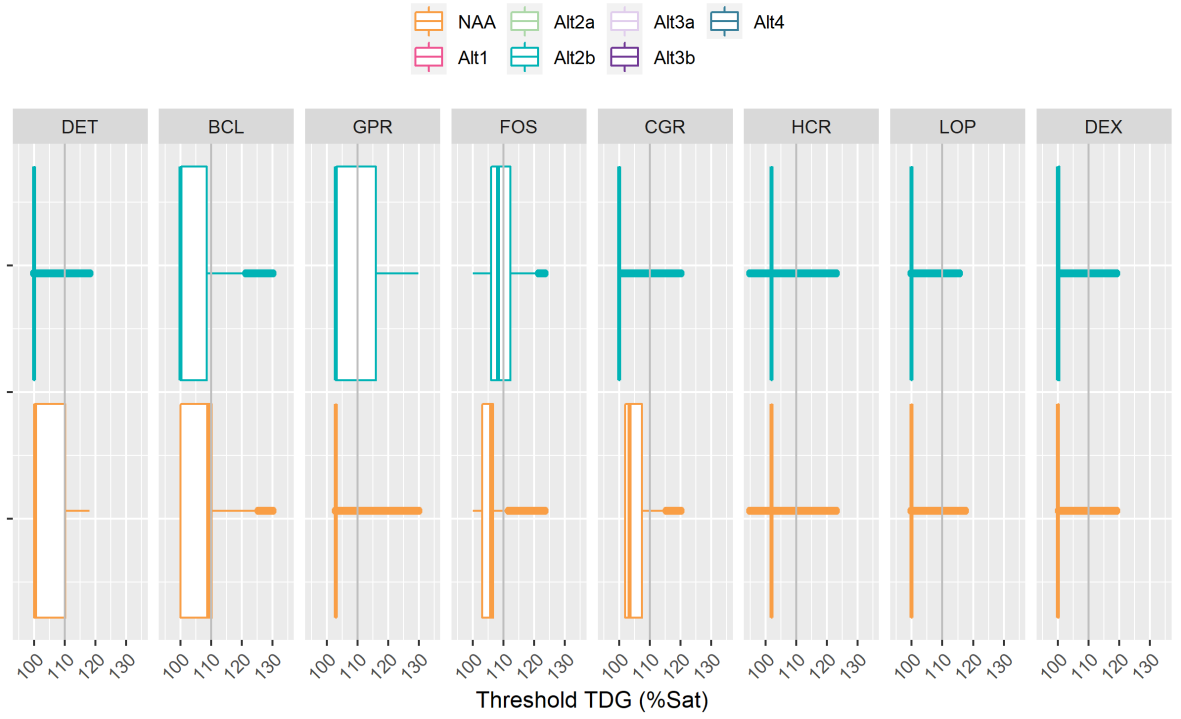


Figure 2-42. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 2b and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.4.1 North Santiam Dam

Under Alternative 2b, the average number of days above 110% TDG levels at Big Cliff is 80 and Detroit is 39 (Figure 2-35). Big Cliff has a reduction in 69 Annual difference in number of days above 110% of TDG exceedances and Detroit is reduced by 77 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Detroit is 62 days and Big Cliff is 87 days (Figure 2-34).

2.2.4.2 South Santiam Dams

There are no TDG measures within Alternative 2b for Green Peter and Foster reservoirs.

Under Alternative 2b, the average number of days above 110% TDG levels at Green Peter is 151 days and Foster is 126 days (Figure 2-35). Green Peter has an increase of 139 days of TDG exceedances and Foster is increased by 94 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 190 days and Foster is 284 days (Figure 2-34).

2.2.4.3 McKenzie Dams

There are no TDG management measures for Alternative 2b for Cougar Reservoir. Under Alternative 2b, the average number of days above 110% TDG levels at Cougar is 27 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is decreased by 30 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 46 days (Figure 2-34).

2.2.4.4 Middle Fork Willamette Dams

There are no TDG measures for Hills Creek, Lookout Point and Dexter dams although model analysis has determined effects to the sub-basin. Under Alternative 2b, Lookout Point has reduction of 0 days and on average 0 days of TDG exceedance for the year (Figure 2-35). Dexter dam TDG is reduced by 0 days and exceeds TDG by 20 days as compared to the average number of days (Figure 2-36). Hills Creek dam has a reduction of 0 days of Annual Difference in Number of Days above 110% and on average number of days exceeds TDG by 18 days as compared to the No Action Alternative. The Average Number of Days of Spill per year at Hills Creek is 129 days, Lookout Point is 50 days, and Dexter is 88 days (Figure 2-34).

2.2.5 Alternative 3a – Operations-Focused Fish Passage

The TDG measure for Alternative 3a includes spreading of water over multiple spillway gates in order to reduce TDG % exceedances at Detroit, Big Cliff, Foster, Lookout Point, and Dexter dams. However, the effect of this measure can only be quantified with the current WILTDG models at Big Cliff Dam due to the presence of this operation in the model calibration dataset. Boxplots in each half-month period and annual boxplots comparing Alternative 3a and NAA are shown in Figure 2-43 and Figure 2-44 respectively.

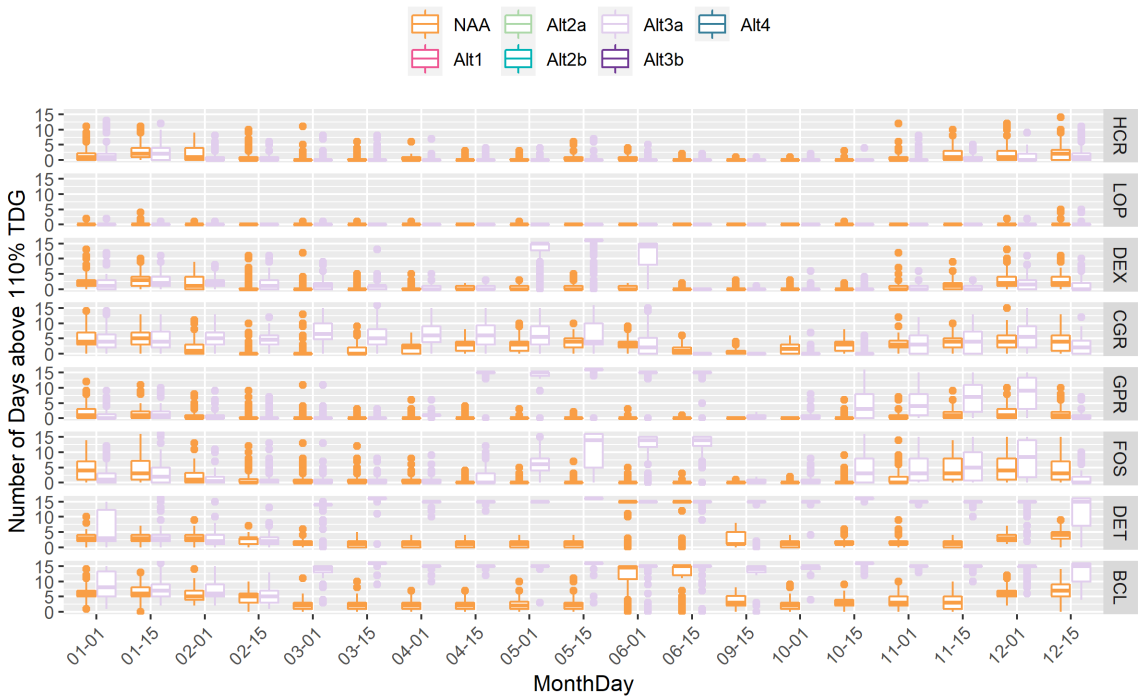


Figure 2-43. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 3a and NAA.

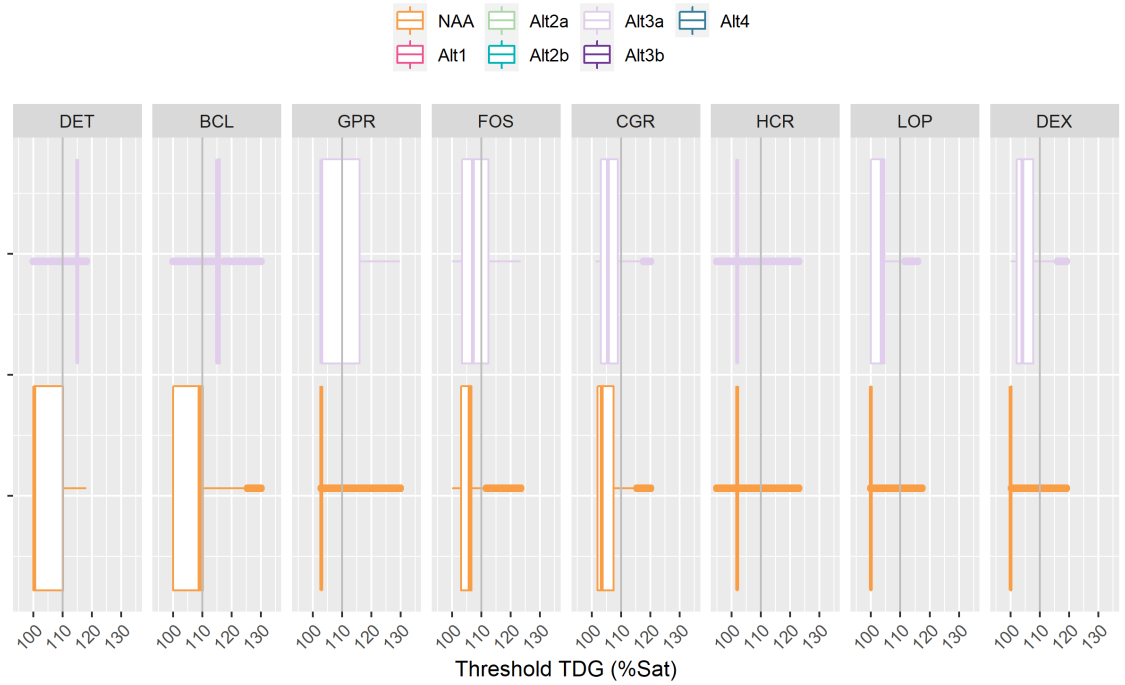


Figure 2-44. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 3a and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.5.1 North Santiam Dam

Under Alternative 3a, the average number of days above 110% TDG levels at Big Cliff is 312 and Detroit is 307 (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Big Cliff has an increase of 164 days and Detroit is increased by 192 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Big Cliff is 147 days and Detroit is 249 (Figure 2-34).

2.2.5.2 South Santiam Dams

Under Alternative 3a, the average number of days above 110% TDG levels at Green Peter is 151 days and Foster is 127 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Green Peter has an increase of 139 days and Foster is 95 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 189 days and Foster is 220 days (Figure 2-34).

2.2.5.3 McKenzie Dams

There are no TDG measures under Alternative 3a for Cougar Reservoir. Under Alternative 3a, the average number of days above 110% TDG levels at Cougar is 77 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is 20 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 240 days (Figure 2-34).

2.2.5.4 Middle Fork Willamette Dams

Under Alternative 3a, the average number of days above 110% TDG levels at Hills Creek is 13 days, Lookout Point is 0 days, and Dexter is 53 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Hills Creek is decreased by 6 days, Lookout Point is 0 days, and Dexter is increased to 33 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Hills Creek is 82 days, Lookout Point is 225 days, and Dexter is 146 days (Figure 2-34).

2.2.6 Alternative 3b – Operations-Focused Fish Passage Alternative (using diversion tunnel at COU)

The TDG measure for Alternative 3b includes spreading of water over multiple spillway gates in order to reduce TDG % exceedances at Detroit, Big Cliff, Foster, Lookout Point, and Dexter dams. However, the effect of this measure can only be quantified with the current WILTDG models at Big Cliff Dam due to the presence of this operation in the model calibration dataset. Boxplots in each half-month period and annual boxplots comparing Alternative 3b and NAA are shown in Figure 2-45 and Figure 2-46 respectively.

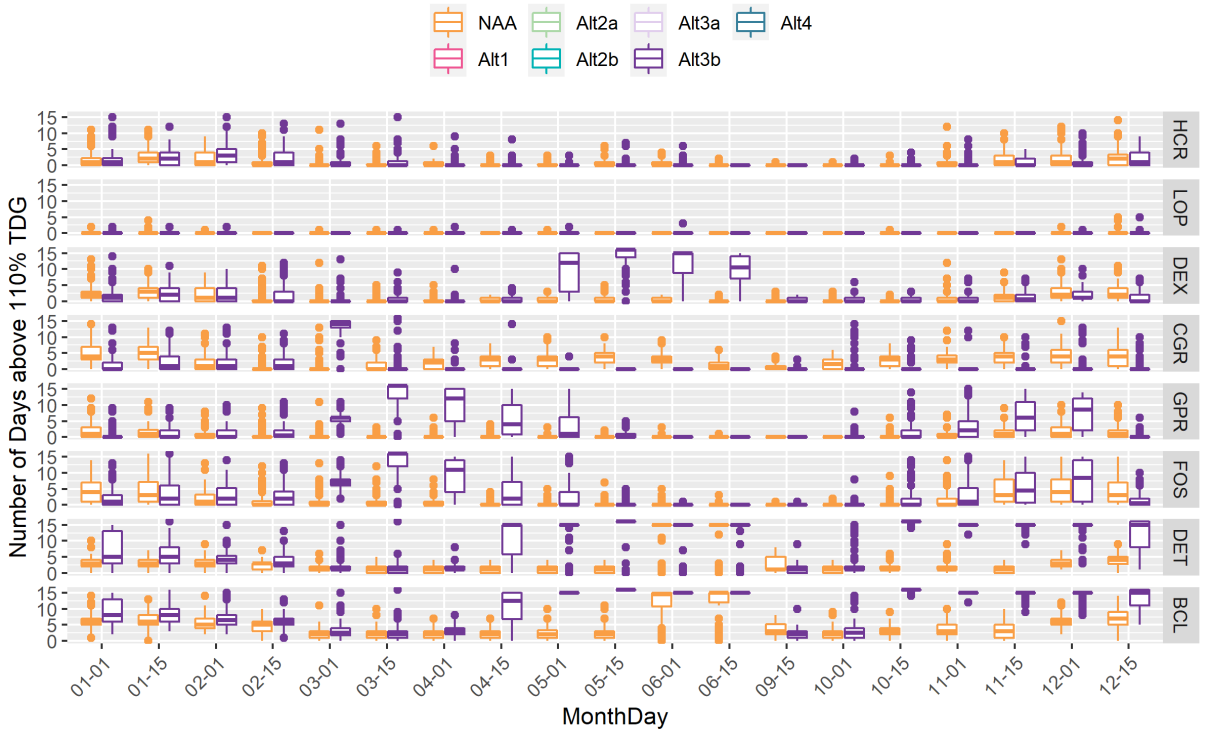


Figure 2-45. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 3b and NAA.

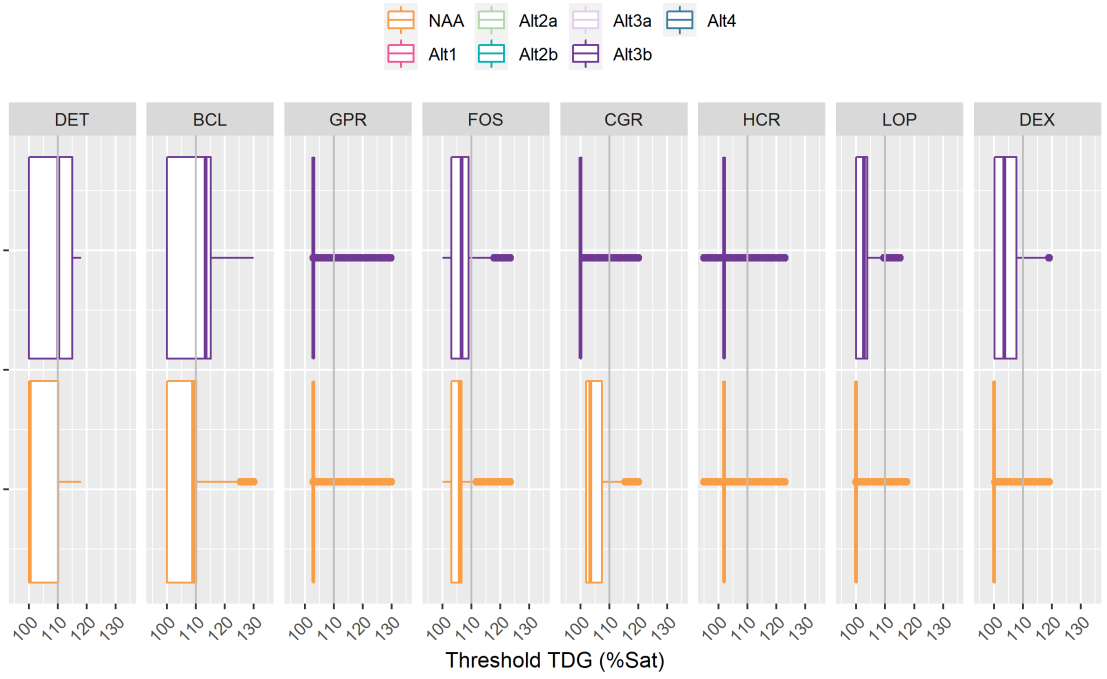


Figure 2-46. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 3b and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.6.1 North Santiam Dam

Under Alternative 3b, the average number of days above 110% TDG levels at Big Cliff is 226 and Detroit is 203 (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Big Cliff has an increase of 78 days and Detroit is increased by 87 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Big Cliff is 125 days and Detroit is 197 (Figure 2-34).

2.2.6.2 South Santiam Dams

Under Alternative 3b, the average number of days above 110% TDG levels at Green Peter is 62 days and Foster is 69 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Green Peter has an increase of 50 days and Foster is 37 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 235 days and Foster is 211 days (Figure 2-34).

2.2.6.3 McKenzie Dams

Under Alternative 3b, the average number of days above 110% TDG levels at Cougar is 26 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is decreased to 31 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 46 days (Figure 2-34).

2.2.6.4 Middle Fork Willamette Dams

Under Alternative 3b, the average number of days above 110% TDG levels at Hills Creek is 19 days, Lookout Point is 0 days, and Dexter is 62 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Hills Creek is 0 days, Lookout Point is 0 days, and Dexter is increased to 42 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Hills Creek is 89 days, Lookout Point is 196 days, and Dexter is 126 days (Figure 2-34).

2.2.7 Alternative 4 – Structures-Based Fish Passage Alternative

Alternative 4 includes structural improvement measures to reduce TDG at Detroit, Big Cliff, Green Peter, Foster, Lookout Point, Dexter, and Cougar dams. Detroit and Lookout Point dams TDG measure would be incorporated into the water temperature control tower design. Measure 174 was included in Alternative 4 at LOP-DEX, CGR, GPR-FOS, and DET-BCL and resulted in an estimated 5% reduction in TDG values above 110% at the control point immediately below the lowest dam in each sub-basin (Figure 2-47, Figure 2-48).

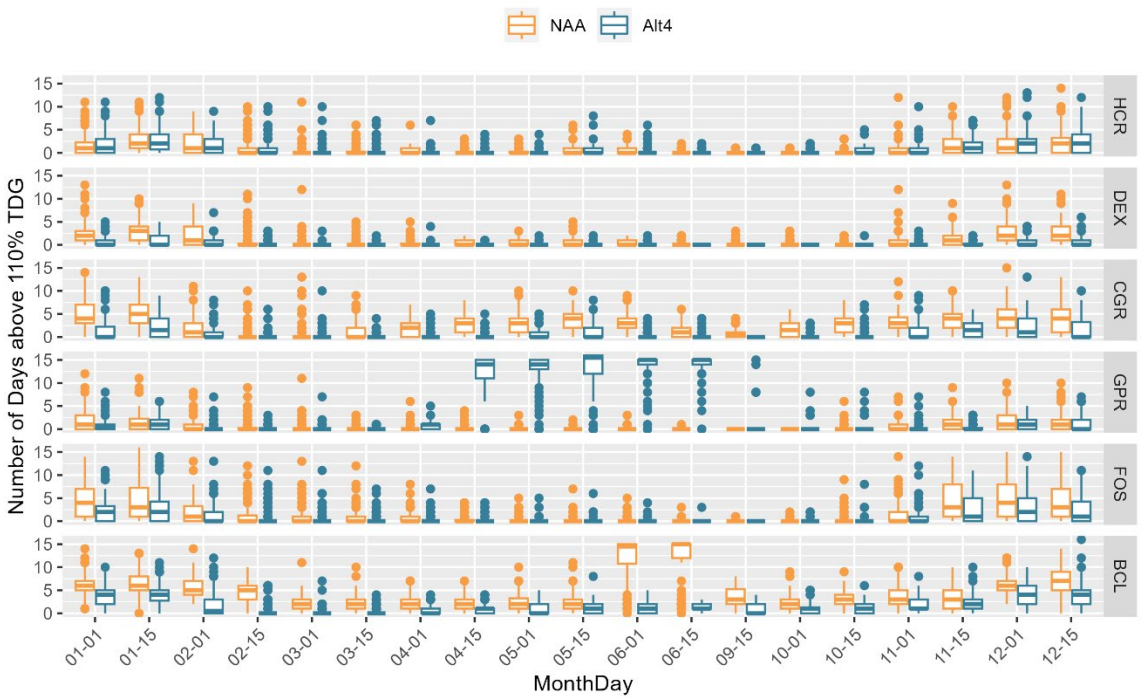


Figure 2-47. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 4 and NAA.

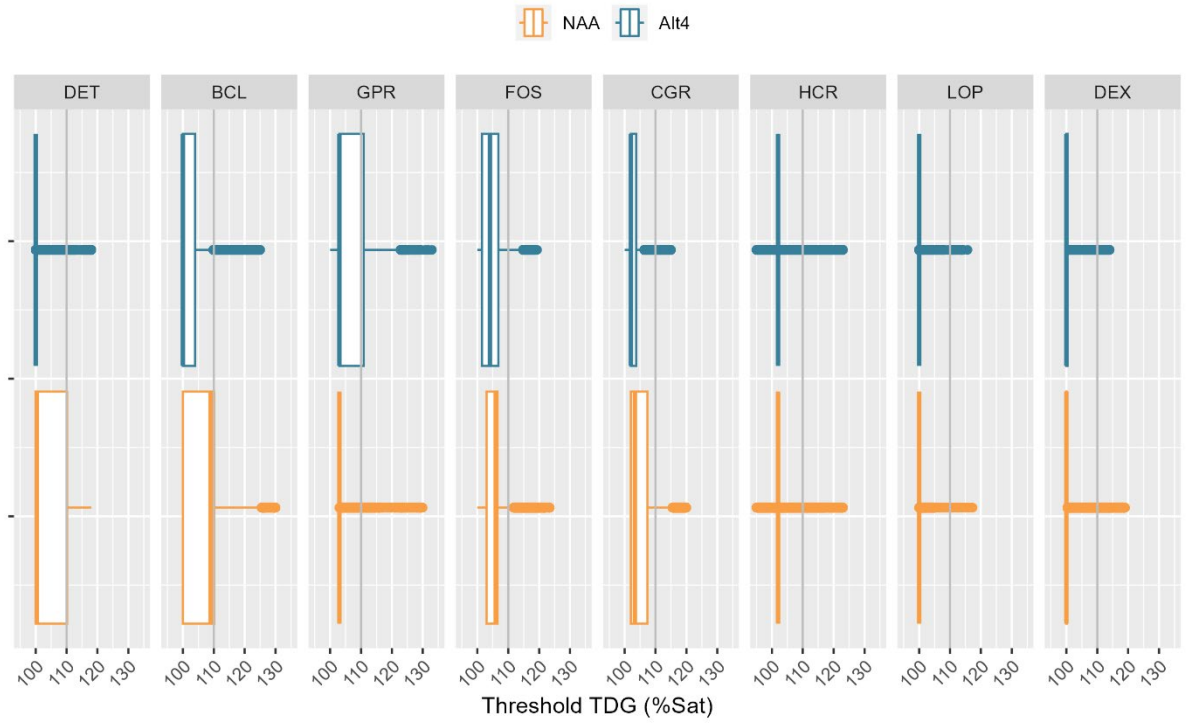


Figure 2-48. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 4 and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.7.1 North Santiam Dam

Structural improvement measures to improve TDG at Detroit reservoir is included in the design of the proposed water temperature control tower under Alternative 4. Under Alternative 4, the average number of days above 110% TDG levels at Big Cliff is 37 and Detroit is 39 (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Big Cliff has a reduction of 111 days and Detroit has a reduction of 77 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Big Cliff is 86 days and Detroit is 62 (Figure 2-34).

2.2.7.2 South Santiam Dams

Structural improvement measures to improve TDG at Foster reservoir are included at the Foster adult fish collection facility. Under Alternative 4, the average number of days above 110% TDG levels at Green Peter is 135 days and Foster is 19 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Green Peter has an increase of 123 days and Foster is decreased to 13 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 185 days and Foster is 211 days (Figure 2-34).

2.2.7.3 McKenzie Dams

Under Alternative 4, the average number of days above 110% TDG levels at Cougar is 17 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is decreased to 41 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 168 days (Figure 2-34).

2.2.7.4 Middle Fork Willamette Dams

Under Alternative 4, the Average number of days above 110% TDG levels at Hills Creek is 9 average days, Lookout Point is 0, and Dexter is 5 average days (Figure 2-35). Hills Creek has a reduction of 9 days of TDG exceedances, Lookout Point has 0 days reduction, and Dexter is reduced by 15 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Hills Creek is 93 days, Lookout Point is 51 days and Dexter is 89 days (Figure 2-34).

2.2.8 Alternative 5 – Preferred Alternative

Alternative 5 has no specific measures to reduce TDG. Alternative 5 is based on Alternative 2b, which had the following measures that affected operations total outflow and spill rates that contributes to TDG:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.

- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.
- Construct temperature control structure at Detroit.
- Deep fall drawdown to 35’ over the regulating outlet at Green Peter, use of RO in fall, use spillway for surface spill in spring and summer.
- Deep spring and fall drawdown to 30 feet over the diversion tunnel at Cougar, with a limited refill window between June 15th and November 15th (essentially a delayed refill).
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.

HEC-ResSim simulations of lake levels and dam outflows were provided as inputs to the WILTDG model to estimate TDG over the period of record in Alternative 5 and is discussed in this section. The underlying assumptions in Alternative 5 were similar to Alternative 2b aside from changes to the spring flow targets at Salem that are lower than BiOp dry year targets in years when water supply forecasted flows at Salem are projected to be less than 25% of normal. This provides additional spring storage in dry years allowing for targets that closely resemble BiOp flow targets to be met in dry summers. A full explanation of the HEC-ResSim analysis and findings can be found in Section 3.2 Hydrologic Processes and Technical Appendix B Hydrology and Hydraulics. Boxplots of TDG in each half-month period, cumulative distribution curves of TDG, and annual boxplots of TDG comparing Alternative 5, Alternative 2b, and NAA are shown in Figure 2-49 and Figure 2-50 respectively.

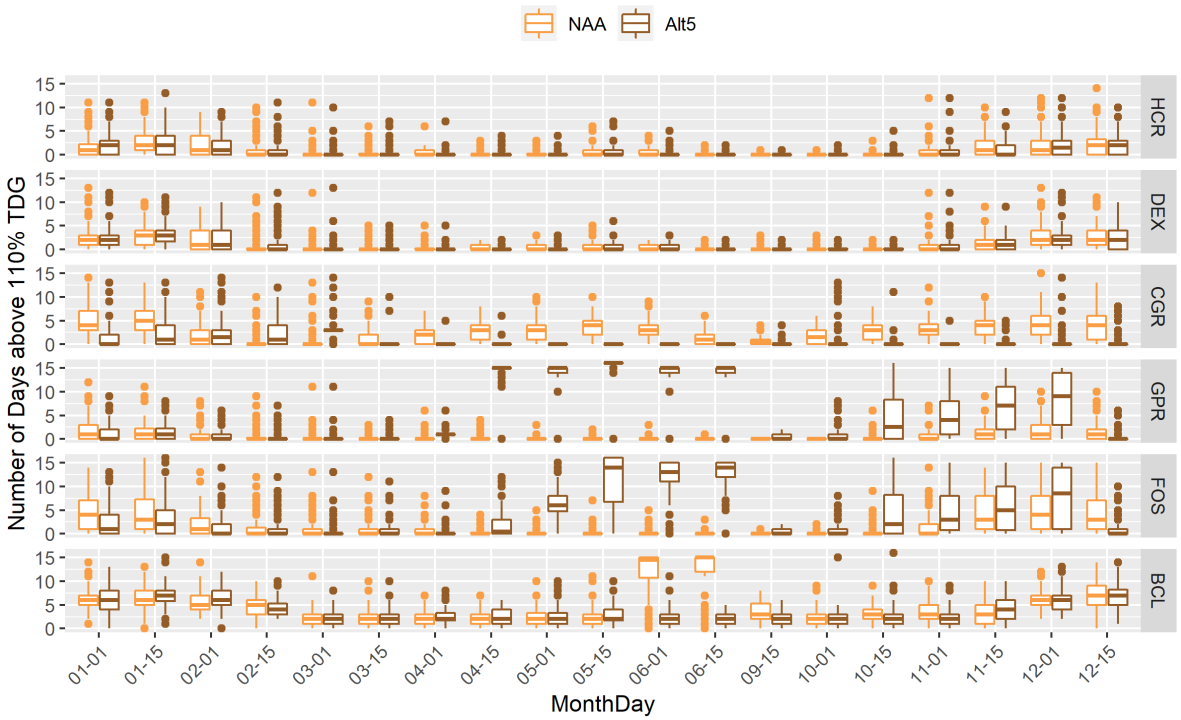


Figure 2-49. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 5 and NAA.

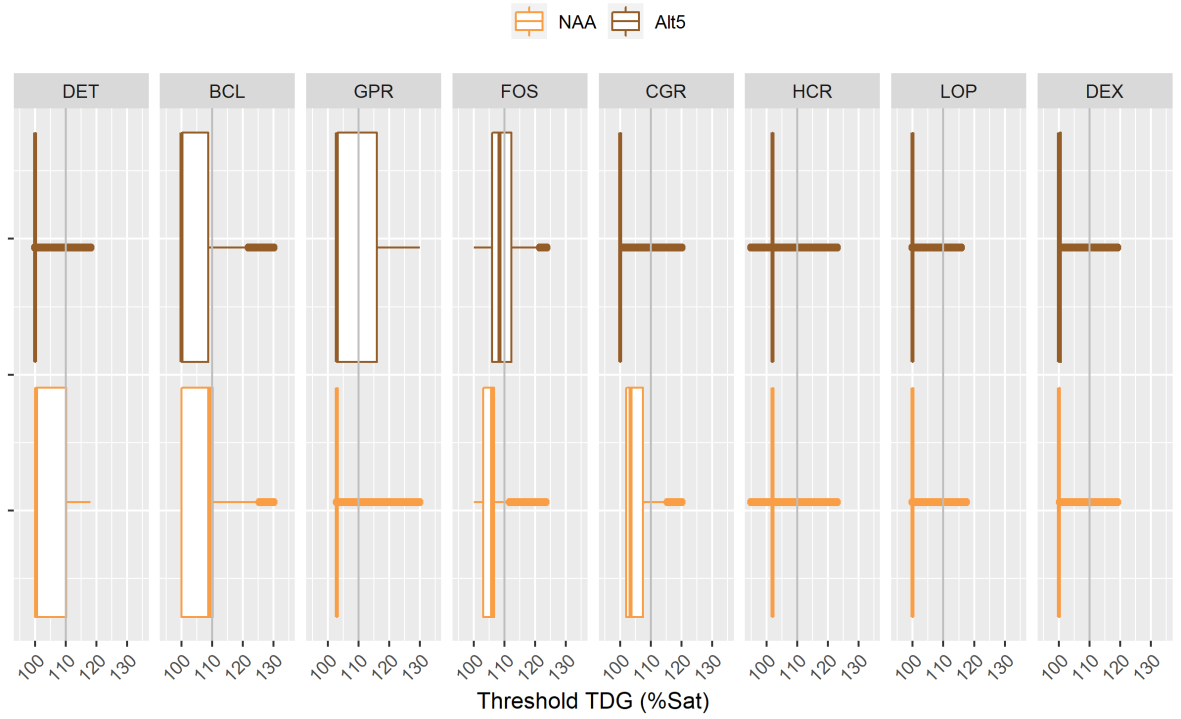


Figure 2-50. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 5 and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.8.1 North Santiam Dam

Under Alternative 5, the average number of days above 110% TDG levels at Big Cliff is 79 and Detroit is 39 (Figure 2-35). North Santiam Alternative 5 TDG effects essentially match those in Alternative 2b with Big Cliff resulting in a reduction of 69 number of days in annual difference the above 110% TDG and Detroit reduced by 77 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Detroit is 62 days and Big Cliff is 86 days (Figure 2-34).

2.2.8.2 South Santiam Dams

There are no TDG measures within Alternative 5 for Green Peter and Foster reservoirs.

South Santiam Alternative 5 TDG effects match those in Alternative 2b, with the average number of days above 110% TDG levels at Green Peter 151 days and Foster at 126 days (Figure 2-35). Green Peter results in an increase of 139 days of TDG exceedances and Foster is increased by 94 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 190 days and Foster is 284 days (Figure 2-34).

2.2.8.3 McKenzie Dams

There are no TDG management measures for Alternative 5 for Cougar Reservoir. Under Alternative 5, the average number of days above 110% TDG levels at Cougar is 13 days (Figure 2-35). The minimal change from Alternative 5 to Alternative 2b is likely due to differences in the draft rate during the spring drawdown at Cougar (for more information, see section 0 and Section 3.2 Hydrologic Processes and Technical Appendix B Hydrology and Hydraulics). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is decreased by 49 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 29 days (Figure 2-34).

2.2.8.4 Middle Fork Willamette Dams

There are no TDG measures for Hills Creek, Lookout Point and Dexter dams although model analysis has determined effects to the sub-basin. Middle Fork Willamette Alternative 5 TDG effects essentially match those in Alternative 2b, with Lookout Point resulting in a reduction of 0 days and on average 0 days of TDG exceedance for the year (Figure 2-35) compared to NAA. Dexter dam has reduction of 16 days and on average 5 days of TDG exceedance for the year (Figure 2-35) compared to NAA. Hills Creek dam has a reduction of 3 days of Annual Difference in Number of Days above 110% and on average number of days exceeds TDG by 18 days as compared to the No Action Alternative. The Average Number of Days of Spill per year at Hills Creek is 138 days, Lookout Point is 52 days, and Dexter is 87 days (Figure 2-34).

2.2.9 Near Term Operations Measure (NTOM) (i.e., Interim Operations)

NTOM is a combination of Alternatives 3a, 3b, 5, and injunction measures with the following measures that affected spill frequency and TDG:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full (similar to Alternatives 2a, 2b, 4, and 5).
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature (similar to Alternatives 2a, 2b, 4, and 5).
- At Detroit, a spring spillway operation when lake is above 1541 ft from 1 April to 15 November. Prioritizing upper and lower ROs when lake elevation is below 1500 feet.
- At Green Peter, a spring spillway operation when lake is above spillway crest (971 ft) from mid-March until 01 May or for 30 days, whichever is longer.
- From early September to 15 December, a deep drawdown at Green Peter to 35 feet above the ROs (target elevation of 780 ft by early- to mid-November) with RO prioritization to improve downstream fish passage (similar to Measure 40 in Alternatives 2a, 2b, 3a, and 3b).
- Spreading of water over multiple spillway gates in order to reduce TDG % exceedances at Detroit, Big Cliff, Foster, Lookout Point, and Dexter dams. However, the effect of this measure can only be quantified with the current WILTDG models at Big Cliff Dam due to the presence of this operation in the model calibration dataset.
- Foster Dam includes a delayed refill and spring spillway use to improve downstream fish passage from 01-February to 15-June (lake elevation 613 ft. from February to May; lake elevation 637 ft. May to July). Summer fish weir use at Foster Dam from 16 June to late-July to improve downstream temperature management and upstream fish migration/passage. Utilize the spillway for improved downstream fish passage in the fall from 01-October to 15-December when the lake is at minimum conservation pool (613 feet).

Boxplots in each half-month period and annual boxplots comparing NTOM and NAA are shown in Figure 2-43 and Figure 2-44 respectively.

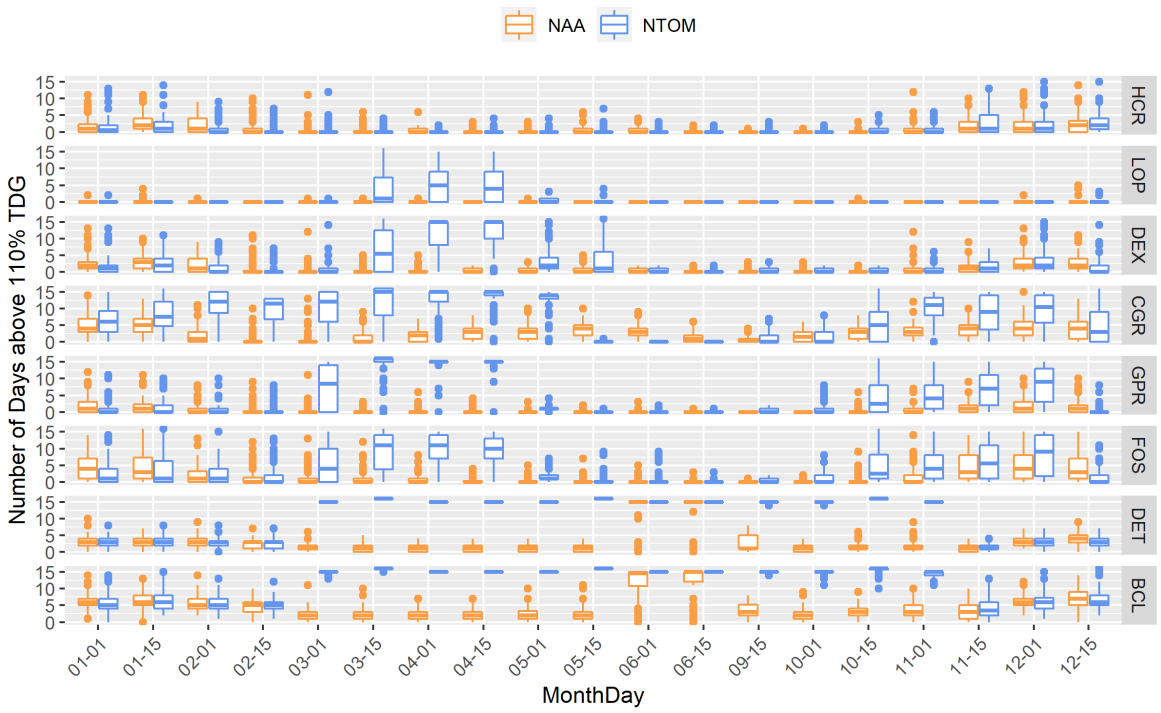


Figure 2-51. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for NTOM and NAA.

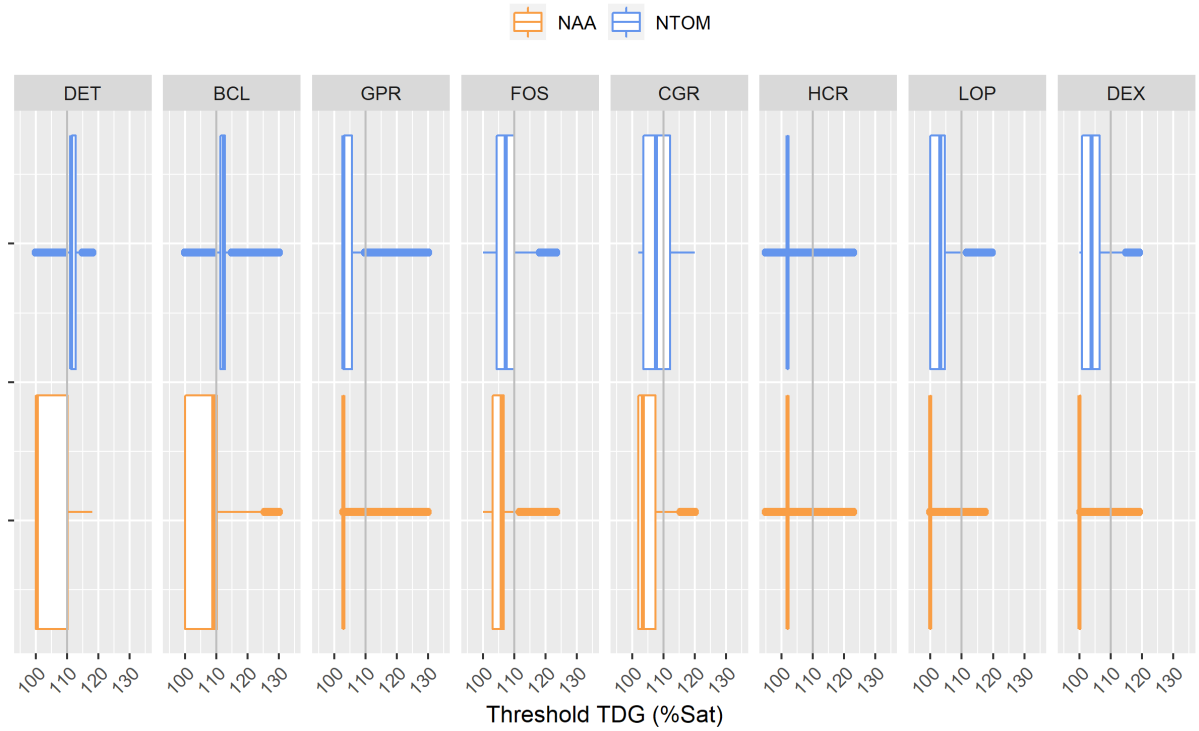


Figure 2-52. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for NTOM and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.9.1 North Santiam Dam

Under NTOM, the average number of days above 110% TDG levels at Big Cliff is 295 and Detroit is 276 (Figure 2-35). Observing the annual difference in number of days above 110% of TDG exceedances Big Cliff has an increase of 147 days and Detroit is increased by 160 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Big Cliff is 89 days and Detroit is 229 (Figure 2-34).

2.2.9.2 South Santiam Dams

Under NTOM, the average number of days above 110% TDG levels at Green Peter is 295 days and Foster is 276 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Green Peter has an increase of 139 days and Foster is 95 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 154 days and Foster is 250 days (Figure 2-34).

2.2.9.3 McKenzie Dams

There are no TDG measures under NTOM for Cougar Reservoir. Under NTOM, the average number of days above 110% TDG levels at Cougar is 135 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is 77 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 262 days (Figure 2-34).

2.2.9.4 Middle Fork Willamette Dams

Under NTOM, the average number of days above 110% TDG levels at Hills Creek is 13 days, Lookout Point is 196 days, and Dexter is 120 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Hills Creek is decreased by 2 days, increased at Lookout Point is 14 days, and increased at Dexter to 32 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Hills Creek is 83 days, Lookout Point is 196 days, and Dexter is 120 days (Figure 2-34).

2.2.10 Supplemental EIS

Dam releases from non-turbine outlets (defined as “spill” in this EIS) are known to produce elevated TDG. The average number of days with spill per year are compared in each Alternative and dam (Figure 2-53) and help to explain locations and alternatives with relatively higher TDG. Generally, TDG is generated initially at the high-head dam when spill occurs (e.g., Detroit Dam) and can increase downstream if spill occurs at the downstream re-regulating dam (e.g., Big Cliff Dam). TDG estimates from WILTDG were then tabulated as the average number of days exceeding 110% TDG per year over all simulations (84 year period of record, 8 dams, 9 alternatives in Figure 2-54 and Table 2-7. The annual number of days above 110% TDG is compared to the NAA for each alternative and summarized in Figure 2-54. *Note: Impacts at GPR, HCR, LOP are under-estimates; extensive TDG data from spillgate operations at these*

*projects did not exist at the time of the EIS development. The number of days (*Figure 2-54*) with spill may be a more appropriate metric for effects at these locations.*

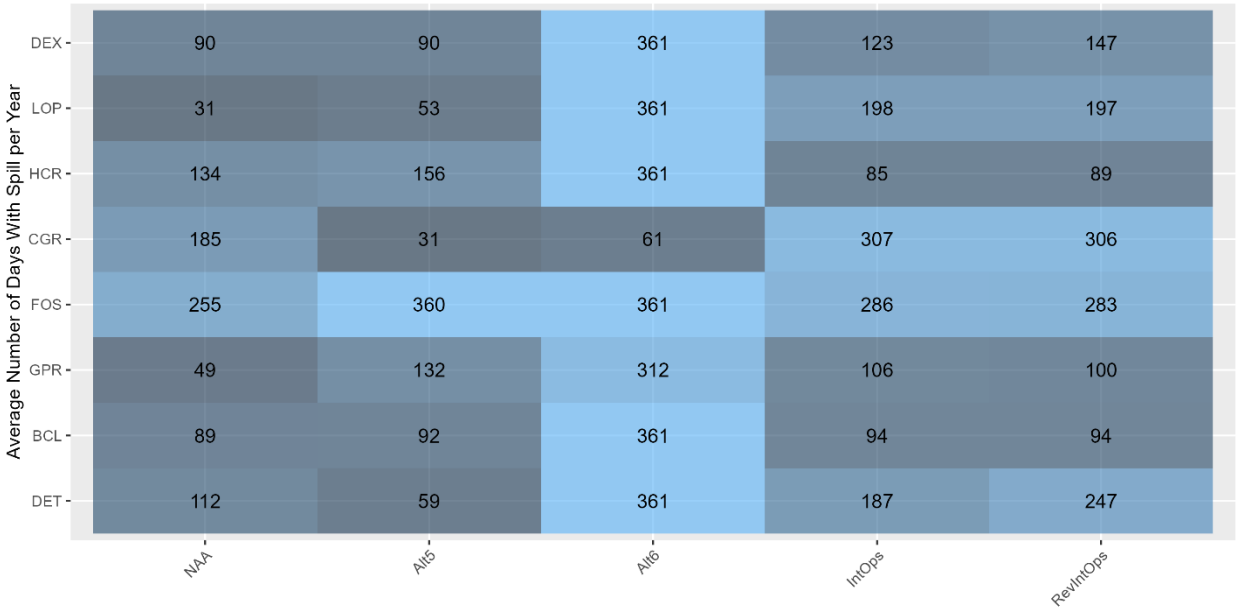


Figure 2-53. Average Number of Days with Spill per Year Under Each Alternative

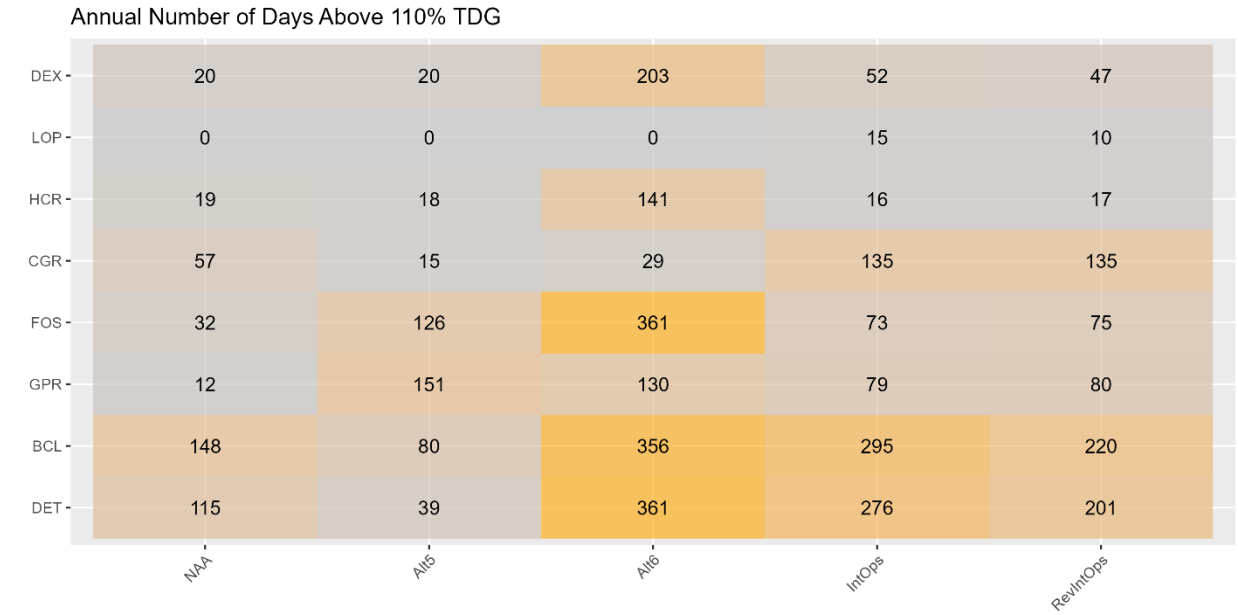


Figure 2-54. Average Number of Days above 110% TDG (numerical values shown) in Dam Tailraces Under Each Alternative. Note: Impacts at GPR, HCR, LOP are under-estimates; extensive TDG data from spillgate operations at these projects did not exist at the time of the EIS development.

Table 2-7. Average Number of Days With TDG Above 110 %.

Location	NAA	Alt5	Alt6	Interim Operations (IntOps)	Interim Operations (RevIntOps)
DEX	20	20	203	52	47
LOP	0	0	0	15	10
HCR	19	18	141	16	17
CGR	57	15	29	135	135
FOS	32	126	361	73	75
GPR	12	151	130	79	80
BCL	148	80	356	295	220
DET	115	39	361	276	201

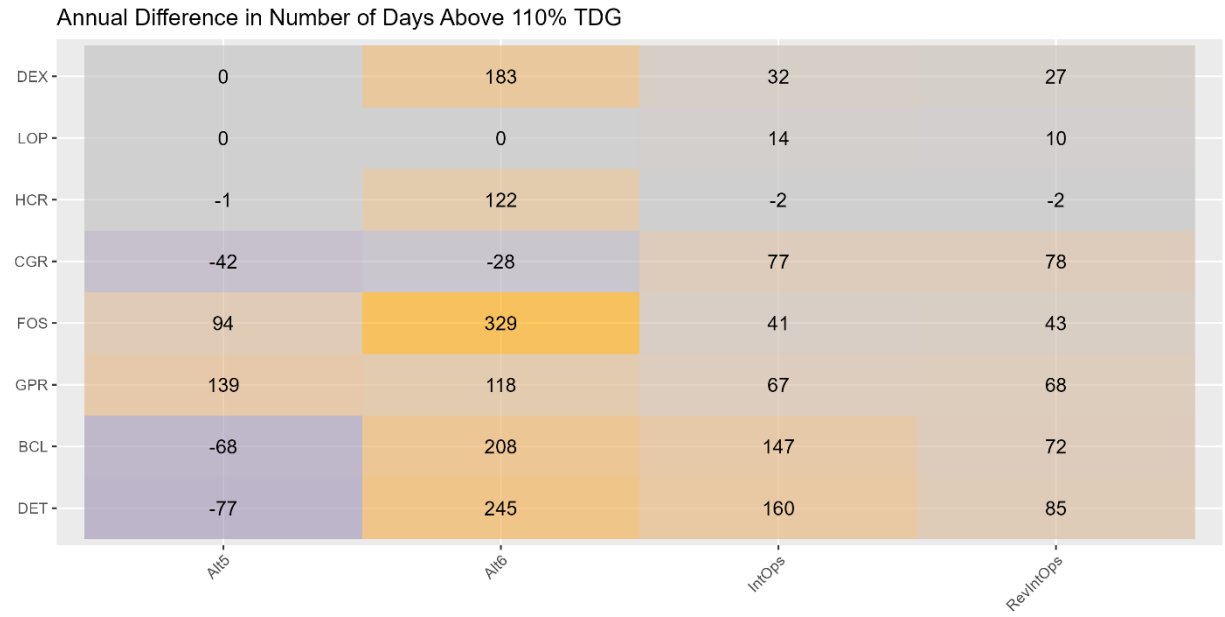


Figure 2-55. Annual Difference in Number of Days Above 110% TDG Compared to the No Action Alternative. Note: Impacts at GPR, HCR, LOP are under-estimates; extensive TDG data from spillgate operations at these projects did not exist at the time of the EIS development.

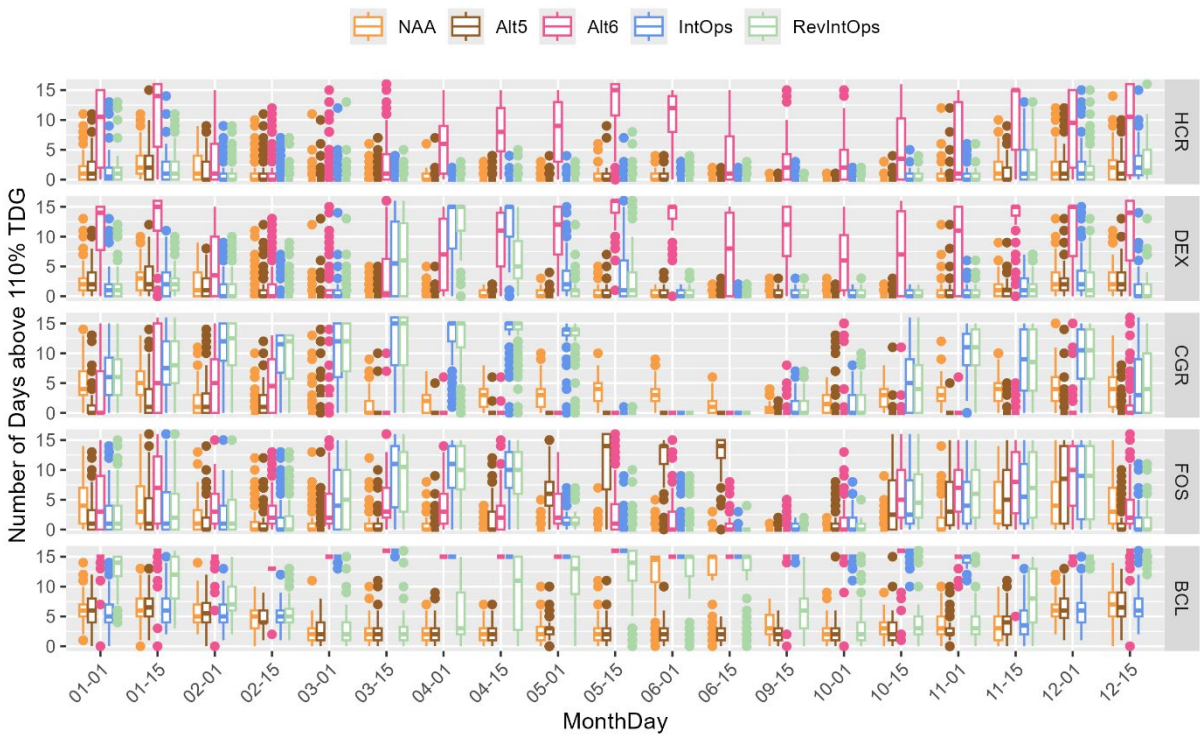


Figure 2-56. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 6 (Alt6), Alternative 5 (Alt5), Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

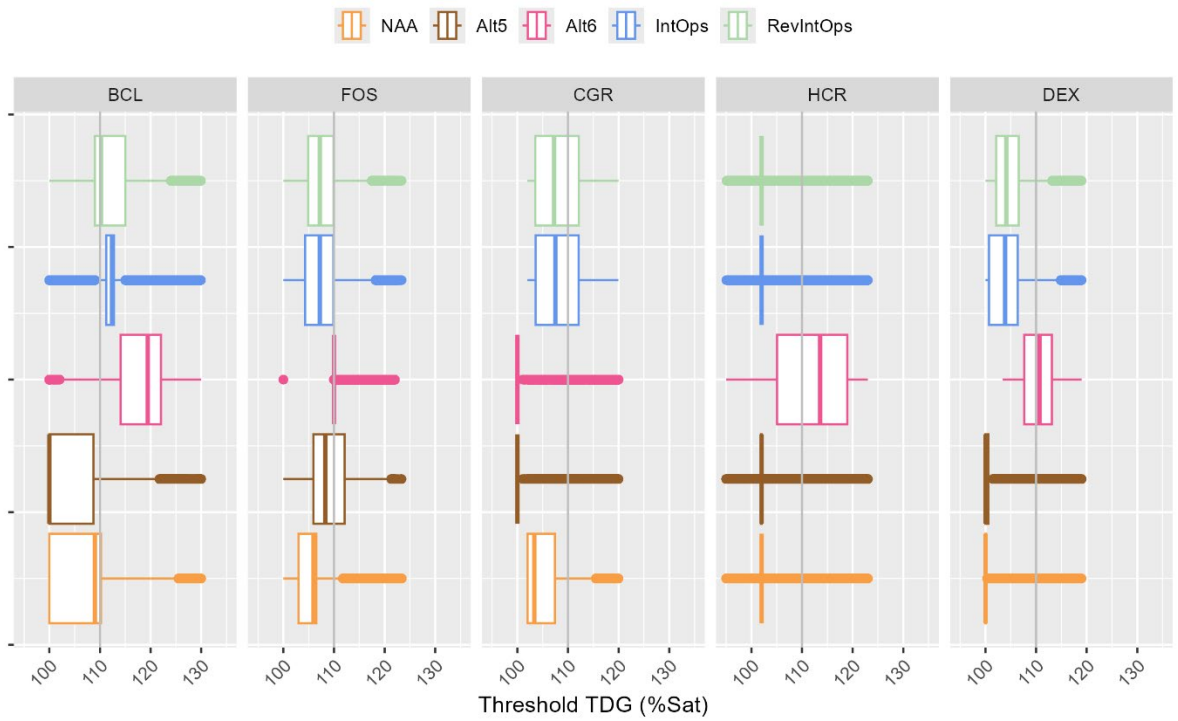


Figure 2-57. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Alternative 6 (Alt6), Alternative 5 (Alt5), Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.10.1 Alternative 6 – No Hydropower

Alternative 6 has no specific measures to reduce TDG. Alternative 6 is based on Alternative 5 and 2b in the Final EIS, with the following changes (relative to NAA) affecting total outflow and spill rates that contributes to TDG:

- Penstocks at Detroit, Big Cliff, Green Peter, Foster, Cougar, Hills Creek, Lookout Point, and Dexter dams pass flow through a modified penstock that is assumed to be controlled via cone valves instead of turbines. While no TDG data exists for cone valves, it is assumed that cone valves would produce TDG similar to ROs or spillways below a dam, given there would be an equivalent amount of energy associated with the water exiting the structure.
- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.

- Construct temperature control structure at Detroit.
- Deep fall drawdown to 35' over the regulating outlet at Green Peter, use of RO in fall, use spillway for surface spill in spring and summer
- Deep spring and fall drawdown to 30 feet over the diversion tunnel at Cougar, with a limited refill window between June 15th and November 15th (essentially a delayed refill).
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.

RES-SIM simulations of lake levels and dam outflows were provided as inputs to the WILTDG model to estimate TDG over the period of record in Alternative 6 and is discussed in this section. Overall, Alternative 6 resutled in significant increases to TDG levels compared to NAA. The underlying assumptions in Alternative 6 were similar to Alternative 5 and 2b aside from the removal of hydropower turbines and changes to the spring flow targets at Salem that are lower than BiOp dry year targets in years when water supply forecasted flows at Salem are projected to be less than 25% of normal. This provides additional spring storage in dry years allowing for targets that closely resemble BiOp flow targets to be met in dry summers. A full explanation of the RES-SIM analysis and findings can be found in the Section 3.2 Hydrologic Processes and Technical Appendix B Hydrology and Hydraulics. Boxplots of TDG in each half-month period and annual boxplots of TDG comparing Alternative 6, Alternative 5, and NAA are shown in Figure 2-56 and Figure 2-57, respectively.

NORTH SANTIAM DAM

Under Alternative 6, the average number of days above 110% TDG levels at Big Cliff is 356 and Detroit is 361 (Figure 2-54). North Santiam Alternative 6 results in an increase of 208 days annual difference above 110% TDG and an increase at Detroit by 245 days as compared to the No Action Alternative (Figure 2-55). The Average Number of Days of Spill per year is 361 days at Detroit and Big Cliff (Figure 2-53).

SOUTH SANTIAM DAMS

There are no TDG measures within Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA for Green Peter and Foster reservoirs. South Santiam Alternative 6 average number of days above 110% TDG at Green Peter was 312 days and 361 days at Foster (Figure 2-54). Green Peter results in an increase of 118 days of TDG exceedances and Foster is increased by 329 days as compared to the No Action Alternative (Figure 2-55). The Average Number of Days of Spill per year is 312 at Green Peter and 361 at Foster (Figure 2-53).

MCKENZIE DAMS

There are no TDG management measures for Alternative 6 (Alt6), Alternative 5 (Alt5), and NAA for Cougar Reservoir. Under Alternative 6, the average number of days above 110% TDG levels

at Cougar is 61 days (Figure 2-54). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is decreased by 28 days as compared to the No Action Alternative (Figure 2-55). The Average Number of Days of Spill per year at Cougar is 61 days (Figure 2-53).

MIDDLE FORK WILLAMETTE DAMS

There are no TDG measures for Hills Creek, Lookout Point and Dexter dams although model analysis has determined effects to the sub-basin. Lookout Point resulted in a reduction of 0 days and on average 0 days of TDG exceedance for the year (Figure 2-54) compared to NAA. However, the WILTDG model underestimates TDG production, due to the lack of data at the time of the model development. For this reason, it is more appropriate to refer to the number of annual average number of spill days at Lookout Point, which was 361, compared to 31 in NAA, a 308 day increase. Dexter dam has an increase of 203 days and on average 5 days of TDG exceedance for the year (Figure 2-55) compared to NAA. Hills Creek dam has an increase of 122 days and on average 141 days of Annual Difference in Number of Days above 110% as compared to the No Action Alternative. The Average Number of Days of Spill per year at Hills Creek is 138 days, Lookout Point is 52 days, and Dexter is 87 days (Figure 2-53).

2.2.10.2 Interim Operations (RevIntOps)

Interim Operations (labeled RevIntOps in figures below) are based on Interim Operations (also referred to as Near Term Operations Measure (NTOM) in Final EIS, Appendix D) with updates to include deep fall/winter drawdown at Detroit Dam and Reservoir and use of the 2008 Biological Opinion minimum flow targets basin wide.

Boxplots in each half-month period and annual boxplots comparing Interim Operations and NAA are shown in Figure 2-58 and **Figure 2-59**, respectively.

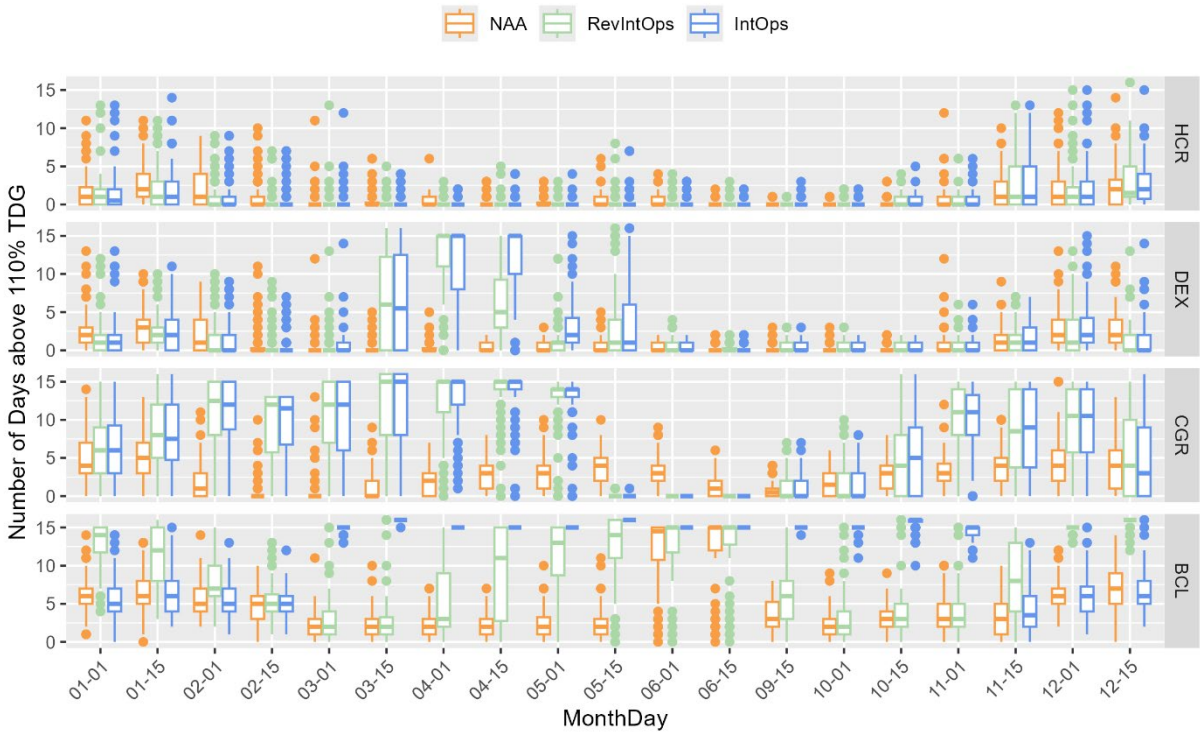


Figure 2-58. Number of days in each half-month period over the period of record (1936-2019) based on WILTDG estimated TDG for Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA.

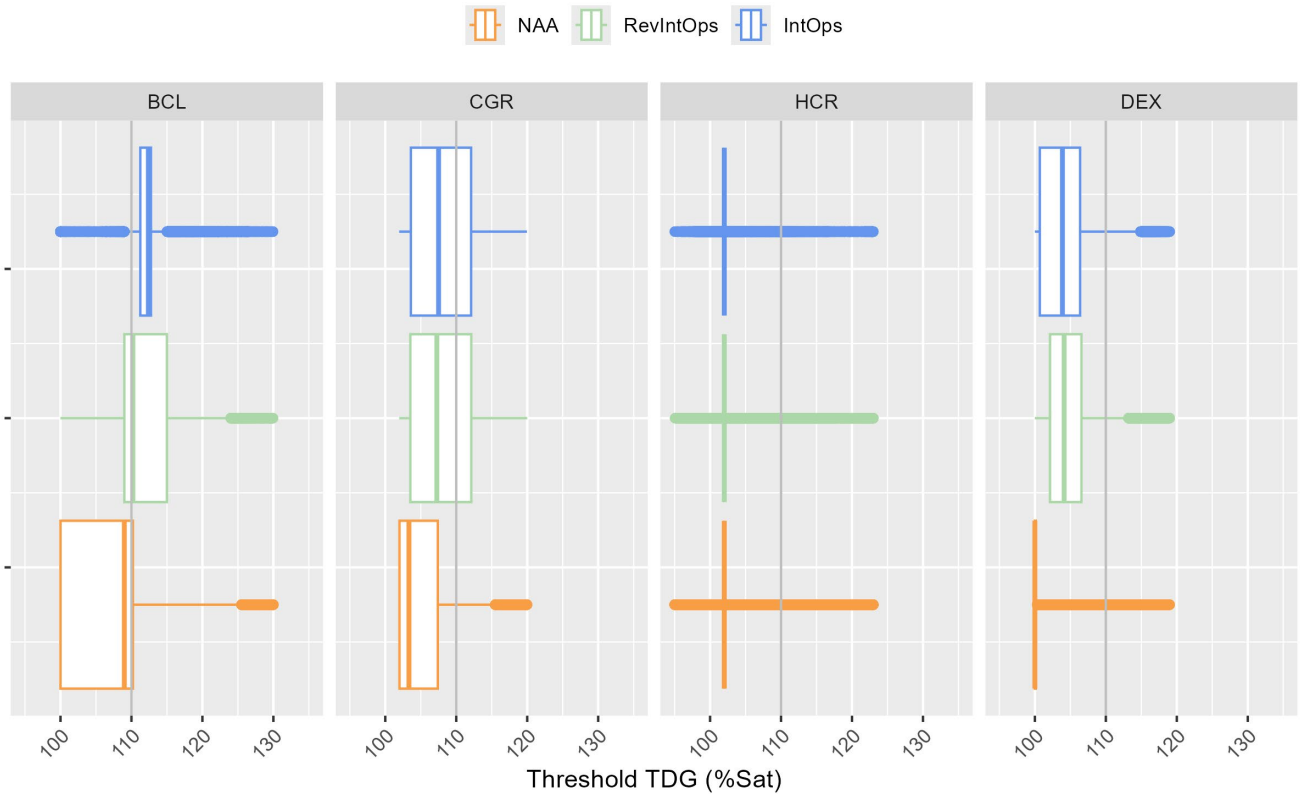


Figure 2-59. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on WILTDG estimated TDG for Interim Operations (IntOps), Interim Operations (RevIntOps), and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

Simulated TDG under RevIntOps was nearly identical to IntOps below all WVS dams except the North Santiam sub-basin (Detroit and Big Cliff). See NTOM in Final EIS, Appendix D, Chapter 2 for more details. Under Interim Operations (RevIntOps), the average number of days above 110% TDG levels at Big Cliff is 220 and Detroit is 201 (Figure 2-35). Observing the annual difference in number of days above 110% of TDG exceedances Big Cliff has an increase of 72 days and Detroit is increased by 85 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Big Cliff is 94 days and Detroit is 247 (Figure 2-34).

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CHAPTER 3 - CLIMATE CHANGE ASSESSMENT FOR WATER TEMPERATURE AND TDG

This appendix to the Willamette Valley EIS describes the methodology for developing qualitative assessments of the effects of climate change on the water temperature and TDG at each listed control point. The qualitative effects of dam operations/structures described in each WV EIS Alternative (Chap 3) have been integrated with qualitative interpretations of unregulated flow and air temperature from the River Joint Operating Committee (RMJOC II) climate projections (representing an 80 Global Circulation Model [GCM] ensemble; Chapter 3.2 (Effects Analysis – Hydrology and Hydraulics) and Technical Appendix B (Hydrology and Hydraulics). For this assessment, the climate impacts are based on data from "Climate Toolbox" (CIRC 2020)., https://climatetoolbox.org/, a regional suite of assessment tools over historical and projected future years (Technical Appendices F1 and F2). Storage/flow determinations from the hydrologic impacts due to climate change section were integrated into the water quality qualitative assessments (Chap 3.5).

The Climate Change Toolbox was created by the University of California Merced and is supported by NOAA-RISA, CIRC, NIDIS, the Northwest Climate Adaptation Science Center and the USDA Northwest Climate Hub. Please note that the Climate Change Toolbox is "a collection of tools for addressing questions relating to climate monitoring, water resources, fire conditions, forecasts, and projections. The tool also includes output directed at "addressing questions relating to agriculture." The Climate Change Toolbox relies upon projections from a variety of climate and downscaled hydrologic datasets. From the tool's metadata file, the following tool background information and context is given.

The 20 climate models and 2 scenarios (RCP 4.5 and 8.5) were downscaled to an approximately 4-km resolution across the US for compatibility with the gridMET data and the tool itself.

Hydrology projections from 10 global climate models (GCMs) and 2 scenarios were simulated using the Variable Infiltration Capacity (VIC v 4.1.1.2) hydrology model, forced with the downscaled MACAv2-Livneh data 1950-2005(historic) and 2006-2100 (future) to 1/16th degree to produce metrics such as snow water equivalent, soil moisture, runoff, and evaporation. The climate data was downscaled using gridded historical observations of meteorology from Livneh (v13 for USA and v14 for British Columbia, Canada).

A smaller ensemble of GCMs will result in less definition of the true model variability and uncertainty. A large sample size (ensemble) will reduce the uncertainty of the probability density function (PDF). Said another way, the mean of the PDF will more closely approximate the true ensemble average, as the sample size increases. This resolution is still useful for inferring future hydroclimate and hydraulic trend direction through the 21st century. Due to incomplete probability description due to a small ensemble, the PDT is cautioned not to use specific numerical results from the toolbox. The Climate Toolbox and RMJOC II study data were developed separately, albeit from similar CMIP5, GCM scenario datasets. The tool and the RMJOC studies used data generated from Coupled Model Intercomparison Project 5 (CMIP5),

but each provides information not provided by the other. Additional information concerning Climate Change Toolbox outputs can be found at the climatetoolbox.org link provided above.

3.1 WATER TEMPERATURE

Projected increases in summer water temperatures for Columbia River tributaries by the end of the century span a wide range, from 1.8 to 9.0 degrees Fahrenheit (1 to 5 degrees Celsius) (e.g., Cristea and Burges 2010; Mantua, Tohver, and Hamlet 2010; Wu et al. 2012; Beechie et al. 2013; Caldwell et al. 2013; Isaak et al. 2017). Previous research on the relationship between air temperature and water temperature has documented a 0.6-0.8°C increase in water temperature for every 1°C increase in air temperature (Morrill, et al., 2005). Similarly, a study on future climate impacts in the North Santiam Basin, Oregon found a 2°C annual air temperature increase translated to a water temperature increase of 1.5°C downstream of Detroit Dam under current operational rules (annual average water-to-air temperature ratio of 0.75) (Buccola, et al., 2016). Determinations of air temperature from the Northwest Climate Toolbox (https://climatetoolbox.org/) at Salem, Oregon (Figure 3-1) indicated a warming of maximum Jun-July-Aug air temperature of 4.7-7.9^{o}F (comparing ensemble 5th and 95th percentiles from 1971-2010, with 2010-2039 and 2040-2069 periods assuming Higher Emissions (RCP 8.5) scenarios in Table 3-1). Applying water-to-air temperature ratio of 0.75 to these air temperature projections to the Willamette Valley, water temperatures downstream of the dams could increase annually 3.5^{o}F – 5.9^{o}F under the 2040-2069 period or 1.9^{o}F – 2.9^{o}F under the 2010-2039 period under current operation regimes. Based on these ranges, an annual warming of 3.5-5.9^{o}F was assigned to “Much Warmer” qualitative assessments, and 1.9^{o}F – 2.9^{o}F assigned to “Warmer” qualitative assessments for the purpose of this EIS.

Table 3-1. Projected air temperature summary at Salem, Oregon based on RCP8.5 (climatetoolbox.org)

Model Statistic	HIST Historical Scenario: 1971-2010	Future Scenario 1: 2010-2039 (Higher Emissions (RCP 8.5))	*Difference* btwn 2010-2039 Future and 1971-2010 Historical	Future Scenario 2: 2040-2069 (Higher Emissions (RCP 8.5))	*Difference* btwn 2040-2069 Future and 1971-2010 Historical
Minimum from Models	78.8	80.9	2.1	82.4	3.6
5 Percentile from Models	79.0	81.5	2.5	83.7	4.6
Mean from Models	79.3	82.3	3.0	85.6	6.2
95 percentile from Models	79.6	83.4	3.8	87.5	7.9
Maximum from Models	79.8	83.7	3.9	88.5	8.8

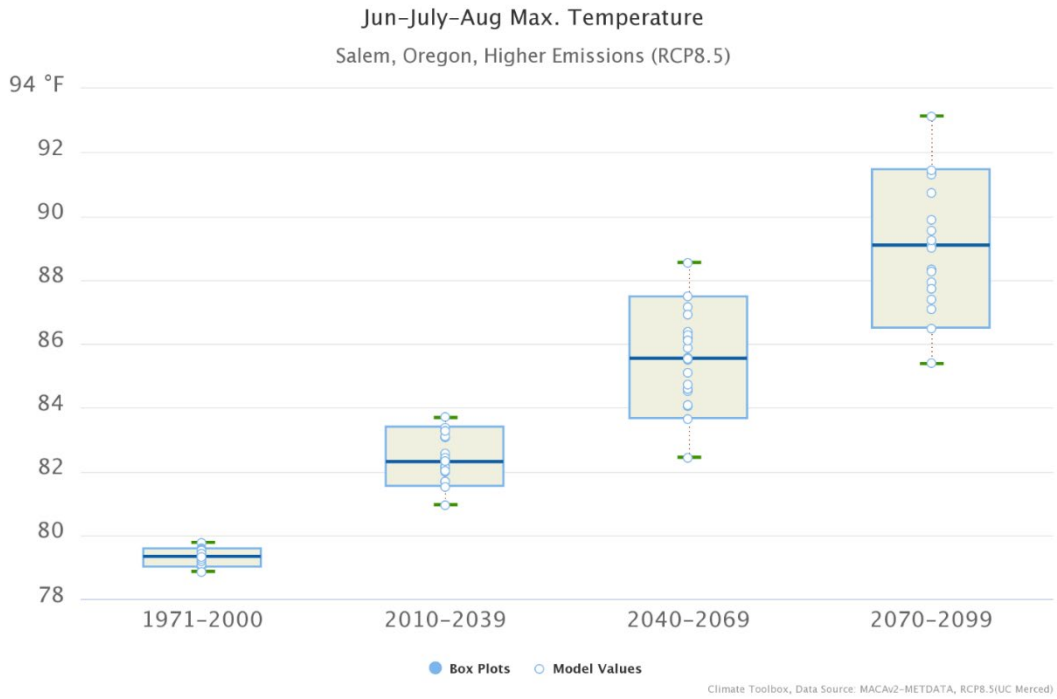


Figure 3-1. Summer Maximum air temperature boxplots at Salem, Oregon. (Source: Northwest Climate Toolbox: https://climatetoolbox.org/tool/Future-Boxplots).

Reservoir storage volume is the primary driver for providing augmentation flows in summer and autumn. Immediately downstream of each dam, water temperature is dependent on temperature management (the ability to mix cooler, deeper lake water with warmer, surface lake water). For alternatives with proposed SWS, the downstream water temperature is less dependent on lake volume as long as the SWS is accessible (wet). For alternatives that rely on existing structures for temperature control, downstream water temperature is dependent on 1) Whether the lake fills above the spillway crest in spring and early summer, and 2) What outlets are available in the autumn to access deeper/cooler water. In-lake temperatures, i.e., the amount of heat stored in the lake during summer, depends on how much lake surface water is released during spring and summer. This directly affects autumn temperatures, as the warmer lake surface water is drawn towards the deeper outlets as the lake is drafted in autumn. Simulated climate change effects on potential operations and structures at Detroit Dam have been shown to exacerbate the dependence of autumn temperature on spring and summer temperature control earlier in a given year (Buccola, et al., 2016). Further downstream, extreme water temperatures can be mitigated to some extent with increased flow that can buffer incoming heat from solar radiation.

3.1.1 Methodology

Assignment of a qualitative category was derived through a combination of the expected climate change impacts to water storage developed in the hydrologic section (Chap 3.2) as well as the water temperature impacts presented in Chap 3.5 for each sub-basin control point. Determinations in the expected climate change impacts to water storage in the Effects Analysis

– Hydrology and Hydraulics (Chapter 3.2) and Technical Appendix B (Hydrology and Hydraulics) of *Summer* category *"less"* were replaced with *"warmer."* Determinations were located and generally dependent on the site immediately below the lowest dam in each sub-basin as follows: Middle Fork Willamette (Lookout Point-Dexter at DEXO), Mckenzie (Cougar at CGRO), South Santiam (Foster at SSFO), North Santiam (Detroit-Big Cliff at BCLO). The mainstem Willamette was determined at Salem (SLMO). The following changes were made to sites immediately below dams:

1. Climate change impacts in alternatives and locations with "*Moderate Beneficial"* or *Major Beneficial*" impacts to either of the "Days Near the Temperature target" water temperature criteria in the WQ Impacts section of the EIS were assigned a climate change impact one step closer to *"Similar."* For example, a determination of "*Much Warmer*" would be moved to "*Warmer*."
2. Climate change impacts in alternatives and locations with "*Moderate Detrimental*" or "*Major Detrimental*" impacts to either of the "Days Near the Temperature target" water temperature criteria in the WQ Impacts section of the EIS were assigned a climate change impact one step closer to *"Similar."* For example, a determination of "*Similar*" would be moved to "*Warmer*."
3. Climate change impacts in alternatives and locations with "*Minor*" or "*Negligible*" impacts to both of the "Days Near the Temperature target" water temperature criteria in the WQ Impacts section of the EIS were assigned the same change provided in the Hydrologic climate impact analysis (Chapter 3.2).

*Note: Due to the existence of a water temperature control tower (WTCT) at Cougar, it was assumed that climate change impacts on temperature below Cougar would be one step closer to *"Similar"* in all alternatives that allow the lake to fill to the operable WTCT lake elevations (Alt 1, 2a, 4). For Alt 2b, 3a, and 3b, the above rules applied.

For sites further downstream at Salem and Albany, no changes were made to those assigned in the Hydrologic climate impact analysis (Chapter 3.2) as there were only "*Minor*" or "*Negligible*" impacts to the "Days Above 18 degrees C" water temperature criteria in the WQ Impacts section of the EIS.

3.2 TOTAL DISSOLVED GAS (TDG)

TDG increases when non-turbine releases, such as RO's or spillway releases increase. These types of releases occur when powerhouse capacity has been exceeded, a non-power outlet is used (e.g., for fish passage or temperature management), or turbine outages (e.g., repair).

3.2.1 Methodology

Determinations were located and generally dependent on the site immediately below the lowest dam in each sub-basin as follows: Middle Fork Willamette (Lookout Point-Dexter at DEXO), McKenzie (Cougar at CGRO), South Santiam (Foster at SSFO), North Santiam (Detroit-Big

Cliff at BCLO). Using the expected climate change impacts to flow volume developed in the hydrologic section (Chapter 3.2), determinations in *Winter* category were used in combination with the effects described in the Water Quality TDG effects section:

1. Climate change impacts in alternatives and locations with "*Moderate Beneficial"* or *Major Beneficial*" impacts to the "Number of Days Above 110% TDG" criteria in the WQ Impacts section of the EIS were assigned a climate change impact one step closer to *"Much Less".* For example, a determination of "*Much More*" would be moved to "*More*."
2. Climate change impacts in alternatives and locations with "*Moderate Detrimental*" or "*Major Detrimental*" impacts to the "Number of Days Above 110% TDG" criteria in the WQ Impacts section of the EIS were assigned a climate change impact one step closer to *"Much More".* For example, a determination of "*Much Less*" would be moved to "*Less*."
3. Climate change impacts in alternatives and locations with "*Minor*" or "*Negligible*" impacts to the "Number of Days Above 110% TDG" criteria in the WQ Impacts section of the EIS were assigned the same change provided in the Hydrologic climate impact analysis.

3.3 ASSESSMENTS BY ALTERNATIVE

3.3.1 No Action Alternative

Please reference Technical Appendices B and F for Climate Change qualitative effects. Water Quality parameters such as Water Temperature and TDG would be influenced by refill timing, storage volume, and outflow at each dam. Climate change projections for the 2030s and 2070s under RCP 8.5 show higher project inflow December-March and lower inflow April-November for the Willamette Basin. Higher winter flow may increase TDG levels if no TDG management is in place, as turbine capacity at power projects would likely be exceeded more often and result in "spill" releases through non-power outlets. Higher winter flows occurring in December-January would not be stored, as the guide curves for Willamette Projects generally begin February 1. Therefore, climate change will likely lead to a decreased release volumes in spring and summer compared to the Affected Environment. Decreased storage will likely decrease the ability to manage dam releases from different outlets for temperature management, leading to less normative release temperatures (cooler in spring-early summer; warmer in autumn).

In the No Action Alternative, Detroit dam, Green Peter dam, Foster dam, Cougar dam, Hills Creek dam, Lookout Point dam, and Mainstem Willamette river would potentially have less flow during the summer which may cause and increase downstream water temperatures.

3.3.2 Alternative 1 – Project Storage Alternative

Please reference Technical Appendices B and F for Climate Change qualitative effects. Compared to NAA, Alternative 1 would potentially increase resiliency against climate change impacts on water temperature and TDG (increased water temperature control) below Detroit and Green Peter as a result of the proposed SWS and TDG abatement measures at each location. Parameters such as Turbidity and Mercury will likely experience similar effects as

those described under NAA. Increased releases from the lake surface via the proposed SWS at Detroit, Green Peter, and Lookout Point combined with reduced summer flow volumes under Alternative 1 could lead to increased phytoplankton (algae) compared to NAA (Technical Appendix B Hydrology and Hydraulics).

3.3.3 Alternative 2a – Hybrid Alternative

Please reference Technical Appendices B and F for Climate Change qualitative effects. Compared to NAA, Alternative 2a would potentially increase resiliency against climate change impacts on water temperature (increased water temperature control) below Detroit and Green Peter as a result of the proposed SWS and operational temperature control measures at those locations. TDG impacts immediately below Detroit would likely be more resilient to climate change under Alternative 2a due to the proposed SWS (reducing the need for operational temperature control). Parameters such as Turbidity and Mercury will likely experience similar effects as those described under NAA. Increased releases from the lake surface via the proposed SWS at Detroit combined with reduced summer flow volumes under Alternative 2a could lead to increased phytoplankton (algae) compared to NAA (Technical Appendix B Hydrology and Hydraulics).

3.3.4 Alternative 2b – Hybrid Alternative

Please reference Technical Appendices B and F for Climate Change qualitative effects. Compared to NAA, Alternative 2b would potentially increase resiliency against climate change impacts on water temperature and TDG (increased water temperature control) below Detroit as a result of the proposed SWS and TDG abatement measures at each location. Parameters such as Turbidity and Mercury will likely experience similar effects as those described under NAA. Increased releases from the lake surface via the proposed SWS at Detroit combined with reduced late summer flow volumes under Alternative 2b could lead to increased phytoplankton (algae) compared to NAA (Technical Appendix B Hydrology and Hydraulics).

3.3.5 Alternative 3a – Operations-Focused Fish Passage

Please reference Technical Appendices B and F for Climate Change qualitative effects. Compared to NAA, Alternative 3a would potentially reduce resiliency against climate change impacts on water temperature (decreased water temperature control) below Detroit, Cougar, Lookout Point, and lower on the mainstem Willamette at Salem as a result of the lower storage and outflows at each location. However, Alternative 3a would potentially increase resiliency against climate change impacts on water temperature (more normative water temperature) below Hills Creek and Green Peter-Foster due to the elevation of the summer lake levels at that project. Resiliency against climate change impacts to TDG would likely decrease below Lookout Point, Green Peter, and Detroit due to decreased storage and increased spill (Appendix D, Chapter 2). Parameters such as Turbidity, HAB's, and Mercury will likely experience similar effects as those described under NAA.

3.3.6 Alternative 3b – Operations-Focused Fish Passage

Please reference Technical Appendices B and F for Climate Change qualitative effects. Compared to NAA, Alternative 3b would potentially reduce resiliency against climate change impacts on water temperature (decreased water temperature control) below Green Peter and lower on the mainstem Willamette at Salem as a result of the lower storage and outflows at each location. However, Alternative 3b would potentially increase resiliency against climate change impacts on water temperature (more normative temperatures) below Lookout Point-Dexter and Hills Creek due to operational lake elevations. Resiliency against climate change impacts to TDG would likely increase below Cougar and decrease below Lookout Point, Green Peter, and Detroit due to the reduced reservoir storage and changes to spill. Parameters such as Turbidity, HAB's, and Mercury will likely experience similar effects as those described under NAA.

3.3.7 Alternative 4 – Structures-Based Fish Passage Alternative

Please reference Technical Appendices B and F for Climate Change qualitative effects. Compared to NAA, Alternative 4 would potentially increase resiliency against climate change impacts on water temperature and TDG (increased water temperature control) below Detroit, Lookout Point, and Hills Creek as a result of the proposed SWS and TDG abatement measures at each location. Parameters such as Turbidity and Mercury will likely experience similar impacts as those described under NAA. Increased releases from the lake surface via the proposed SWS at Detroit, Lookout Point, and Hills Creek combined with reduced summer flow volumes under Alternative 1 could lead to increased phytoplankton (algae) compared to NAA (Technical Appendix B Hydrology and Hydraulics).

3.3.8 Alternative 5 – Preferred Alternative

Please reference Technical Appendices B and F for Climate Change qualitative effects closely matched to Alternative 2b. Compared to the No Action Alternative, Alternative 5 would potentially increase resiliency against climate change impacts on water temperature and TDG (increased water temperature control) below Detroit-Big Cliff as a result of the proposed SWS and TDG abatement measures at each location.

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CHAPTER 4 - OTHER IN-RESERVOIR WATER QUALITY BACKGROUND INFORMATION

This Chapter is intended to provide background information regarding the physical, chemical, nutrients, and phytoplankton data that has been collected by the Corps since 2007. The data summaries provided in this section were gathered during synoptic surveys of the Willamette reservoirs, which generally occur on a rotating 5-year schedule contingent on funding. Figure 4-1 provides a count of the site visits per year since 2007 at each site. Each (monthly) survey consisted of a boat-based visit to the forebay of the reservoir, typically near the deepest location near the upstream face of the dam where the following data are collected:

- Temperature (Figure 4-2), dissolved oxygen (Figure 4-3), specific conductivity, pH, turbidity, phycocyanin, chlorophyl measured with depth
- Water samples at 3 depths (near surface, middle of thermocline, and near the lakebed) are sent to an external lab for dissolved and total nutrient analysis (Figure 4-4).
- Near surface grab-sample for phytoplankton identification and enumeration done by external lab.
- Sample from plankton net tow in top 3 meters of the lake are sent to external lab for identification and enumeration of zooplankton.

Dissolved oxygen is typically above 50% at most reservoirs throughout the summer season, except for Fern Ridge, Fall Creek, Dorena, and Cottage Grove, where periods of low dissolved oxygen can exist for some periods (typically late summer).

Total nitrogen and total phosphorus concentrations are typically below 0.3 mg/L and 0.05 mg/L, respectively. The exception is Fern Ridge reservoir, which is relatively shallow and well-mixed and can experience wind-driven mixing events that can lead to cyanobacteria blooms in summer. Depth-averaged ratios of total nitrogen to total phosphorus were calculated and are shown for each site and survey in Figure 4-5. N:P ratios are typically below 20, indicating that most reservoirs are nitrogen limited. While a nitrogen limitation increases the potential for cyanobacteria blooms (favoring nitrogen-fixing bacteria), the relatively low nutrient concentrations in Willamette Project reservoirs likely prevents large-scale blooms from occurring in every year throughout the Willamette Project.

Trophic State Index (TSI) was originally defined by Carlson (1977) to categorize the overall water quality and biologic productivity. The TSI was calculated across the Willamette Project reservoirs and nutrient availability depending on Chlorophyl, Total Nitrogen, and Total Phosphorus data using the method described by State of Florida (1996) and in Figure 4-6. Results indicate that most lakes in the Willamette Project are categorized as oligotrophic to mesotrophic or of generally “good” water quality (0-59: good, 60-69: fair, 70-100: poor as defined by State of Florida, 1996).

Annual phytoplankton biovolume (Log-10 base) is summarized by species in Figure 4-7. Cyanobacteria bloom timing is summarized in Figure 4-8 for each project. Dolichospermum and Aphanizomenon were present in all reservoirs. It was most typical for Dolichospermum bloom to peak in May/June.

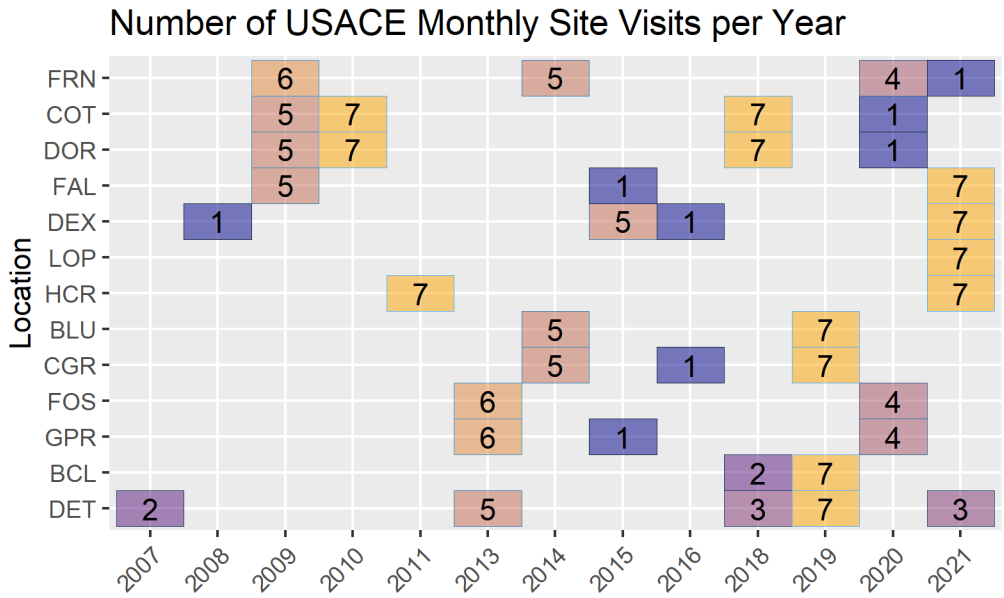


Figure 4-1. Number of surveys per year and site.

4.1 PHYSICAL –CHEMICAL CONSTITUENTS

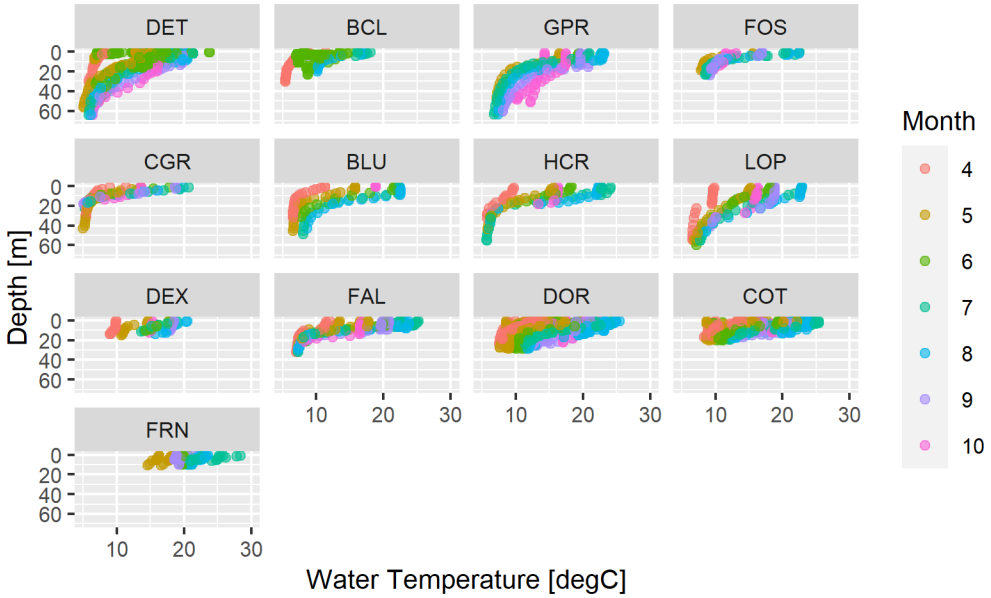


Figure 4-2. Water temperature profiles collected during each synoptic survey (2007-2021) displayed by month.

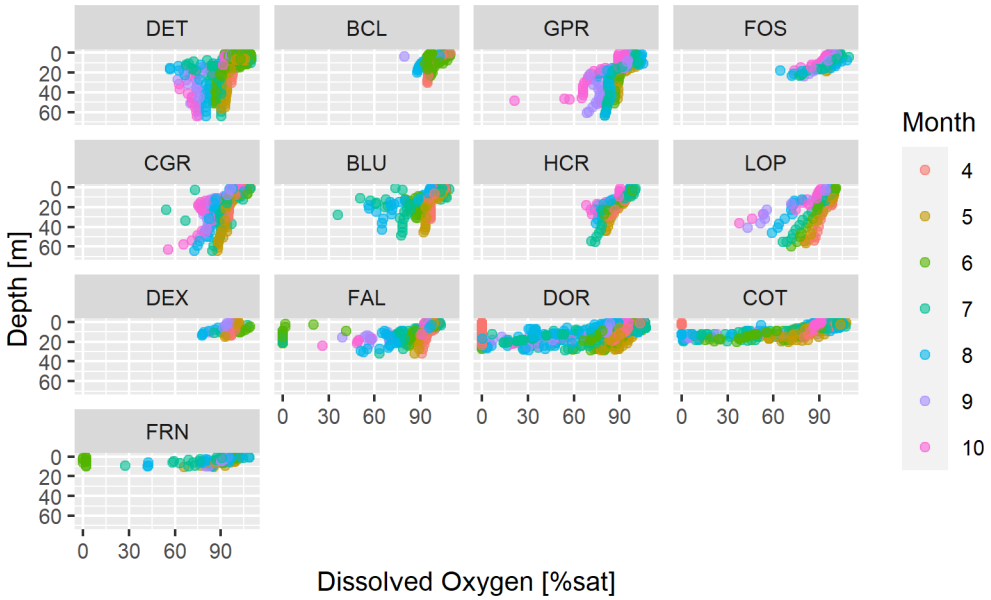


Figure 4-3. Dissolved oxygen profiles collected during each synoptic survey (2007-2021) displayed by month.

4.2 NITROGEN AND PHOSPHORUS

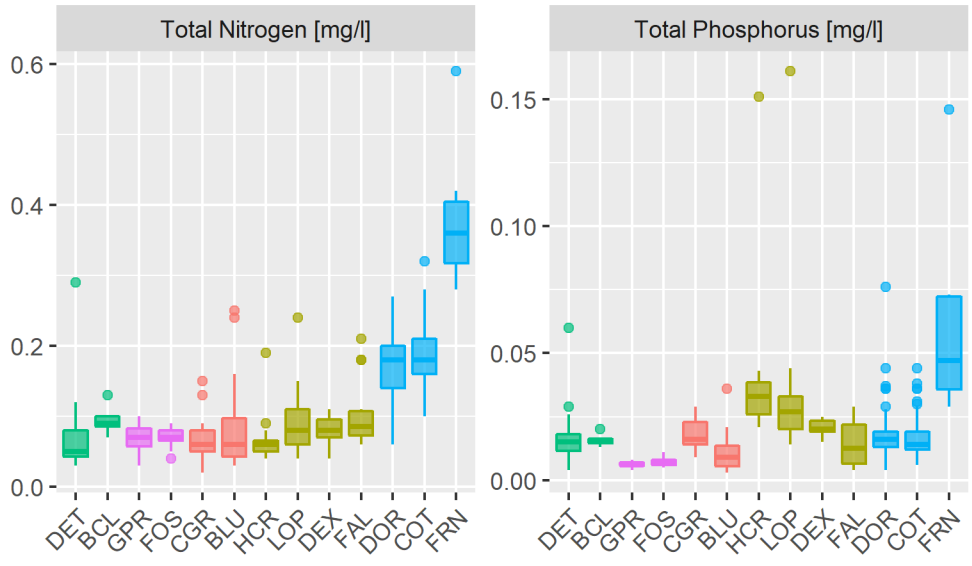


Figure 4-4. Boxplots of total nitrogen and total phosphorus measurements at each WVP location.

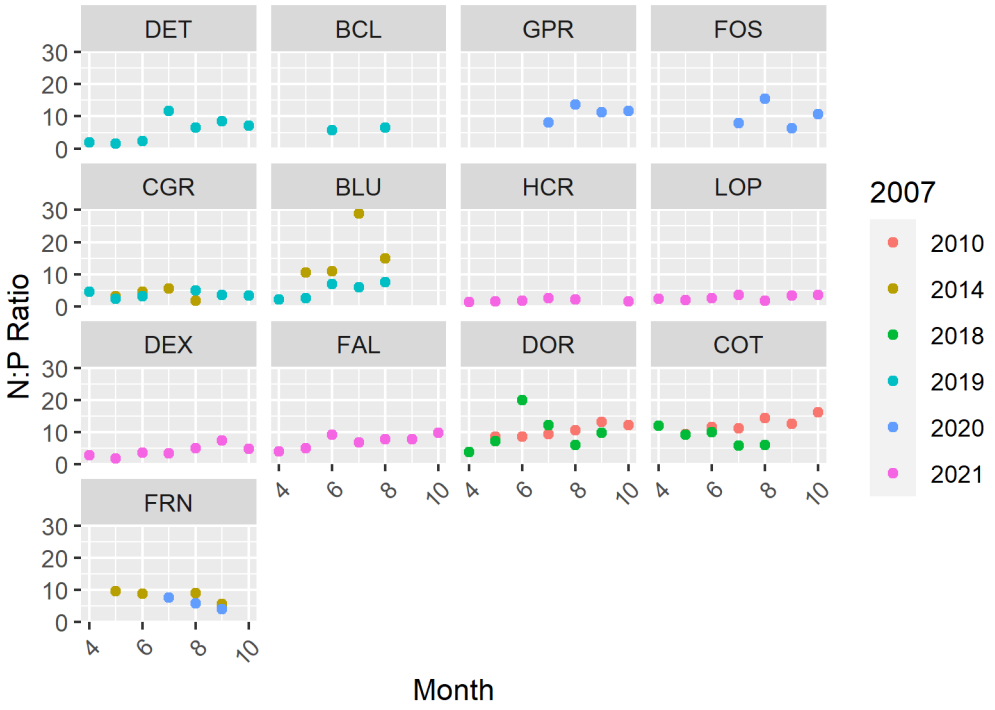


Figure 4-5. Depth-averaged nitrogen to phosphorus ratio at each WVP reservoir forebay location.

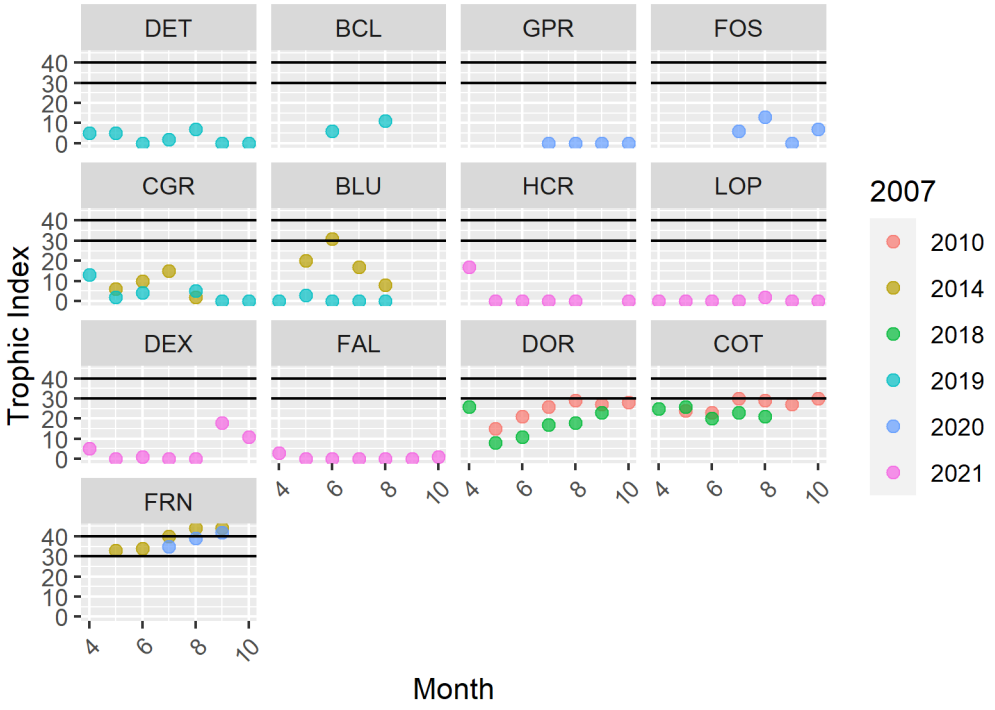


Figure 4-6. Depth-averaged trophic state at each WVP reservoir forebay location using equations from State of Florida (1996).

4.3 PHYTOPLANKTON

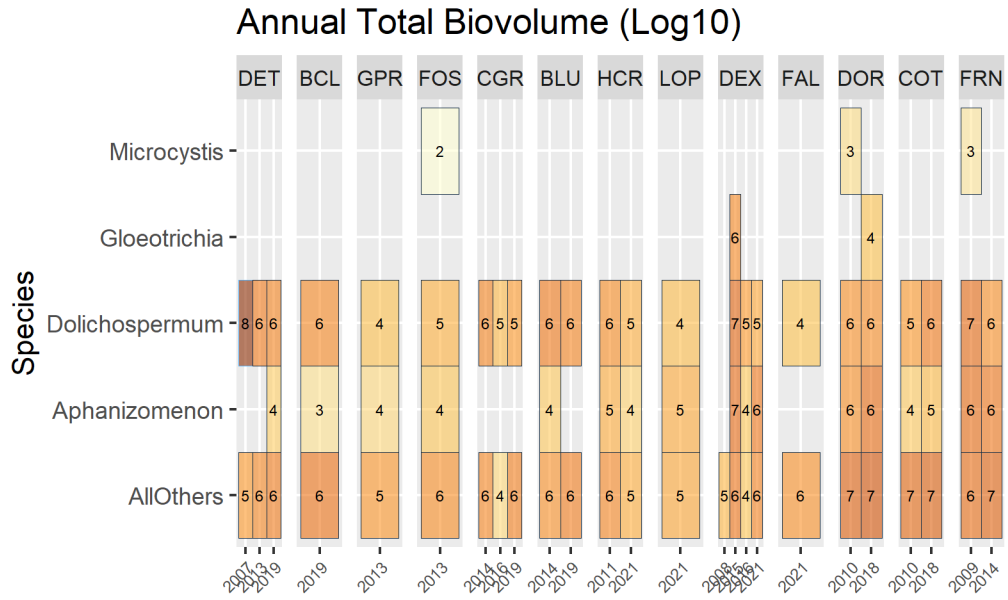


Figure 4-7. Annual total biovolume for each species of cyanobacteria present in WVP forebays (2007-2021).

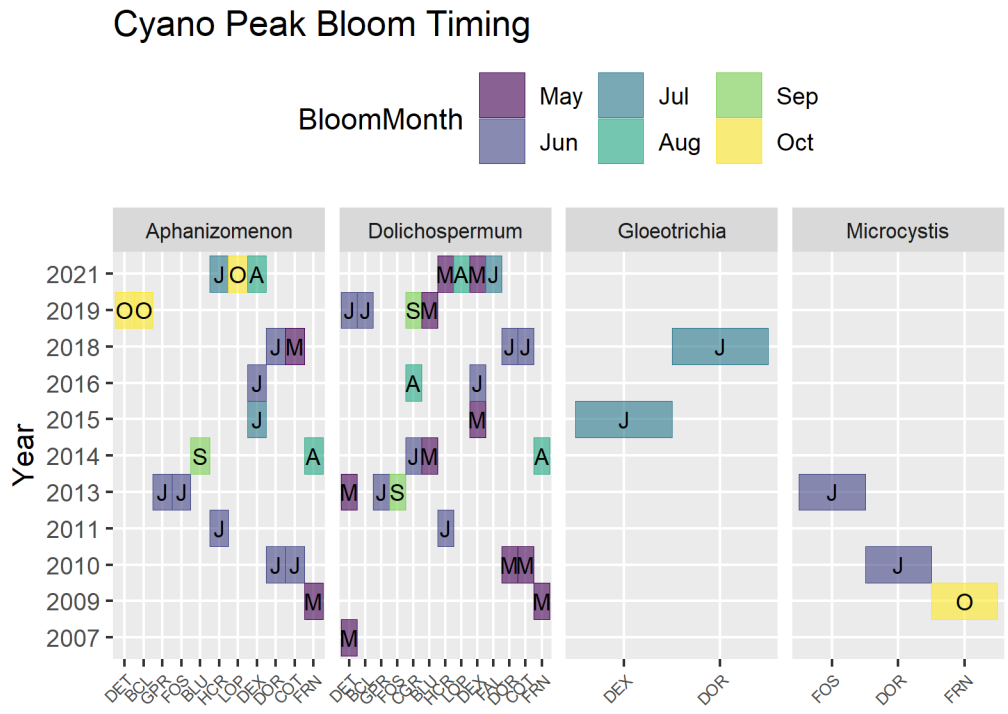


Figure 4-8. Month in which peak cyanobacteria biovolume occurred during years sampled at each WVP forebay.

4.4 REFERENCES

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