



Draft Columbia River System Operations Environmental Impact Statement

Appendix D Water and Sediment Quality

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43

Table of Contents

CHAPTER 1 - Introduction 1-1

CHAPTER 2 - General Methodology..... 2-1

 2.1 Overview 2-1

 2.2 Study Area..... 2-1

 2.2.1 Columbia River/Lower Snake Mainstem Modeling 2-3

 2.2.2 Lower Snake River Model for the Multiple Objective 3 Alternative 2-5

 2.2.3 Pend Oreille River (Albeni Falls Reach) Modeling..... 2-6

 2.3 Period of Record Mapping 2-6

 2.4 Empirical Analysis Tools 2-7

 2.5 Qualitative Analysis..... 2-7

 2.6 Impact Framework..... 2-8

 2.7 Limitations, Assumptions, and Uncertainty..... 2-10

 2.7.1 Water Quality..... 2-10

 2.7.2 Sediment Quality 2-10

CHAPTER 3 - No Action Alternative 3-1

 3.1 Upper Columbia River Basin 3-4

 3.1.1 Water Temperature 3-4

 3.1.2 Total Dissolved Gas 3-10

 3.1.3 Other Physical, Chemical, and Biological Processes 3-18

 3.2 Lower Snake River Basin 3-23

 3.2.1 Water Temperature 3-24

 3.2.2 Total Dissolved Gas 3-28

 3.2.3 Other Physical, Chemical, and Biological Processes 3-35

 3.3 Lower Columbia River 3-36

 3.3.1 Water Temperature 3-36

 3.3.2 Total Dissolved Gas 3-39

 3.3.3 Other Physical, Chemical, and Biological Processes 3-44

 3.4 Sediment Throughout the System 3-45

 3.4.1 Upper Columbia River Basin 3-46

 3.4.2 Lower Snake River 3-47

 3.4.3 Lower Columbia River 3-48

 3.4.4 Chemicals of Concern 3-49

 3.5 Water and Sediment Quality Conclusions 3-50

CHAPTER 4 - Multiple Objective Alternative 01 4-1

 4.1 Upper Columbia River Basin 4-1

 4.1.1 Water Temperature 4-1

 4.1.2 Total Dissolved Gas 4-10

 4.1.3 Other Physical, Chemical and Biological Processes 4-17

 4.2 Lower Snake River Basin 4-20

 4.2.1 Water Temperature 4-20

 4.2.2 Total Dissolved Gas 4-26

 4.2.3 Other Physical, Chemical, and Biological Processes 4-34

44	4.3	Lower Columbia River	4-35
45	4.3.1	Water Temperature	4-35
46	4.3.2	Total Dissolved Gas	4-38
47	4.3.3	Other Physical, Chemical, and Biological Processes	4-45
48	4.4	Sediment Processes	4-46
49	4.4.1	Sediment Sources	4-46
50	4.4.2	Chemicals of Concern	4-46
51	4.5	Conceptual Site Model.....	4-46
52	4.6	Water and Sediment Quality Conclusions	4-47
53	4.6.1	Multiple Objective Alternative 1 Results–Water Temperature.....	4-47
54	4.6.2	Multiple Objective Alternative 1 Results–Total Dissolved Gas.....	4-48
55	4.6.3	Multiple Objective Alternative 1 Results –Other Water Quality Impacts	4-48
56	4.6.4	Multiple Objective Alternative 1 Results –Sediment Quality	4-48
57	CHAPTER 5 - Multiple Objective Alternative 2		5-1
58	5.1	Upper Columbia River Basin	5-1
59	5.1.1	Water Temperature	5-1
60	5.1.2	Total Dissolved Gas	5-13
61	5.1.3	Other Physical, Chemical, and Biological Processes	5-22
62	5.2	Lower Snake River Basin	5-26
63	5.2.1	Water Temperature	5-28
64	5.2.2	Total Dissolved Gas	5-33
65	5.2.3	Other Physical, Chemical and Biological Processes	5-52
66	5.3	Lower Columbia River	5-52
67	5.3.1	Water Temperature	5-52
68	5.3.2	Total Dissolved Gas	5-55
69	5.3.3	Other Physical, Chemical, and Biological Processes	5-65
70	5.4	Sediment Processes	5-67
71	5.4.1	Sediment Sources	5-67
72	5.4.2	Chemicals of Concern	5-67
73	5.5	Conceptual Site Model.....	5-68
74	5.6	Water and Sediment Quality Conclusions	5-68
75	5.6.1	Multiple Objective Alternative 2 Results – Water Temperature.....	5-68
76	5.6.2	Multiple Objective Alternative 2 Results –Total Dissolved Gas.....	5-69
77	5.6.3	Multiple Objective Alternative 2 Results –Other Water Quality Impacts	5-69
78	5.6.4	Multiple Objective Alternative 2 Results –Sediment Quality	5-70
79	CHAPTER 6 - Multiple Objective Alternative 3		6-1
80	6.1	Upper Columbia River Basin	6-1
81	6.1.1	Water Temperature	6-1
82	6.1.2	Total Dissolved Gas	6-12
83	6.1.3	Other Physical, Chemical, and Biological Processes	6-20
84	6.2	Lower Snake River Basin	6-24
85	6.2.1	Water Temperature	6-24
86	6.2.2	Total Dissolved Gas	6-39
87	6.2.3	Other Physical, Chemical, and Biological Processes	6-41

88	6.3	Lower Columbia River	6-45
89	6.3.1	Water Temperature	6-45
90	6.3.2	Total Dissolved Gas	6-48
91	6.3.3	Other Physical, Chemical, and Biological Processes	6-58
92	6.4	Sediment Processes	6-61
93	6.4.1	Columbia River Sediment.....	6-61
94	6.4.2	Lower Snake River Sediment	6-61
95	6.4.3	McNary Reservoir	6-66
96	6.4.4	Water Quality Issues	6-66
97	6.4.5	Future Research	6-69
98	6.5	Water and Sediment Quality Conclusions	6-70
99	6.5.1	Multiple Objective Alternative 3 Results – Water Temperature.....	6-71
100	6.5.2	Multiple Objective Alternative 3 Results – Total Dissolved Gas.....	6-71
101	6.5.3	Multiple Objective Alternative 3 Results – Other Water Quality Impacts	6-72
102	6.5.4	Multiple Objective Alternative 3 Results – Sediment Quality	6-73
103	CHAPTER 7 - Multiple Objective Alternative 4		7-1
104	7.1	Upper Columbia River Basin	7-1
105	7.1.1	Water Temperature	7-1
106	7.1.2	Total Dissolved Gas	7-14
107	7.1.3	Other Physical, Chemical, and Biological Processes	7-22
108	7.2	Lower Snake River Basin	7-25
109	7.2.1	Water Temperature	7-25
110	7.2.2	Total Dissolved Gas	7-29
111	7.2.3	Other Physical, Chemical, and Biological Processes	7-39
112	7.3	Lower Columbia River	7-40
113	7.3.1	Water Temperature	7-40
114	7.3.2	Total Dissolved Gas	7-43
115	7.3.3	Other Physical, Chemical, and Biological Processes	7-53
116	7.4	Sediment Processes	7-55
117	7.4.1	Sediment Sources	7-55
118	7.4.2	Chemicals of Concern	7-56
119	7.5	Conceptual Site Model.....	7-56
120	7.6	Water and Sediment Quality Conclusions	7-56
121	7.6.1	Multiple Objective Alternative 4 Results – Water Temperature.....	7-57
122	7.6.2	Multiple Objective Alternative 4 Results – Total Dissolved Gas.....	7-57
123	7.6.3	Multiple Objective Alternative 4 Results – Other Water Quality Impacts	7-58
124	7.6.4	Multiple Objective Alternative 4 Results – Sediment Quality	7-58
125	CHAPTER 8 - Preferred Alternative.....		8-1
126	8.1	Upper Columbia River Basin	8-1
127	8.1.1	Water Temperature	8-1
128	8.1.2	Total Dissolved Gas	8-10
129	8.1.3	Other Physical, Chemical and Biological Processes	8-18
130	8.2	Lower Snake River Basin	8-21
131	8.2.1	Water Temperature	8-22

132	8.2.2	Total Dissolved Gas	8-28
133	8.2.3	Other Physical, Chemical and Biological Processes	8-43
134	8.3	Lower Columbia River	8-43
135	8.3.1	Water Temperature	8-43
136	8.3.2	Total Dissolved Gas	8-46
137	8.3.3	Other Physical, Chemical and Biological Processes	8-56
138	8.4	Sediment Processes	8-57
139	8.4.1	Sediment Sources	8-57
140	8.4.2	Chemicals of Concern	8-57
141	8.5	Conceptual Site Model.....	8-58
142	8.5.1	Multiple Objective Alternative 4 Results – Water Temperature.....	8-58
143	8.5.2	Multiple Objective Alternative 4 Results – Total Dissolved Gas.....	8-58
144	8.5.3	Multiple Objective Alternative 4 Results – Other Water Quality Impacts	8-59
145	8.5.4	Multiple Objective Alternative 4 Results – Sediment Quality	8-59
146	CHAPTER 9 - Conclusions		9-1
147	9.1	Upper Columbia River Basin	9-2
148	9.2	Lower Snake River Basin	9-3
149	9.3	Lower Columbia River	9-4
150	CHAPTER 10 - References		10-1

151

152

List of Tables

153	Table 2-1. Comparison of TMDL and CRSO EIS Analyses.....	2-5
154	Table 5-1. Monthly Average Temperature Differences Between Multiple Objective	
155	Alternative 2 and the No Action Alternative Model Results at Dworshak Dam	
156	Outflow for Five Flow and Meteorological Conditions.....	5-29
157	Table 6-1. Changes in the Percent of Time Water Temperatures Would be Greater than	
158	68°F if Multiple Objective Alternative 3 is Implemented at the Four Lower	
159	Snake River Projects.....	6-33
160	Table 6-2. Number of Days per Month when Daily Maximum Water Temperatures at the	
161	Current Lower Granite Tailwater Station Location Would be Within Selected	
162	Temperature Ranges Under Multiple Objective Alternative 3.....	6-33
163	Table 6-3. Number of Days Per Month when Daily Maximum Water Temperatures at the	
164	Current Little Goose Tailwater Station Location Would be Within Selected	
165	Temperature Ranges Under Multiple Objective Alternative 3.....	6-34
166	Table 6-4. Number of Days per Month when Daily Maximum Water Temperatures at the	
167	Current Lower Monumental Tailwater Station Location Would be Within	
168	Selected Temperature Ranges Under Multiple Objective Alternative 3.....	6-35
169	Table 6-5. Number of Days per Month when Daily Maximum Water Temperatures at the	
170	Current Ice Harbor Tailwater Station Location Would be Within Selected	
171	Temperature Ranges Under Multiple Objective Alternative 3.....	6-36
172	Table 6-6. Average Monthly Lewiston, Idaho, Air Temperatures and Snake River Flows	
173	for 1956, 1957, 1958, and 2011 to 2015	6-39

174 Table 6-7. Number of Days when the Volume-Weighted Average Dissolved Oxygen
175 Concentration in Lower Monumental Reservoir is Estimated to be Below
176 Selected Criteria During the Two Peaks in Suspended Sediment Derived from a
177 Hypothetical Dam Breach 6-44
178 Table 6-8. Summary of Conceptual Model for Dam Breach-Related Sediment Releases
179 Over Time..... 6-63
180 Table 6-9. Estimated Suspended Solids Concentrations During Dam Breaching Process..... 6-66
181 Table 6-10. Number of Days Below Dissolved Oxygen Thresholds in Lower Monumental
182 Reservoir 6-67
183 Table 7-1. Changes in the Number of Days Total Dissolved Gas Would be Greater or Less
184 Than the 2016 Tailwater Criteria Under Multiple Objective Alternative 4
185 Relative to No Action Alternative 7-34
186 Table 7-2. Change in the Number of days Total Dissolved Gas Would be Greater or Less
187 Than the 2016 Forebay Criteria Under Multiple Objective Alternative 4 Relative
188 to No Action Alternative 7-39
189 Table 8-1. Monthly Average Temperature Differences (°F) Between the Preferred
190 Alternative and the No Action Model Results at Dworshak Dam for Five Flow
191 and Meteorological Conditions 8-23
192 Table 8-2. Changes in the Number of Days During the Month when Maximum Tailwater
193 Temperatures Would be Greater than 68°F Under the Preferred Alternative
194 when compared to the No Action Alternative for the Five Flow and Air
195 Temperature Conditions at the Four Lower 8-28
196 Table 8-3. Changes in the percent of time Dworshak Tailwater TDG saturation would
197 occur within selected ranges if PA2 would be implemented compared to the
198 NAA for the five flow and air temperature conditions by month 8-30
199 Table 8-4. Number of days that the tailwater 12-hour TDG would be greater the current
200 120 percent for the No Action Alternative and the Preferred Alternative 8-36
201 Table 8-5. Number of days that the forebay 12-hour TDG would be greater the current
202 115 percent for the No Action Alternative and the Preferred Alternative. 8-41
203 Table 9-1. Summary of Water Temperature Effects by EIS Alternative 9-1
204 Table 9-2. Summary of Total Dissolved Gas Effects by EIS Alternative 9-2
205

List of Figures

206
207 Figure 2-1. Columbia River System Operations Environmental Impact Statement Water
208 Quality Study Area Map..... 2-2
209 Figure 2-2. Columbia River System Operations Environmental Impact Statement Water
210 Quality Modeling Framework..... 2-4
211 Figure 2-3. Water Temperature Impact Framework and Decision Criteria..... 2-9
212 Figure 3-1. Kootenai River Temperatures Measured at Libby Dam Tailwater Over Several
213 Years, Representative of Differing Drawdown and Inflow Conditions..... 3-6
214 Figure 3-2. Modeled Water Temperature for the No Action Alternative at Albeni Falls
215 Dam Forebay and Tailwater Under a 3-Year Range of River and Meteorological
216 Conditions 3-8

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

217 Figure 3-3. Modeled Tailwater Temperature for the No Action Alternative at Grand
 218 Coulee Dam Under a 5-year Range of River and Meteorological Conditions 3-9
 219 Figure 3-4. Modeled Tailwater Temperature for the No Action Alternative at Chief
 220 Joseph Dam Under a 5-Year Range of River and Meteorological Conditions 3-10
 221 Figure 3-5. ResSim Modeled Spillway Flows and Number of Days Exceeding 110 Percent
 222 at Libby Dam for the 80-Year Period from 1928 to 2008 3-12
 223 Figure 3-6. ResSim Modeled Spillway Flows and Number of Days Exceeding 110 Percent
 224 at Hungry Horse Dam for the 80-Year Period from 1928 to 2008 3-13
 225 Figure 3-7. ResSim Spillway Flows Modeled at Albeni Falls Dam for the 80-Year Period
 226 from 1928 to 2008 3-14
 227 Figure 3-8. Modeled Total Dissolved Gas, in Percent Saturation, for the No Action
 228 Alternative Above and Below Grand Coulee Dam Under a 5-Year Range of River
 229 and Meteorological Conditions 3-16
 230 Figure 3-9. Modeled Total Dissolved Gas, in Percent Saturation, for the No Action
 231 Alternative Above and Below Chief Joseph Dam Under a 5-Year Range of River
 232 and Meteorological Conditions 3-18
 233 Figure 3-10. Exceedance Plot of Water Surface Elevation (feet NGVD29) for Select
 234 Months 3-23
 235 Figure 3-11. Modeled Tailwater Temperature for the No Action Alternative at Dworshak
 236 Dam Under a 5-year Range of River and Meteorological Conditions 3-25
 237 Figure 3-12. Modeled Tailwater Temperatures for the No Action Alternative at Lower
 238 Granite and Little Goose Dams Under a 5-Year Range of River and
 239 Meteorological Conditions 3-26
 240 Figure 3-13. Modeled Tailwater Temperatures for the No Action Alternative at Lower
 241 Monumental and Ice Harbor Dams Under a 5-Year Range of River and
 242 Meteorological Conditions 3-27
 243 Figure 3-14. Frequency Distributions of the Temperature Greater than the 68°F
 244 Washington Standard that Would Occur at the Four Lower Snake River Dam
 245 Tailwater Fixed Monitoring Stations for Each Flow/Temperature Condition 3-28
 246 Figure 3-15. Modeled Tailwater Total Dissolved Gas for the No Action Alternative at
 247 Dworshak Dam Under a 5-year Range of River and Meteorological Conditions 3-29
 248 Figure 3-16. Frequency Distributions of the Hourly Total Dissolved Gas Values Greater
 249 than Idaho’s 110% Water Quality Standard that Would Occur at the Dworshak
 250 Dam Tailwater Fixed Monitoring Station for Each Flow/Temperature Condition 3-30
 251 Figure 3-17. Modeled Tailwater Total Dissolved Gas for the No Action Alternative at
 252 Lower Granite and Little Goose Dams Under a 5-Year Range of River and
 253 Meteorological Conditions 3-31
 254 Figure 3-18. Modeled Tailwater Total Dissolved Gas for the No Action Alternative at
 255 Lower Monumental and Ice Harbor Dams Under a 5-Year Range of River and
 256 Meteorological Conditions 3-32
 257 Figure 3-19. Frequency Distributions of the Daily 12-hour Maximum Average Total
 258 Dissolved Gas Values Greater than Washington’s 120 Percent Criteria at the
 259 Four Lower Snake River Dam Tailwater Fixed Monitoring Stations for each
 260 Flow/Temperature Condition Between April 1 and August 31 3-33

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

261 Figure 3-20. Modeled Forebay Total Dissolved Gas for the No Action Alternative at
262 Lower Granite and Little Goose Dams Under a 5-Year Range of River and
263 Meteorological Conditions 3-33

264 Figure 3-21. Modeled Forebay Total Dissolved Gas for the No Action Alternative at
265 Lower Monumental and Ice Harbor Dams Under a 5-Year Range of River and
266 Meteorological Conditions 3-34

267 Figure 3-22. Frequency Distributions of the Daily 12-hour Maximum Average Total
268 Dissolved Gas Values Greater than Washington’s 115 Percent Criteria at the
269 Four Lower Snake River Dam Forebay Fixed Monitoring Stations for Each
270 Flow/Temperature Condition Between April 1 and August 31 3-34

271 Figure 3-23. Modeled Tailwater Temperature For the No Action Alternative at McNary
272 and John Day Dams Under a 5-Year Range of River and Meteorological
273 conditions 3-38

274 Figure 3-24. Modeled Tailwater Temperature For the No Action Alternative at The Dalles
275 and Bonneville Dams Under a 5-Year Range of River and Meteorological
276 conditions 3-39

277 Figure 3-25. Modeled Forebay Total Dissolved Gas for the No Action Alternative at
278 McNary and John Day Dams Under a 5-Year Range of River and Meteorological
279 Conditions 3-41

280 Figure 3-26. Modeled Forebay Total Dissolved Gas for the No Action Alternative at The
281 Dalles and Bonneville Dams Under a 5-Year Range of River and Meteorological
282 Conditions 3-42

283 Figure 3-27. Modeled Tailwater Total Dissolved Gas for the No Action Alternative at
284 McNary, and John Day Dams Under a 5-Year Range of River and Meteorological
285 Conditions 3-43

286 Figure 3-28. Modeled Tailwater Total Dissolved Gas for the No Action Alternative at The
287 Dalles and Bonneville Dams Under a 5-Year Range of River and Meteorological
288 Conditions 3-44

289 Figure 4-1. Libby Dam-Lake Kocanusa Summary Forebay Elevations for Multiple
290 Objective Alternative 1 Versus No Action Alternative 4-2

291 Figure 4-2. Libby Dam-Lake Kocanusa Summary Outflows for Multiple Objective
292 Alternative 1 Versus No Action Alternative 4-3

293 Figure 4-3. Hungry Horse Summary Forebay Elevations for Multiple Objective Alternative
294 1 Versus No Action Alternative Showing the Operational Range of the Selective
295 Withdrawal Structure. 4-4

296 Figure 4-4. Modeled Forebay Temperatures for the No Action Alternative and Multiple
297 Objective Alternative 1 at Albeni Falls from 2004 to 2006 4-6

298 Figure 4-5. Modeled Tailwater Temperatures for the No Action Alternative and Multiple
299 Objective Alternative 1 at Albeni Falls from 2004 to 2006 4-6

300 Figure 4-6. Modeled Tailwater Temperature for the No Action Alternative and Multiple
301 Objective Alternative 1 at Grand Coulee Dam Under a 5-year Range of River
302 and Meteorological Conditions Compared to the Confederated Colville Tribe 1-
303 D Maximum Water Quality Standard 4-8

*Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix*

304 Figure 4-7. Chief Joseph Dam-Rufus Woods Lake Forebay Elevations Multiple Objective
305 Alternative 1 Versus No Action Alternative 4-9

306 Figure 4-8. Modeled Tailwater Temperature for the No Action Alternative and Multiple
307 Objective Alternative 1 at Chief Joseph Dam Under a 5-Year Range of River and
308 Meteorological Conditions 4-10

309 Figure 4-9. Modeled Tailwater Total Dissolved Gas and Spillway Flows for the No Action
310 Alternative and Multiple Objective 1 at Libby Dam over an 80-Year Period 4-11

311 Figure 4-10. Modeled Tailwater Total Dissolved Gas 110 Percent Exceedance Days for
312 the No Action Alternative and Multiple Objective Alternative 1 at Libby Dam
313 over an 80-Year Period 4-12

314 Figure 4-11. Number of Days that Total Dissolved Gas is Above the 110 Percent State
315 Water Quality Standard Under the No Action Alternative and Multiple
316 Objective Alternative 1 at Hungry Horse Dam 4-12

317 Figure 4-12. Modeled Tailwater Spillway Flows for the No Action Multiple Objective
318 Alternative 1 at Albeni Falls Dam over an 80-Year Period 4-13

319 Figure 4-13. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and
320 Multiple Objective Alternative 1 at Grand Coulee Dam Under a 5-Year Range of
321 River and Meteorological Conditions 4-15

322 Figure 4-14. Modeled Forebay Total Dissolved Gas Saturations for the No Action
323 Alternative and Multiple Objective Alternative 1 at Chief Joseph Dam Under a
324 5-Year Range of River and Meteorological Conditions..... 4-16

325 Figure 4-15. Modeled Tailwater Total Dissolved Gas Saturations for the No Action
326 Alternative and Multiple Objective Alternative 1 at Chief Joseph Dam Under a
327 5-Year Range of River and Meteorological Conditions..... 4-16

328 Figure 4-16. Modeled Forebay Elevations for the No Action Alternative and Multiple
329 Objective 1 at Grand Coulee Dam Under a 5-Year Range of River and
330 Meteorological Conditions 4-20

331 Figure 4-17. Modeled Tailwater Temperature for the No Action Alternative and Multiple
332 Objective Alternative 1 at Dworshak Dam Under a 5Year Range of River and
333 Meteorological Conditions 4-21

334 Figure 4-18. Modeled Tailwater Temperatures for the No Action Alternative and
335 Multiple Objective Alternative 1 at Lower Granite Dam Under a 5Year Range of
336 River and Meteorological Conditions 4-23

337 Figure 4-19. Modeled Tailwater Temperatures for the No Action Alternative and
338 Multiple Objective Alternative 1 at Little Goose Dam Under a 5Year Range of
339 River and Meteorological Conditions 4-23

340 Figure 4-20. Modeled Tailwater Temperatures for the No Action Alternative and
341 Multiple Objective Alternative 1 at Lower Monumental and Ice Harbor Dams
342 Under a 5-Year Range of River and Meteorological Conditions..... 4-24

343 Figure 4-21. Modeled Tailwater Temperatures for the No Action Alternative and
344 Multiple Objective Alternative 1 at Lower Monumental and Ice Harbor Dams
345 Under a 5-Year Range of River and Meteorological Conditions..... 4-24

346 Figure 4-22. Number of Days During the Year when There Would be Greater than One
347 Degree Temperature Increase at the Four Lower Snake River Dam Tailwater

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

348	Locations Under Multiple Objective Alternative 1 Relative to the No Action	
349	Alternative	4-25
350	Figure 4-23. Number of Additional Days During the Year when the Washington 68 °F	
351	Temperature Standard Would be Exceeded at the Four Lower Snake River Dam	
352	Tailwater Locations Under Multiple Objective Alternative 1 relative to the No	
353	Action Alternative	4-25
354	Figure 4-24. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and	
355	Multiple Objective Alternative 1 at Dworshak Dam Under a 5-Year Range of	
356	River and Meteorological Conditions	4-27
357	Figure 4-25. Increases and Decreases in the Number of Hours the Idaho 110 Percent	
358	Total Dissolved Gas Standard Would be Met at the Dworshak Dam Tailwater	
359	Location for Each Flow/Temperature Condition Under Multiple Objective	
360	Alternative 1 Relative to the No Action Alternative	4-27
361	Figure 4-26. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and	
362	Multiple Objective Alternative 1 at Lower Granite and Little Goose Dams Under	
363	a 5-Year Range of River and Meteorological Conditions.....	4-29
364	Figure 4-27. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and	
365	Multiple Objective Alternative 1 at Lower Monumental and Ice Harbor Dams	
366	Under a 5-Year Range of River and Meteorological Conditions.....	4-30
367	Figure 4-28. Increases and Decreases in the Number of Days the Washington 120	
368	Percent Total Dissolved Gas Standard Would be Met at the Lower Snake River	
369	Dam Tailwater Locations for each Flow/Temperature Condition Under Multiple	
370	Objective Alternative 1 Relative to the No Action Alternative.....	4-31
371	Figure 4-29. Modeled Forebay Total Dissolved Gas for the No Action Alternative and	
372	Multiple Objective Alternative 1 at Lower Granite and Little Goose Dams Under	
373	a 5-Year Range of River and Meteorological Conditions.....	4-32
374	Figure 4-30. Modeled Forebay Total Dissolved Gas for the No Action Alternative and	
375	Multiple Objective Alternative 1 at Lower Monumental and Ice Harbor Dams	
376	Under a 5-Year Range of River and Meteorological Conditions.....	4-33
377	Figure 4-31. Increases and Decreases in the Number of Days the Washington 115	
378	Percent Total Dissolved Gas Standard Would be Met at the Lower Snake River	
379	Dam Forebay Locations for each Flow/Temperature Condition Under Multiple	
380	Objective Alternative 1 Relative to the No Action Alternative.....	4-34
381	Figure 4-32. Modeled Tailwater Temperature for Multiple Objective Alternative 1 at	
382	McNary Dam Under a 5-Year Range of River and Meteorological Conditions	4-35
383	Figure 4-33. Modeled Tailwater Temperature for Multiple Objective Alternative 1 at	
384	John Day Dam Under a 5-Year Range of River Meteorological Conditions.....	4-36
385	Figure 4-34. Modeled Tailwater Temperature for Multiple Objective Alternative 1 at The	
386	Dalles Dam Under a 5-Year Range of River and Meteorological Conditions.....	4-36
387	Figure 4-35. Modeled Tailwater Temperature for Multiple Objective Alternative 1 at	
388	Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions	4-37
389	Figure 4-36. Frequency of Modeled Tailwater Temperature Violations of State Water	
390	Quality Standards for the No Action Alternative and Multiple Objective	

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

391 Alternative 1 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-
392 Year Range of River and Meteorological Conditions..... 4-37
393 Figure 4-37. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 1 at
394 McNary Dam Under a 5-Year Range of River and Meteorological Conditions 4-39
395 Figure 4-38. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 1 at
396 John Day Dam Under a 5-Year Range of River and Meteorological Conditions..... 4-39
397 Figure 4-39. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 1 at
398 The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions..... 4-40
399 Figure 4-40. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 1 at
400 Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions 4-40
401 Figure 4-41. Frequency of Modeled Forebay Total Dissolved Gas for the No Action
402 Alternative and Multiple Objective Alternative 1 at McNary, John Day, The
403 Dalles, and Bonneville Dams Under a 5-Year Range of River and Meteorological
404 Conditions 4-41
405 Figure 4-42. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 1
406 at McNary Dam Under a 5-Year Range of River and Meteorological Conditions 4-42
407 Figure 4-43. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 1
408 at John Day Dam Under a 5-Year Range of River and Meteorological Conditions 4-42
409 Figure 4-44. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 1
410 at The Dalles Dam Under a 5-Year Range of River and Meteorological
411 Conditions 4-43
412 Figure 4-45. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 1
413 at Bonneville Dam Under a 5-Year Range of River and Meteorological
414 Conditions 4-43
415 Figure 4-46. Frequency of Modeled Tailwater Total Dissolved for the No Action
416 Alternative and Multiple Objective Alternative 1 at McNary, John Day, The
417 Dalles, and Bonneville Dams Under a 5-Year Range of River and Meteorological
418 Conditions 4-44
419 Figure 4-47. Modeled Forebay Elevation for Multiple Objective Alternative 1 at John Day
420 Dam Under a 5-Year Range of River and Meteorological Conditions 4-45
421 Figure 5-1. Libby Dam-Lake Kocanusa Summary Forebay Elevations for Multiple
422 Objective Alternative 2 Versus the No Action Alternative 5-2
423 Figure 5-2. Libby Dam-Lake Kocanusa Summary Outflows for Multiple Objective
424 Alternative 2 Versus the No Action Alternative 5-3
425 Figure 5-3. Hungry Horse Reservoir Summary Elevation Hydrograph for Multiple
426 Objective Alternative 2 Versus the No Action Alternative 5-5
427 Figure 5-4. Albeni Falls Dam Summary Elevation Hydrograph for Multiple Objective
428 Alternative 2 Versus the No Action Alternative 5-6
429 Figure 5-5. Albeni Falls Dam Summary Outflows for Multiple Objective Alternative 2
430 Versus the No Action Alternative 5-7
431 Figure 5-6. Modeled Forebay Temperatures for the No Action Alternative and Multiple
432 Objective Alternative 2 at Albeni Falls from 2004 to 2006 5-7
433 Figure 5-7. Modeled Tailwater Temperatures for the No Action Alternative and Multiple
434 Objective Alternative 2 at Albeni Falls from 2004 to 2006 5-8

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

435 Figure 5-8. Modeled Tailwater Temperatures for the No Action Alternative and Multiple
436 Objective Alternative 2 at Grand Coulee Dam Under a 5-Year Range of River
437 and and Meteorological Conditions Compared to the Confederated Colville
438 Tribe 1-D Maximum Water Quality Standard..... 5-10
439 Figure 5-9. Chief Joseph Dam-Rufus Woods Lake Outflows for Multiple Objective
440 Alternative 2 Versus the No Action Alternative 5-11
441 Figure 5-10. Chief Joseph Dam-Rufus Woods Lake Forebay Elevations for Multiple
442 Objective Alternative 2 Versus the No Action Alternative 5-12
443 Figure 5-11. Modeled Tailwater Temperature for the No Action Alternative and Multiple
444 Objective Alternative 2 at Chief Joseph Dam Under a 5-Year Range of River and
445 Meteorological Conditions 5-13
446 Figure 5-12. Modeled Tailwater Total Dissolved Gas and Spillway Flows for the No Action
447 Alternative and Multiple Objective Alternative 2 at Libby Dam over an 80Year
448 Period..... 5-14
449 Figure 5-13. Number of Days Modeled Tailwater Total Dissolved Gas Exceeds the 110
450 Percent State Water Quality Standards for the No Action Alternative and
451 Multiple Objective Alternative 2 at Libby Dam over an 80- Year Period 5-15
452 Figure 5-14. Number of Days that Total Dissolved Gas is Above the 110 Percent State
453 Water Quality Standard Under the No Action Alternative and Multiple
454 Objective Alternative 2 at Hungry Horse Dam 5-15
455 Figure 5-15. Modeled Tailwater Spillway Flows for the No Action Alternative and
456 Multiple Objective Alternative 2 at Albeni Falls Dam over an 80-Year Period 5-16
457 Figure 5-16. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and
458 Multiple Objective Alternative 2 at Grand Coulee Dam Under a 5-Year Range of
459 River and Meteorological Conditions 5-19
460 Figure 5-17. Modeled Range of Tailwater Total Dissolved Gas for the No Action
461 Alternative and Multiple Objective Alternative 2 at Grand Coulee Dam Under a
462 5-Year Range of River and Meteorological Conditions..... 5-20
463 Figure 5-18. Modeled Forebay and Tailwater Total Dissolved Gas Saturations for the No
464 Action Alternative and Multiple Objective Alternative 2 at Chief Joseph Dam
465 Under a 5-Year Range of River and Meteorological Conditions..... 5-21
466 Figure 5-19. Days Exceeding the 110 Percent Total Dissolved Gas Criteria for the No
467 Action Alternative and Multiple Objective Alternative 2 at Chief Joseph Dam
468 Tailwater Under a 5-Year Range of River and Meteorological Conditions..... 5-22
469 Figure 5-20. Hungry Horse Dam Outflows for Multiple Objective Alternative 2 Versus the
470 No Action Alternative 5-24
471 Figure 5-21. Modeled Forebay Elevations for the No Action Alternative and Multiple
472 Objective Alternative 2 at Grand Coulee Dam Under a 5-Year Range of River
473 and Meteorological Conditions 5-26
474 Figure 5-22. Dworshak Reservoir Pool Elevations for Multiple Objective Alternative 2 and
475 No Action Alternative for the 5-Year Range of Flow and Meteorological
476 Conditions Modeled 5-27

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

477 Figure 5-23. Differences Between Dworshak Reservoir Pool Elevations for Multiple
478 Objective Alternative 2 and the No Action Alternative for the 5-Year Range of
479 Flow and Meteorological Conditions Modeled 5-28
480 Figure 5-24. Modeled Tailwater Temperature for the No Action Alternative and Multiple
481 Objective Alternative 2 at Dworshak Dam Under a 5-Year Range of River and
482 Meteorological Conditions 5-29
483 Figure 5-25. Modeled Tailwater Temperatures for the No Action Alternative and
484 Multiple Objective Alternative 2 at Lower Granite and Little Goose Dams Under
485 a 5-Year Range of River and Meteorological Conditions..... 5-30
486 Figure 5-26. Modeled Tailwater Temperatures for the No Action Alternative and
487 Multiple Objective Alternative 2 at Lower Monumental and Ice Harbor Dams
488 Under a 5-Year Range of River and Meteorological Conditions..... 5-31
489 Figure 5-27. 5-32
490 Figure 5-28. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and
491 Multiple Objective Alternative 2 at Dworshak Dam Under a 5-Year Range of
492 River and Meteorological Conditions 5-34
493 Figure 5-29. Percent of the Monthly Total Dissolved Gas Data that is Greater than 110
494 Percent for the Multiple Objective Alternative 2 and No Action Alternative
495 Modeled for Dworshak Dam Tailwater by Month for Five Meteorological
496 Conditions 5-34
497 Figure 5-30. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and
498 Multiple Objective Alternative 2 at Lower Granite and Little Goose Dams Under
499 a 5-Year Range of River and Meteorological Conditions..... 5-36
500 Figure 5-31. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and
501 Multiple Objective Alternative 2 at Lower Monumental and Ice Harbor Dams
502 Under a 5-year Range of River and Meteorological Conditions..... 5-37
503 Figure 5-32. Differences to the Percent of Total Dissolved Gas that Would Occur Within
504 Selected Ranges if Multiple Objective Alternative 2 is Implemented when
505 Compared to the No Action Alternative at the Four Lower Snake River Dam
506 Tailwater Locations Under a 5-Year Range of River and Meteorological
507 Conditions 5-38
508 Figure 5-33. Differences in the Percent of Time that Total Dissolved Gas Would be
509 Within Selected Ranges if Multiple Objective Alternative 2 is Implemented
510 when Compared to the No Action Alternative at Lower Granite Dam Tailwater
511 Under a 5-Year Range of River and Meteorological Conditions..... 5-39
512 Figure 5-34. Differences in the Percent of Time that Total Dissolved Gas Would be
513 Within Selected Ranges if Multiple Objective Alternative 2 is Implemented
514 when Compared to the No Action Alternative at Little Goose Dam Tailwater
515 Under a 5-Year Range of River and Meteorological Conditions..... 5-40
516 Figure 5-35. Differences in the Percent of Time that Total Dissolved Gas Would be
517 Within Selected Ranges if Multiple Objective Alternative 2 is Implemented
518 when Compared to the No Action Alternative at Lower Monumental Dam
519 Tailwater Under a 5-Year Range of River and Meteorological Conditions..... 5-41

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

520 Figure 5-36. Differences in the Percent of Time that Total Dissolved Gas Would be
521 Within Selected Ranges if Multiple Objective Alternative 2 is Implemented
522 when Compared to the No Action Alternative at Ice Harbor Dam Tailwater
523 Under a 5-year Range of River and Meteorological Conditions..... 5-42
524 Figure 5-37. Maximum Total Dissolved Gas that Would be Expected at the Four Lower
525 Snake River Dam Tailwater Locations During the Fish Passage Season if
526 Multiple Objective Alternative 2 is Implemented Under a 5-Year Range of River
527 and Meteorological Conditions 5-43
528 Figure 5-38. Modeled Forebay Total Dissolved Gas for the No Action Alternative and
529 Multiple Objective Alternative 2 at Lower Granite and Little Goose Dams Under
530 a 5-Year Range of River and Meteorological Conditions..... 5-45
531 Figure 5-39. Modeled Forebay Total Dissolved Gas for the No Action Alternative and
532 Multiple Objective Alternative 2 at Lower Monumental and Ice Harbor Dams
533 Under a 5-Year Range of River and Meteorological Conditions..... 5-46
534 Figure 5-40. Maximum Total Dissolved Gas that Would be Expected at the Four Lower
535 Snake River Dam Forebay Locations During the Fish Passage Season if Multiple
536 Objective Alternative 2 is Implemented Under a 5-Year Range of River and
537 Meteorological Conditions 5-47
538 Figure 5-41. Differences to the Percent of Total Dissolved Gas that Would Occur Within
539 Selected Ranges from April Through August if Multiple Objective Alternative 2
540 is Implemented when Compared to No Action Alternative at the Four Lower
541 Snake River Dam Forebay Locations Under a 5-Year Range of River and
542 Meteorological Conditions 5-48
543 Figure 5-42. Differences in the Percent of Time Total Dissolved Gas Would be Within
544 Selected Ranges if Multiple Objective Alternative 2 is Implemented when
545 Compared to the No Action Alternative at Little Goose Dam Forebay Under a 5-
546 Year Range of River and Meteorological Conditions..... 5-49
547 Figure 5-43. Differences in the Percent of Time Total Dissolved Gas Would be Within
548 Selected Ranges if Multiple Objective Alternative 2 is Implemented when
549 Compared to the No Action Alternative at Lower Monumental Dam Forebay
550 Under a 5-Year Range of River and Meteorological Conditions..... 5-50
551 Figure 5-44. Differences in the Percent of Time Total Dissolved Gas Would be Within
552 Selected Ranges if Multiple Objective Alternative 2 is Implemented when
553 Compared to the No Action Alternative at Ice Harbor Dam Forebay Under a 5-
554 Year Range of River and Meteorological Conditions..... 5-51
555 Figure 5-45. Modeled Tailwater Temperature for Multiple Objective Alternative 2 at
556 McNary Dam Under a 5-Year Range of River and Meteorological Conditions 5-53
557 Figure 5-46. Modeled Tailwater Temperature for Multiple Objective Alternative 2 at
558 John Day Dam Under a 5-Year Range of River and Meteorological Conditions..... 5-53
559 Figure 5-47. Modeled Tailwater Temperature for Multiple Objective Alternative 2 at The
560 Dalles Dam Under a 5-Year Range of River and Meteorological Conditions..... 5-54
561 Figure 5-48. Modeled Tailwater Temperature for Multiple Objective Alternative 2 at
562 Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions 5-54

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

563 Figure 5-49. Frequency of Modeled Tailwater Temperature Violations to State Water
564 Quality Standards for the No Action Alternative and Multiple Objective
565 Alternative 2 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-
566 Year Range of River and Meteorological Conditions..... 5-55
567 Figure 5-50. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 2 at
568 McNary Dam Under a 5-Year Range of River and Meteorological Conditions 5-57
569 Figure 5-51. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 2 at
570 John Day Dam Under a 5-Year Range of River and Meteorological Conditions..... 5-57
571 Figure 5-52. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 2 at
572 The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions..... 5-58
573 Figure 5-53. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 2 at
574 Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions 5-58
575 Figure 5-54. Frequency of Modeled Forebay Total Dissolved Gas Outside of Current Fish
576 Passage Spill Season for the No Action Alternative and Multiple Objective
577 Alternative 2 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-
578 Year Range of River and Meteorological Conditions..... 5-59
579 Figure 5-55. Frequency of modeled forebay Total Dissolved Gas violations of current 115
580 percent Total Dissolved Gas State water quality standards during current fish
581 passage spill season for the No Action Alternative and Multiple Objective
582 Alternative 2 at McNary, John Day, The Dalles, and Bonneville Dams under a 5-
583 year range of river and meteorological conditions 5-60
584 Figure 5-56. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 2
585 at McNary Dam Under a 5-Year Range of River and Meteorological Conditions 5-61
586 Figure 5-57. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 2
587 at John Day Dam Under a 5-Year Range of River and Meteorological Conditions 5-61
588 Figure 5-58. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 2
589 at The Dalles Dam Under a 5-Year Range of River and Meteorological
590 Conditions 5-62
591 Figure 5-59. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 2
592 at Bonneville Dam Under a 5-Year Range of River and Meteorological
593 Conditions 5-62
594 Figure 5-60. Frequency of Modeled Tailwater Total Dissolved Gas Outside of Current
595 Fish Passage Spill Season for the No Action Alternative and Multiple Objective
596 Alternative 2 at McNary, John Day, and The Dalles Dams Under a 5-Year Range
597 of River and Meteorological Conditions 5-63
598 Figure 5-61. Frequency of Modeled Forebay Total Dissolved Gas Violations of Current
599 120 percent Total Dissolved Gas State Water Quality Standards During Fish
600 Passage Spill Season for the No Action Alternative and Multiple Objective
601 Alternative 2 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-
602 Year Range of River and Meteorological Conditions..... 5-64
603 Figure 5-62. Modeled Forebay Elevation for Multiple Objective Alternative 2 at McNary
604 Dam Under a 5-Year Range of River and Meteorological Conditions 5-65
605 Figure 5-63. Modeled Forebay Elevation for Multiple Objective Alternative 2 at John Day
606 Dam Under a 5-Year Range of River and Meteorological Conditions 5-66

*Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix*

607 Figure 5-64. Modeled Forebay Elevation for Multiple Objective Alternative 2 at The
608 Dalles Dam Under a 5-Year Range of River and Meteorological Conditions..... 5-66
609 Figure 5-65. Modeled Forebay Elevation for Multiple Objective Alternative 2 at
610 Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions 5-67
611 Figure 6-1. Libby Dam-Lake Koochanusa Summary Forebay Elevations for Multiple
612 Objective Alternative 3 Versus the No Action Alternative 6-2
613 Figure 6-2. Libby Dam-Lake Koochanusa Summary Outflows for Multiple Objective
614 Alternative 3 Versus No Action Alternative..... 6-3
615 Figure 6-3. Hungry Horse Reservoir Summary Elevation Hydrograph for Multiple
616 Objective Alternative 3 Versus No Action Alternative 6-5
617 Figure 6-4. Albeni Falls Reservoir Summary Elevation Hydrographs and Outflows for
618 Multiple Objective Alternative 3 Versus No Action Alternative..... 6-6
619 Figure 6-5. Modeled Forebay Temperatures for No Action Alternative and Multiple
620 Objective Alternative 3 at Albeni Falls for 2004 to 2006..... 6-7
621 Figure 6-6. Modeled Tailwater Temperatures for No Action Alternative and Multiple
622 Objective Alternative 3 at Albeni Falls for 2004 to 2006..... 6-7
623 Figure 6-7. Modeled Tailwater Temperature for the No Action Alternative and Multiple
624 Objective Alternative 3 at Grand Coulee Dam Under a 5-Year Range of River
625 and Meteorological Conditions Compared to the Confederated Colville Tribe 1-
626 D Maximum Water Quality Standard 6-9
627 Figure 6-8. Chief Joseph Dam-Rufus Woods Lake Outflows for Multiple Objective
628 Alternative 3 Versus No Action Alternative..... 6-10
629 Figure 6-9. Chief Joseph Dam-Rufus Woods Lake Forebay Elevations Multiple Objective
630 Alternative 3 Versus No Action Alternative..... 6-10
631 Figure 6-10. Modeled Tailwater Temperature for the No Action Alternative and Multiple
632 Objective Alternative 3 at Chief Joseph Dam Under a 5-Year Range of River and
633 Meteorological Conditions 6-11
634 Figure 6-11. Modeled Tailwater Total Dissolved Gas and Spillway Flows for the No Action
635 Alternative and Multiple Objective Alternative 3 at Libby Dam over an 80-Year
636 Period..... 6-12
637 Figure 6-12. Number of Days Modeled Tailwater Total Dissolved Gas Exceeds the 110
638 percent State of Montana Water Quality Standards for the No Action
639 Alternative and Multiple Objective Alternative 3 at Libby Dam over an 80-Year
640 Period..... 6-13
641 Figure 6-13. Number of Days that Total Dissolved Gas is Above the 110 percent State
642 Water Quality Standard Under the No Action Alternative and Multiple
643 Objective Alternative 3 at Hungry Horse Dam 6-14
644 Figure 6-14. Modeled Tailwater Spillway Flows for the No Action Alternative and
645 Multiple Objective Alternative 3 at Albeni Falls Dam over an 80-Year Period 6-15
646 Figure 6-15. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and
647 Multiple Objective Alternative 3 at Grand Coulee Dam Under a 5-Year Range of
648 River and Meteorological Conditions 6-17

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

649 Figure 6-16. Modeled Range of Tailwater Total Dissolved Gas for the No Action
650 Alternative and Multiple Objective Alternative 3 at Grand Coulee Dam Under a
651 5-Year Range of River and Meteorological Conditions..... 6-17
652 Figure 6-17. Modeled Forebay Total Dissolved Gas Saturations for the No Action
653 Alternative and Multiple Objective Alternative 3 at Chief Joseph Dam Under a
654 5-Year Range of River and Meteorological Conditions..... 6-18
655 Figure 6-18. Modeled Tailwater Total Dissolved Gas Saturations for the No Action
656 Alternative and Multiple Objective Alternative 3 at Chief Joseph Dam Under a
657 5-Year Range of River and Meteorological Conditions..... 6-19
658 Figure 6-19. Days Exceeding the 110 percent TDG criteria for the No Action Alternative
659 and Multiple Objective Alternative 3 at Chief Joseph Dam Tailwater Under a 5-
660 Year Range of River and Meteorological Conditions..... 6-19
661 Figure 6-20. Summary Discharge Hydrograph, Grand Coulee Dam, for Multiple Objective
662 Alternative 3 Versus No Action Alternative..... 6-22
663 Figure 6-21. Modeled Forebay Elevations for the No Action Alternative and Multiple
664 Objective Alternative 3 at Grand Coulee Dam Under a 5-Year Range of River
665 and Meteorological Conditions 6-23
666 Figure 6-22. Modeled Tailwater Temperature for the No Action Alternative and Multiple
667 Objective Alternative 3 at Dworshak Dam Under a 5-Year Range of River and
668 Meteorological Conditions 6-24
669 Figure 6-23. Modeled Tailwater Temperatures for the No Action Alternative and
670 Multiple Objective Alternative 3 at Lower Granite Dam for Individual Flow and
671 Meteorological Conditions and Averaged 5-Year Conditions 6-27
672 Figure 6-24. Modeled Tailwater Temperatures for the No Action Alternative and
673 Multiple Objective Alternative 3 at Little Goose Dam for Individual Flow and
674 Meteorological Conditions and Averaged 5-Year Conditions 6-28
675 Figure 6-25. Modeled Tailwater Temperatures for the No Action Alternative and
676 Multiple Objective Alternative 3 at Lower Monumental Dam for Individual Flow
677 and Meteorological Conditions and Averaged 5-Year Conditions 6-29
678 Figure 6-26. Modeled Tailwater Temperatures for the No Action Alternative and
679 Multiple Objective Alternative 3 at Ice Harbor Dam for Individual Flow and
680 Meteorological Conditions and Averaged 5-Year Conditions 6-30
681 Figure 6-27. Average Temperature Differences Between Multiple Objective Alternative 3
682 and No Action Alternative for each Month at the Four Lower Snake River Dam
683 Locations 6-31
684 Figure 6-28. Model Results for the Maximum Daily Temperatures that Would be
685 Anticipated at the Four Lower Snake River Dam Locations if Multiple Objective
686 Alternative 3 is Implemented 6-32
687 Figure 6-29. Average Diel Temperature Differences by Month that Would Occur at the
688 Four Current Lower Snake River Station Locations if Multiple Objective
689 Alternative 3 is Implemented 6-37
690 Figure 6-30. Comparison of Average Multiple Objective Alternative 3 and No Action
691 Alternative Model Results for the Current Lower Granite Tailwater Location to

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

692	Historical Snake River Water Temperatures Recorded near Central Ferry and	
693	Clarkston, Washington.....	6-38
694	Figure 6-31. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and	
695	Multiple Objective Alternative 3 at Dworshak Dam Under a 5-Year Range of	
696	River and Meteorological Conditions	6-40
697	Figure 6-32. Modeled Tailwater Temperature for Multiple Objective Alternative 3 at	
698	McNary Dam Under a 5-Year Range of River and Meteorological Conditions	6-46
699	Figure 6-33. Modeled Tailwater Temperature for Multiple Objective Alternative 3 at	
700	John Day Dam Under a 5-Year Range of River and Meteorological Conditions.....	6-46
701	Figure 6-34. Modeled Tailwater Temperature for Multiple Objective Alternative 3 at The	
702	Dalles Dam Under a 5-Year Range of River and Meteorological Conditions.....	6-47
703	Figure 6-35. Modeled Tailwater Temperature for Multiple Objective Alternative 3 at	
704	Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions	6-47
705	Figure 6-36. Frequency of Modeled Tailwater Temperature Violations to State Water	
706	Quality Standards for the No Action Alternative and Multiple Objective	
707	Alternative 3 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-	
708	Year Range of River and Meteorological Conditions.....	6-48
709	Figure 6-37. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 3 at	
710	McNary Dam Under a 5-Year Range of River and Meteorological Conditions	6-50
711	Figure 6-38. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 3 at	
712	John Day Dam Under a 5-Year Range of River and Meteorological Conditions.....	6-50
713	Figure 6-39. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 3 at	
714	The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions.....	6-51
715	Figure 6-40. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 3 at	
716	Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions	6-51
717	Figure 6-41. Frequency of Modeled Forebay Total Dissolved Gas Outside of Current Fish	
718	Passage Spill Season for the No Action Alternative and Multiple Objective	
719	Alternative 3 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-	
720	Year Range of River and Meteorological Conditions.....	6-52
721	Figure 6-42. Frequency of Modeled Forebay Total Dissolved Gas Violations of Current	
722	115 Percent Total Dissolved Gas State Water Quality Standards During Current	
723	Fish Passage Spill for the No Action Alternative and Multiple Objective	
724	Alternative 3 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-	
725	Year Range of River And Meteorological Conditions	6-53
726	Figure 6-43. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 3	
727	at McNary Dam Under a 5-Year Range of River and Meteorological Conditions	6-54
728	Figure 6-44. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 3	
729	at John Day Dam Under a 5-Year Range of River and meteorological Conditions.....	6-54
730	Figure 6-45. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 3	
731	at The Dalles Dam Under a 5-Year Range of River and Meteorological	
732	Conditions	6-55
733	Figure 6-46. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 3	
734	at Bonneville Dam Under a 5-Year Range of River and Meteorological	
735	Conditions	6-55

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

736 Figure 6-47. Frequency of Modeled Tailwater Total Dissolved Gas Outside of Current
737 Fish Passage Spill Season for the No Action Alternative and Multiple Objective
738 Alternative 3 at McNary, John Day, and The Dalles Dams Under a 5-Year Range
739 of Meteorological Conditions 6-56
740 Figure 6-48. Frequency of Modeled Forebay Total Dissolved Gas During Current Fish
741 Passage Spill Season for the No Action Alternative and Multiple Objective
742 Alternative 3 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-
743 Year Range of River and Meteorological Conditions..... 6-57
744 Figure 6-49. Modeled Forebay Elevation for Multiple Objective Alternative 3 at McNary
745 Dam Under a 5-Year Range of River and Meteorological Conditions 6-59
746 Figure 6-50. Modeled Forebay Elevation for Multiple Objective Alternative 3 at John Day
747 Dam Under a 5-Year Range of River and Meteorological Conditions 6-59
748 Figure 6-51. Modeled Forebay Elevation for Multiple Objective Alternative 3 at The
749 Dalles Dam Under a 5-Year Range of River and Meteorological Conditions..... 6-60
750 Figure 6-52. Modeled Forebay Elevation for Multiple Objective Alternative 3 at
751 Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions 6-60
752 Figure 6-53. Conceptual Model of Sediment Within River System After Dam Breach 6-62
753 Figure 7-1. Libby Dam–Lake Kocanusa Summary Forebay Elevations for Multiple
754 Objective Alternative 4 Versus No Action Alternative. 7-2
755 Figure 7-2. Libby Dam–Lake Kocanusa Summary Outflows for Multiple Objective
756 Alternative 4 Versus No Action Alternative..... 7-3
757 Figure 7-3. Hungry Horse Summary Forebay Elevations for Multiple Objective Alternative
758 4 Versus No Action Alternative..... 7-4
759 Figure 7-4. Albeni Falls Dam Summary Elevation Hydrographs and Outflows for Multiple
760 Objective Alternative 4 Versus the No Action Alternative 7-6
761 Figure 7-5. Modeled Forebay Temperatures for Multiple Objective Alternative 4 and No
762 Action Alternative at Albeni Falls for 2004 to 2006..... 7-7
763 Figure 7-6. Modeled Tailwater Temperatures for Multiple Objective Alternative 4 and No
764 Action Alternative at Albeni Falls for 2004–2006..... 7-7
765 Figure 7-7. Grand Coulee Reservoir Summary Elevation Hydrograph for Multiple
766 Objective Alternative 4 Versus No Action Alternative 7-9
767 Figure 7-8. Grand Coulee Dam Summary Outflows for Multiple Objective Alternative 4
768 Versus No Action Alternative..... 7-10
769 Figure 7-9. Modeled Tailwater Temperature for Multiple Objective Alternative 4 and No
770 Action Alternative at Grand Coulee Dam Under a 5-year Range of River and
771 Meteorological Conditions Compared to the Confederated Colville Tribe 1-D
772 Maximum Water Quality Standard..... 7-11
773 Figure 7-10. Modeled Tailwater Temperature for Multiple Objective Alternative 4 and
774 No Action Alternative at Wells Dam Under a 5-year Range of River and
775 Meteorological Conditions 7-11
776 Figure 7-11. Modeled Tailwater Temperature for Multiple Objective Alternative 4 and
777 No Action Alternative at Rocky Reach Dam Under a 5-year Range of River and
778 Meteorological Conditions 7-12

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

779 Figure 7-12. Chief Joseph Dam–Rufus Woods Lake Outflows for Multiple Objective
780 Alternative 4 Versus No Action Alternative 7-13
781 Figure 7-13. Chief Joseph Dam–Rufus Woods Lake Forebay Elevations for Multiple
782 Objective Alternative 4 Versus No Action Alternative 7-13
783 Figure 7-14. Modeled tailwater temperature for Multiple Objective Alternative 4 and No
784 Action Alternative at Chief Joseph Dam Under a 5-year Range of River and
785 Meteorological Conditions 7-14
786 Figure 7-15. Modeled Tailwater Total Dissolved Gas and Spillway Flows for Multiple
787 Objective Alternative 4 and No Action Alternative at Libby Dam over an 80-year
788 period..... 7-15
789 Figure 7-16. Number of Days Modeled Tailwater Total Dissolved Gas Exceeds the 110
790 percent State Water Quality Standards for Multiple Objective Alternative 4 and
791 No Action Alternative at Libby Dam over an 80-year Period 7-16
792 Figure 7-17. Number of Days Modeled Tailwater Total Dissolved Gas Exceeds the 110
793 percent State Water Quality Standards for Multiple Objective Alternative 4 and
794 No Action Alternative at Hungry Horse Dam over an 80-year Period..... 7-16
795 Figure 7-18. Modeled Tailwater Spillway Flows for Multiple Objective Alternative 4 and
796 No Action Alternative at Albeni Falls Dam over an 80-year Period..... 7-17
797 Figure 7-19. Modeled Tailwater Total Dissolved Gas 5-year Daily Average, Minimum, and
798 Maximum for Multiple Objective Alternative 4 and No Action Alternative at
799 Grand Coulee Dam..... 7-19
800 Figure 7-20. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4
801 and No Action Alternative at Grand Coulee Dam Under a 5-year Range of River
802 and Meteorological Conditions 7-19
803 Figure 7-21. Modeled forebay and tailwater Total Dissolved Gas saturations for Multiple
804 Objective Alternative 4 and No Action Alternative at Chief Joseph Dam Under a
805 5-year Range of River and Meteorological Conditions..... 7-21
806 Figure 7-22. Days Exceeding the 110 percent Total Dissolved Gas Criteria for Multiple
807 Objective Alternative 4 and No Action Alternative at Chief Joseph Dam
808 Tailwater Under a 5-year Range of River and Meteorological Conditions..... 7-22
809 Figure 7-23. Modeled Forebay Elevations for Multiple Objective Alternative 4 and No
810 Action Alternative Grand Coulee Dam Under a 5-year Range of River and
811 Meteorological Conditions 7-24
812 Figure 7-24. Modeled Retention Times at Lake Roosevelt for No Action Alternative and
813 Multiple Objective Alternative 4 7-25
814 Figure 7-25. Modeled Tailwater Temperature for Multiple Objective Alternative 4 and
815 No Action Alternative at Dworshak Dam Under a 5-year Range of River and
816 Meteorological Conditions 7-26
817 Figure 7-26. Modeled Tailwater Temperatures for Multiple Objective Alternative 4 and
818 No Action Alternative at Lower Granite and Little Goose Dams Under a 5-year
819 Range of River and Meteorological Conditions 7-27
820 Figure 7-27. Modeled Tailwater Temperatures for Multiple Objective Alternative 4 and
821 No Action Alternative at Lower Monumental and Ice Harbor Dams Under a 5-
822 year Range of River and Meteorological Conditions 7-28

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

823 Figure 7-28. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4
824 and No Action Alternative at Dworshak Dam Under a 5-year Range of River and
825 Meteorological Conditions 7-30
826 Figure 7-29. Difference in the Number of Hours each Year when Total Dissolved Gas
827 Would Violate Idaho's 110 percent Water Quality Standard at the Dworshak
828 Dam Tailwater Fixed Monitoring Station, for Each Flow/Temperature
829 Condition, Under Multiple Objective Alternative 4 and No Action Alternative 7-30
830 Figure 7-30. Modeled Tailwater Total Dissolved Gas for the Multiple Objective
831 Alternative 4 and No Action Alternative at Lower Granite and Little Goose
832 Dams Under a 5-year Range of River and Meteorological Conditions 7-31
833 Figure 7-31. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4
834 and No Action Alternative at Lower Monumental and Ice Harbor Dams Under a
835 5-year Range of River and Meteorological Conditions 7-32
836 Figure 7-32. No Action Alternative and Multiple Objective Alternative 4 March through
837 August Frequency Distributions for Selected Tailwater Total Dissolved Gas
838 Intervals at the Four Lower Snake River Projects 7-33
839 Figure 7-33. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 4
840 and No Action Alternative at Lower Granite and Little Goose Dams Under a 5-
841 year Range of River and Meteorological Conditions 7-36
842 Figure 7-34. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 4
843 and No Action Alternative at Lower Monumental and Ice Harbor Dams Under a
844 5-year Range of River and Meteorological Conditions 7-37
845 Figure 7-35. No Action Alternative and Multiple Objective Alternative 4 March through
846 August Frequency Distributions for Selected Forebay Total Dissolved Gas
847 Intervals 7-38
848 Figure 7-36. Modeled Tailwater Temperature for Multiple Objective Alternative 4 at
849 McNary Dam Under a 5-year Range of River and Meteorological Conditions 7-40
850 Figure 7-37. Modeled Tailwater Temperature for Multiple Objective Alternative 4 at
851 John Day Dam Under a 5-year Range of River and Meteorological Conditions 7-41
852 Figure 7-38. Modeled Tailwater Temperature for Multiple Objective Alternative 4 at The
853 Dalles Dam Under a 5-year Range of River and Meteorological Conditions 7-41
854 Figure 7-39. Modeled Tailwater Temperature for Multiple Objective Alternative 4 at
855 Bonneville Dam Under a 5-year Range of River and Meteorological Conditions 7-42
856 Figure 7-40. Frequency of Modeled Tailwater Temperature Violations of State Water
857 Quality Standards for Multiple Objective Alternative 4 and No Action
858 Alternative at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-
859 year Range of River and Meteorological Conditions 7-42
860 Figure 7-41. Modeled Forebay Total Dissolved Gas for the Multiple Objective Alternative
861 4 at McNary Dam Under a 5-year Range of River and Meteorological Conditions 7-44
862 Figure 7-42. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 4 at
863 John Day Dam Under a 5-year Range of River and Meteorological Conditions 7-45
864 Figure 7-43. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 4 at
865 The Dalles Dam Under a 5-year Range of River and Meteorological Conditions 7-45

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

866 Figure 7-44. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 4 at
867 Bonneville Dam Under a 5-year Range of River and Meteorological Conditions 7-46
868 Figure 7-45. Frequency of Modeled Forebay Total Dissolved Gas Outside of Current Fish
869 Passage Spill Season for Multiple Objective Alternative 4 and No Action
870 Alternative at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-
871 year Range of River and Meteorological Conditions 7-47
872 Figure 7-46. Frequency of Modeled Forebay Total Dissolved Gas During Current Fish
873 Passage Spill Season for Multiple Objective Alternative 4 and No Action
874 Alternative at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-
875 year Range of River and Meteorological Conditions 7-48
876 Figure 7-47. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4
877 at McNary Dam Under a 5-year Range of River and Meteorological Conditions 7-49
878 Figure 7-48. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4
879 at John Day Dam Under a 5-year Range of River and Meteorological Conditions..... 7-49
880 Figure 7-49. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4
881 at The Dalles Dam Under a 5-year Range of River and Meteorological
882 Conditions 7-50
883 Figure 7-50. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4
884 at Bonneville Dam Under a 5-year Range of River and Meteorological
885 Conditions 7-50
886 Figure 7-51. Frequency of Modeled Tailwater Total Dissolved Gas Outside of Current
887 Fish Passage Spill Season for Multiple Objective Alternative 4 and No Action
888 Alternative at McNary, John Day, and The Dalles Dams Under a 5-year Range of
889 River and Meteorological Conditions 7-51
890 Figure 7-52. Frequency of Modeled Forebay Total Dissolved Gas During Current Fish
891 Passage Spill Season for Multiple Objective Alternative 4 and No Action
892 Alternative at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-
893 year Range of River and Meteorological Conditions 7-52
894 Figure 7-53. Modeled Forebay Elevation for Multiple Objective Alternative 4 at McNary
895 Dam Under a 5-year Range of River and Meteorological Conditions 7-53
896 Figure 7-54. Modeled Forebay Elevation for Multiple Objective Alternative 4 at John Day
897 Dam Under a 5-year Range of River and Meteorological Conditions 7-54
898 Figure 7-55. Modeled Forebay Elevation for Multiple Objective Alternative 4 at The
899 Dalles Dam Under a 5-year Range of River and Meteorological Conditions..... 7-54
900 Figure 7-56. Modeled Forebay Elevation for Multiple Objective Alternative 4 at
901 Bonneville Dam Under a 5-year Range of River and Meteorological Conditions 7-55
902 Figure 8-1. Libby Dam–Lake Koochanusa Summary Elevations for Preferred Alternative
903 Versus No Action Alternative..... 8-2
904 Figure 8-2. Libby Dam–Lake Koochanusa Summary Outflows for Preferred Alternative
905 Versus No Action Alternative..... 8-3
906 Figure 8-3. Albeni Falls Dam Summary Elevation Hydrographs and Outflows for Preferred
907 Alternative Versus the No Action Alternative 8-5
908 Figure 8-4. Modeled Forebay Temperatures for Preferred Alternative and No Action
909 Alternative at Albeni Falls for 2004 to 2006 8-6

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

910 Figure 8-5. Modeled Tailwater Temperatures for Preferred Alternative and No Action
911 Alternative at Albeni Falls for 2004–2006 8-6
912 Figure 8-6. Modeled Range of Tailwater Total Dissolved Gas for the No Action
913 Alternative and Multiple Objective Alternative 2 at Grand Coulee Dam Under a
914 5-Year Range of River and Meteorological Conditions..... 8-7
915 Figure 8-7. Chief Joseph Dam–Rufus Woods Lake Forebay Elevations for Preferred
916 Alternative Versus No Action Alternative..... 8-8
917 Figure 8-8. Chief Joseph Dam–Rufus Woods Lake Outflows for Preferred Alternative
918 Versus No Action Alternative..... 8-9
919 Figure 8-9. Modeled tailwater temperature for Preferred Alternative and No Action
920 Alternative at Chief Joseph Dam Under a 5-year Range of River and
921 Meteorological Conditions 8-9
922 Figure 8-10. Modeled Tailwater Total Dissolved Gas and Spillway Flows for Preferred
923 Alternative and No Action Alternative at Libby Dam over an 80-year period 8-11
924 Figure 8-11. Number of Days Modeled Tailwater Total Dissolved Gas Exceeds the 110
925 percent State Water Quality Standards for Preferred Alternative and No Action
926 Alternative at Libby Dam over an 80-year Period 8-12
927 Figure 8-12. Modeled Tailwater Total Dissolved Gas and Spillway Flows for Preferred
928 Alternative and No Action Alternative at Hungry Horse Dam over an 80-year
929 period..... 8-12
930 Figure 8-13. Modeled Tailwater Spillway Flows for Preferred Alternative and No Action
931 Alternative at Albeni Falls Dam over an 80-year Period..... 8-14
932 Figure 8-14. Modeled forebay and tailwater Total Dissolved Gas saturations for
933 Preferred Alternative and No Action Alternative at Grand Coulee Dam Under a
934 5-year Range of River and Meteorological Conditions..... 8-15
935 Figure 8-15. Modeled forebay and tailwater Total Dissolved Gas saturations for
936 Preferred Alternative and No Action Alternative at Chief Joseph Dam Under a
937 5-year Range of River and Meteorological Conditions..... 8-17
938 Figure 8-16. Days Exceeding the 110 percent Total Dissolved Gas Criteria for Preferred
939 Alternative and No Action Alternative at Chief Joseph Dam Tailwater Under a
940 5-year Range of River and Meteorological Conditions..... 8-18
941 Figure 8-17. Modeled Forebay Elevations for the No Action Alternative and the
942 Preferred Alternative at Grand Coulee Dam Under a 5-Year Range of River and
943 Meteorological Conditions 8-21
944 Figure 8-18. Differences Between Dworshak Reservoir Pool Elevations for the Preferred
945 Alternative and the No Action Alternative for the 5-Year Range of Flow and
946 Meteorological Conditions Modeled 8-22
947 Figure 8-19. Modeled Tailwater Temperature for the Preferred Alternative and No
948 Action Alternative at Dworshak Dam Under a 5-year Range of River and
949 Meteorological Conditions 8-23
950 Figure 8-20. Modeled Tailwater Temperatures for the Preferred Alternative and No
951 Action Alternative at Lower Granite and Little Goose Dams Under a 5-year
952 Range of River and Meteorological Conditions 8-25

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

953 Figure 8-21. Modeled Tailwater Temperatures for the Preferred Alternative and No
954 Action Alternative at Lower Monumental and Ice Harbor Dams Under a 5-year
955 Range of River and Meteorological Conditions 8-26
956 Figure 8-22. Average Temperature Differences Between the Preferred Alternative and
957 the No Action Alternative for April Through September at the Four Lower
958 Snake River Dam Tailwater Locations for the Five Flow and Air Temperature
959 Conditions 8-27
960 Figure 8-23. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative and No
961 Action Alternative at Dworshak Dam Under a 5-Year Range of River and
962 Meteorological Conditions 8-29
963 Figure 8-24. Frequency Distributions for Dworshak Tailwater Total Dissolved Gas for the
964 No Action Alternative and Preferred Alternative for April through August
965 during the five flow and air temperature conditions 8-30
966 Figure 8-25. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative and No
967 Action Alternative at Lower Granite and Little Goose Dams Under a 5-year
968 Range of River and Meteorological Conditions 8-33
969 Figure 8-26. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative and No
970 Action Alternative at Lower Monumental and Ice Harbor Dams Under a 5-year
971 Range of River and Meteorological Conditions 8-34
972 Figure 8-27. No Action Alternative and Preferred Alternative April through August
973 Frequency Distributions for Selected Tailwater Total Dissolved Gas Intervals at
974 the Four Lower Snake River Projects 8-35
975 Figure 8-28. Maximum monthly tailwater TDG modeled for the No Action and Preferred
976 Alternatives for the 5 flow and air temperature conditions 8-37
977 Figure 8-29. Modeled Forebay Total Dissolved Gas for Preferred Alternative and No
978 Action Alternative at Lower Granite and Little Goose Dams Under a 5-year
979 Range of River and Meteorological Conditions 8-38
980 Figure 8-30. Modeled Forebay Total Dissolved Gas for Preferred Alternative 4 and No
981 Action Alternative at Lower Monumental and Ice harbor Dams Under a 5-year
982 Range of River and Meteorological Conditions 8-39
983 Figure 8-31. No Action Alternative and Preferred Alternative April through August
984 Frequency Distributions for Selected Forebay Total Dissolved Gas Intervals at
985 the Four Lower Snake River Projects 8-40
986 Figure 8-32. Maximum monthly forebay TDG modeled for the No Action and Preferred
987 Alternatives for the 5 flow and air temperature conditions. 8-42
988 Figure 8-33. Modeled Tailwater Temperature for the Preferred Alternative at McNary
989 Dam Under a 5-year Range of River and Meteorological Conditions 8-44
990 Figure 8-34. Modeled Tailwater Temperature for the Preferred Alternative at John Day
991 Dam Under a 5-year Range of River and Meteorological Conditions 8-44
992 Figure 8-35. Modeled Tailwater Temperature for the Preferred Alternative at The Dalles
993 Dam Under a 5-year Range of River and Meteorological Conditions 8-45
994 Figure 8-36. Modeled Tailwater Temperature for the Preferred Alternative at Bonneville
995 Dam Under a 5-year Range of River and Meteorological Conditions 8-45

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

996 Figure 8-37. Frequency of Modeled Tailwater Temperature Violations of State Water
997 Quality Standards the Preferred Alternative and No Action Alternative at
998 McNary, John Day, The Dalles, and Bonneville Dams Under a 5-year Range of
999 River and Meteorological Conditions 8-46
1000 Figure 8-38. Modeled Forebay Total Dissolved Gas for the Preferred Alternative at
1001 McNary Dam Under a 5-year Range of River and Meteorological Conditions..... 8-48
1002 Figure 8-39. Modeled Forebay Total Dissolved Gas for the Preferred Alternative at John
1003 Day Dam Under a 5-year Range of River and Meteorological Conditions 8-48
1004 Figure 8-40. Modeled Forebay Total Dissolved Gas for Preferred Alternative at The
1005 Dalles Dam Under a 5-year Range of River and Meteorological Conditions..... 8-49
1006 Figure 8-41. Modeled Forebay Total Dissolved Gas for the Preferred Alternative at
1007 Bonneville Dam Under a 5-year Range of River and Meteorological Conditions 8-49
1008 Figure 8-42. Frequency of Modeled Forebay Total Dissolved Gas Outside of Current Fish
1009 Passage Spill Season for the Preferred Alternative and No Action Alternative at
1010 McNary, John Day, The Dalles, and Bonneville Dams Under a 5-year Range of
1011 River and Meteorological Conditions 8-50
1012 Figure 8-43. Frequency of Modeled Forebay Total Dissolved Gas During Current Fish
1013 Passage Spill Season for the Preferred Alternative and No Action Alternative at
1014 McNary, John Day, The Dalles, and Bonneville Dams Under a 5-year Range of
1015 River and Meteorological Conditions 8-51
1016 Figure 8-44. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative at
1017 McNary Dam Under a 5-year Range of River and Meteorological Conditions..... 8-52
1018 Figure 8-45. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative at John
1019 Day Dam Under a 5-year Range of River and Meteorological Conditions 8-52
1020 Figure 8-46. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative at The
1021 Dalles Dam Under a 5-year Range of River and Meteorological Conditions..... 8-53
1022 Figure 8-47. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative at
1023 Bonneville Dam Under a 5-year Range of River and Meteorological Conditions 8-53
1024 Figure 8-48. Frequency of Modeled Tailwater Total Dissolved Gas Outside of Current
1025 Fish Passage Spill Season for the Preferred Alternative and No Action
1026 Alternative at McNary, John Day, and The Dalles Dams Under a 5-year Range of
1027 River and Meteorological Conditions 8-54
1028 Figure 8-49. Frequency of Modeled Forebay Total Dissolved Gas During Current Fish
1029 Passage Spill Season for the Preferred Alternative and No Action Alternative at
1030 McNary, John Day, The Dalles, and Bonneville Dams Under a 5-year Range of
1031 River and Meteorological Conditions 8-55
1032 Figure 8-50. Modeled Forebay Elevation for the Preferred Alternative at John Day Dam
1033 Under a 5-year Range of River and Meteorological Conditions..... 8-57
1034
1035

1036

ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	micrograms per liter
1D	one-dimensional
2D	two-dimensional
AF/AT	average flow/average temperature
AF/LT	average inflow/low temperature
amsl	above mean sea level
BiOp	biological opinion
Bonneville Corps	Bonneville Power Administration U.S. Army Corps of Engineers
CRSO	Columbia River System Operations
CWA	Clean Water Act
DO	dissolved oxygen
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FRM	flood risk management
g/m ² /day	grams per meter squared per day
HEC	Hydrologic Engineering Center
HEC-RAS	HEC River Analysis System
HF/LT	high inflow/low temperature
IDEQ	Idaho Department of Environmental Quality
kaf	thousand acre-feet
kcfs	thousand cubic feet per second
LF/AT	low flow/average temperature
LF/HT	low flow/high temperature
LSR	Lower Snake River
Maf	million acre-feet
Mcy	million cubic yards
MFWP	Montana Fish, Wildlife, and Parks
mg/L	milligrams per liter
MO	Multiple Objective Alternative
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PCBs	polychlorinated biphenyls

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

Reclamation	U.S. Bureau of Reclamation
ResSim	Reservoir System Simulation
RM	River Mile
RSET	Northwest Regional Sediment Evaluation Team
SEF	Sediment Evaluation Framework
SOD	sediment oxygen demand
SRD	storage reservation diagram
SWS	selective withdrawal structure
TDG	total dissolved gas
TMDL	total maximum daily load
TN:TP	total nitrogen to total phosphorus
TSS	total suspended solids
U.S.	United States
USGS	U.S. Geological Survey
W2	CE-QUAL-W2 model

1037

1038

CHAPTER 1 - INTRODUCTION

1039 The Columbia River System is composed of 12 U.S. Army Corps of Engineers (Corps)
1040 hydroelectric projects and 2 U.S. Bureau of Reclamation (Reclamation) hydroelectric projects
1041 located throughout the Pacific Northwest in the states of Idaho, Oregon, Montana, and
1042 Washington. Bonneville Power Administration (Bonneville) markets and transmits the
1043 hydropower generated from these projects. These projects are operated in a coordinated
1044 manner for purposes specifically authorized by Congress: flood risk management, navigation,
1045 fish and wildlife conservation, hydropower generation, recreation, irrigation, water quality, and
1046 municipal and industrial water supply. The system is operated for the maximum sustained
1047 benefit for the public good, and the equitable distribution of benefits through coordination
1048 with other project operators in the Columbia River Basin and with Bonneville. Through the
1049 National Environmental Policy Act (NEPA) process, water and sediment quality impacts
1050 resulting from operational and configuration changes, as identified in the environmental impact
1051 statement (EIS) alternatives, are evaluated to inform the selection of a preferred alternative.

1052 Water and sediment quality are related, and human actions that affect water quality may also
1053 affect sediment quality. However, sediment is a distinct phase that is held in the watershed
1054 much longer than water. Most sediment moves downstream only periodically in response to
1055 high flow conditions, while water moves continually through the system. Because sediment
1056 tends to move more slowly, pollutants associated with the sediment are held in the system
1057 longer than pollutants in the water. Pollutants in the water can move into the sediment and
1058 sediment pollutants can move into the water, but not all of the pollutants and quality issues are
1059 the same for water and sediment. For example, total dissolved gas (TDG) is an issue for water
1060 but not for sediment. Water and sediment quality impacts are both discussed in this appendix,
1061 but they are addressed separately for each alternative.

1062 Chapter 2 of this appendix describes the models and other methods used to predict impacts to
1063 water quality from each alternative. Subsequent chapters summarize predicted future water
1064 and sediment quality conditions for Columbia River System Operations (CRSO) EIS alternatives.
1065 Water quality parameters such as water temperature, TDG, dissolved oxygen, pH, specific
1066 conductivity, general water chemistry, water clarity, nutrients, contaminants, plankton,
1067 microbes, and chlorophyll are addressed.

1068 Five alternatives are evaluated for water and sediment quality impacts, including the No Action
1069 Alternative and four Multiple Objective Alternatives (MOs; see Chapter 2 of the main EIS report
1070 for detailed descriptions of alternatives). Each MO includes specific measures intended to
1071 achieve those objectives; the MOs include proposed actions at multiple locations. The focus of
1072 this chapter is the water and sediment quality throughout the CRSO study area. The
1073 alternatives are not presented in order of preference. Water and sediment quality impacts are
1074 two of the many considerations for the selection of a preferred alternative. The
1075 recommendations for the implementation of any alternatives or actions are found in Chapter 7.

1076

CHAPTER 2 - GENERAL METHODOLOGY

2.1 OVERVIEW

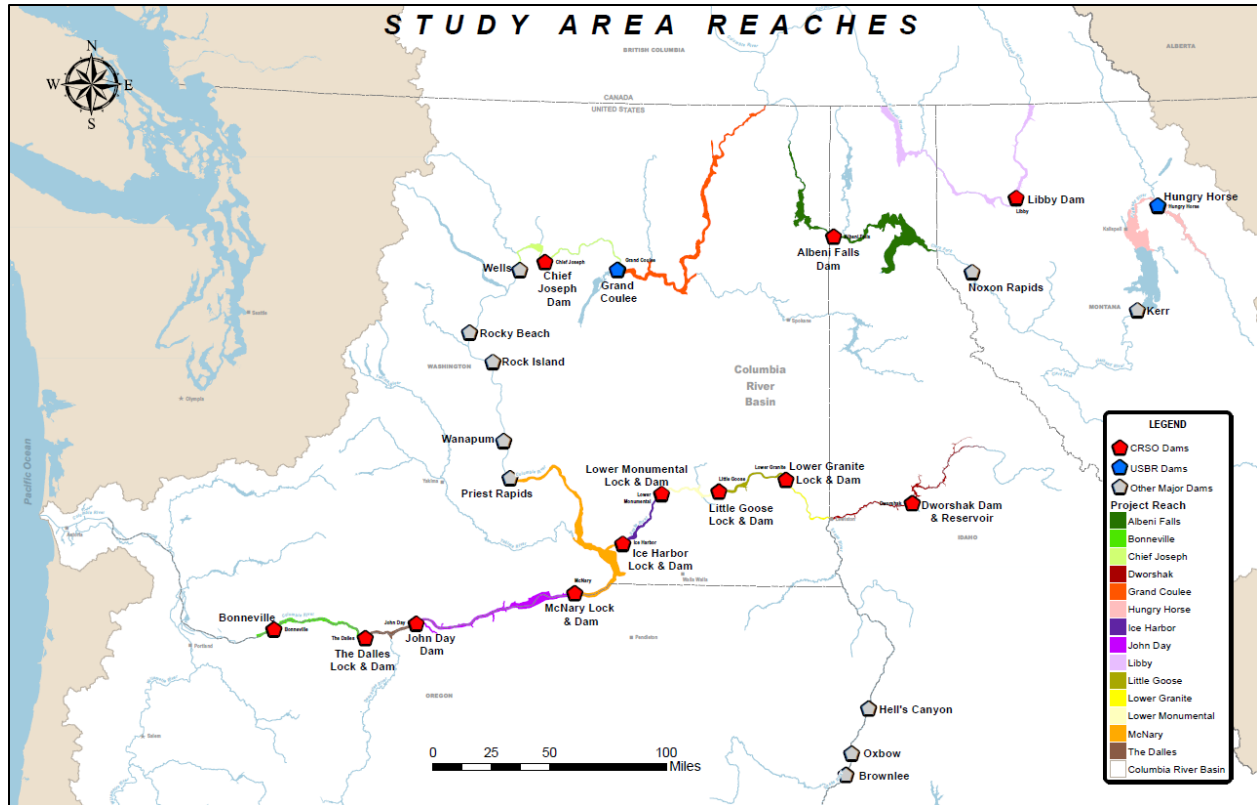
1078 Impacts to water quality from CRSO EIS alternatives were evaluated using numerical modeling
1079 and qualitative analysis methods. Numerical modeling was used to simulate the effects of the
1080 CRSO EIS alternatives on water temperature and TDG, while qualitative analysis methods were
1081 used to predict impacts to other physical, chemical, and biological processes. Numerical
1082 modeling is described in Sections 2.2 and 2.3, and qualitative analysis methods are discussed in
1083 Sections 2.4 and 2.5. Numerical modeling assumes a standard set of assumptions, and does not
1084 capture real-time adaptive management. So model results may be imprecise in some regards,
1085 but are useful tools to use in comparative studies like this EIS. The numerical models were also
1086 not used to predict future impacts from climate change. Instead, qualitative assessments were
1087 conducted to make predictions of the effects of climate change on water quality conditions.
1088 This information can be found in Chapter 4 of the EIS.

1089 Numerical water quality modeling of rivers requires river condition, reservoir operation, and
1090 meteorological data (such as wind speed and direction, air temperature, and barometric
1091 pressure) to predict water temperature and TDG. River condition and reservoir operation data,
1092 including total discharge, spillway and powerhouse operations, miscellaneous discharge, and
1093 reservoir/tailwater elevation data, was derived from the Corps Hydrologic Engineering Center
1094 (HEC) Reservoir System Simulation (ResSim) model as informed by HydSim. ResSim is a Corps
1095 reservoir operation model while HydSim is a Bonneville hydropower operation model. The
1096 purpose of the Corps model is to evaluate flood risk management, whereas the Bonneville
1097 model is for determining hydropower operations. For this EIS, flow datasets from the ResSim
1098 model were used in the water quality models to simulate the effects that each EIS alternatives
1099 may have on water quality.

1100 Sediment quality impacts were evaluated qualitatively. There are no sediment quality models
1101 for the CRSO EIS. Sediment quality was evaluated based on the known existing sediment
1102 characteristics and professional assessment of the impact of sediment movement on the
1103 conditions in the river. Estimates of sediment transport and channel bed changes were
1104 provided by the Geomorphology Team (Appendix C, *River Mechanics*).

2.2 STUDY AREA

1106 The area considered in this water and sediment quality evaluation consists of the Columbia
1107 River and its tributaries (Snake, Clearwater, Pend Oreille, Flathead, and Kootenai Rivers) from
1108 the U.S.-Canada border to downstream of Bonneville Dam at Warrendale, Oregon. This includes
1109 the Federal dams of Hungry Horse, Libby, Albeni Falls, Grand Coulee, Chief Joseph, Dworshak,
1110 Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and
1111 Bonneville (Figure 2-1.).



1112
1113 **Figure 2-1. Columbia River System Operations Environmental Impact Statement Water**
1114 **Quality Study Area Map**

1115 The area downstream of Warrendale, Oregon, to the outlet of the Columbia is not included in
1116 this evaluation of water quality, as the effects of CSRO on water quality downstream of the
1117 Columbia River System dams is considered out of scope. Sediment within the Columbia River
1118 Basin moves downstream, but the movement is interrupted by the dams and sediment in
1119 general does not move past Bonneville Dam, except for small amounts of fine suspended
1120 material that are carried to the ocean. It is recognized that the operation of the dams may
1121 impact the estuary and downstream Columbia River conditions, simply because the natural
1122 processes in the river system have been disrupted by the dams, but the effect of the presence
1123 of the dams on the estuary is not the issue addressed in this water quality analysis. Other
1124 downstream conditions, such as the water and sediment quality in the Portland, Oregon, area,
1125 are affected by factors outside the scope of this study and control of CSRO, and those
1126 downstream conditions may be more pertinent to the estuary conditions than the upstream
1127 dam operations.

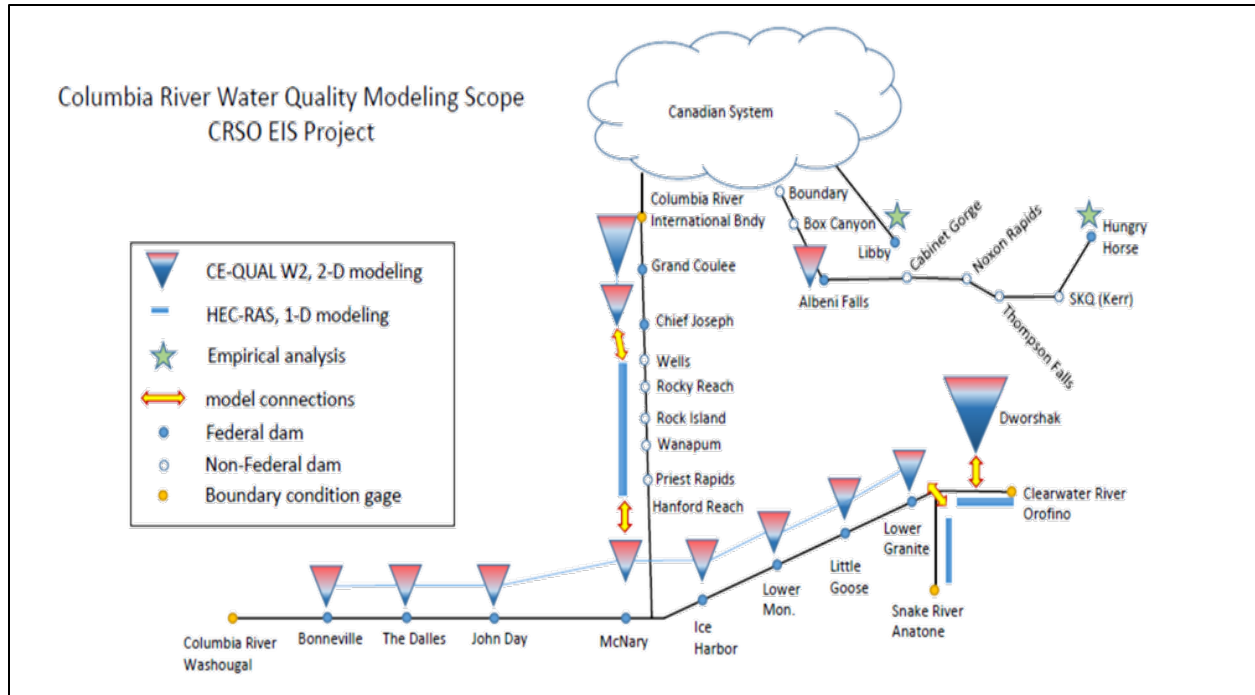
1128 A whole suite of water quality parameters have been measured for several years throughout
1129 the CSRO study area. For EIS analysis, water quality parameters are separated in three major
1130 categories: (1) water temperature, (2) TDG, and (3) other physical, chemical, and biological
1131 conditions. This information is presented in the paragraphs below and is compared to the no
1132 action results for each alternative in the sections below.

1133 Montana, Idaho, Washington, and Oregon are the states within the CRSO study area. Each have
1134 established their own water quality standards and monitoring programs in response to the
1135 mandate of the Clean Water Act (CWA). In addition, the Columbia River Basin is regulated by
1136 tribal and local agencies along specific river segments. These standards are used as the metrics
1137 against which all results for EIS alternatives are compared.

1138 **2.2.1 Columbia River/Lower Snake Mainstem Modeling**

1139 The system water quality model uses two model software packages. The CE-QUAL-W2 (W2)
1140 model (Version 4.2) was used for reservoirs in the Columbia River System to simulate water
1141 temperature and TDG two-dimensionally (vertically and longitudinally), and the HEC River
1142 Analysis System (HEC-RAS) model (Version 5.0.3) was used for water temperature simulation of
1143 riverine sections in one dimension. (A one-dimensional [1D] model has changes only in one
1144 direction along the channel, while a two-dimensional [2D] model allows changes in two
1145 directions.) The model domain consists of the Columbia River mainstem from the U.S.-Canada
1146 border to Bonneville Dam; the Clearwater River/lower Snake River from Dworshak Reservoir on
1147 the North Fork of the Clearwater; the mainstem Clearwater River at Orofino, Idaho; and the
1148 Snake River at Anatone, Washington, to the mouth of the Snake River. The model includes 11
1149 Federal dams: Grand Coulee, Chief Joseph, Dworshak, Lower Granite, Little Goose, Lower
1150 Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville. It also includes five
1151 non-Federal dams on the Columbia River mainstem: Wells, Rocky Reach, Rock Island, Wanapum
1152 and Priest Rapids. These five additional dams impact water quality (temperature and TDG) and
1153 are included in the modeling schema to more accurately describe the river conditions, however
1154 data related to these dams is not presented or discussed in this document. There are three
1155 longer river reaches not interrupted by dams: the Hanford Reach between Priest Rapids Dam
1156 and McNary Reservoir at Pasco, Washington, the Clearwater River upstream of Lower Granite
1157 Reservoir, and the Snake River upstream of the City of Asotin, Washington. These
1158 uninterrupted river sections function similarly to a free-flowing river (Figure 2-2.).

1159 The system model is limited by available data and run times, so modeling long-term record sets
1160 was not possible for EIS analysis. Instead, a 5-year period (2011–2015) that represent a wide
1161 range of environmental response to hydrology (wet, dry, average) and weather conditions (hot,
1162 cold, average) were selected to model each EIS alternative against. Dam operations, as
1163 described in each EIS alternative, were imposed on these selected years through the use of the
1164 ResSim model and fed into the system water quality model. The following years were selected
1165 for water and sediment quality analysis:



1166
1167 **Figure 2-2. Columbia River System Operations Environmental Impact Statement Water**
1168 **Quality Modeling Framework**

- 1169 • 2011: During this year there were high values observed for the TDG metrics and low values
1170 for the temperature metrics. There was adequate data for temperature and TDG tailwater
1171 sites. It was a fairly extreme high-flow year but with a normal air temperature metric. The
1172 years 1996 and 1997 appear to be similar but do not have as much data.
- 1173 • 2012: During this year there were high values observed for the TDG metrics and low values
1174 for the temperature metrics. There was adequate data for temperature and TDG tailwater
1175 sites. It was a fairly average flow year with a normal air temperature metric.
- 1176 • 2013: During this year there were high values observed for the air temperature metric with
1177 lower than average flow conditions. The water temperature response was near average,
1178 and TDG response was slightly below average.
- 1179 • 2014: During this year there were high values observed for the air temperature metric with
1180 near average flow conditions. The water temperature response was near average, and TDG
1181 response was slightly below average.
- 1182 • 2015: During this year there were high values observed for the temperature metrics
1183 (second highest for the average of the site exceedances, since 1995) and the lowest for TDG
1184 metrics. There is adequate data for temperature and TDG tailwater sites. It was a fairly
1185 extreme low-flow year but with slightly above average air temperature metrics. The year
1186 2001 is similar but does not have as much data.

1187 These years are represented in figures below as the following: 2011 = High Inflow/Low
1188 Temperature (HF/LT), 2012 = Average Inflow/Low Temperature (AF/LT), 2013 = Low

1189 Flow/Average Temperature (LF/AT), 2014 = Average Flow/Average Temperature (AF/AT), and
 1190 2015 = Low Flow/High Temperature (LF/HT).

1191 Simulated water temperature and TDG data are compared to state, Federal and tribal
 1192 temperature and TDG standards to quantify expected changes under the No Action Alternative
 1193 and MOs. This information is also used to inform impacts to other resources such as
 1194 anadromous and resident fish, waterfowl, and tribal fishing and recreation.

1195 **2.2.2 Lower Snake River Model for the Multiple Objective 3 Alternative**

1196 The Multiple Objective Alternative 3 (MO3) Lower Snake River (LSR) Model was developed to
 1197 evaluate the breaching of all four dams on the lower Snake River over a 5-year period, spanning
 1198 2011 to 2015. MO3 has several notable measures, the most significant of which is the breaching
 1199 of the lower Snake River dams. The MO3 LSR Model, unlike other CRSO models used in the EIS,
 1200 uses the 1D HEC-RAS model instead of the 2D W2 model. The driving force for this decision is
 1201 the complexity of setting up a free-flowing riverine system in the W2 model. Details regarding
 1202 development of the MO3 LSR model can be found in Annex A of this document.

1203 Over the past two years, EPA has updated the RMB10 1D temperature model to assess
 1204 Columbia and Snake River water temperatures and evaluate the impacts from the federal dams
 1205 as part of the reinitiation of the TMDL project. Preliminary results have been shared across the
 1206 region, which has led some stakeholders to compare the scenarios analyzed in the TMDL effort
 1207 against CRSO EIS results. There are similarities in the TMDL and CRSO EIS modeling
 1208 assessments of the Snake River, and both project teams have evaluated the similarities and
 1209 differences in the models as part of uncertainty assessment. At the same time, direct
 1210 comparisons are not appropriate given the differences between scenarios and assumptions
 1211 made among the two projects. These differences are described so that the reader has a clear
 1212 understanding of the two efforts (Table 2-1).

1213 **Table 2-1. Comparison of TMDL and CRSO EIS Analyses.**

	Preliminary TMDL Analysis	CRSO EIS Analysis
Tools Utilized*	RBM10 (1D)	CE-QUAL W2 (2D) & HEC-RAS (1D)
Temperature Metric	Daily average	Daily maximum
Calibration Period	2011 – 2016	2011-2015
Time step	Daily	Hourly
Meteorological Data Inputs	Prioritized stations with long term dataset, i.e. airports (1970-2016)	Prioritized stations with highest spatial resolution, includes airports and Agrimet.
Focus of Analysis	Analysis is used as an assessment of the sources of thermal load.	Analysis is focused on operational changes (timing, magnitude and route of water passage) of the CRSO dams.
Baseline Conditions	Existing Conditions: Observed flow and dam operations for 2011-2016.	No Action: 2016 dam operations and configuration overlaid on 2011-2015 meteorological conditions and channel geometry.

	Preliminary TMDL Analysis	CRSO EIS Analysis
No Dams Conditions	<p>RBM-10 was utilized for the “free-flowing” scenario.</p> <p>The free-flowing scenario includes the absence of Grand Coulee, Chief Joseph, the 5 mid-Columbia PUD dams, the lower four Columbia River and the lower four Snake River dams.</p> <p>Dworshak Dam is a boundary conditions and uses observed flows and temperatures.</p> <p>2010 channel bathymetry is utilized throughout system.</p> <p>The TMDL assessment focused on quantifying the thermal load of the dams by comparing existing conditions to a free-flowing scenario.</p>	<p>HEC-RAS was utilized for the MO3 EIS Alternative for the lower Snake River; CE-QUAL W2 was used for the other mainstem CRSO dams.</p> <p>MO3 includes breaching the four lower Snake River dams in which the concrete sections of each dam is removed, leaving the earthen embankments in place. All other CRSO dams remain in place.</p> <p>Dworshak Dam uses modeled flows and temperature.</p> <p>1934 (pre-dam) channel bathymetry is utilized throughout lower Snake River; 2010 geometry used elsewhere in the system.</p> <p>The CRSO EIS assessment focused on predicting water temperature and TDG conditions under the MO3 alternative, which included a measure for breaching all four lower Snake River dams.</p>

1214 **2.2.3 Pend Oreille River (Albeni Falls Reach) Modeling**

1215 The Albeni Falls W2 model was run separately from the system model, since Albeni Falls Dam is
 1216 located on the Pend Oreille River approximately 100 river miles upstream from its confluence
 1217 with the Columbia River. Moreover, downstream of Albeni Falls Dam, the Pend Oreille River is
 1218 influenced by two non-Federal U.S. dams and two Canadian dams before flowing into the
 1219 Columbia River. The Albeni Falls W2 model was used to simulate impacts from the operation of
 1220 Albeni Falls Dam only, and not impacts from dams such as Boundary or Box Canyon, which fall
 1221 outside of the scope of this EIS. The Albeni Falls W2 model domain extends from the outlet of
 1222 Lake Pend Oreille near Sandpoint, Idaho, downstream to Albeni Falls Dam. The model simulates
 1223 water temperatures which are compared to temperature standards for evaluation.

1224 TDG production at Albeni Falls Dam is addressed qualitatively, since studies indicate that a
 1225 direct relationship between spillway discharge and TDG exchange is not consistently observed
 1226 (Schneider et al. 2007). The TDG saturations observed at the dam’s fixed monitoring station are
 1227 a weak function of spill discharge. Developing a reliable empirical model to estimate TDG
 1228 saturations in the Pend Oreille River downstream of Albeni Falls Dam is not possible because of
 1229 the lack of a relationship between spillway discharge and TDG production.

1230 **2.3 PERIOD OF RECORD MAPPING**

1231 Water quality modeling is a time and data intensive procedure. Recent data exist to calibrate
 1232 water quality models for water temperature and TDG in the CSRO study area, but few observed
 1233 water quality data are available to use these data-intensive models for historical years.
 1234 Historical flow data do exist for the study area, and are used to predict water temperature and

1235 TDG outside of the water quality models for the selected period of record years of 1928 to
1236 2008. This larger dataset feeds the Comprehensive Passage Model, the Comparative Survival
1237 Study fish model, and other fish impacts analysis for this EIS.

1238 To predict water temperature and TDG data for the period of record, simulated water
1239 temperature data from the years 2011 to 2015 were mapped to the historical period. For water
1240 temperature, historical monthly water temperatures were generated based on monthly flow
1241 and air temperature data derived from long-term gaging stations located near Bonneville, Ice
1242 Harbor, and Priest Rapids Dams (Annex B). For TDG, the period of record data was estimated
1243 using the equations and parameters found within the W2 models. These equations calculate
1244 TDG directly below a dam (referred to as the tailwater), and the area just before the next
1245 downstream dam (referred to as the forebay). The initial conditions at a particular dam:
1246 upstream forebay TDG (estimated), total spill, total flow, forebay elevation, and tailwater
1247 elevation (simulated from the ResSim models), and long-term historical monthly average
1248 barometric pressure and wind speed. Changes to TDG through each reservoir reach are based
1249 on monthly average environmental conditions.

1250 **2.4 EMPIRICAL ANALYSIS TOOLS**

1251 Where numerical models do not exist or are too outdated to be easily updated for use in this
1252 EIS, empirical analysis tools have been developed to predict TDG generation at Libby and
1253 Hungry Horse Dams, while qualitative analysis is used to predict impacts to downstream water
1254 temperature management. The TDG tools use empirically derived TDG production equations to
1255 predict TDG generated under the various flow regimes as prescribed in the alternatives. A
1256 qualitative assessment is used to evaluate whether the various alternatives are likely to
1257 adversely impact the ability to continue managing downstream water temperatures using the
1258 selective withdrawal structures (SWSs) that exist at both dams. This is achieved through the
1259 evaluation of reservoir summary elevation hydrographs (storage diagrams) developed from
1260 ResSim model output. Specifically, the following approach was used for the water temperature
1261 impact assessment:

- 1262 1. Evaluate whether an alternative falls within the range of historical water level conditions
1263 and operational range of the SWS (if water hydrologic and operational conditions fall within
1264 the historical ranges, it will be assumed that historical release temperatures can be
1265 assessed in the alternative);
- 1266 2. Conduct a comparison between historical operations and operations under the specific
1267 alternative;

1268 Conduct a comparison of reservoir drawdown elevations and the resulting temperature
1269 releases during summer months.

1270 **2.5 QUALITATIVE ANALYSIS**

1271 Outside of water temperature (with exceptions at Libby and Hungry Horse Dams) and TDG
1272 (with the exception of Albeni Falls), water quality impacts are assessed qualitatively using

1273 information of reservoir and river operations from ResSim paired with professional judgement
1274 based on experience with reservoir operations. Data from model output, multiple technical
1275 reports, past studies, and field data was considered. Information such as total discharge, spill,
1276 and reservoir elevation was used to predict how reservoir and river conditions may change
1277 under a given alternative, and how these changes may affect water quality parameters such as
1278 turbidity, and nutrient and contaminant loading.

1279 **2.6 IMPACT FRAMEWORK**

1280 A framework was developed to define the overall level of water temperature and TDG impact
1281 for each CRSO EIS alternative as compared to the No Action Alternative. For water
1282 temperature, the level of impact (negligible, minor, moderate, or major) was defined based on
1283 the absolute change in the maximum and minimum water temperatures as averaged over the
1284 five year simulation period (2011-2015). If the absolute change in water temperature between
1285 the MO Alternative and No Action Alternative was less than 0.4°F, the water temperature
1286 impact was considered negligible. If the absolute change in average minimum and maximum
1287 values was greater than 0.4°F, but less than 2°F, the impact was considered negligible, minor or
1288 moderate based on the time of year (season) the impact occurred and whether the impact
1289 increased the number of days that State water quality standard (WQS) criteria was not met and
1290 by how much. Absolute water temperature changes of >2°F, or an increase in water
1291 temperature WQS exceedances of greater than 10 days, were considered a major impact
1292 (Figure 2-3).

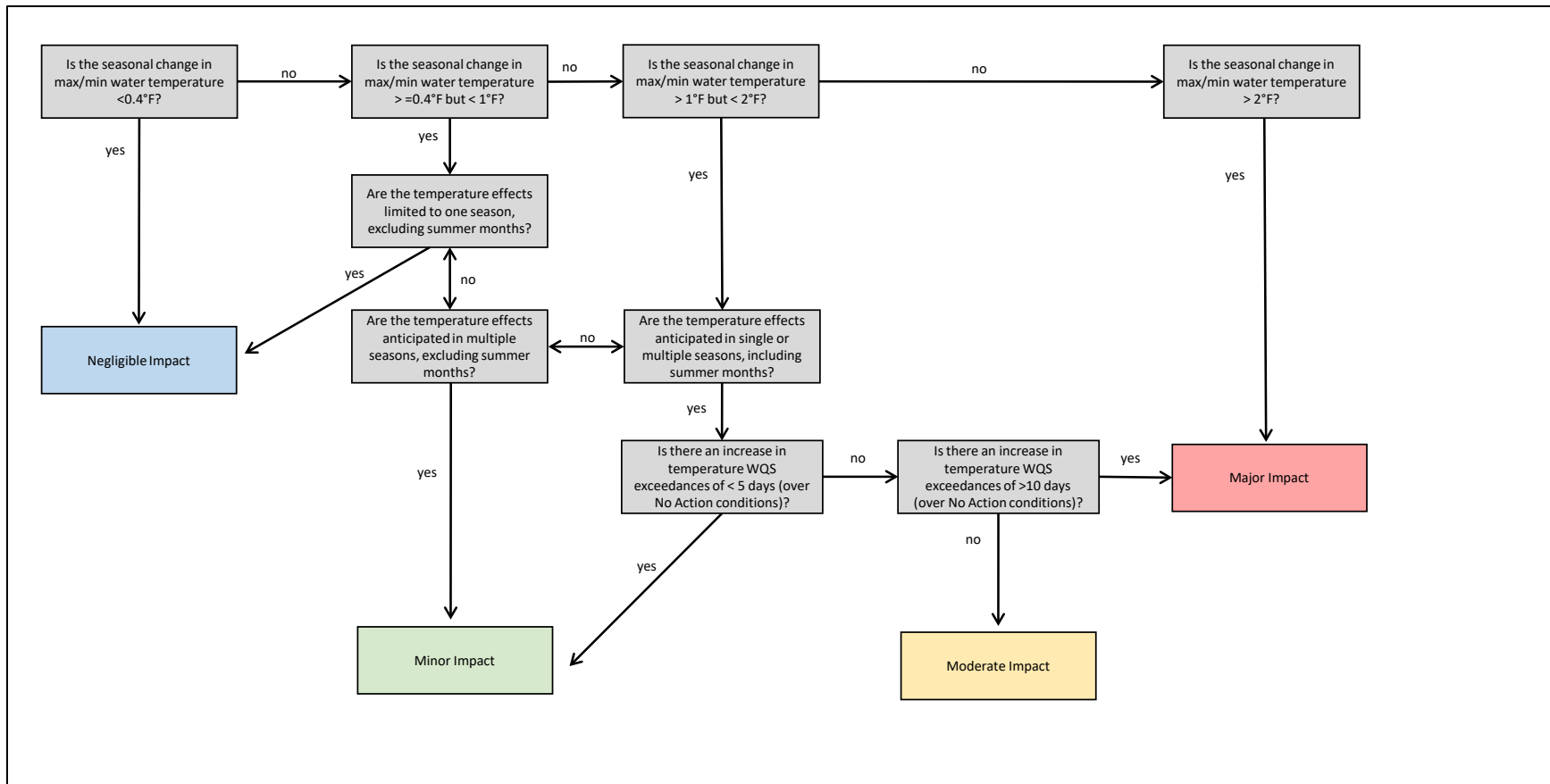
1293 For total dissolved gas, the following decision criteria was used to determine level of impact:

- 1294 • Negligible: <=1% change in the five year average maximum TDG as compared to the No
1295 Action Alternative.
- 1296 • Minor: >=1% but <2% change in the five year average maximum TDG as compared to the No
1297 Action Alternative.
- 1298 • Moderate: >=2% but <3% change in the five year average maximum TDG as compared to
1299 the No Action Alternative.
- 1300 • Major: >=3% change in the five year average maximum TDG as compared to the No Action
1301 Alternative.

1302 These descriptors are used to summarize the overall impact of each EIS Alternative as described
1303 in the sections below.

1304

*Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix*



1305
1306

Figure 2-3. Water Temperature Impact Framework and Decision Criteria

1307 **2.7 LIMITATIONS, ASSUMPTIONS, AND UNCERTAINTY**

1308 **2.7.1 Water Quality**

- 1309 • The Canadian portion of the Columbia River was not included in the evaluation. Operational
1310 changes from headwater Columbia River System projects (Libby, Hungry Horse, and Albeni
1311 Falls Dams) are represented as flow changes into the system water quality model but
1312 changes to inflowing water temperature and TDG are not contemplated, introducing
1313 uncertainty to the boundary condition of the system model.
- 1314 • The impact of the non-Federal dams are not evaluated in this EIS. The mid-Columbia Public
1315 Utility District dams are represented in the model schema to more accurately describe the
1316 river conditions, however data related to these dams is not presented or discussed in this
1317 report.
- 1318 • The estuary, including the reach from downstream of the Bonneville Dam tailrace to
1319 Astoria, is not include in the water quality analysis for this EIS.
- 1320 • The impact of operations to temperature and TDG were quantified using mechanistic
1321 models. All models are simplifications of the real world and we have strode to represent
1322 the processes that are important to water temperature and TDG.
- 1323 • Uncertainty is introduced into the model results through simplified representation of
1324 physical processes, inputs, parameters and applicability to new operations. Uncertainty
1325 was reduced and evaluated, to the extent practicable.
- 1326 • The effects of nutrient cycling and algae on TDG are not included in our analysis of TDG;
1327 instead focus is given to the TDG produced by the operation of the Columbia River System
1328 dams.
- 1329 • The analysis of other biological, physical, and chemical water quality constituents is
1330 qualitative; simulated water temperature and TDG data is used to inform changes to those
1331 constituents.

1332 **2.7.2 Sediment Quality**

1333 Throughout the evaluation of alternatives, some assumptions related to sediment quality are
1334 consistently made.

- 1335 • Water quality changes (temperature, pH, dissolved gases) may affect sediment quality in
1336 minor ways, including changing the rate of biodegradation of pollutants or organic matter in
1337 the sediment, or affecting the oxidation state of metals. Minor impacts to sediment quality
1338 due to water quality changes are not evaluated.
- 1339 • The total flow through a dam or river reach affects sediment movement; however, the
1340 distribution of that flow through the dam (spillway verses hydropower unit, for example)
1341 would not affect sediment movement in the channel. Because the total flow in the river
1342 channel is what affects sediment movement, alternatives that only change the distribution

1343 of flows or location of discharges, but that do not change the total flow, are considered to
1344 have a negligible effect on sediment quantity and quality.

1345 • Coarser-grained sediment settles to the bottom of the river or reservoir and is trapped
1346 behind the dams. Fine-grained sediment that remains in suspension may move downstream
1347 from a dam with the water that flows either as spill or through the hydropower units.
1348 Proposed actions or alternatives that do not affect the often coarser-grained, shoaled
1349 (settled) sediment are considered to have no impacts to sediment, because the fine
1350 materials that already move through the system will continue to do so. Sediment impacts
1351 evaluated are only impacts to the shoaled materials.

1352 • Sediment movement and quantity is informed by river mechanics. Appendix C, River
1353 Mechanics, should be referenced for details on sediment movement, while this appendix is
1354 focused on the issues of sediment quality (pollutants) and management.

1355

CHAPTER 3 - NO ACTION ALTERNATIVE

1356 The No Action Alternative is defined as the future water quality condition within the CRSO
1357 study area, without any changes in system configuration or operation. In other words, the No
1358 Action Alternative shows what would happen if the proposed action was not taken (Bass,
1359 Henderson, and Bogdan 2001) and project operations and configuration remained the same as
1360 they were in 2016 (EIS Notice to Proceed date). For this No Action Alternative assessment,
1361 future water and sediment quality conditions are evaluated for the next 25 years using 2016
1362 Fish Operations Plan spill operations in accordance with the 2014 National Oceanic and
1363 Atmospheric Administration (NOAA) Fisheries Federal Columbia River Power System
1364 Supplemental Biological Opinion (2014 BiOp)¹.

1365 The 2008 National Marine Fisheries Service (NMFS) BiOp (2008 BiOp), supplemented in 2010
1366 and 2014 (2014 BiOp), includes RPA action 29 that states that the Corps and Bonneville will
1367 provide spill to improve juvenile fish passage while avoiding high TDG supersaturation levels or
1368 adult fallback problems. Specific spill levels will be provided for juvenile fish passage at each
1369 project, not to exceed established TDG levels (either 110 percent TDG standard, or as modified
1370 by State water quality waivers, currently up to 115 percent TDG in the dam forebay and up to
1371 120 percent TDG in the project tailwater, or if spill to these levels would compromise the
1372 likelihood of meeting performance standards). The dates and levels for spill at each dam may
1373 be modified through the implementation planning process and adaptive management
1374 decisions². Future Water Management Plans will contain the annual work plans for these
1375 operations and spill programs, and will be coordinated through the Technical Management
1376 Team. The Co-Lead Agencies will continue to evaluate and optimize juvenile spill passage
1377 survival to meet both the hydrosystem performance standards and the requirements of the
1378 CWA.

1379 It is assumed that under the No Action Alternative, some existing projects related to water and
1380 sediment quality would continue. For example, use of Dworshak Dam for downstream water
1381 temperature management of the lower Snake River would continue to occur. Similarly, use of
1382 the SWS at Libby and Hungry Horse Dams would continue to provide as close to naturally
1383 occurring water temperatures as possible downstream of the dams for fish, including the

¹ The 2014 Supplemental BiOp considered the Co-Lead Agencies' 2014–2018 Implementation Plan and incorporates both the 2008 BiOp and the 2010 Supplemental BiOp.

² Spill operations have been in flux in recent years. On January 8, 2018, the U.S. District Court for the District of Oregon issued an Order (Court Order) for spring 2018 juvenile fish passage spill operations. The Court Order, along with the 2018 Spring Fish Operations Plan, describes Corps' project operations for juvenile fish passage at its four lower Snake and four lower Columbia River projects during the spring juvenile migration season, generally April 3 through June 20, 2018. The Court Order directed the Corps to maximize juvenile fish passage spill to the extent feasible in a manner consistent with the Oregon and Washington state water quality standards for total dissolved gas (TDG) (i.e. Gas Cap spill). During the spring 2018 spill season, Washington's criteria adjustment for TDG allowed for 115 percent TDG as measured in the forebay and 120 percent TDG as measured in the tailraces of the dams. Oregon's standard modification allowed for spill up to 120 percent TDG as measured in the tailraces of the dams. The Corps applies the more stringent standard when operating under all applicable state TDG standards. After spring, the Corps implemented the 2018 Summer Fish Operations Plan which was developed to be consistent with the 2008 BiOp.

1384 endangered Kootenai River white sturgeon, and threatened bull trout and west-slope cutthroat
1385 trout fish populations. TDG control through operational and structural means would also
1386 continue, particularly at the lower eight dams during the downstream juvenile fish migration
1387 season. Areas which historically have required dredging (lock chamber approaches, the
1388 confluence of the Snake and Clearwater Rivers, harbor and port berthing areas and entrances)
1389 would still experience shoaling (the build-up of sediment into shallow areas that obstruct
1390 navigation). Navigation channel and private dockface/berthing area dredging conducted by the
1391 Corps to maintain navigation, would still occur. Sediment management activities in the Snake
1392 River (as described in the Programmatic Sediment Management Plan, Corps 2014 and other
1393 documents) would continue as currently planned. The Corps would periodically evaluate
1394 sediment quality following the Sediment Evaluation Framework (Northwest Regional Sediment
1395 Evaluation Team [RSET] 2018) or other applicable guidance, particularly as supporting
1396 documentation prior to the implementation of navigational maintenance dredging but also as
1397 part of other studies. It is also assumed that other agencies which may be involved in water or
1398 sediment studies (e.g., U.S. Environmental Protection Agency [EPA] and U.S. Geological Survey
1399 [USGS]) or soil/sediment management (e.g., National Resources Conservation Services) would
1400 continue their actions as directed and funded by Congress or by the states.

1401 In a similar manner, existing environmental regulatory programs and actions would continue.
1402 The CWA would control point and non-point discharges; CWA Sections 401 and 404 would be
1403 the main controlling Federal regulation for sediment projects. State, Tribal and local water
1404 quality, natural resource, and land use regulations would also continue as currently
1405 implemented. As additional scientific information becomes available over time, standards may
1406 be updated and revised; future reservoir operations and future projects would be consistent
1407 with the regulations at the time of implementation. Remediation programs, at both the Federal
1408 and state level, would continue as authorized and funded.

1409 Some of the existing water and sediment quality issues in the Columbia River Basin would be
1410 addressed under the No Action Alternative:

- 1411 • Libby Dam-Lake Koochanusa Selenium Monitoring and Research Group, a partnership
1412 between the United States and Canada consisting of Federal, state, provincial, tribal, and
1413 mining groups, will research selenium and nitrate within Lake Koochanusa.
- 1414 • EPA Cold Water Refuges is a study of cold water refuges along the lower Columbia River,
1415 and is mandated by the NOAA Biological Opinion on the Oregon temperature standard. The
1416 study will assess current refuge conditions and potential restoration methods. A final report
1417 is expected in 2020.
- 1418 • Columbia and Lower Snake River Temperature Total Maximum Daily Load (TMDL), an EPA-
1419 led study aimed at developing a temperature TMDL for the Columbia and lower Snake
1420 Rivers. Partners include Idaho, Oregon, and Washington, the Confederated Tribes of the
1421 Colville Reservation, and the Spokane Tribe of Indians.
- 1422 • The U.S. Department of State is leading an effort to negotiate with Canada to modernize the
1423 Columbia River Treaty. Key objectives include flood risk management through coordinated

- 1424 operations of hydroelectric dams on both sides of the U.S.-Canada border, maintaining a
1425 reliable and economical power supply, and managing the Columbia River System in a way
1426 that improves ecosystem benefits.
- 1427 • The Idaho Conservation League has petitioned EPA to review, disapprove, and revise the
1428 Snake River–Hells Canyon TMDL and provide full protection against phosphorus pollution
1429 loadings between River Mile (RM) 272.5 and 409.
 - 1430 • Lake Roosevelt sediment was contaminated by past smelter waste discharges. A
1431 remediation project to remove some slag contaminated materials has been implemented.
1432 Litigation continues and the litigants request additional cleanup actions (Washington
1433 Department of Ecology 2018).
 - 1434 • The Hanford Site is a former nuclear production site near Richland, Washington, located
1435 along the Columbia River upstream of its confluence with the Snake River. Cleanup of the
1436 Hanford site started in 1989 and is anticipated to continue (Hanford Site 2018)
 - 1437 • The Columbia River Restoration Act was authorized by Congress to provide funding to clean
1438 up pollutants in the Columbia River ecosystem. Funding is provided by grants to
1439 stakeholders who work cooperatively with EPA and other agencies.
 - 1440 • Existing water quality and fish tissue quality problems, identified under CWA Section 303d,
1441 would continue until the sources of the impairments are addressed. Fish tissue
1442 contaminants are related to sediment contamination. Although there are currently no
1443 basin-wide sediment contaminant removal/remediation projects for the Columbia River
1444 Basin, there are a few site specific projects occurring such as a Bradford Island.
 - 1445 • Through numerous Endangered Species Act (ESA) consultations over the last 25 years with
1446 NMFS and the U.S. Fish and Wildlife Service (USFWS), the Corps has implemented
1447 operational and structural measures to improve the survival of ESA-listed salmon and
1448 steelhead, Kootenai River white sturgeon, bull trout, other non-listed salmonids, Pacific
1449 lamprey, and burbot (a freshwater fish species in the Kootenai River). Starting in 1999, the
1450 NMFS BiOp, which focuses on ESA-listed salmon and steelhead, has included measures to
1451 spill at the Lower Snake and Lower Columbia dams during juvenile fish passage season.
1452 Operating the CRSO projects to meet the most current BiOps is expected to continue.
 - 1453 • A Flexible Spill Agreement (herein referred to as Spill Agreement) regarding 2019-2021 spill
1454 operations at the eight Federal dams on the lower Snake and Columbia Rivers has been
1455 signed by the states of Washington and Oregon, the Nez Perce Tribe, Bonneville, the Corps,
1456 and Reclamation. The Spill Agreement is supported by the states of Idaho and Montana,
1457 and the Columbia River Inter-Tribal Fish Commission. The purpose of the 2019-2021 Flex
1458 Spill Operation Agreement is to benefit juvenile spring fish passage, provide federal power
1459 system benefits no worse financially compared to the 2018 spring juvenile fish passage
1460 operations, and provide operational feasibility for implementation. This agreement reflects
1461 the intent of the signatory parties to work collaboratively on fish passage spill operations
1462 during the NEPA remand period or until the CRSO EIS is final.

1463 • The flexible spill (Flex Spill) operations included in the Spill Agreement are contingent on
1464 short term modifications being issued from Oregon and Washington to provide juvenile fish
1465 passage spring spill. Washington will provide a short-term modification to the adjusted TDG
1466 criteria at Washington Administrative Code 173-201A-200(1)(f)(ii) for both 120% TDG in the
1467 tailrace in 2019 and up to 125% TDG in the tailrace starting in 2020 for the spring juvenile
1468 fish passage period. The flexible spill operations starting in 2020 is also contingent on a
1469 short-term modification of the Oregon TDG water quality standard to 125% tailrace for the
1470 spring juvenile fish passage period.

1471 The list above is not intended to be an all-inclusive list of environmentally related actions that
1472 may occur outside of the implementation of any alternatives identified in this study.

1473 **3.1 UPPER COLUMBIA RIVER BASIN**

1474 Study waterbodies in the upper basin include the Columbia River from the U.S.-Canada border
1475 to the tailwater of Chief Joseph Dam; the length of the Pend Oreille River system that includes
1476 the South Fork Flathead River (Hungry Horse Reservoir and tailwater), Flathead River and Lake,
1477 Clark Fork River, Lake Pend Oreille, and the Pend Oreille River from Lake Pend Oreille to the
1478 Albeni Falls Dam tailwater; and the length of the Kootenai River which includes Lake Kooconusa
1479 starting at the U.S.-Canada border to the Libby Dam tailwater.

1480 **3.1.1 Water Temperature**

1481 Water temperature varies longitudinally along a river and vertically within a lake or reservoir. It
1482 is well understood that the warming/cooling trends of large, deep reservoirs tend to lag behind
1483 the thermal response that is found in unregulated rivers, creating outflow temperatures that
1484 are cooler in the spring and warmer in the fall compared to natural or pre-dam thermal
1485 conditions. This is apparent in most reservoirs within the Upper Columbia River Basin.

1486 **3.1.1.1 Libby and Hungry Horse Dams and Reservoirs**

1487 Lake Kooconusa and Hungry Horse Reservoir both thermally stratify in the summer and can
1488 provide some downstream water temperature management through use of the SWSs equipped
1489 at both dams. Through BiOp agreements, water temperatures in the river reaches below these
1490 dams are purposefully managed to benefit threatened and endangered species.

1491 The Libby Dam selective SWS is designed to take advantage of the seasonal, though variable,
1492 temperature stratification that occurs in the dam's forebay. Temperature stratification is
1493 particularly important when the objective is to provide warmer discharge temperatures to
1494 support sturgeon spawning and early life-stage development. When temperature stratification
1495 occurs, the result is cooler, denser water deeper down in the vicinity of the powerhouse intake
1496 penstocks, and warmer, less dense water nearer the surface. The SWS provides some ability to
1497 manipulate where in the water column water entering the powerhouse penstocks is drawn
1498 from. This is accomplished by the placement of the bulkheads. When few or no bulkheads are
1499 deployed, powerhouse intake water will come from lower in the water column. When

1500 bulkheads are deployed close to the forebay water surface, powerhouse intake water will come
1501 from higher in the water column. SWS operating protocol calls for maintaining at least 30 feet
1502 of submergence over the top row of bulkheads for hydraulic stability.

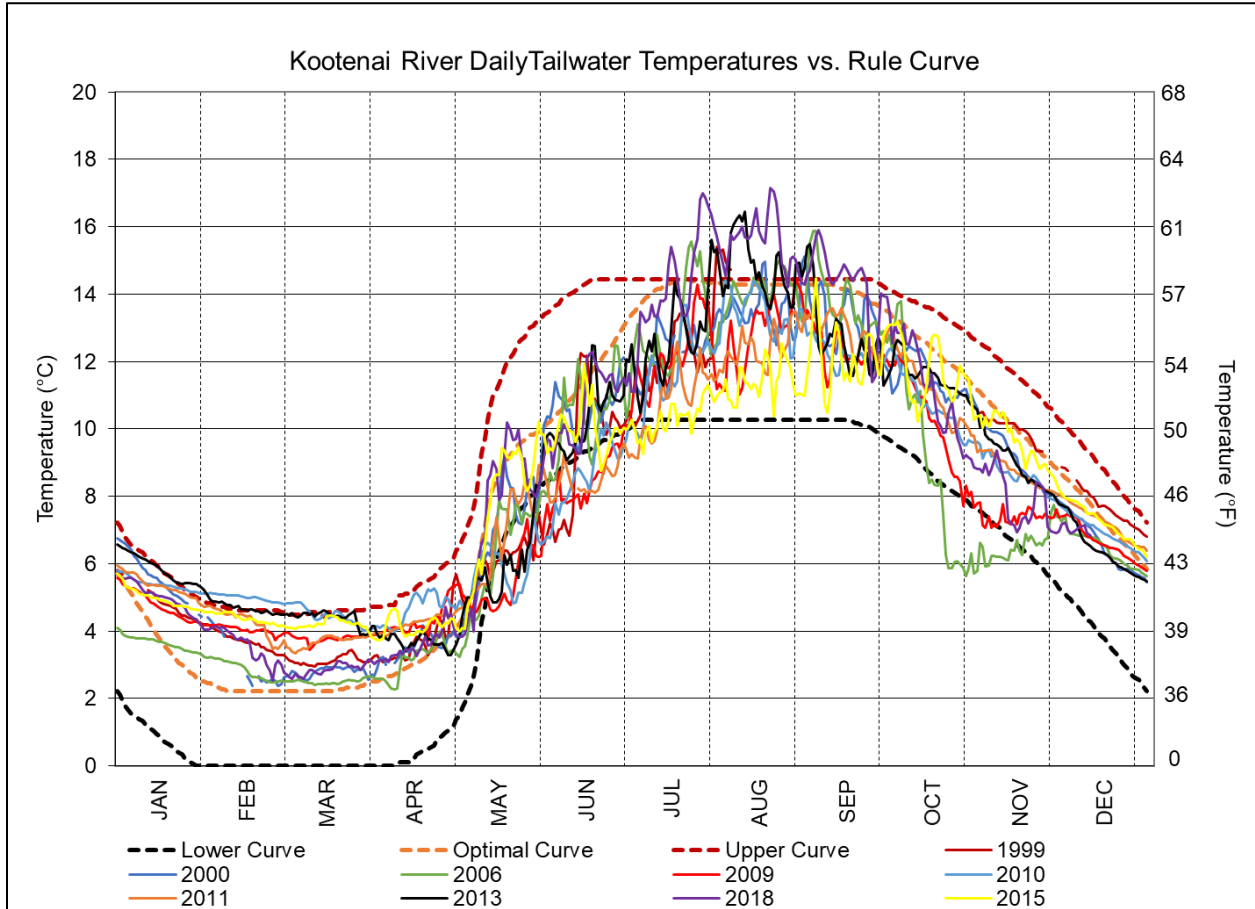
1503 The ability of the SWS to manage downstream water temperatures at Libby Dam is dependent
1504 on the temperature stratification present in the forebay. The reservoir generally becomes
1505 isothermic in December, and remains so until early April. Discharge temperatures cannot be
1506 managed to be warmer than the warmest temperatures present, or colder than the coldest
1507 temperatures present. The stratification of temperatures needed for effective temperature
1508 management, particularly for warmer discharge temperatures, has proven to be fragile.
1509 Meteorological conditions such as changes in air temperature and the presence, speed, and
1510 direction of wind can effectively mix the water in the forebay, eliminating or greatly reducing
1511 the degree of stratification.

1512 The SWS only provides temperature management for powerhouse discharges. The other two
1513 discharge mechanisms, the spillway and the regulating outlets, are not equipped with
1514 temperature management capabilities. The selective withdrawal system is operated to provide
1515 a temperature range as close to a free flowing river temperature range as possible downstream
1516 in the Kootenai River throughout the year. However, given the presence of a large deep
1517 reservoir (which changes temperature slowly) as the source of water to the river, outflow
1518 temperatures can be cooler in the spring and warmer in the late fall compared to the natural
1519 pre-dam Kootenai River. Given this, the selective withdrawal system is operated to follow, as
1520 close as possible, temperature objectives (rule curve) developed by the Corps and Montana
1521 Fish, Wildlife, and Parks (MFWP). However, more recent operations in coordination with MFWP
1522 have diverged from these objectives in order to make the river warmer during the summer. The
1523 water temperature rule curve, developed using pre-dam daily temperatures collected in the
1524 Kootenai River from 1967 to 1972, is presented in Figure 3-1. together with a summary of
1525 release water temperatures from Libby Dam for a series of years chosen to be representative of
1526 the following conditions:

- 1527 • Large Drawdown/High Inflow: 1999 and 2011
- 1528 • Large Drawdown/Low Inflow: 2000
- 1529 • Small Drawdown/High Inflow: 2006 and 2013
- 1530 • Small Drawdown/Low Inflow: 2009 and 2010
- 1531 • More recent operations: 2015 and 2018

1532 In general, the SWS has the ability to manage discharge temperatures under a wide variety of
1533 drawdown and inflow conditions. However, downstream river temperatures during the fall and
1534 winter are generally several degrees warmer than pre-dam Kootenai River conditions, while
1535 water released from the dam during the spring and summer is generally several degrees cooler
1536 than natural river conditions.

1537 Modeled forebay elevations under the No Action Alternative are predicted to be within the
 1538 operating range of the SWS and similar to the ranges observed in the historical years presented
 1539 in Figure 3-1.. Given this, use of the SWS to manage discharge temperatures is expected to
 1540 continue under the No Action Alternative.



1541
 1542 **Figure 3-1. Kootenai River Temperatures Measured at Libby Dam Tailwater Over Several**
 1543 **Years, Representative of Differing Drawdown and Inflow Conditions**

1544 Note: The MFWP temperature rule curve developed from pre-dam temperatures from 1967 to 1972 is shown.

1545 The SWS at Hungry Horse Dam is operated from approximately June to the end of October to
 1546 release warmer water that matches water temperatures on the Middle and North Fork
 1547 Flathead Rivers for the benefit of resident fish. The SWS is composed of independent structures
 1548 for each of the penstock intakes, allowing withdrawals of warmer waters from near the surface
 1549 of the reservoir during the summer, when the reservoir is thermally stratified. The system
 1550 performs over the full range of the reservoir, up to 160 feet below the maximum reservoir
 1551 water surface elevation. When not in use, the control gates are lowered to their lowest position
 1552 and the relief gates are raised to the top of the trash rack structure to minimize system head
 1553 loss (Reclamation 2006).

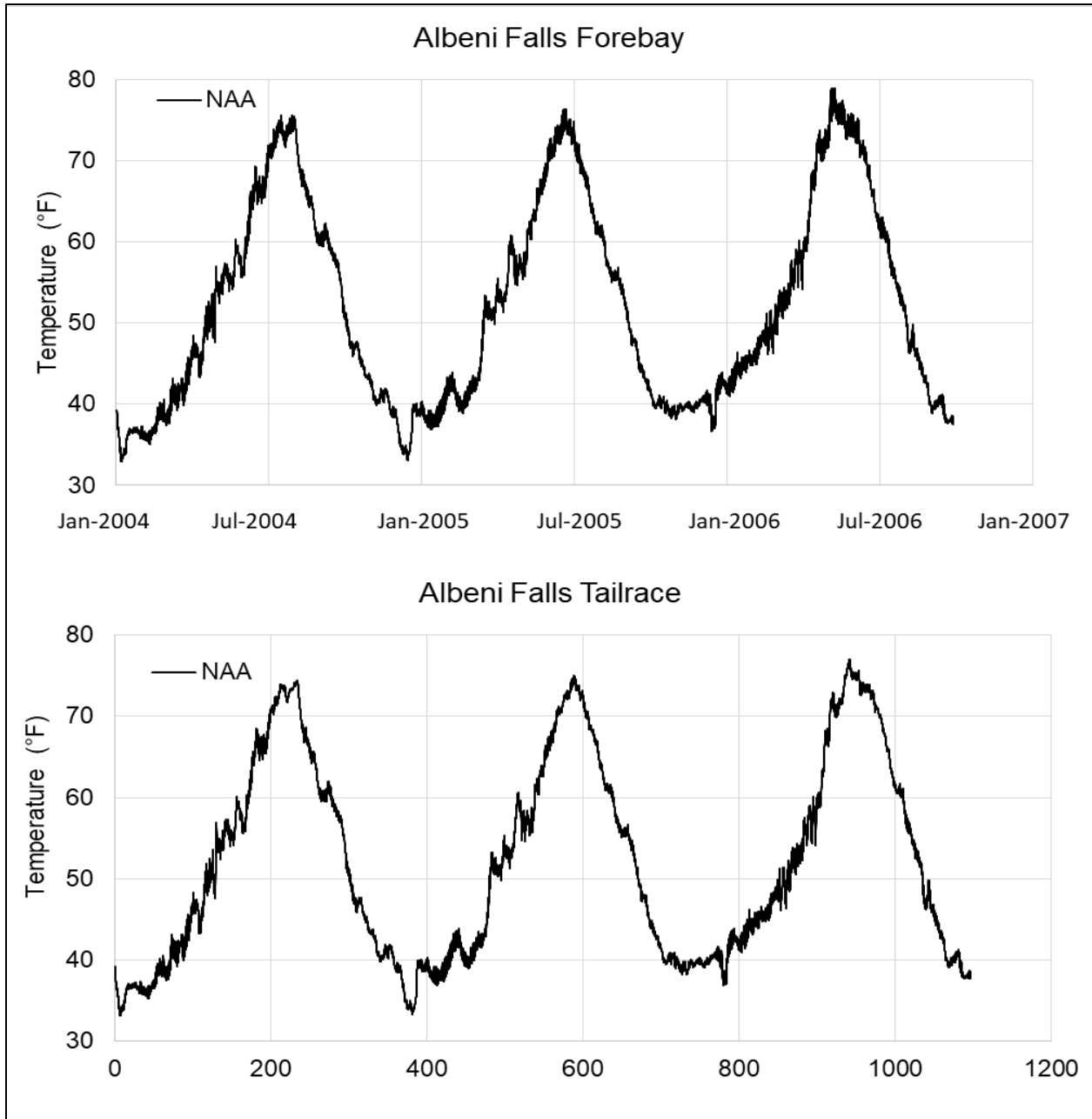
1554 Since completion of the SWS, thermal issues in the river have been minimal. An agreement with
 1555 MFWP allows Reclamation to operate the SWS to achieve a temperature regime that mimics

1556 natural conditions (Christenson, Sund, and Marotz 1996). Historically, cooler discharges from
1557 Hungry Horse Dam lowered primary productivity and had cascading effects on cutthroat/bull
1558 trout growth rates, and lake trout predation. The current operation provides enhanced primary
1559 production and reduces the likelihood of lake trout predation on native cutthroat and bull
1560 trout. As presented in the Hungry Horse Selective Withdrawal System Evaluation Report
1561 (Reclamation 2006), temperatures between 50°F and 59°F (10°C and 15°C) are optimal for trout
1562 growth and the SWS has been successful in maintaining these optimum water temperatures
1563 during the summer months. The report notes how temperature (epilimnion thickness and
1564 thermocline strength) in the reservoir is relatively uniform from year to year, despite drastically
1565 different hydrologic conditions. However, during winter and spring months, the reservoir is
1566 nearly isothermal, making selective withdrawal operations ineffective. Under the No Action
1567 Alternative, it is likely that these conditions would continue.

1568 **3.1.1.2 Albeni Falls Dam and Reservoir**

1569 Although Lake Pend Oreille strongly stratifies in the summer, water temperatures downstream
1570 in the Pend Oreille River are generally more uniform and warmer because of the naturally
1571 shallow low water channel properties in the transitional reach from the lake to the river. A
1572 shallow low water channel acts as a barrier to the transport of much colder subsurface water
1573 from Lake Pend Oreille into the Pend Oreille River. Lake surface waters pass through Albeni
1574 Falls Dam followed by a series of non-Federal and Canadian projects downstream. A water
1575 temperature TMDL has been established for the Pend Oreille River from Lake Pend Oreille
1576 downstream to the U.S.-Canada border.

1577 Water temperatures at Albeni Falls Dam forebay and tailwater under the No Action Alternative
1578 were modeled for the years 2004 to 2006 using W2. Figure 3-2. shows the modeled
1579 temperatures using the ResSim flow datasets. As shown, there is little difference between
1580 predicted forebay and tailwater temperatures. It is expected that there would be little change
1581 in temperatures at Albeni Falls Dam under the No Action Alternative.



1582
1583
1584

Figure 3-2. Modeled Water Temperature for the No Action Alternative at Albeni Falls Dam Forebay and Tailwater Under a 3-Year Range of River and Meteorological Conditions

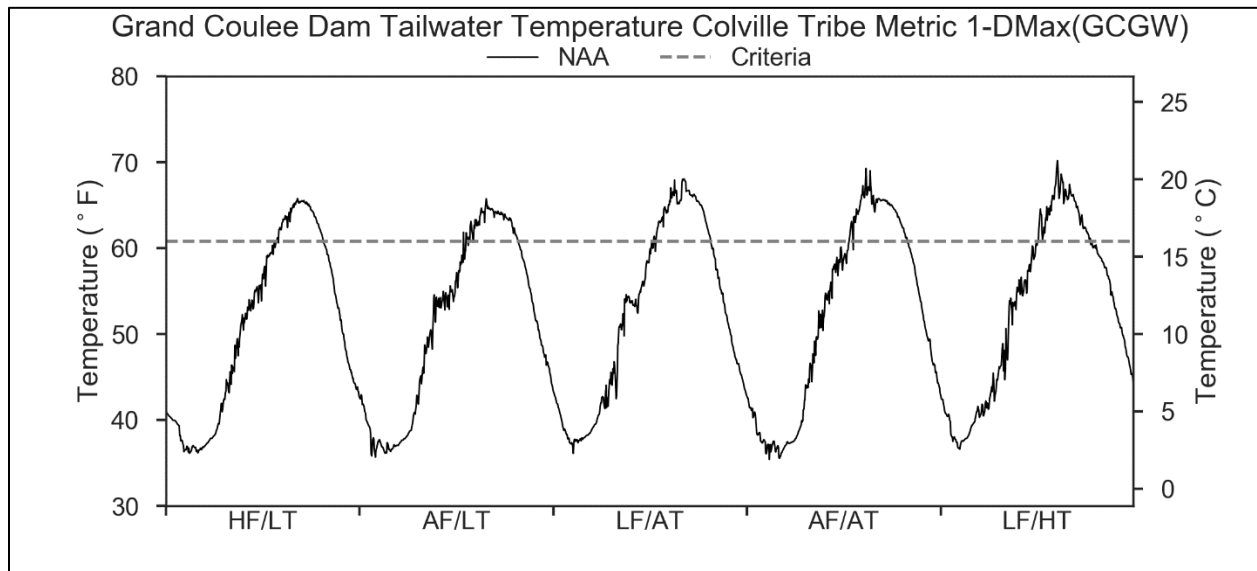
1585 **3.1.1.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

1586 Lake Roosevelt undergoes weak and shallow thermal stratification during late spring and early
1587 summer but is completely mixed (isothermal) part of the time (weakly stratified reservoirs are
1588 subject to periodic mixing, followed by restratification throughout the summer). Lake Rufus
1589 Woods does not stratify due to the shallow character of the channel behind the dam, and the
1590 short residence time of water passing through this reach of river. Expected operations under

1591 the No Action Alternative would provide little opportunity for downstream water temperature
1592 management due to the weak to no thermal stratification observed in both reservoirs.

1593 Grand Coulee Dam outflow water temperature has a temporal lag behind the warming/cooling
1594 trends observed at the U.S.-Canada border, representing the inflow to Lake Roosevelt. In
1595 general, water temperatures released from Grand Coulee tend to be cooler than reservoir
1596 inflows throughout much of the spring and early summer, and warmer in late summer/fall.
1597 Because Lake Rufus Woods does not stratify and has a residence time of about 4 days, it passes
1598 on the lagged water temperatures created by Lake Roosevelt.

1599 The No Action Alternative was modeled for a 5-year period using W2 and river and reservoir
1600 operations data from ResSim. Figure 3-3. shows that daily average water temperatures
1601 downstream of Grand Coulee Dam generally range from about 36°F (2°C) in early February and
1602 peak around 68°F (20°C) in August. Lake Roosevelt is listed as impaired for temperature on the
1603 Washington State 303(d) list.

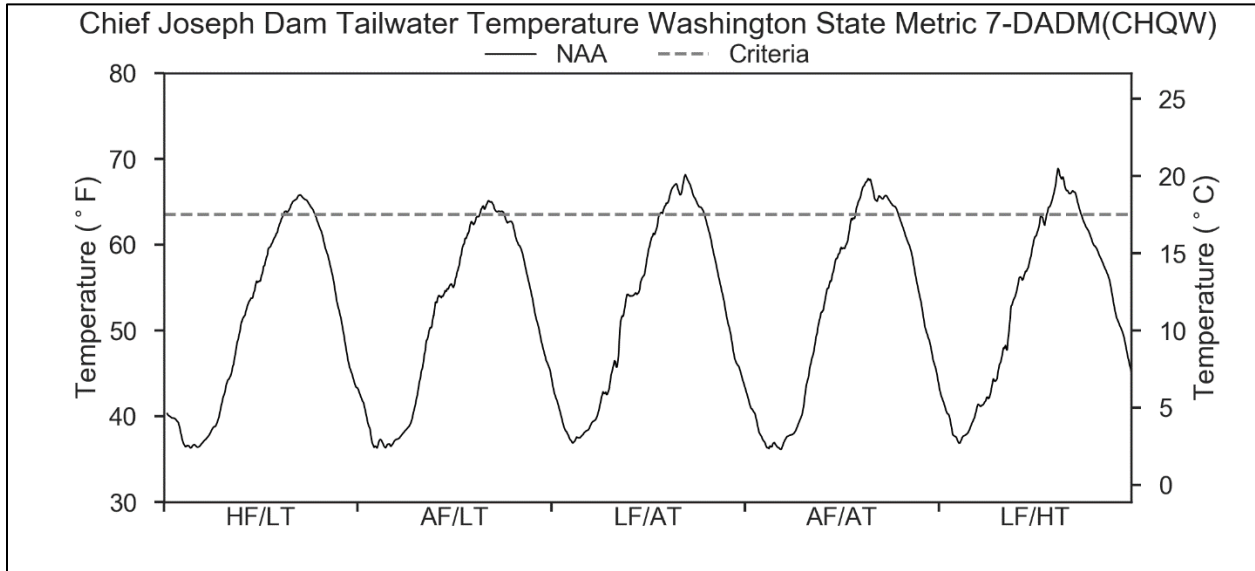


1604 **Figure 3-3. Modeled Tailwater Temperature for the No Action Alternative at Grand Coulee**
1605 **Dam Under a 5-year Range of River and Meteorological Conditions**
1606

1607 Observed water temperatures measured immediately downstream of Chief Joseph Dam at
1608 tailwater station CHQW are generally greater than the Washington State standard of 63.5°F
1609 (17.5°C) as measured by the 7-day average of the daily maximum temperature from about the
1610 beginning of August through the end of September. Columbia River water temperatures under
1611 the No Action Alternative were modeled for the period 2011 to 2015 using the CE-QUAL W2
1612 model which has been described in Section 2.2.1. This 5-year period was representative of a
1613 wide variety of flow and air temperature conditions, including HF/LT, AF/LT, LF/AT, AF/AT, and
1614 LF/HT.

1615 Modeled temperatures under the No Action Alternative at Chief Joseph Dam tailwater are
1616 similar to what has been described under the Affected. There is little difference in temperature

1617 between Grand Coulee Dam (Figure 3-3.) and Chief Joseph Dam (Figure 3-4.) showing that
1618 water temperatures released from Lake Roosevelt are passed through Rufus Woods Lake and
1619 downstream of Chief Joseph Dam. In general water temperatures were greatest in the LF/HT
1620 year and lowest in the HF/LT year. Temperature conditions modeled for the No Action
1621 Alternative at Chief Joseph Dam tailwater, under a wide range of flow and air temperature
1622 conditions, are expected to be similar for the next 25 years.



1623
1624 **Figure 3-4. Modeled Tailwater Temperature for the No Action Alternative at Chief Joseph**
1625 **Dam Under a 5-Year Range of River and Meteorological Conditions**

1626 **3.1.2 Total Dissolved Gas**

1627 TDG saturations in rivers are increased when dams release water through spillways and other
1628 non-turbine outlets. Spilling water at a dam results in increased TDG levels in downstream
1629 waters by plunging the aerated spill water to depths where hydrostatic pressure increases the
1630 solubility of atmospheric gases. Elevated TDG saturations, above the state water quality
1631 standard of 110% saturation, generated by spill releases from dams are of concern because
1632 high saturations can promote the potential for gas bubble trauma in downstream aquatic biota
1633 (Weitkamp and Katz 1980; Weitkamp et al. 2002).

1634 **3.1.2.1 Libby and Hungry Horse Dams and Reservoirs**

1635 Libby and Hungry Horse Dams are both high head dams that tend to generate TDG even when
1636 small discharges are released through their non-turbine outlets. Spill discharges at Libby are
1637 infrequent because Libby is managed to avoid spilling. Given this, TDG exceedances are not as
1638 commonly seen as in other parts of the CRSO study area. Spill discharges happen more
1639 frequently at Hungry Horse Dam as compared to Libby Dam. TDG during these spill events,
1640 which are often of short duration, rarely exceeds 110 percent.

1641 A detailed TDG study at Libby Dam was conducted in 2002 (Schneider 2003). This investigation
1642 determined the TDG exchange in spillway flows ranged from 104 to 134 percent saturation and
1643 was a direct function of spillway discharge. The TDG saturation in spillway releases, as
1644 measured immediately below the stilling basin, increased as an exponential function of the
1645 spillway discharge, and increased abruptly from 104 to 129 percent saturation as spill
1646 discharges increased from 700 to 3,900 cfs. A mild increase in TDG saturations from 129 to 134
1647 percent was observed as spillway discharges increased from about 3,900 to 15,500 cfs. The
1648 passage of water through the powerhouse did not change the TDG saturations in the Kootenai
1649 River, and TDG pressures in powerhouse releases measured during the test ranged from 102 to
1650 104 percent.

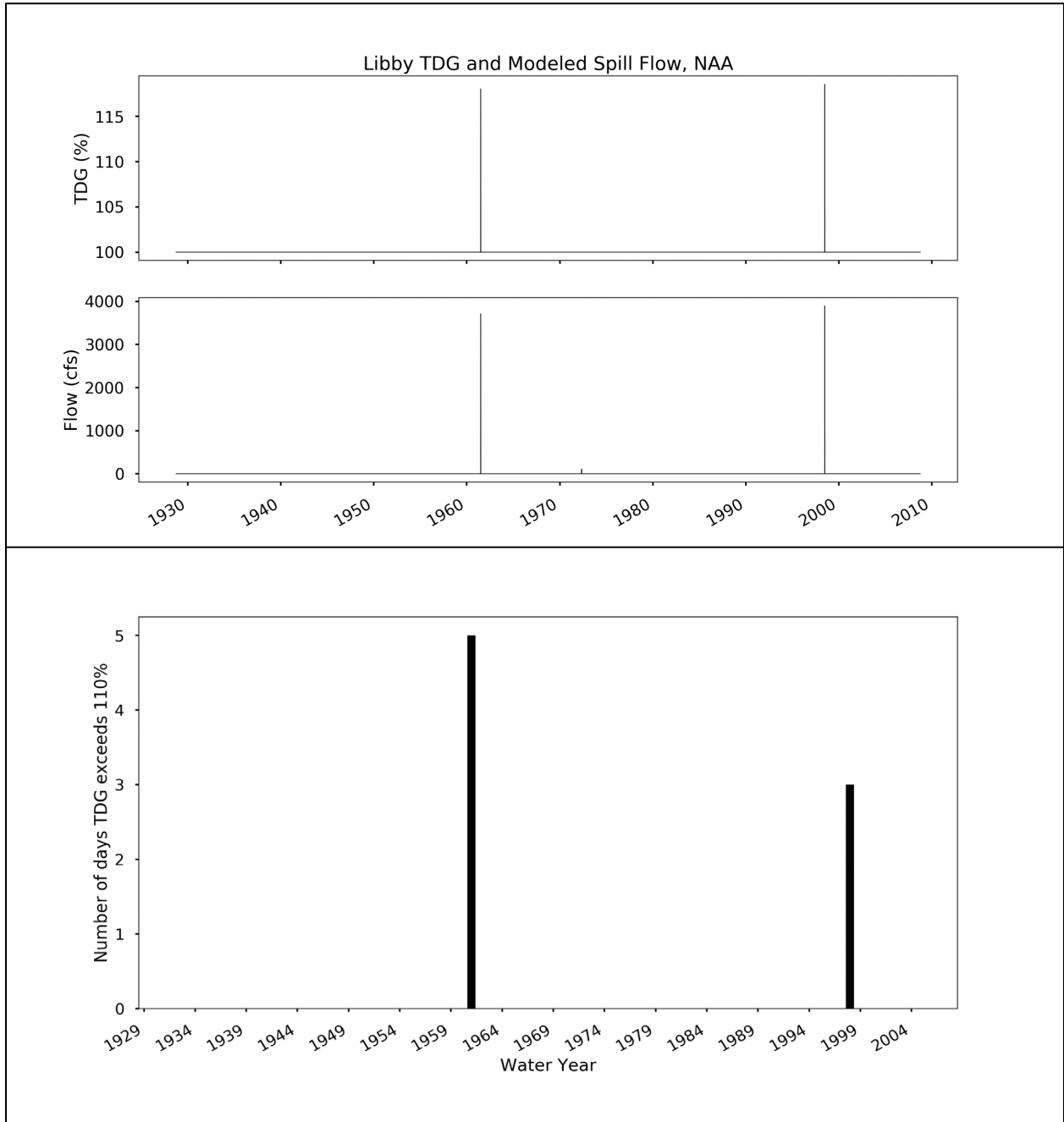
1651 The TDG characteristics in the Kootenai River below Libby Dam are dominated by the
1652 development of a mixing zone between spillway and powerhouse releases and in-river
1653 processes such as degassing at the air/water interface, lateral mixing, and thermal heat
1654 exchange. The rapid development of a mixing zone and in-river processes, results in decreasing
1655 TDG saturations in the Kootenai River downstream of the dam. TDG saturations in the Kootenai
1656 River are generally well mixed by about 8.7 miles (14 kilometers) downstream (Schneider 2003).

1657 Historical data shows that Libby Dam spills infrequently. No Action Alternative ResSim modeled
1658 flows for the 80-year period from 1928 to 2008 are presented in Figure 3-5.. The ResSim model
1659 predicts only 3 years with spill for the 80year period. However, since the dam became
1660 operational in 1975, Libby Dam has experienced forced spill in 5 out of 44 years. The ResSim
1661 model appears to under predict the amount of spill at Libby Dam. Such differences are likely
1662 due to ResSim using different operational and forecasting procedures than previously used at
1663 Libby which have resulted in reduced spill in the modeling runs. Regardless, the frequency of
1664 spills from Libby Dam are not anticipated to change under the No Action Alternative.

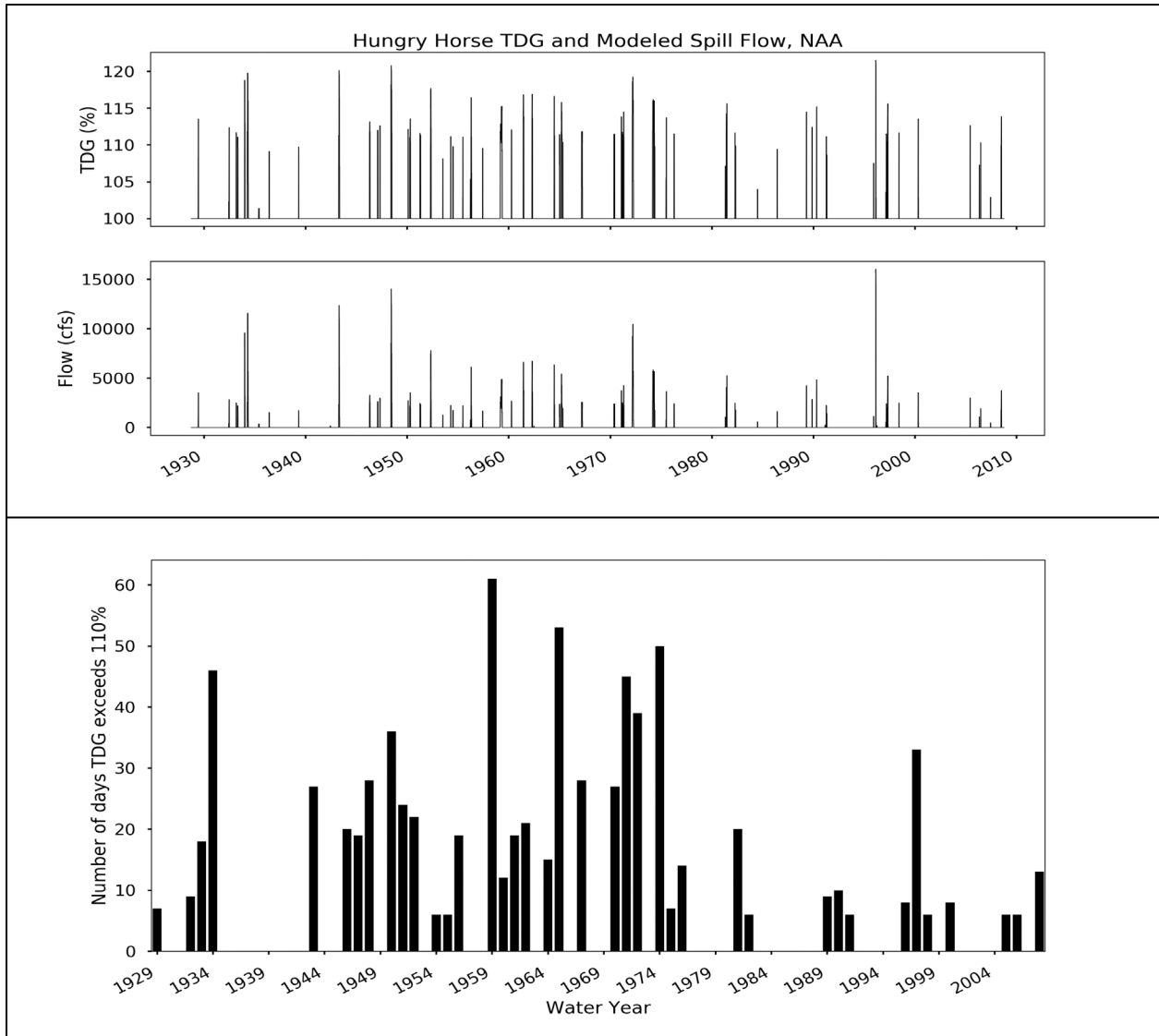
1665 TDG downstream of Hungry Horse Dam has been a concern in the past. TDG often does not
1666 meet the Montana state standard of 110 percent below the dam in high water years when
1667 inflows exceed the available storage and/or power generation capacity at the dam. Model
1668 results are presented in Figure 3-6.. The figure summarizes spill and TDG from Hungry Horse
1669 Dam over the 80-year record under the No Action Alternative. The figure has three panels. The
1670 bottom panel shows the number of days, in each year modeled, that exceeded 110 percent
1671 TDG. This ranges between 0 to 57 days—with an average of about 3 weeks. Total discharge and
1672 corresponding expected TDG are shown in the middle and top panels, respectively. TDG in the
1673 river below the dam occurred in only the highest water years for durations of generally less
1674 than 3 weeks. TDG above 116 percent occurred 147 times over the 80-year period and never
1675 exceeded 120 percent.

1676 Although the results presented in Figure 3-6. are realistic, they likely overestimate the amount
1677 of TDG that would actually occur in the South Fork of the Flathead River below the dam. The
1678 modeled results follow current water management plan rules and do not account for adaptive
1679 management. Adaptive management allows water managers to deviate from the water
1680 management rules by adjusting reservoir drafts (e.g., drafting deeper) in anticipation of

1681 potential high inflows or restricted outflows from the reservoir that would have otherwise
 1682 required higher spill and TDG, had additional space in the reservoir not been created.



1683 **Figure 3-5. ResSim Modeled Spillway Flows and Number of Days Exceeding 110 Percent at**
 1684 **Libby Dam for the 80-Year Period from 1928 to 2008**
 1685



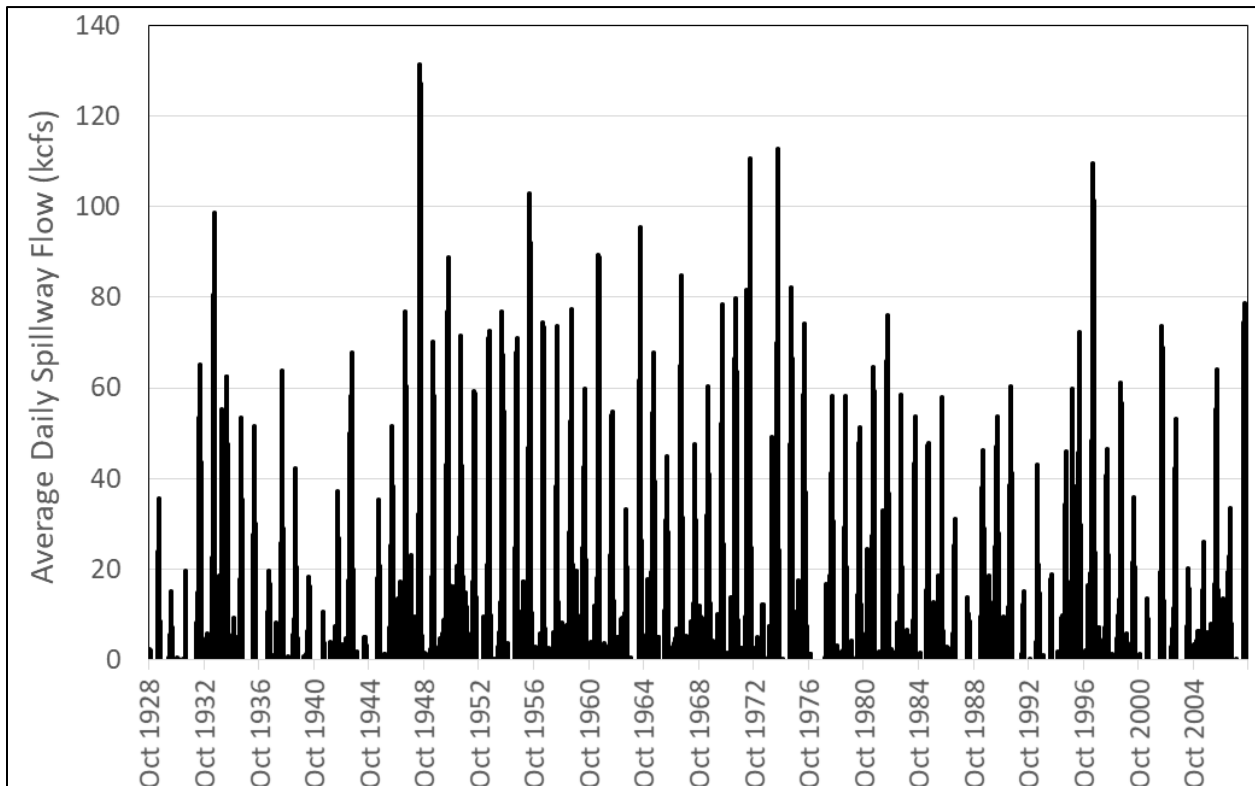
1686
1687 **Figure 3-6. ResSim Modeled Spillway Flows and Number of Days Exceeding 110 Percent at**
1688 **Hungry Horse Dam for the 80-Year Period from 1928 to 2008**

1689 **3.1.2.2 Albeni Falls Dam and Reservoir**

1690 TDG production at Albeni Falls Dam is addressed qualitatively, because past studies indicate a
1691 lack of consistent empirical relationship between spillway discharge and TDG (Schneider et al.
1692 2007). The elevated TDG pressures observed below the spillway prior to dilution from
1693 powerhouse flows, are a function of the initial forebay TDG pressure, spill pattern, total project
1694 head, aerated depth of flow below the spillway, and downstream submergence of the spill gate
1695 lip. The lack of a direct empirical relationship between spill discharge and TDG production is
1696 attributed to the dam’s low head, shallow stilling basin channel depth, wide spillway
1697 configuration, and the submergence of the spill gates. The TDG exchange associated with
1698 spillway operation at Albeni Falls Dam is best described by determining the increase in TDG
1699 pressure above the forebay levels (Schneider et al. 2007).

1700 During high flow spring runoff periods, TDG in the Pend Oreille River upstream of Albeni Falls
1701 dam can be greater than 110 percent largely because of spillway releases from Cabinet Gorge
1702 Dam located on the Clark Fork River about 55 miles (88.5 kilometers) upstream of Albeni Falls
1703 Dam. In general, when spill is spread evenly across the spillway, spillway discharges up to about
1704 10 kcfs can increase TDG saturations over forebay levels by about 1 to 2 percent. Spillway
1705 discharges between about 10,000 to 50,000 cfs can increase TDG saturations by about 5 to 9
1706 percent below Albeni Falls Dam. However, when flows in the Pend Oreille River exceed about
1707 50,000 to 60,000 cfs, the Albeni Falls Dam powerhouse operations are suspended and the
1708 spillway gates are raised, allowing the river to flow relatively un-impounded across the dam.
1709 Under these highflow conditions, Albeni Falls Dam produces no TDG as the river is essentially
1710 free flowing.

1711 Spillway flows at Albeni Falls Dam were modeled under the No Action Alternative for the 80-
1712 year period from 1928 to 2008 using the ResSim model (Figure 3-7.). In general, spillway flows
1713 were predicted to range between 1 and 50 kcfs in nearly every year at Albeni Falls Dam, with
1714 many years having spill exceed about 60 kcfs resulting in free-flowing conditions. These spillway
1715 conditions are similar to historical ones, and are not expected to change under the No Action
1716 Alternative.

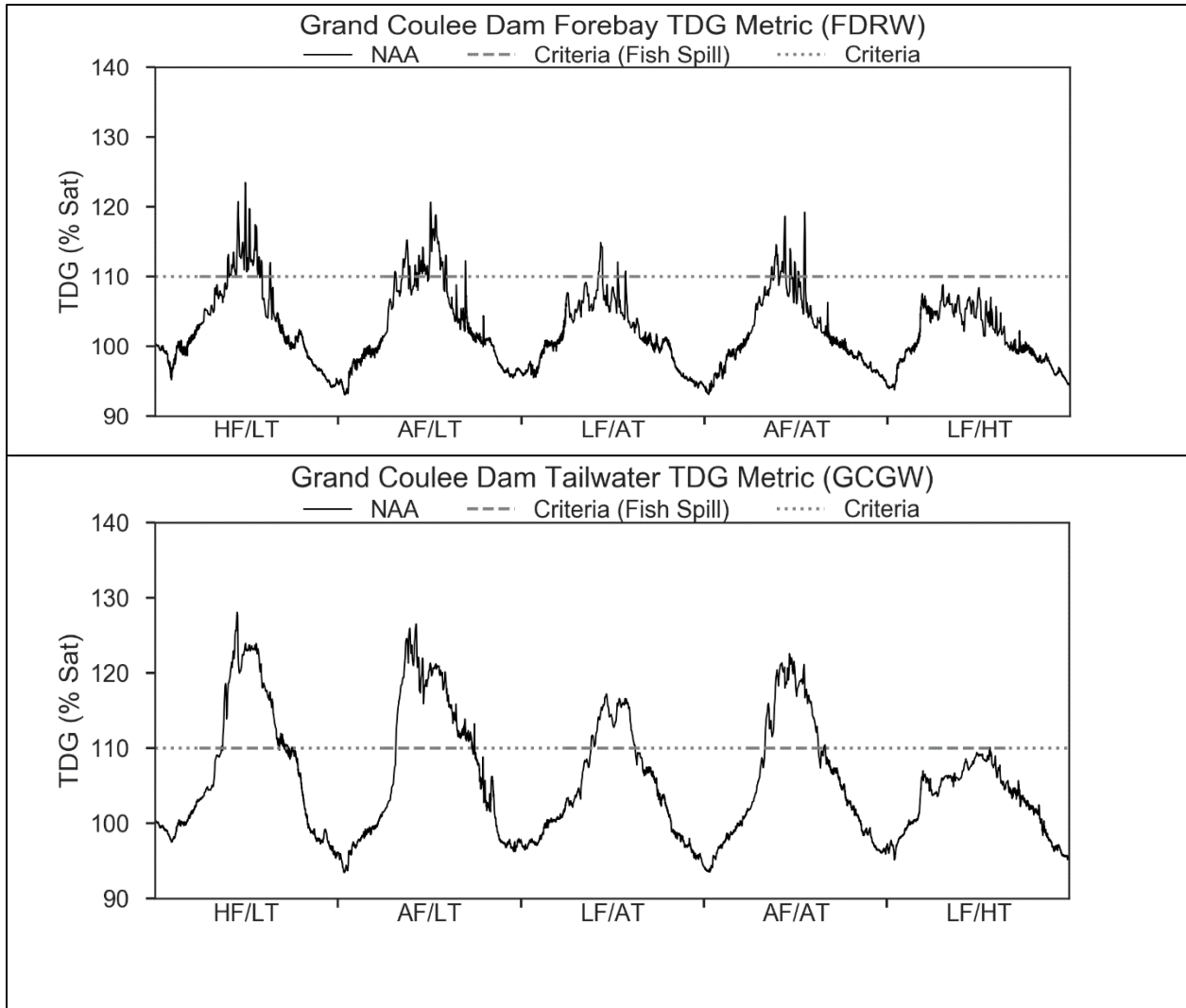


1717
1718 **Figure 3-7. ResSim Spillway Flows Modeled at Albeni Falls Dam for the 80-Year Period from**
1719 **1928 to 2008**

1720 **3.1.2.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

1721 The outlet tubes, and to a lesser extent the drum gates, at Grand Coulee Dam are known to
1722 produce elevated TDG when in operation. When reservoir elevations are greater than 1,266
1723 feet above mean sea level (amsl), the 11 drum gates can be used to discharge water
1724 downstream. The drum gates generate much less TDG than the outlet tubes, and are the
1725 preferred outlet when available. The 40 regulating outlets are used to discharge water
1726 downstream when forebay elevation is below 1,266 feet, at which point the drum gates
1727 become inoperable. The 40 regulating outlets are configured in two distinct rows along the face
1728 of the dam: 20 regulating outlet tubes are located at 1,050 feet amsl and 20 regulating outlet
1729 tubes are located at 1,150 feet amsl. Operating the outlet tubes in a specific spill pattern,
1730 referred to as an overunder configuration, is currently employed to reduce the concentration of
1731 TDG produced by the outlet tubes. This operational measure can result in less TDG production
1732 in the river below.

1733 TDG was modeled under the No Action Alternative to predict conditions above Grand Coulee
1734 Dam in the forebay and directly below the dam in the tailwater (Figure 3-8.) using W2. Both
1735 figures show daily average TDG conditions over a 5-year period that vary in flow and climatic
1736 conditions. Results from No Action Alternative modeling show that TDG concentrations are
1737 lowest in winter and highest in late spring and early summer when spill is highest (June/July).
1738 Early summer spill generally occurs when water must be evacuated from the reservoir to
1739 maintain flood control space and/or when required discharge does not meet turbine capacity.
1740 Under the No Action Alternative, there is generally a shift in the timing of elevated TDG
1741 concentration to earlier in the water year under high flow water years. This is because space
1742 must be made in the reservoir to capture high spring runoff for flood control. The additional
1743 drawdown often requires large amounts of water to be passed through the dam in a short
1744 amount of time. As the forebay is drawn down below the elevation of 1,266 feet AMSL, drum
1745 gates become unusable and all water is discharged through turbines or spilled through the
1746 dam's regulating outlet works, which produce the greatest amount of TDG. Additionally, in high
1747 water years, elevated TDG levels in Lake Roosevelt due to the influence of upstream dams (that
1748 fall outside the scope of this EIS) are expected. The No Action Alternative model predicts that,
1749 under such operations, average daily forebay TDG concentrations will continue to range
1750 between 92 and 121 percent annually; TDG below the dam is expected to range between 94
1751 and 130 percent. Realtime constraints and conditions, could result in TDG in excess of 130
1752 percent when TDG is high in the forebay and large amounts of spill are required. Both Lake
1753 Roosevelt and the Columbia River below the Grand Coulee Dam are listed on the Washington
1754 State 303(d) list for TDG impairment.



1755
1756 **Figure 3-8. Modeled Total Dissolved Gas, in Percent Saturation, for the No Action Alternative**
1757 **Above and Below Grand Coulee Dam Under a 5-Year Range of River and Meteorological**
1758 **Conditions**

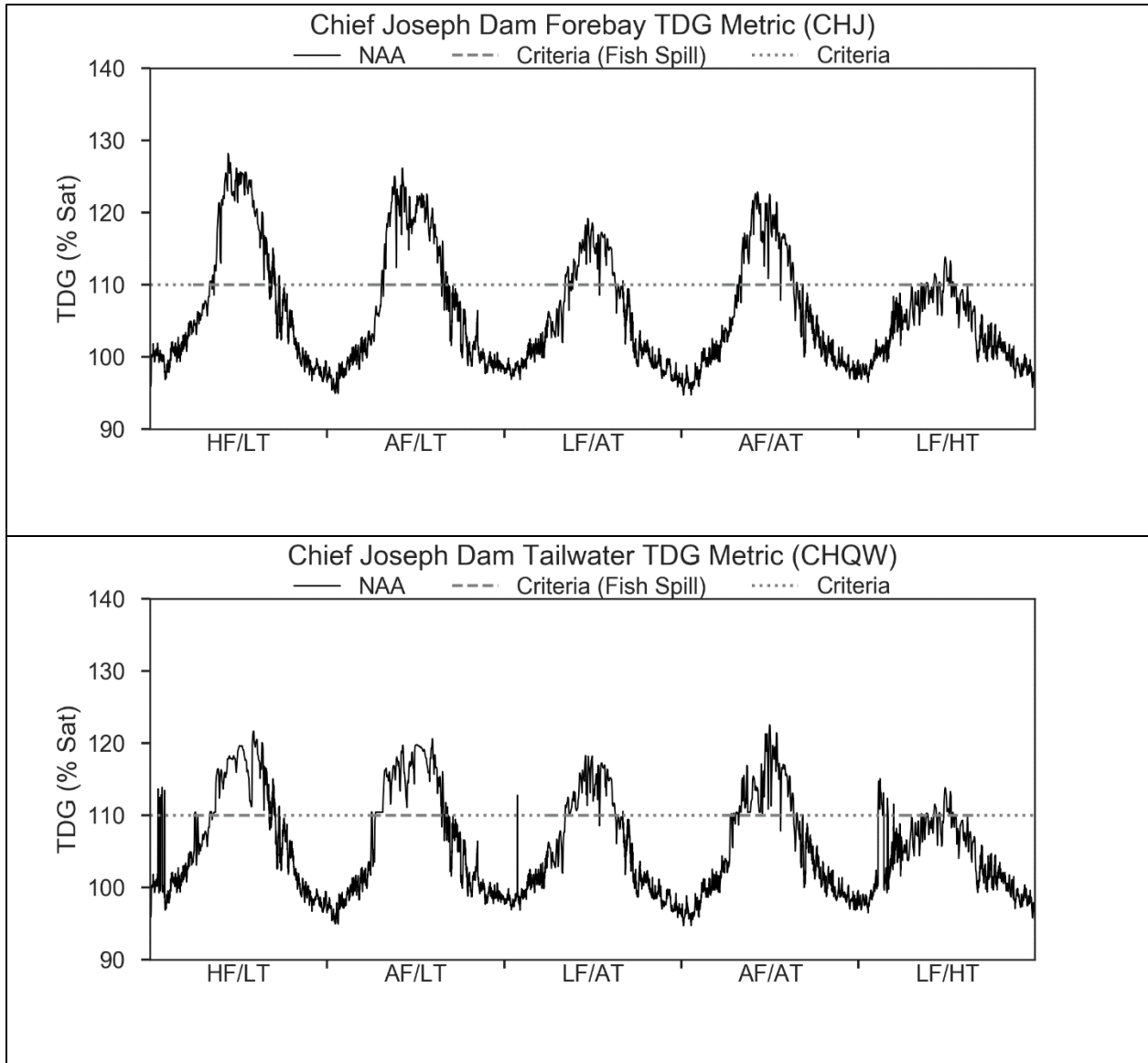
1759 TDG supersaturation is generated in the Columbia River during spillway flows at Chief Joseph
1760 Dam. Flow deflectors were added to all 19 spillbays in 2009. These deflectors are designed to
1761 reduce plunging flow from a spillway and create a skimming flow, thereby reducing the TDG
1762 saturations downstream. A detailed investigation of pre-deflector TDG exchange was
1763 conducted at Chief Joseph Dam in 1999 and an investigation of post-deflector TDG exchange
1764 was conducted in 2009 (Schneider and Carroll 1999; Schneider 2012). The pre-deflector study
1765 determined that TDG saturations in spillway flows ranged from about 111 to 134 percent and
1766 were an exponential function of spillway discharge, weakly related to tailwater depth of flow,
1767 and with little powerhouse entrainment. A post-deflector TDG study was conducted at Chief
1768 Joseph Dam in 2009 to determine TDG exchange characteristics for Chief Joseph Dam with
1769 deflectors. Results showed that TDG saturations during spillway operations with deflectors
1770 were greatly reduced compared to non-deflector operations, with measured TDG saturations

1771 ranging from about 110 to 120 percent during the study (Schneider 2012). TDG saturations
1772 were lowest for uniform spillway conditions and influenced by tailwater depth, with deeper
1773 tailwater resulting in greater TDG saturations. When forebay TDG saturations are greater than
1774 about 120 percent, spill over the deflectors at Chief Joseph Dam has been shown to degas the
1775 high incoming TDG to saturations less than 120 percent.

1776 TDG at the forebay of Chief Joseph Dam is largely a function of the TDG saturations produced
1777 upstream from Lake Roosevelt and Grand Coulee Dam, because little degassing occurs in Rufus
1778 Woods Lake. High spill volumes via the outlet tubes at Grand Coulee Dam can increase TDG
1779 saturations in Rufus Woods Lake at the Chief Joseph Dam forebay to over 130 percent,
1780 especially when inflows entering Lake Roosevelt are already at elevated TDG levels. During
1781 periods of high TDG entering and exiting Lake Roosevelt, discharge of water over the Chief
1782 Joseph Dam spillway deflectors can degas supersaturated conditions generated upstream.
1783 Spilling at Chief Joseph Dam when incoming TDG levels are above approximately 120 percent
1784 can reduce downstream system TDG loading, therefore Chief Joseph Dam is often used to help
1785 manage overall system TDG production in the mainstem Columbia. In addition, to avoid spilling
1786 through the outlet tubes at Grand Coulee Dam, spill is often shifted from Grand Coulee Dam to
1787 Chief Joseph Dam to take advantage of the lower TDG produced by spilling over the deflectors.
1788 These operational strategies are expected to continue under the No Action Alternative.

1789 Chief Joseph Dam TDG saturations at the forebay and tailwater were modeled under the No
1790 Action Alternative using flows from the ResSim model (Figure 3-9.). Predicted forebay and
1791 tailwater TDG levels show that the greatest TDG saturations occurred during HF/LT year and the
1792 lowest TDG saturations during the LF/HT year.

1793 Under the No Action Alternative, the model predicts a decrease in TDG saturations between the
1794 forebay and tailwater at Chief Joseph during high flow and high spill years. This decrease in
1795 tailwater TDG saturations, when the forebay TDG is elevated, is due to the spillway deflectors at
1796 Chief Joseph Dam, and is similar to historical conditions monitored at the dam. It is expected
1797 that under the No Action Alternative, Chief Joseph Dam will continue to decrease TDG during
1798 high flow years when elevated TDG saturations occur in the forebay. In addition, spilling at
1799 Chief Joseph Dam when forebay TDG saturations are low, will continue to generate elevated
1800 saturations up to about 120 percent downstream of the dam.



1801
1802 **Figure 3-9. Modeled Total Dissolved Gas, in Percent Saturation, for the No Action Alternative**
1803 **Above and Below Chief Joseph Dam Under a 5-Year Range of River and Meteorological**
1804 **Conditions**

1805 **3.1.3 Other Physical, Chemical, and Biological Processes**

1806 Watershed land use can significantly affect surface water quality. Urban runoff, agriculture,
1807 mining, atmospheric deposition of pollutants, and industry can pollute rivers and streams,
1808 creating an unhealthy environment for fish and other aquatic biota. Past impacts from human
1809 activity in the upper Columbia River Basin include contamination, and increased sediment and
1810 nutrient loading from mining activities, and are expected to continue to impact future water
1811 quality.

1812 **3.1.3.1 Libby and Hungry Horse Dams and Reservoirs**

1813 Lake Koochanusa is classified as an oligotrophic to lower mesotrophic waterbody based on
1814 summer concentrations of total phosphorus, chlorophyll a, and transparency. The reservoir
1815 experiences weak thermal stratification, and is well oxygenated throughout the entire water
1816 column, although lower dissolved oxygen concentrations (4 to 6 milligrams per liter [mg/L])
1817 periodically occur near the water bottom in a shallow reach near the U.S.-Canada border.

1818 Total phosphorus concentrations in Lake Koochanusa are low and increase during spring runoff,
1819 then decrease during the summer and fall. Total phosphorus concentrations are typically two to
1820 five times greater at the U.S.-Canada border than near Libby Dam, suggesting that Lake
1821 Koochanusa is a phosphorus sink. Low annual total phosphorus concentrations downstream in
1822 the Kootenai River further support this conclusion.

1823 Concentrations of nitrate have been increasing at all stations in Lake Koochanusa since the early
1824 2000s. Median nitrate concentrations in the epilimnion and hypolimnion increased between
1825 two-fold and three-fold from 2006 to 2016. Concentrations are only slightly greater at the U.S.-
1826 Canada border compared to near Libby Dam, suggesting that nitrate is moving through the
1827 reservoir. The major change in the Lake Koochanusa watershed over the past 20 years is an
1828 increase in coal mining operations in the Elk and Fording River watersheds in British Columbia,
1829 and a corresponding increase in nitrate loading from the waste spoils runoff. The estimated
1830 amount of waste spoils from coal mining operations increased ten-fold from 1997 to 2016.

1831 Despite rising nitrate concentrations in both hypolimnetic and epilimnetic waters, algal blooms
1832 (measured as chlorophyll a) appear to have been kept in check by strong phosphorus limitation,
1833 as indicated by low phosphorus concentrations and high total nitrogen to total
1834 phosphorus(TN:TP) ratios at all stations in Lake Koochanusa. However, these conditions also
1835 indicate that the lake could be susceptible to increased algal blooms, including blooms
1836 dominated by nuisance species, if phosphorus loading increases significantly in the future. Such
1837 increases could come from changes in upstream land uses that result in soil erosion, or
1838 additional waste inputs.

1839 The USGS has estimated that increased coal mining in the Elk and Fording Rivers has increased
1840 selenium loading to Lake Koochanusa fivefold over the past 20 years. There does not appear to
1841 be a substantial seasonal trend in water column selenium data, but concentrations were
1842 generally higher in the spring and fall, and lower in the summer at all stations. Median selenium
1843 concentrations in the epilimnion and hypolimnion at the border (1.0 and 1.1 micrograms per
1844 liter [$\mu\text{g/L}$], respectively) were slightly greater than at the forebay (0.8 and 1.03 $\mu\text{g/L}$,
1845 respectively).

1846 Lake Koochanusa water column phytoplankton populations were dominated by a wide mixture
1847 of diatoms, cryptophytes, and chrysophytes at all stations from 2008 to 2013 and by select
1848 diatoms and chrysophytes from 2014 to 2016. A substantial increase in phytoplankton
1849 biovolume and density was measured at all stations from 2014 to 2016. Although biovolumes
1850 were high from 2014 through 2016, species diversity was relatively low with often only one or

1851 two dominant phytoplankton species. From 2014 to 2016, the phytoplankton assemblage was
1852 largely dominated by a few diatoms (*Cyclotella* spp., *Fragilaria* spp., and *Synedra* spp.) and the
1853 chrysophyte, *Dinobryon* spp. The large increase in phytoplankton biovolume and density from
1854 2014 to 2016 may be partly due to the increased nitrogen loadings and the relatively stable
1855 loadings of phosphorus, resulting in extremely high nitrogen to phosphorus ratios. Additionally,
1856 the changes in species diversity and composition measured since 2014 may also be due to the
1857 increased nitrogen loadings to Lake Kootenai.

1858 The composition of zooplankton in Lake Kootenai has shown seasonal and annual differences.
1859 Zooplankton densities from 2006 through 2010 were dominated by copepods, which accounted
1860 for about 40 to 90 percent of the total density depending on the month. However, from 2011 to
1861 2014 rotifers have dominated the Lake Kootenai zooplankton population accounting for
1862 about 40 to nearly 100 percent of the total density depending on the month. In general, rotifers
1863 were dominated by *Keretella* spp., *Kellicottia longispina*, and *Polyarthra* spp.; copepods were
1864 dominated by *Nauplii* and *Diacyclops* spp.; while cladocerans were dominated by *Daphnia* spp.
1865 and *Bosmina longirostris*.

1866 Over the next 25 years, it is expected that mining, such as the coal production in the Kootenai
1867 River watershed above Libby Dam, may continue to increase as it has over the past 20 years
1868 (<https://www.nwd.usace.army.mil/CRSO/Documents/>). It is possible that without water quality
1869 treatment, the increased coal mining may lead to additional selenium contamination and
1870 nitrate loading into Lake Kootenai. Increased selenium loading may impact fish and wildlife
1871 species in the Lake Kootenai area. In addition, increased nitrate concentrations may alter the
1872 phytoplankton and zooplankton density and dominant species, possibly resulting in impacts to
1873 the local fishery.

1874 Hungry Horse Reservoir has no known water quality issues. The reservoir is an oligotrophic
1875 waterbody with high water quality. It is located high in the watershed. Only a few processes are
1876 likely to influence water quality with respect to nutrients and/or sediment: forestry operations,
1877 road building, natural disasters (e.g., forest fires) and atmospheric deposition. Water quality
1878 and associated processes are expected to remain unchanged under the No Action Alternative.

1879 **3.1.3.2 Albeni Falls Dam and Reservoir**

1880 Lake Pend Oreille is the largest and deepest lake in Idaho and the fifth deepest lake in the
1881 United States. In general, summer total phosphorus concentrations are low, water clarity is
1882 high, and algal growth (as determined by chlorophyll a concentrations) is moderate. Lake Pend
1883 Oreille would be classified as oligotrophic based on summer concentrations of these
1884 parameters, and oligotrophic/mesotrophic based on annual concentrations. Solar heating is
1885 sufficient to develop thermal stratification and a thermocline in the deeper regions of the lake
1886 during the spring and summer months. However, a shallow, low water outlet channel acts as a
1887 barrier to the transport of cold subsurface water from the deeper regions of Lake Pend Oreille
1888 into the Pend Oreille River. In general, both the lake and river are well oxygenated throughout
1889 the entire water column.

1890 Pend Oreille River pH values measured at the forebay of Albeni Falls Dam are occasionally
1891 greater than the downstream State of Washington standard of 8.5. These elevated pH values
1892 are uniformly distributed in the water column and are likely the result of photosynthetic
1893 activity. In general, concentrations of dissolved metals in Lake Pend Oreille and the Pend Oreille
1894 River are near or below the laboratory detection limits, with the exception of aluminum, and
1895 periodic detections of copper and zinc.

1896 Total phosphorus concentrations in Lake Pend Oreille and the Pend Oreille River are low, and
1897 follow a similar seasonal pattern of increasing during spring runoff and decreasing during the
1898 summer and fall. In general, total phosphorus concentrations are greatest at the inflow and
1899 slightly reduced in the lake and downstream river. This slight reduction in total phosphorus
1900 from the inflow, to the lake, to the downstream river, indicates that Lake Pend Oreille is
1901 retaining some total phosphorus. Summer nearshore nutrient concentrations were similar to
1902 epilimnetic concentrations measured in Lake Pend Oreille. An increase in total nitrogen and
1903 concurrent decrease in total phosphorus has been measured in the lake since 2014. The TN:TP
1904 ratio suggests that phosphorus is the limiting nutrient in the Pend Oreille system.

1905 Lake Pend Oreille water column phytoplankton populations were dominated by a mixture of
1906 diatoms, cryptophytes, and chrysophytes from 2005 to 2014, with few cyanobacteria detected.
1907 However, from 2015 to 2016, phytoplankton was largely dominated by a few diatoms
1908 (*Cyclotella spp.*, and *Fragilaria spp.*), cyanobacteria (*Aphanocapsa spp.*, *Aphanothece spp.*, and
1909 *Planktolyngbya spp.*), and the chrysophyte, *Dinobryon spp.* The increase in phytoplankton
1910 biovolume and density in 2015 and 2016, together with a substantial increase in cyanobacteria,
1911 may be partly due to an increase in the TN:TP ratio in Lake Pend Oreille and the Pend Oreille
1912 River measured during this period. The cyanobacteria species that has dominated Lake Pend
1913 Oreille and the Pend Oreille River since 2015 (*Planktolyngbya spp.*) is non-heterocystous and
1914 cannot fix nitrogen.

1915 A nearshore TMDL for nutrients was developed for Lake Pend Oreille in 2002 in response to
1916 increasing nuisance algal growth in nearshore areas. Elevated nutrients in nearshore areas is
1917 likely due to human activity (stormwater runoff, wastewater treatment, land use). It is possible
1918 that if nearshore nutrient concentrations increase, nuisance aquatic growth may further impair
1919 beneficial uses. Increased nutrient concentrations in Lake Pend Oreille and the Pend Oreille
1920 River will likely continue to be a concern under the No Action Alternative.

1921 **3.1.3.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

1922 Lake Roosevelt has a total storage capacity of about 9 million acre-feet (Maf) of water; annual
1923 flows through the lake average nearly 80 Maf per year, which results in some dilution of local
1924 water pollution. Lake Roosevelt, however, is listed on the Washington State 303(d) list for
1925 dioxin impairment. A TMDL for dioxin was completed by the state in 1991 and is still in effect.

1926 Lake Roosevelt exhibits low nitrogen, phosphorus, and chlorophyll a concentrations and high
1927 water clarity, which act collectively as proxies for primary productivity and classify Lake
1928 Roosevelt as oligotrophic. Populations of phytoplankton and zooplankton are also found in low

1929 concentrations. The notable exception to the low nutrient levels, is in the reach of reservoir
1930 where the Spokane River flows in, which is more productive due to municipal and agricultural
1931 nutrient inputs. Data suggests that phosphorous concentrations in the overall reservoir have
1932 remained relatively stable; however, primary productivity has trended slightly.

1933 Lake Roosevelt is listed on the State of Washington 303(d) list for dissolved oxygen impairment.
1934 The Columbia River between Grand Coulee Dam and Chief Joseph Dam is also listed. Dissolved
1935 oxygen in the main portion of the reservoir is generally above the required Washington State
1936 dissolved oxygen standard of 9.5 mg/L; however, concentrations can periodically decrease
1937 below that threshold during the summer months. Dissolved oxygen where the Spokane River
1938 flows in to the reservoir, tends to be well below the standard for several months each year.

1939 Turbidity, a measure of water clarity, in Lake Roosevelt is well below the Washington State
1940 standard. The processes that would likely increase turbidity in Lake Roosevelt are sediment
1941 additions to the waterbody through mass wasting events such as landslides and rill erosion, or
1942 wave action on unprotected shorelines. Reservoir fluctuations, which average 90 feet annually,
1943 create bank shoaling and erosion of shorelines. Increased landslides have also been correlated
1944 with past drawdowns that exceeded 1.5 feet per day (Reidel et al. 1997). Rill and wave action
1945 sedimentation and turbidity increases are highest when large vertical extents of shoreline are
1946 exposed (e.g., during periods of lower lake elevations).

1947 Water level fluctuations may also influence mercury cycling in a waterbody. Recent studies of
1948 reservoir systems along the Snake River suggest that exposing lake sediments that contain
1949 mercury may oxidize the toxic metal and make it available to higher-order organisms (USGS
1950 2016). These can bioaccumulate in fish and other large biota through the process of
1951 methylation in the waterbody. Additionally, the timing of elevation fluctuations may increase
1952 methylation rates. Most fish species exhibit their greatest growth rates from January to July
1953 when reservoir fluctuations generally occur. The modeled No Action Alternative water
1954 elevations are depicted in Figure 3-10..

1955 Water temperature, dissolve oxygen concentrations, and trophic status are expected to
1956 continue as described above and not change under the No Action Alternative. Climate change
1957 effects, as described in Chapter 4, could impact future conditions.

1958 Rufus Woods Lake is classified as oligotrophic to oligo/mesotrophic based on summer
1959 concentrations of total phosphorus, chlorophyll a, and transparency. The lake is a well
1960 oxygenated, near neutral to slightly basic pH waterbody with low to moderate nutrient
1961 concentrations. Small increases in total phosphorus and ammonia concentrations measured
1962 downstream of aquaculture facilities in Rufus Woods Lake suggest that these facilities may be a
1963 source of these nutrients. In general, Rufus Woods Lake metal concentrations are low and
1964 below the laboratory detection limit. However, periodic detections of copper at low
1965 concentrations have occurred. Water column phytoplankton populations are dominated by
1966 diatoms and cryptomonads at all stations. Very little cyanobacteria has been detected in water
1967 column phytoplankton samples. Zooplankton populations are dominated by rotifers in the
1968 spring and early summer, and by copepods in the late summer and fall.

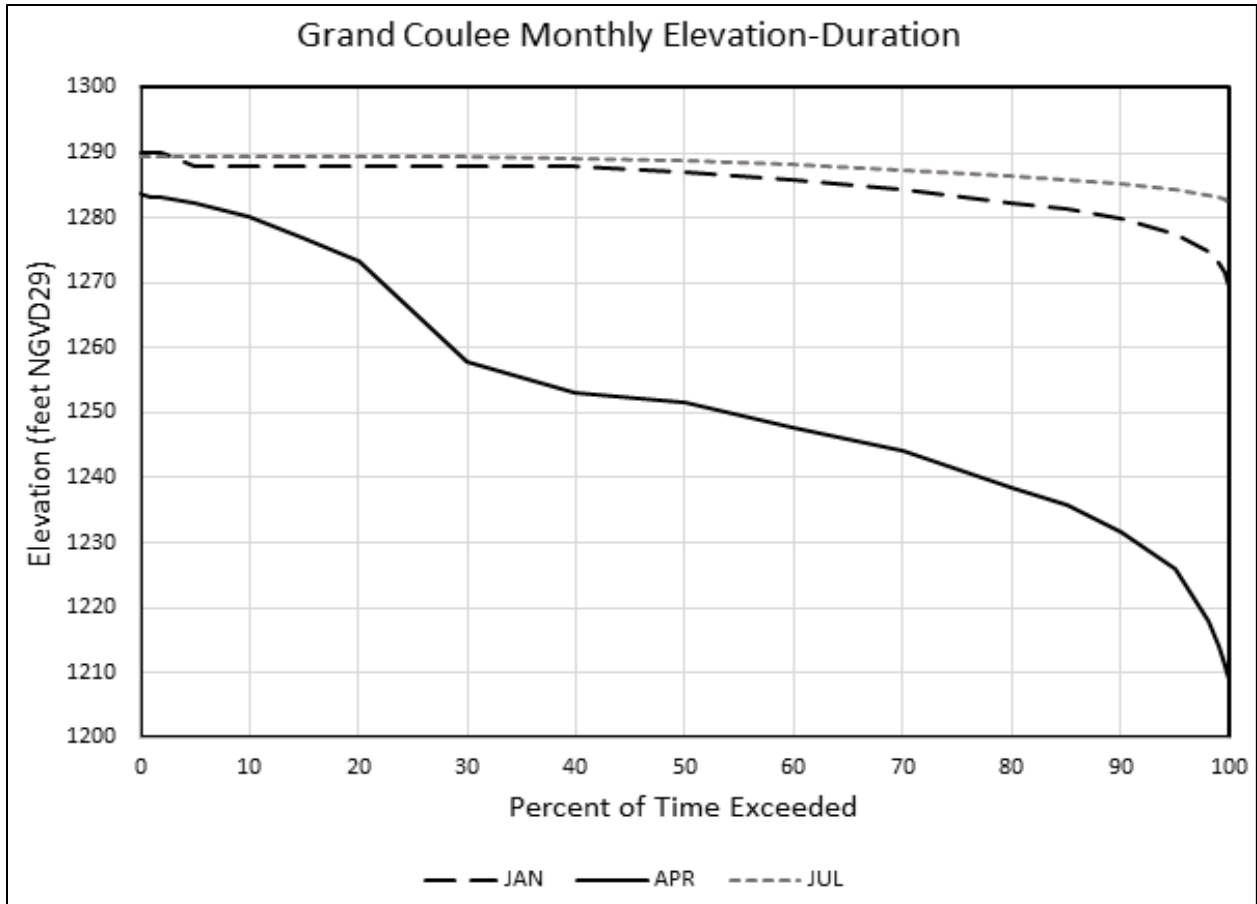


Figure 3-10. Exceedance Plot of Water Surface Elevation (feet NGVD29) for Select Months

Note: April and July are the lowest and highest water surface elevation months each year, respectively. The January exceedance plot displays the water surface elevation before drawdown occurs in the early spring. In this prediction at the 50 percent exceedance interval, the water surface elevation varies approximately 35 feet between max drawdown and max refill, the reservoir takes approximately 3 months to drawdown, and remains low for much of April and May, then takes approximately 2 months to refill. Data from ResSim results from system operations modeling.

Since 2011, Rufus Woods Lake has experienced annual harmful algae blooms characterized by floating algal surface mats and the algal toxin, anatoxin-a. The floating surface mats are dominated by diatoms and cyanobacteria, with the dominant cyanobacteria being *Oscillatoria sp.* Other cyanobacteria occasionally found in the floating mats are *Anabaena sp.* and *Aphanizomenon sp.* The presence of these harmful algae blooms upstream of aquaculture facilities, suggests that they are not attributed to these facilities. It is not known why the blooms are occurring, and based on their regular occurrence since 2011 they are expected to continue to occur annually under the No Action Alternative.

3.2 LOWER SNAKE RIVER BASIN

The lower Snake River Basin includes the North Fork Clearwater River at Dworshak Dam downstream to the confluence with the Snake River, and the Snake River below the Hells Canyon Complex, from Lower Granite Dam to downstream of Ice Harbor Dam and the

1989 confluence of the Snake River with the Columbia River. Dworshak Dam is a high head, cold
1990 water project with a maximum depth of 650 feet. The lower four Snake River dams are
1991 considered run-of-river and, from upstream to downstream, are Lower Granite, Little Goose,
1992 Lower Monumental, and Ice Harbor Dams.

1993 **3.2.1 Water Temperature**

1994 Water temperatures in the lower Snake River are primarily determined by a combination of the
1995 temperature of the water originating from the middle Snake River and the Clearwater River.
1996 Lower and middle Snake River maximum summer temperatures exceeded the current 68°F
1997 (20°C) Washington standard before the dams were constructed (Corps 2002, Peery et al. 2003).
1998 Historical temperatures in the lower Snake River basin prior to the construction of the lower
1999 Snake River dams and the Hells Canyon Complex show that temperatures in the free-flowing
2000 lower Snake River often exceeded 68°F (20°C) in July and August and occasionally exceeded
2001 25°C. These measurements were taken near the mouth of the Snake River from 1955 to 1958.
2002 Cold-water releases from Dworshak Dam have been used successfully to reduce water
2003 temperatures at Lower Granite Dam to the 68°F (20°C) criteria since the early 1990s. However,
2004 the cooling effect of the Dworshak releases are attenuated as the Snake River flows towards
2005 the confluence with the Columbia River.

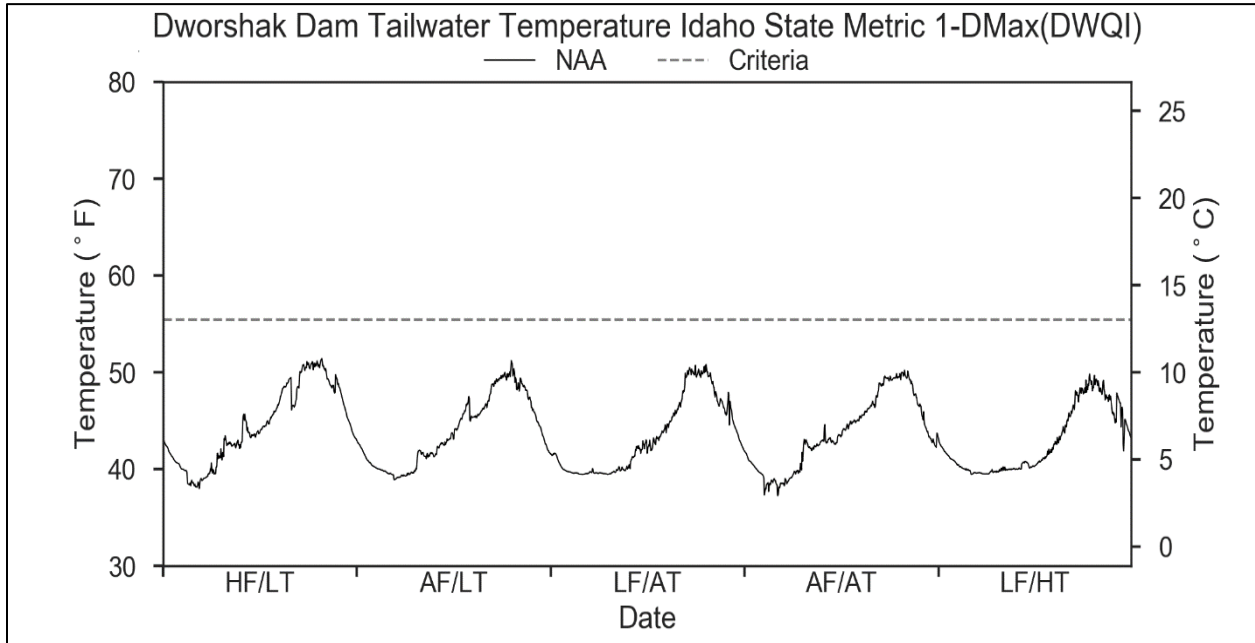
2006 **3.2.1.1 Dworshak Dam and Reservoir**

2007 Dworshak is a deep reservoir that typically starts to thermally stratify in the late spring or early
2008 summer as air temperatures increase. Surface temperatures remain above 68°F (20°C) in the
2009 upper 20 to 26 feet during the summer, but can exceed 77°F (25°C) in August. However, the
2010 deeper, colder layer of the reservoir that accounts for up to 70 percent of the volume remains
2011 cold at 40°F to 48°F (4°C to 9°C). During the first two decades of operation, the project's
2012 selective withdrawal structures were used to keep the outflow temperatures between 48°F and
2013 54°F (9°C and 12°C) to meet the needs of the downstream Dworshak National Fish Hatchery.
2014 However, since the mid-1990s there has been a greater emphasis on operating the project to
2015 provide a larger volume of cold water through the lower dam outlets during the summer to
2016 reduce water temperatures in the Lower Snake River. Summer release water temperatures are
2017 now typically between 43°F and 46°F (6°C and 8°C), and the average maximum summer
2018 temperatures in the downstream mainstem of the Clearwater River are approximately 16
2019 degrees Fahrenheit less than they were prior to construction of the dam. Complete mixing of
2020 the upper two-thirds of the reservoir occurs in the fall, and part of that reach is typically
2021 covered with ice during the winter. The lower 20 miles of the reservoir does not mix completely
2022 until February, and usually does not ice over.

2023 Current operations do not change the thermal structure of the reservoir, and temperature
2024 stratification is not anticipated to change under the No Action alternative.

2025 Dworshak Dam releases will continue to be used to moderate water temperatures in the Lower
2026 Snake River during the summer under the No Action Alternative. The model results for the five
2027 representative years show that tailwater temperatures would be less than the State of Idaho's

2028 Cold Water Communities Salmonid Spawning (COLD/SS) standard of 55.4°F (13°C) for every
2029 condition (Figure 3-11.).



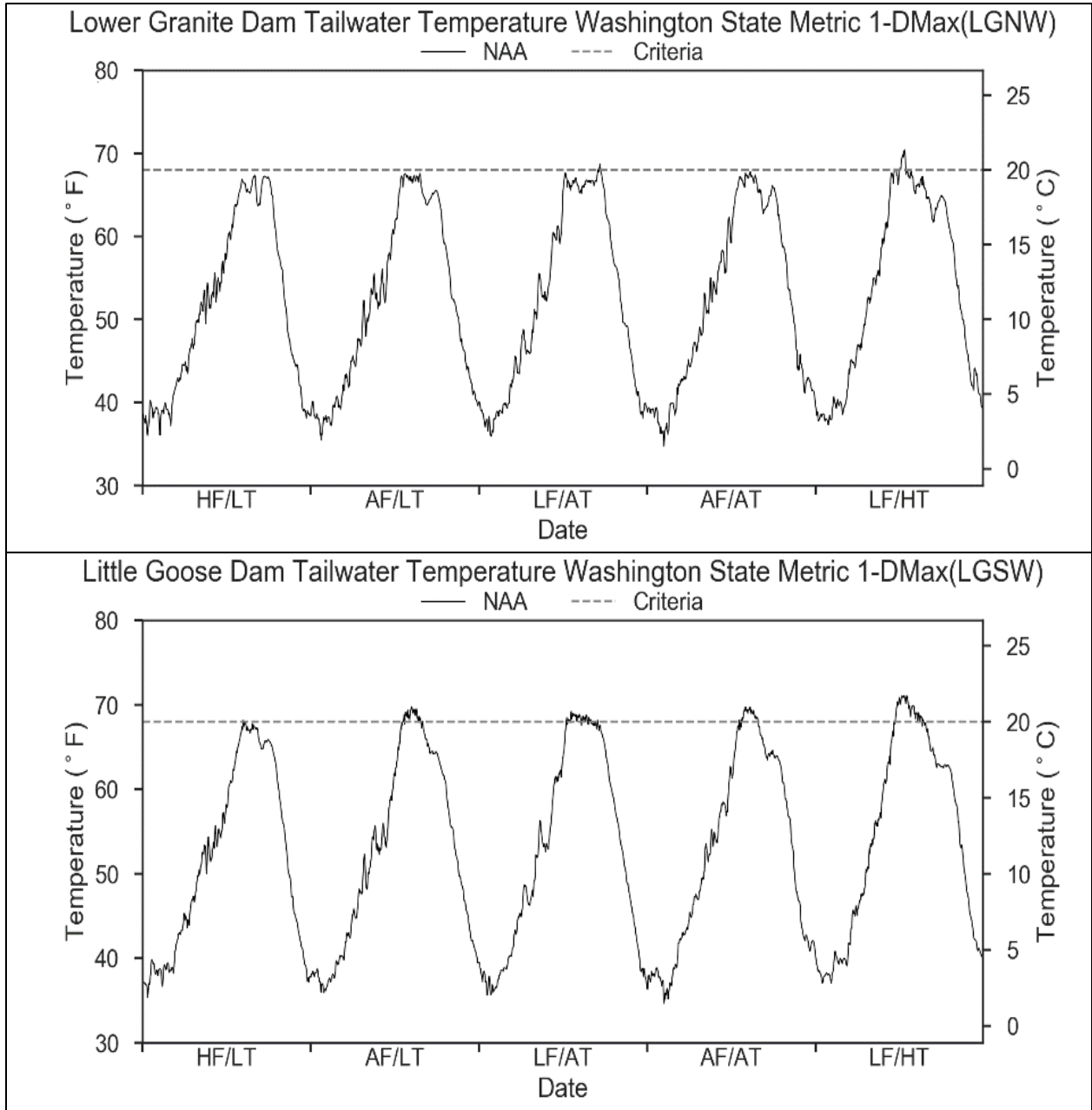
2030
2031 **Figure 3-11. Modeled Tailwater Temperature for the No Action Alternative at Dworshak Dam**
2032 **Under a 5-year Range of River and Meteorological Conditions**

2033 **3.2.1.2 Lower Granite, Little Goose, Lower Monumental and Ice Harbor Dams and Reservoirs**

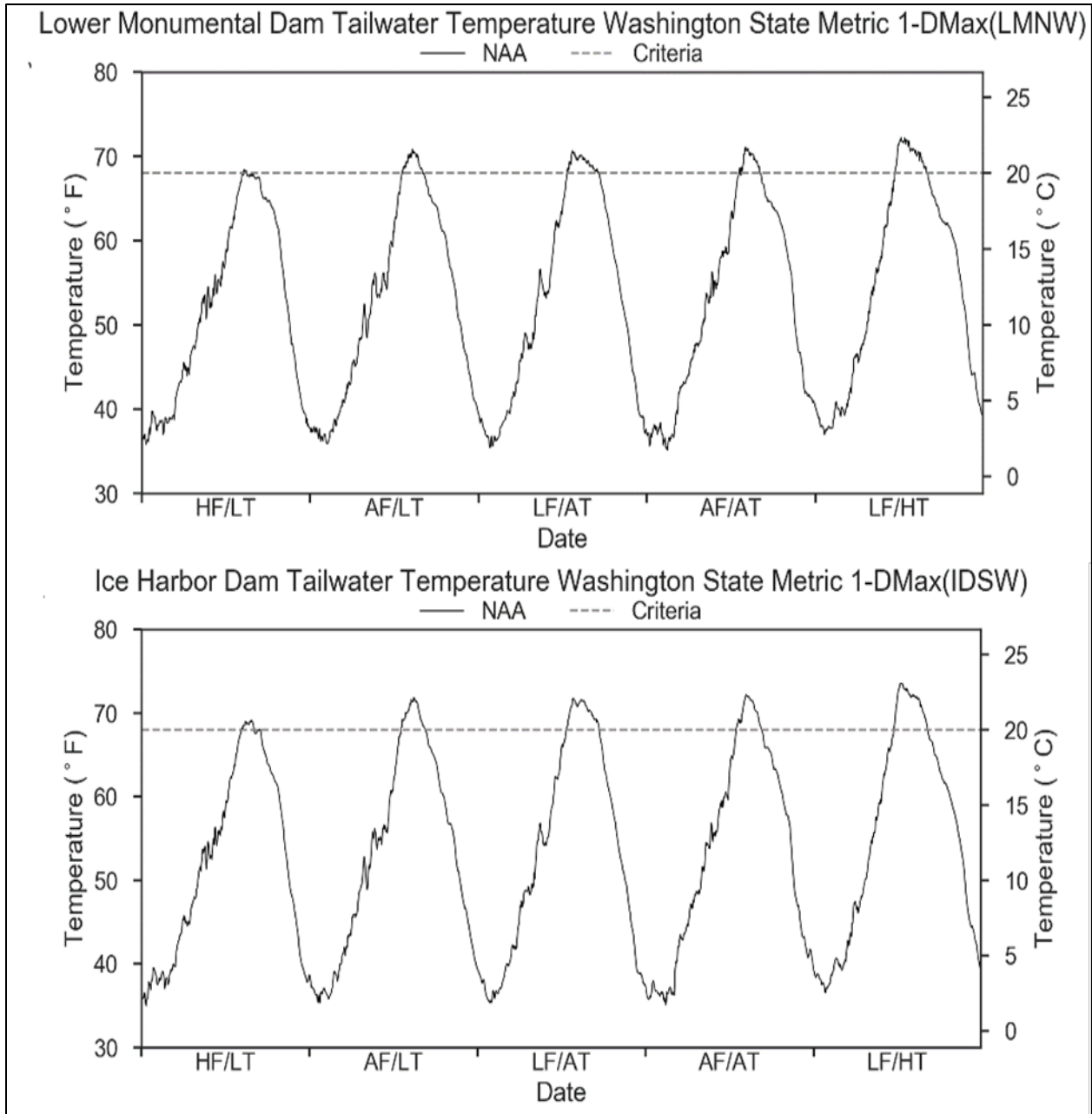
2034 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Reservoirs do not thermally
2035 stratify to the extent that Dworshak Reservoir and other deep reservoirs do. This is attributed
2036 to their short residence, wind and flow-induced turbulent diffusion, and convective mixing.
2037 However, vertical temperatures gradients can exist and are more pronounced in the reservoirs
2038 now than they were prior to the implementation of cold-water releases from Dworshak Dam.
2039 The effect from these cold-water releases are most apparent at Lower Granite Dam, but is
2040 observed as far downstream as Ice Harbor Dam. These releases are expected to continue for
2041 the period considered under the No Action Alternative.

2042 The modeled results show that water temperatures increase downstream for each
2043 flow/temperature condition (Figure 3-12. and Figure 3-13.). At Lower Granite Dam, water
2044 temperatures greater than the Washington state standard of 68°F (20°C) are not expected to
2045 occur during high-flow and average-flow years. The standard would be surpassed for about 5
2046 days during a LF/AT year, and 17 days during a LF/HT year. At the Little Goose and Lower
2047 Monumental Projects, the frequency of exceeding the standard downstream from the dam
2048 during either average-flow year condition is 38 and 45 days, respectively. The frequency of
2049 exceedances would increase during low flow years: 47 and 60 days with average temperature
2050 and high temperatures, respectively, at Little Goose Dam and 69 days at Lower Monumental
2051 Dam regardless of the air temperatures. Water temperatures downstream from Ice Harbor
2052 Dam would be warmer than at the other three dams, with the frequency of exceeding 68°F

2053 (20°C) ranging from 28 days during a high flow year to 73 days during a LF/HT year. Tailwater
 2054 temperatures could surpass 72°F (22°C) at Ice Harbor Dam during AF /AT and LF /HT years.

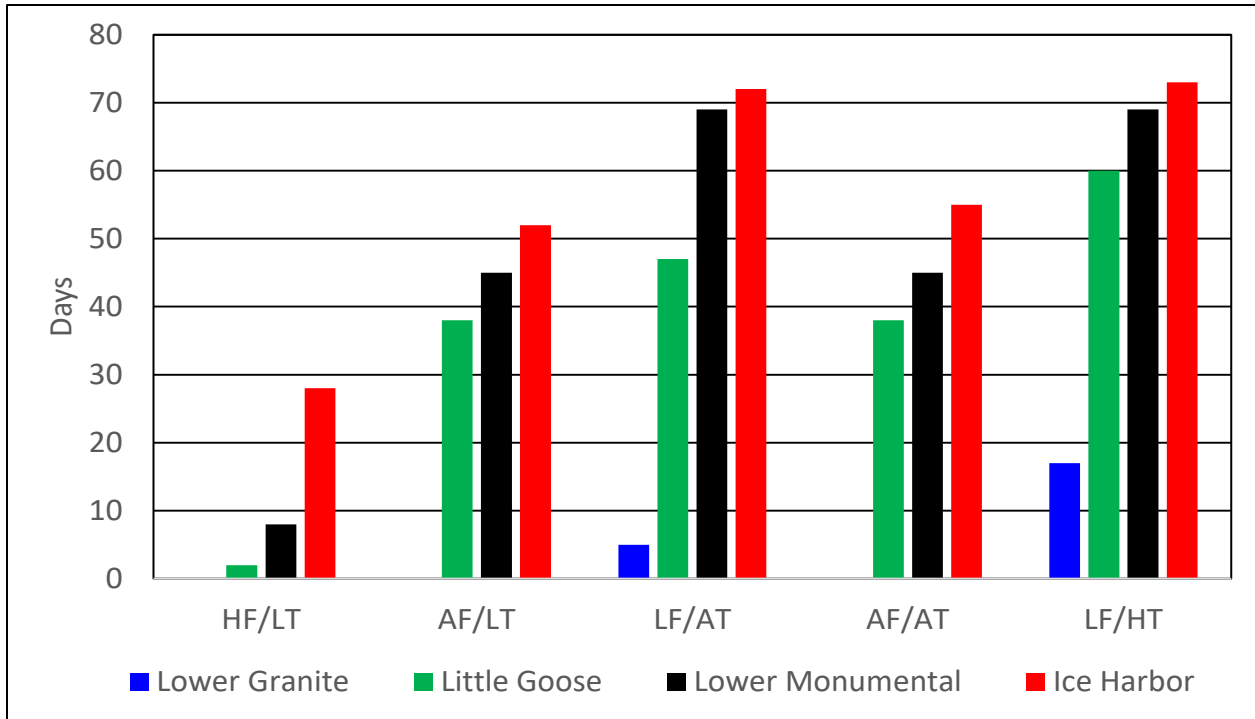


2055
 2056 **Figure 3-12. Modeled Tailwater Temperatures for the No Action Alternative at Lower Granite**
 2057 **and Little Goose Dams Under a 5-Year Range of River and Meteorological Conditions**



2058
2059
2060
2061

Figure 3-13. Modeled Tailwater Temperatures for the No Action Alternative at Lower Monumental and Ice Harbor Dams Under a 5-Year Range of River and Meteorological Conditions



2062
 2063 **Figure 3-14. Frequency Distributions of the Temperature Greater than the 68°F Washington**
 2064 **Standard that Would Occur at the Four Lower Snake River Dam Tailwater Fixed Monitoring**
 2065 **Stations for Each Flow/Temperature Condition**

2066 **3.2.2 Total Dissolved Gas**

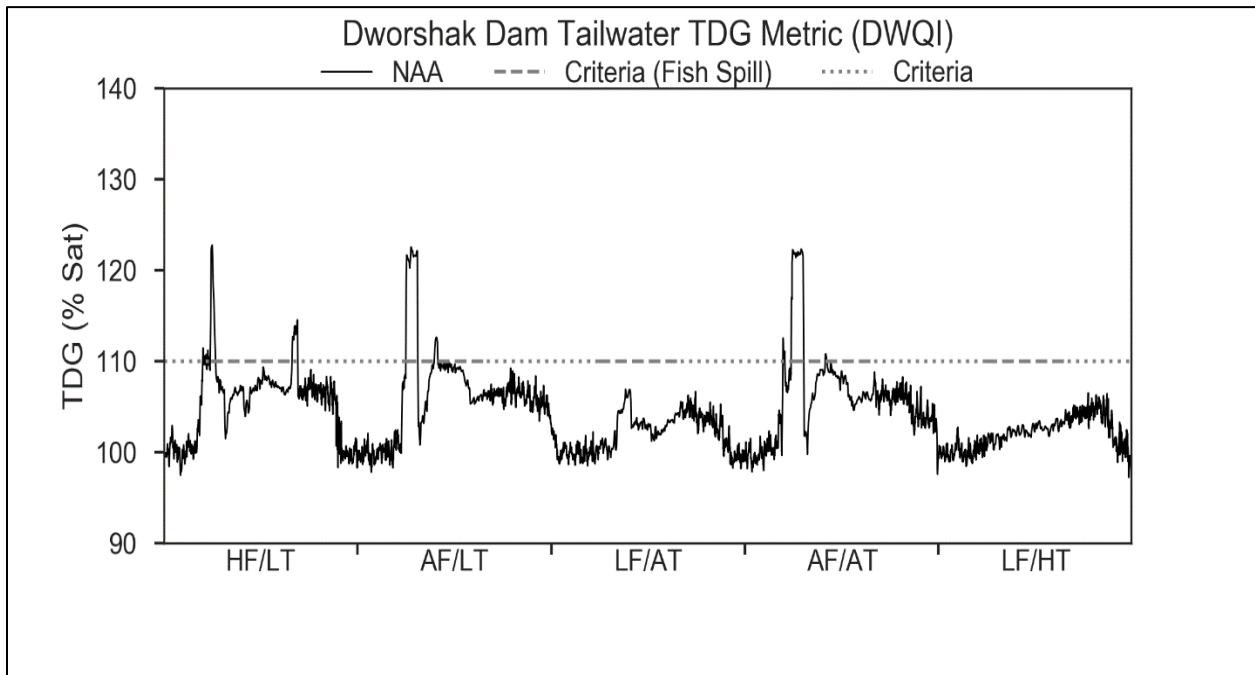
2067 High TDG is infrequently measured below Dworshak Dam, but does occur during high flow
 2068 events when total discharges exceed powerhouse capacity. Spill for juvenile fish passage does
 2069 not occur at Dworshak Dam. Conversely, the lower Snake River dams are operated for juvenile
 2070 fish passage during the months of April through August. During the juvenile fish passage
 2071 season, the co-lead agencies manage spill levels for juvenile fish passage to avoid exceeding 120
 2072 percent TDG in project tailraces, and 115 percent TDG in the forebay of the next project
 2073 downstream, consistent with the current State of Washington percent TDG limits³. Generally,
 2074 TDG exceedances above these thresholds are uncommon during the juvenile fish passage
 2075 season, and can be attributed to the structural enhancements and operational strategies that
 2076 have been implemented over the years. A TMDL for TDG for the Lower Snake River was
 2077 completed by the state in 2003 and is still in effect.

³ The 2014 Supplemental BiOp provides: “Specific spill levels will be provided for juvenile fish passage at each project, not to exceed established TDG levels (either 110 percent TDG standard, or as modified by State water quality waivers, currently up to 115 percent TDG in the dam forebay and up to 120 percent TDG in the project tailwater...”. In February 2009, Oregon modified its 5-year waiver to remove the 115 percent forebay TDG limit, but Washington did not. The Corps will continue to manage to 120 percent and 115 percent (the Washington TDG standard) which is the more restrictive TDG limit in effect during juvenile fish passage spill season..in 2016.

2078 **3.2.2.1 Dworshak Dam and Reservoir**

2079 Discharges from the spillway gates or regulating outlets are the primary sources of TDG
2080 generation at Dworshak Dam; TDG saturations above Idaho's state water quality standard of
2081 110 percent are typically exceeded when spill through these outlets is greater than 14 kcfs.
2082 Additionally, powerhouse flows can increase gas saturation when turbine units are operated at
2083 low flows of less than about 1.6 kcfs. Under these circumstances vacuum breakers within the
2084 units admit air into the turbine hub and draft tube to prevent cavitation. The Corps generally
2085 operates Dworshak Dam outside of these conditions to minimize TDG exceedances above the
2086 110 percent threshold. Since elevated TDG is detrimental to fish, the Dworshak National Fish
2087 Hatchery, located at the confluence of the North Fork and mainstem Clearwater Rivers
2088 downstream of Dworshak Dam, installed a degassing system to strip TDG from water that is
2089 pumped into the hatchery from the river.

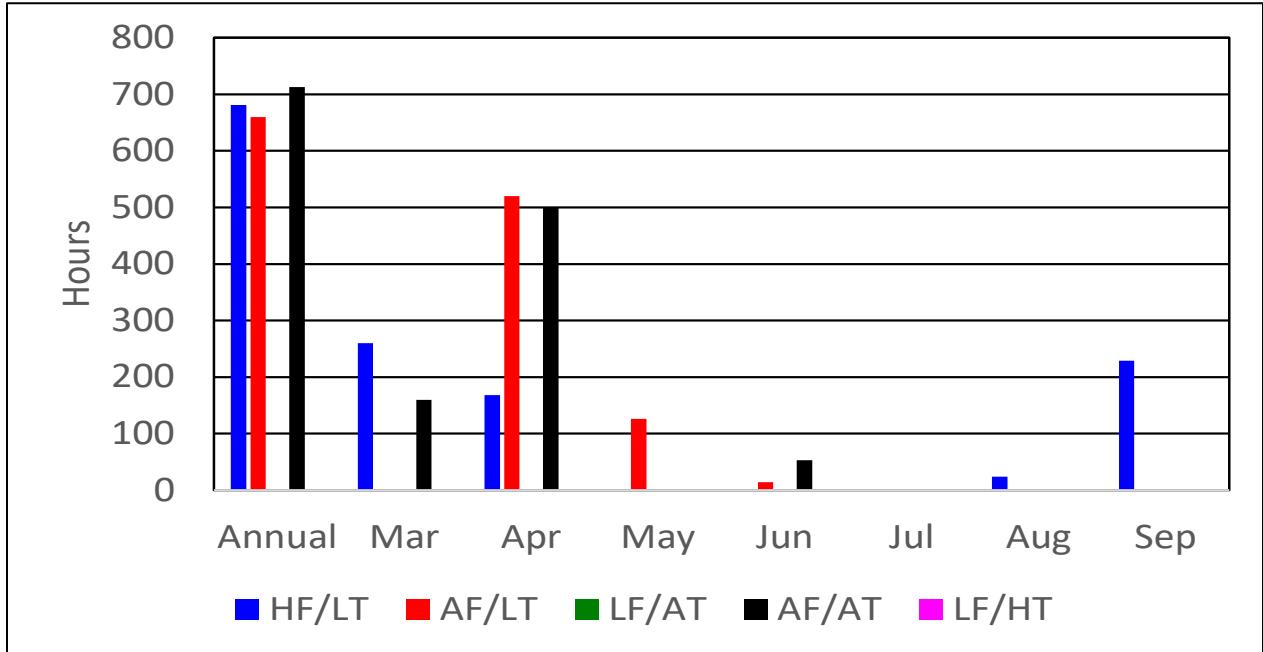
2090 Operation of the dam to stay below Idaho's 110 percent TDG standard, as well as the de-
2091 gassing system installed at the hatchery are expected to continue under the No Action
2092 Alternative. The primary deviations will occur during spring of average and high flow years
2093 (Figure 3-15.), when additional water is released for flood control purposes to keep the
2094 reservoir elevation aligned with the rule curve, as well as aiding the outmigration of hatchery
2095 releases.



2096
2097 **Figure 3-15. Modeled Tailwater Total Dissolved Gas for the No Action Alternative at**
2098 **Dworshak Dam Under a 5-year Range of River and Meteorological Conditions**

2099 An evaluation of the frequency of exceedances provides additional information regarding the
2100 timing and levels of gas saturation that would occur under the No Action Alternative
2101 (Figure 3-16.). During an average flow year, the TDG standard would be exceeded

2102 approximately 500 hours during April. The standard would be exceeded more than 200 hours in
 2103 March and September during a high flow year, but none would occur during May, June, and
 2104 July. No exceedances would be anticipated during any month of a low flow year, regardless of
 2105 the temperature conditions.



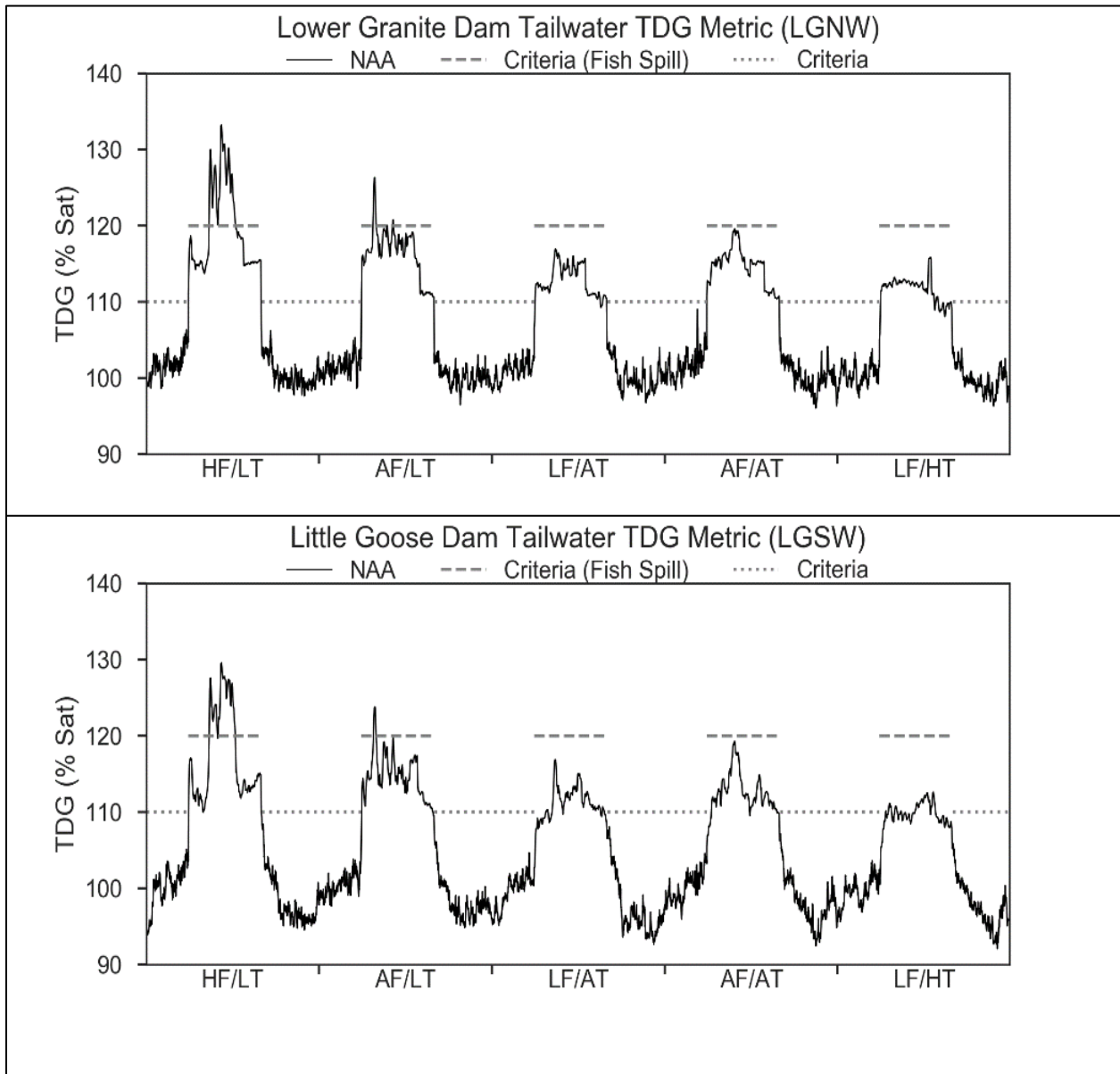
2106
 2107 **Figure 3-16. Frequency Distributions of the Hourly Total Dissolved Gas Values Greater than**
 2108 **Idaho's 110% Water Quality Standard that Would Occur at the Dworshak Dam Tailwater Fixed**
 2109 **Monitoring Station for Each Flow/Temperature Condition**

2110 **3.2.2.2 Lower Granite, Little Goose, Lower Monumental and Ice Harbor Dams and Reservoirs**

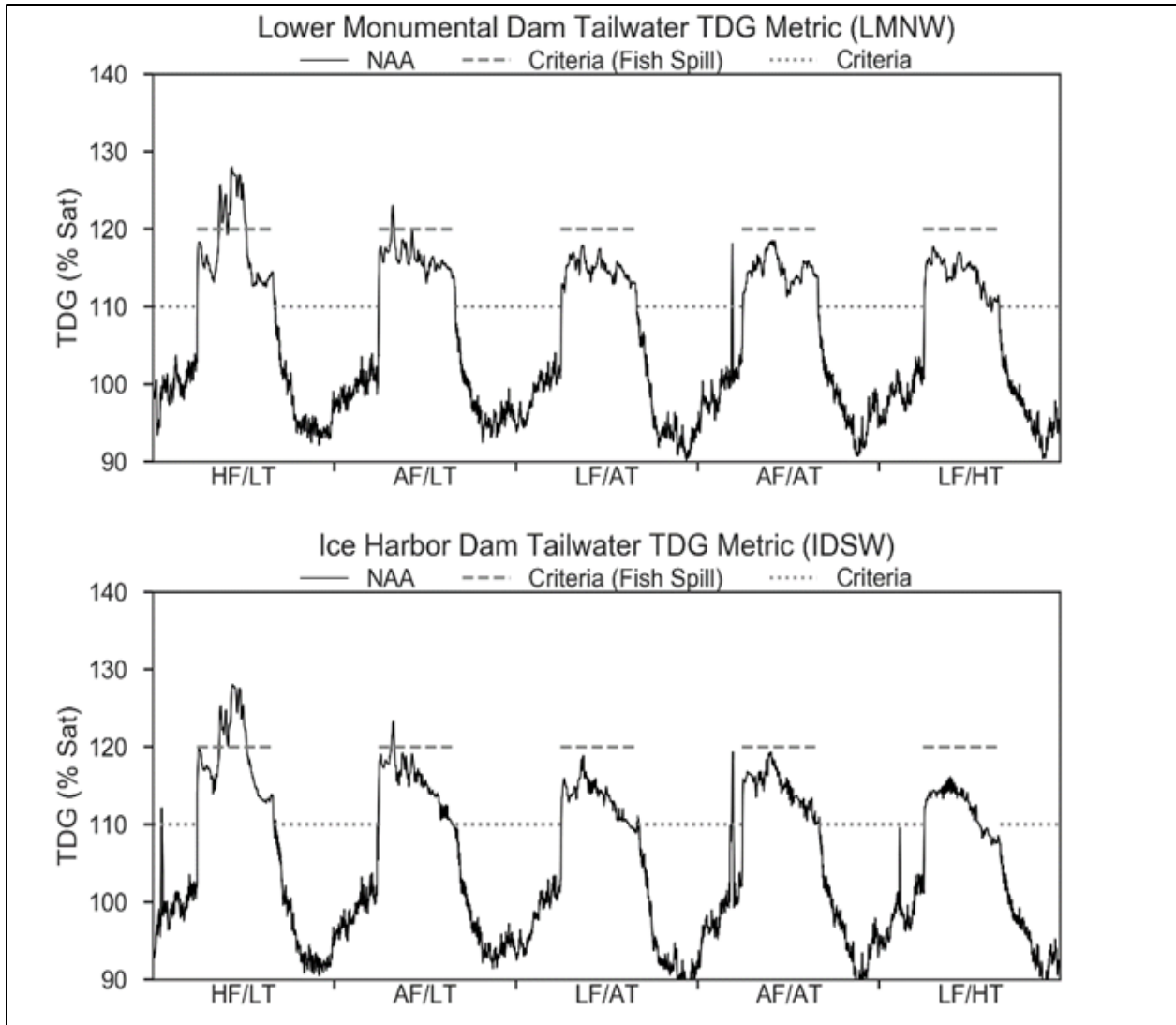
2111 To minimize TDG production during the juvenile fish passage spill season and during flood
 2112 events, spillway deflectors were installed at the spillbays of all four dams. These deflectors help
 2113 to redirect the spill jet from a plunging flow that transports air bubbles deep into the stilling
 2114 basin to a horizontal jet that maintains entrained air much closer to the water surface. Other
 2115 TDG abatement measures include limiting the amount of spill that is released from the dams
 2116 and implementing spill patterns that distribute spillbay flows uniformly across the entire
 2117 spillway.

2118 It is expected that juvenile downstream fish passage spill operations will continue to be
 2119 implemented for the years encompassed by the No Action Alternative. These operations are
 2120 regionally supported since they have proven beneficial for downstream juvenile fish passage. In
 2121 the future, it is unknown how impacts to water quality, namely TDG, may limit spill at the lower
 2122 four Snake River dams. There has been an increasing interest by some stakeholders to loosen
 2123 constraints on TDG water quality state waivers, and increase spill released from the lower
 2124 Snake River dams. These stakeholder efforts are expected to continue under the No Action
 2125 Alternative.

2126 Tailwater gas saturation at the four Lower Snake River projects were modeled for the five
2127 flow/air temperature conditions considered for the No Action Alternative. The W2 simulations
2128 for each project tailwater are shown in Figure 3-17.. The number of days when the 120 percent
2129 Washington standard that applies during the fish spill season would be exceeded, is similar at
2130 each project under a given flow/temperature scenario (Figure 3-19.). The highest occurrence
2131 was determined for the HF/LT scenario when the standard would be exceeded for more than 50
2132 days between April 1 and August 31 at each project. The frequency decreases to less than 10
2133 days at each dam for the AF/LT condition. No exceedances are predicted for the LF/AT, AF/AT,
2134 and LF/HT conditions.



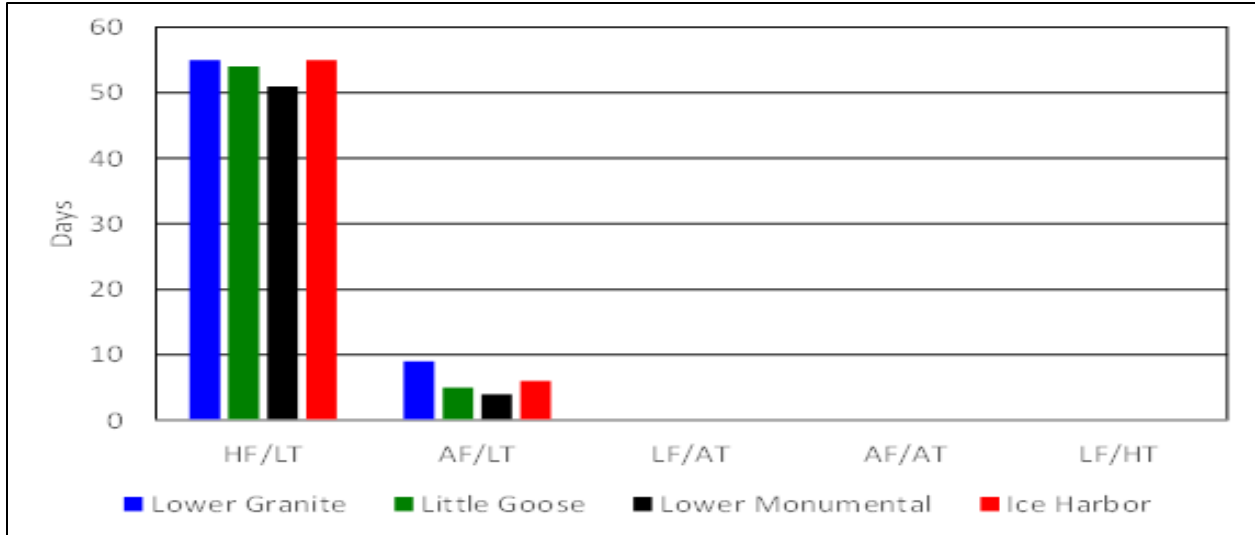
2135
2136 **Figure 3-17. Modeled Tailwater Total Dissolved Gas for the No Action Alternative at Lower**
2137 **Granite and Little Goose Dams Under a 5-Year Range of River and Meteorological Conditions**



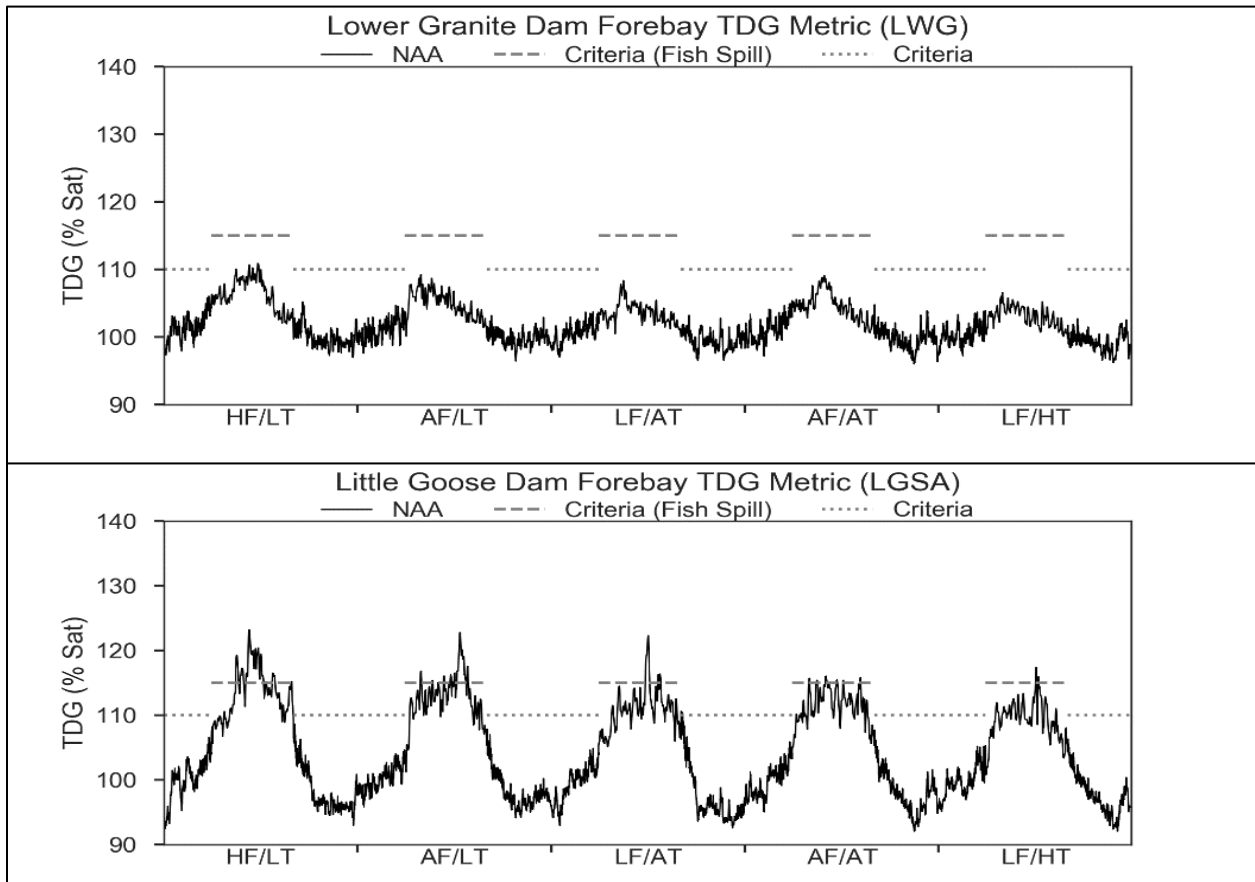
2138
2139
2140
2141

Figure 3-18. Modeled Tailwater Total Dissolved Gas for the No Action Alternative at Lower Monumental and Ice Harbor Dams Under a 5-Year Range of River and Meteorological Conditions

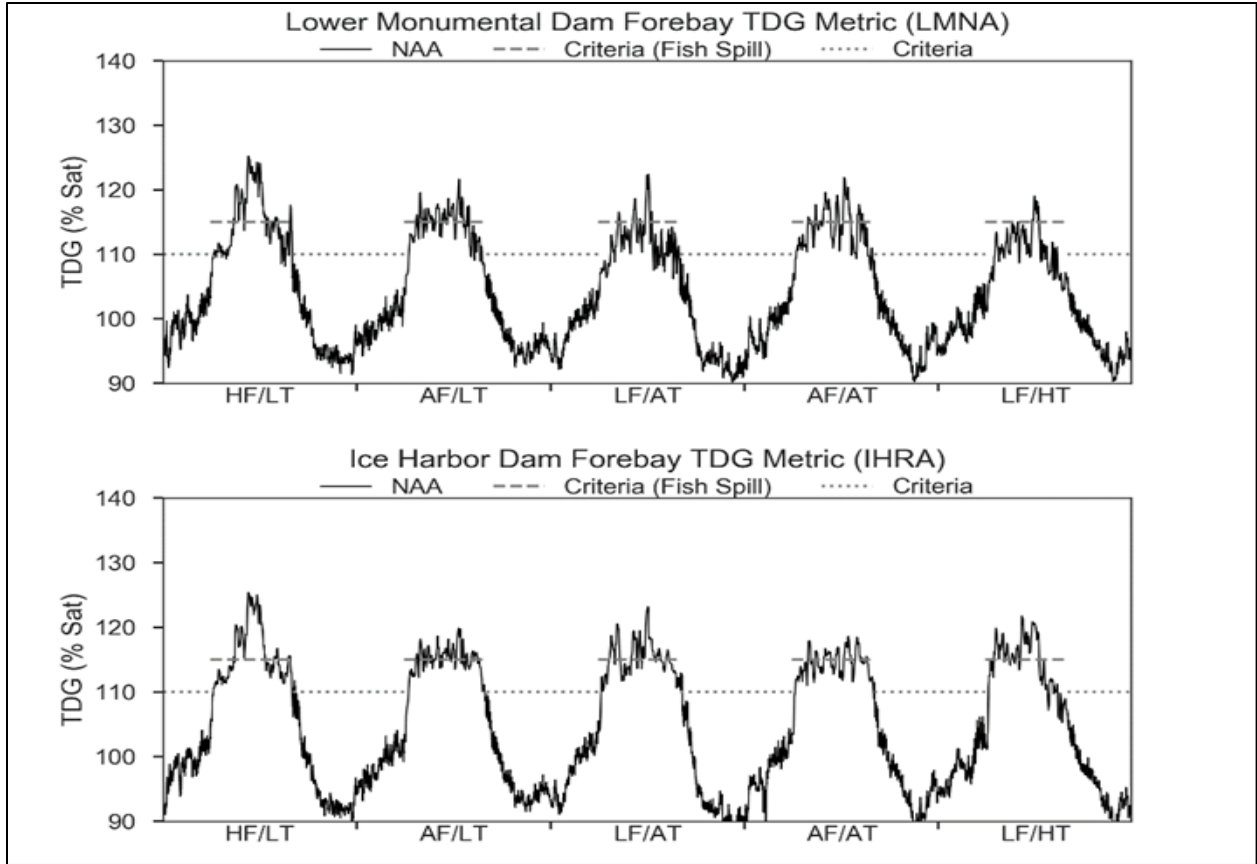
2142 Forebay TDG is dependent on several factors, including tailwater TDG at the upstream dam, the
2143 amount of degassing that occurs between projects, and water temperatures. The modeled TDG
2144 conditions show that the 115 percent Washington TDG standard that applies during the
2145 juvenile fish spill season would not be exceeded at Lower Granite Dam during any scenario
2146 (Figure 3-20.). However, the frequency of exceedances would increase at each successive
2147 downstream project regardless of the flow/temperature condition modeled (Figure 3-22.). At
2148 the Little Goose and Lower Monumental Projects the greatest number of exceedances would
2149 occur during HF/LT conditions, followed by an AF/LT year. For both of these projects, the lowest
2150 number of exceedances would occur during a LF/HT year. Ice Harbor forebay is expected to
2151 have the highest number of exceedances for any condition, with approximately 70 days during
2152 AF/LT, LF/AT, and LF/HT years. The frequency of exceedances would be least during an AF/AT
2153 year, but still number more than 50 days per spill season.



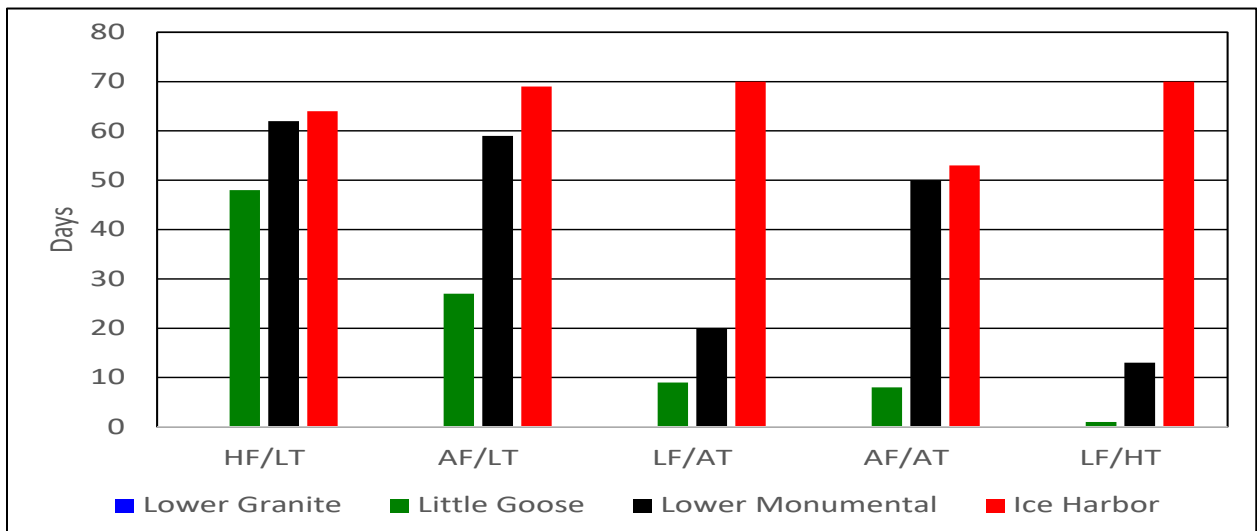
2154
 2155 **Figure 3-19. Frequency Distributions of the Daily 12-hour Maximum Average Total Dissolved**
 2156 **Gas Values Greater than Washington's 120 Percent Criteria at the Four Lower Snake River Dam**
 2157 **Tailwater Fixed Monitoring Stations for each Flow/Temperature Condition Between April 1 and**
 2158 **August 31**



2159
 2160 **Figure 3-20. Modeled Forebay Total Dissolved Gas for the No Action Alternative at Lower**
 2161 **Granite and Little Goose Dams Under a 5-Year Range of River and Meteorological Conditions**



2162
 2163 **Figure 3-21. Modeled Forebay Total Dissolved Gas for the No Action Alternative at Lower**
 2164 **Monumental and Ice Harbor Dams Under a 5-Year Range of River and Meteorological**
 2165 **Conditions**



2166
 2167 **Figure 3-22. Frequency Distributions of the Daily 12-hour Maximum Average Total Dissolved**
 2168 **Gas Values Greater than Washington's 115 Percent Criteria at the Four Lower Snake River**
 2169 **Dam Forebay Fixed Monitoring Stations for Each Flow/Temperature Condition Between April**
 2170 **1 and August 31**

2171 **3.2.3 Other Physical, Chemical, and Biological Processes**

2172 The physicochemical and biological characteristics of the reservoirs are influenced by natural
2173 processes and human activities. Organic and inorganic materials from upland erosion and
2174 atmospheric deposition are transported to the reservoirs along with runoff. A portion of these
2175 materials will be used by the biota, and the remainder will either settle to the bottom or be
2176 transported downstream to the next reservoir or river. These erosive processes are accelerated
2177 as a result of wildfire, which will also change the chemical composition of the runoff. Human
2178 activities contribute to the sediment, nutrient, and chemical loading of the reservoirs via
2179 agricultural practices, timber harvesting, mining, and urban runoff.

2180 **3.2.3.1 Dworshak Dam and Reservoir**

2181 Dworshak Reservoir is long, relatively narrow, and ranges from oligotrophic to lower-
2182 mesotrophic due to low nutrient concentrations and primary productivity rates. In 2007, the
2183 Corps, in conjunction with Idaho Fish and Game, began a nutrient fertilization project to
2184 increase the biological productivity in the reservoir. Concentrations of nitrate, total
2185 phosphorus, and chlorophyll a have decreased throughout the reservoir since samples were
2186 collected in the mid-1990s and mid-2000s, but it is not clear whether these decreases are due
2187 to the nitrification program, different analytical techniques, and/or nutrient loading. Diatom
2188 biovolume has also decreased throughout the reservoir, with a concurrent shift towards more
2189 edible forms. Ephemeral blooms consisting of 60 to 80 percent blue-green *Anabaena* sp.
2190 blooms are common but declining in some areas of the reservoir, while other species of blue-
2191 green algae, as well as green algae, have become more prevalent. Zooplankton consume algae;
2192 *Daphnia* are a primary food source for planktivorous fish, and their biomass has increased at
2193 some areas of the reservoir, but remained the same, or decreased, at other locations. Similarly,
2194 copepod density has increased at most of the sampling stations.

2195 Dissolved oxygen concentrations in the reservoir are dependent on several factors, including
2196 algae. Percent saturation in the epilimnion is usually close to 100 percent and occasionally
2197 increases to 120 percent (probably a result of algal photosynthesis). However, episodes of low
2198 dissolved oxygen in the metalimnion are becoming more common, and may be due to an
2199 increase in oxygen demand during the decay of dead phytoplankton biomass that sinks to
2200 denser metalimnion waters. There will likely continue to be shifts in the chemical and biological
2201 characteristics of the reservoir during the period considered for the No Action Alternative. The
2202 nitrification program is now funded annually, and some water quality monitoring will continue.
2203 This action should help identify whether the identified shifts are due to the nitrification
2204 program, changes related to the inflows, natural aging of the lake, or other unidentified causes.

2205 **3.2.3.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
2206 **Reservoirs**

2207 The physicochemical and biological attributes of the lower Snake River reservoirs are, to a large
2208 extent, governed by the inflowing Snake River. Total suspended solids concentrations are
2209 highest during peak runoff events, whereas the concentrations of dissolved constituents are

2210 highest during low flow conditions. The concentrations of these constituents, as well as Secchi
2211 disk depth, are similar for the entire length of the lower Snake River. Chlorophyll a
2212 concentrations and algal biovolume typically increase from the upper end of Lower Granite
2213 Lake to the mid-reaches of Lake Bryan and Lake Herbert G. West, and then gradually decline at
2214 the downstream reservoirs. However, growing season median concentrations are not
2215 demonstrably different due to the variability within the datasets. The algal community is
2216 dominated by the diatoms, although blue-green algal blooms also occur periodically in each
2217 reservoir, especially in the forebay and swim areas, but it is unknown if toxins such as anatoxin,
2218 saxitoxin, and microcystin are produced by these blooms. Blue-green algal blooms will be more
2219 prevalent during LF/HT conditions when the water is warmer and the hydrologic residence time
2220 of the reservoirs increase. Zooplankton biomass also tends to increase from the upper reaches
2221 of Lower Granite Lake to Lake Herbert G. West and decrease thereafter. Copepods are
2222 consistently present and usually account for the largest percentage of the biomass. However,
2223 cladocera, primarily *Daphnia retrocurva*, usually surpasses the combined biomass of all other
2224 zooplankton during the summer months.

2225 It is unlikely that the lower Snake River reservoirs would become truly eutrophic with each
2226 reservoir remaining in the mesotrophic to eutrophic state. This premise is based primarily on
2227 comparisons of the 2008 - 2010 datasets to analogous information collected in the mid-1990s,
2228 and in some cases the mid-1970s. The results show that inter-annual variability does occur, but
2229 there are no definitive temporal changes. Additionally, the reservoirs experience high water
2230 velocities with each spring freshet, and fine organic material containing nutrients is largely
2231 flushed from the river and prevented from accumulating. Given this, existing water quality
2232 impairments are likely to continue.

2233 **3.3 LOWER COLUMBIA RIVER**

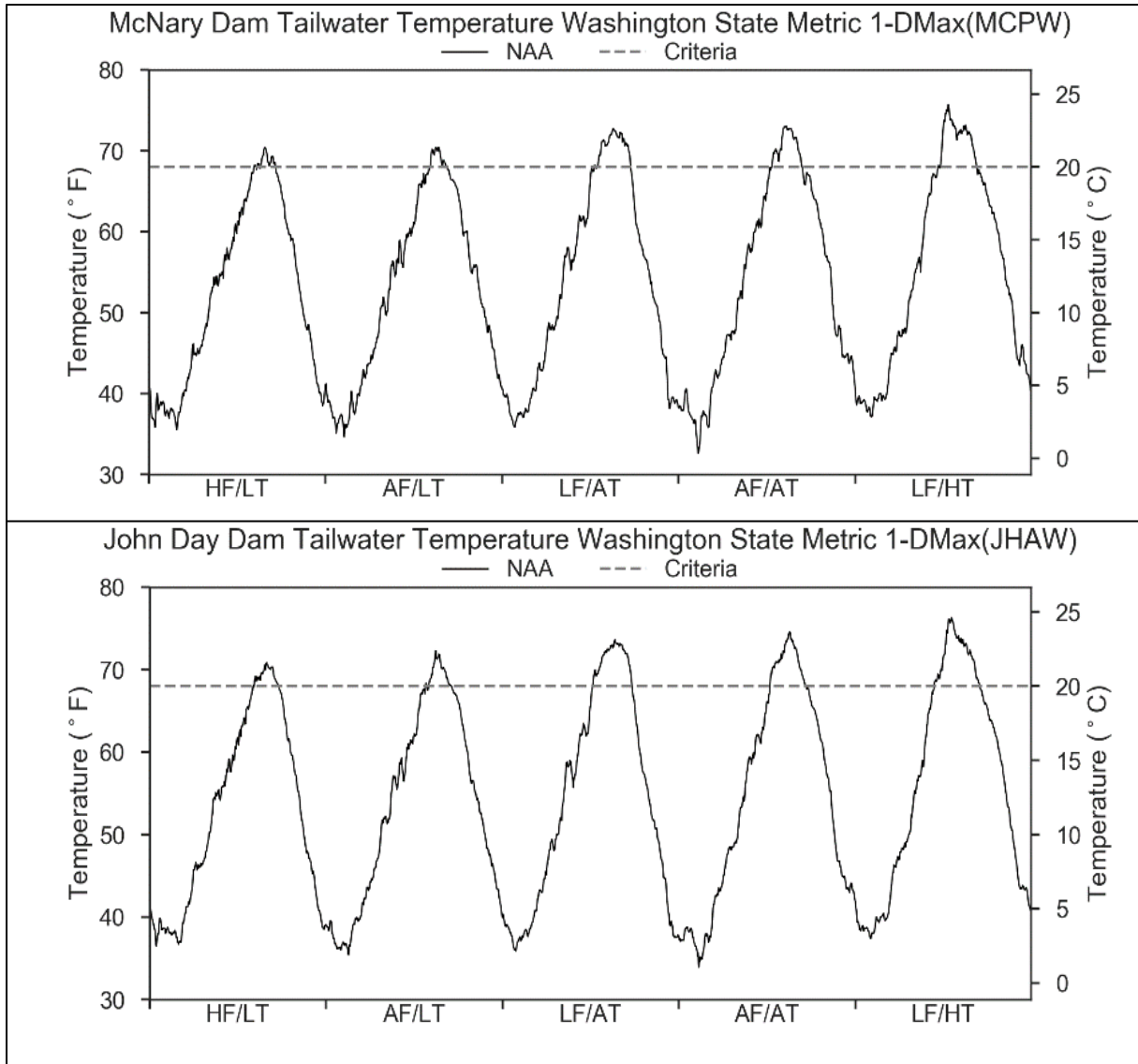
2234 The lower Columbia River includes the Columbia River at the confluence of the Columbia and
2235 Snake Rivers above McNary Dam, extending to Bonneville Dam (the downstream limit of this
2236 study). Similar to the lower Snake River, the lower Columbia River dams are operated for
2237 juvenile fish passage during the months of April through August.

2238 **3.3.1 Water Temperature**

2239 Water temperatures in the lower Columbia River are highly influenced by upstream dams, and
2240 are similar in all of the lower Columbia River reservoirs. The four lower Columbia River
2241 reservoirs show weak (McNary and John Day) to no (The Dalles and Bonneville) thermal
2242 stratification during the summer months, largely due to the short residence time, wind and
2243 flow-induced turbulent diffusion, and convective mixing that occurs in the reservoirs. All four
2244 reservoirs are on the Washington and/or Oregon 303(d) lists for impaired water temperatures
2245 due to high water temperatures that exist during the late summer/early fall. When high water
2246 temperatures occur in the lower Columbia River, many adult anadromous fish will seek cool
2247 water, referred to as "cold water refuges," in tributaries to the mainstem river, which may
2248 impact their ultimate migration and spawning success (High et al. 2006; Palmer 2017). For
2249 example, steelhead that pass Bonneville Dam in late July/early August have been observed to

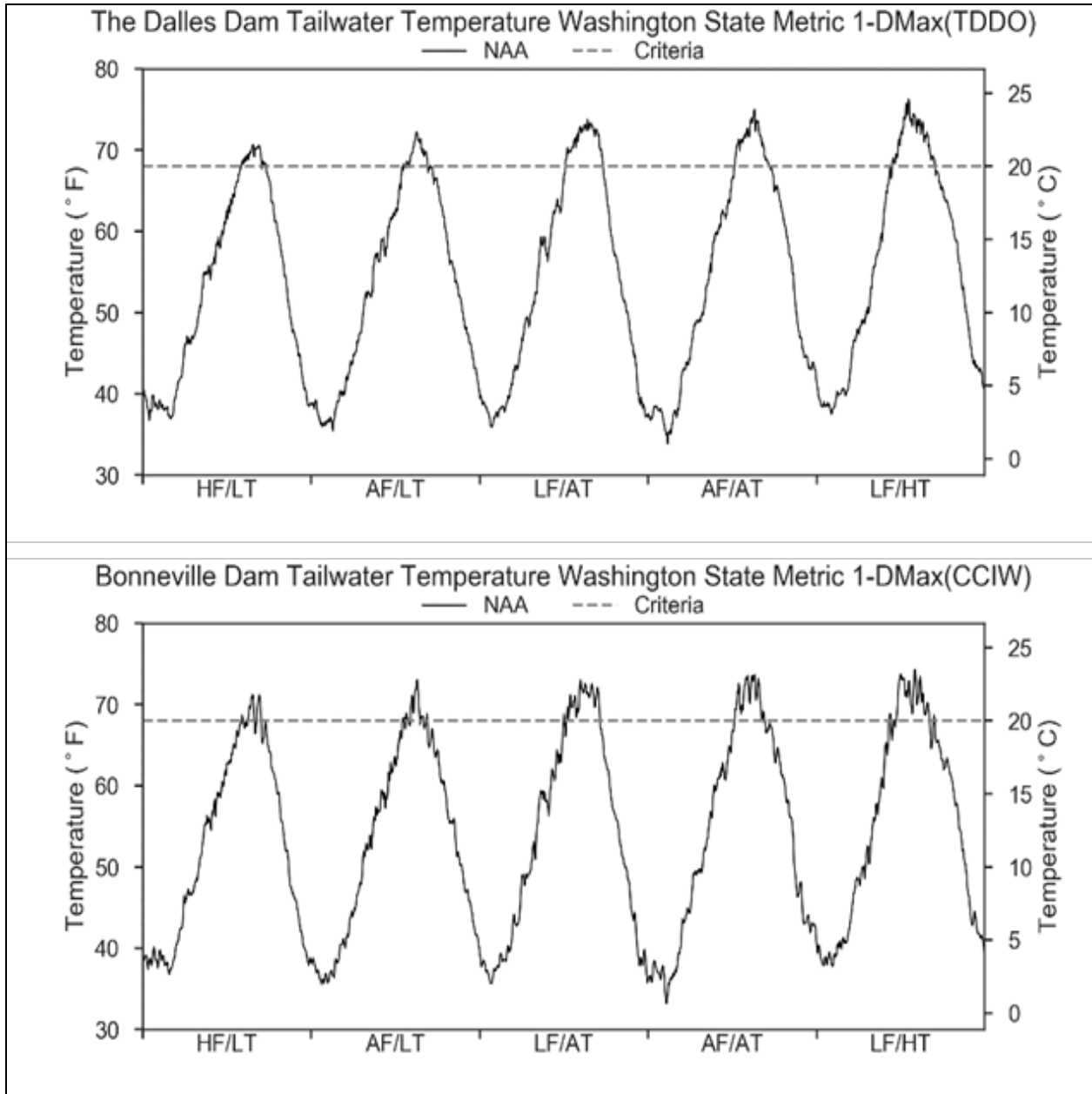
2250 delay their upstream migration until September while seeking refuge in cold water areas
2251 between Bonneville Dam and The Dalles Dam (Palmer 2017). The management of water
2252 temperatures in a manner similar to the strategies used on the lower Snake River is not
2253 effective in this river reach since there is not an upstream source of very cold water. Thus,
2254 access to off-channel thermal refugia is critical; protecting and restoring these cold water
2255 refuges is likely to be important for the recovery of salmon and steelhead populations in the
2256 Columbia River Basin. The importance of protecting and restoring these cold water refuges may
2257 take on more significance due to climate change, which is expected to increase the water
2258 temperatures in both the tributaries and the Columbia River (Palmer 2017).

2259 The tailwater temperatures for the No Action Alternative at McNary, John Day, The Dalles, and
2260 Bonneville Dams were modeled under a 5-year range of river and meteorological conditions
2261 (Figure 3-23.). The modeled results show that tailwater temperatures can exceed 68°F (20°C) at
2262 all four dams during any of the years and conditions presented, and maximum water
2263 temperatures and the number of water temperature exceedances would be higher during a
2264 year when river flows were lower than normal, and summer ambient air temperatures were
2265 higher (such as in 2015). Thus, the high water temperatures that exist in each reservoir during
2266 the late summer/early fall are expected to continue under the No Action Alternative for a wide
2267 range of river and meteorological conditions.



2268
2269
2270

Figure 3-23. Modeled Tailwater Temperature For the No Action Alternative at McNary and John Day Dams Under a 5-Year Range of River and Meteorological conditions



2271
 2272 **Figure 3-24. Modeled Tailwater Temperature For the No Action Alternative at The Dalles and**
 2273 **Bonneville Dams Under a 5-Year Range of River and Meteorological conditions**

2274 **3.3.2 Total Dissolved Gas**

2275 The lower Columbia River dams are operated for juvenile fish passage during the months of
 2276 April through August. These spill operations are managed to keep TDG saturation levels at or
 2277 below state water quality standard waivers of 120 percent in the downstream tailwater and
 2278 115 percent in the next downstream forebay. For the most part, TDG exceedances above these
 2279 thresholds are minimal during the juvenile fish passage and this success can be attributed to
 2280 the structural enhancements (e.g., spill deflectors at some dams) and/or operational strategies
 2281 (e.g., spill pattern, spill priority list) that have been implemented over the years. Nonetheless,

2282 there are TDG TMDLs in place at all four lower Columbia River reservoirs. A joint TMDL for TDG
2283 for the Lower Columbia River was completed by the states in 2002 and is still in effect.

2284 To minimize TDG production during the juvenile fish passage spill season and during flood
2285 events, spillway deflectors were installed at the spillbays of all four dams. These deflectors help
2286 to redirect the spill jet from a plunging flow that transports air bubbles deep into the stilling
2287 basin, to a horizontal jet that maintains entrained air much closer to the water surface. Other
2288 TDG abatement measures include limiting the amount of spill that is released from the dams
2289 and implementing spill patterns that distribute spillbay flows uniformly across the entire
2290 spillway.

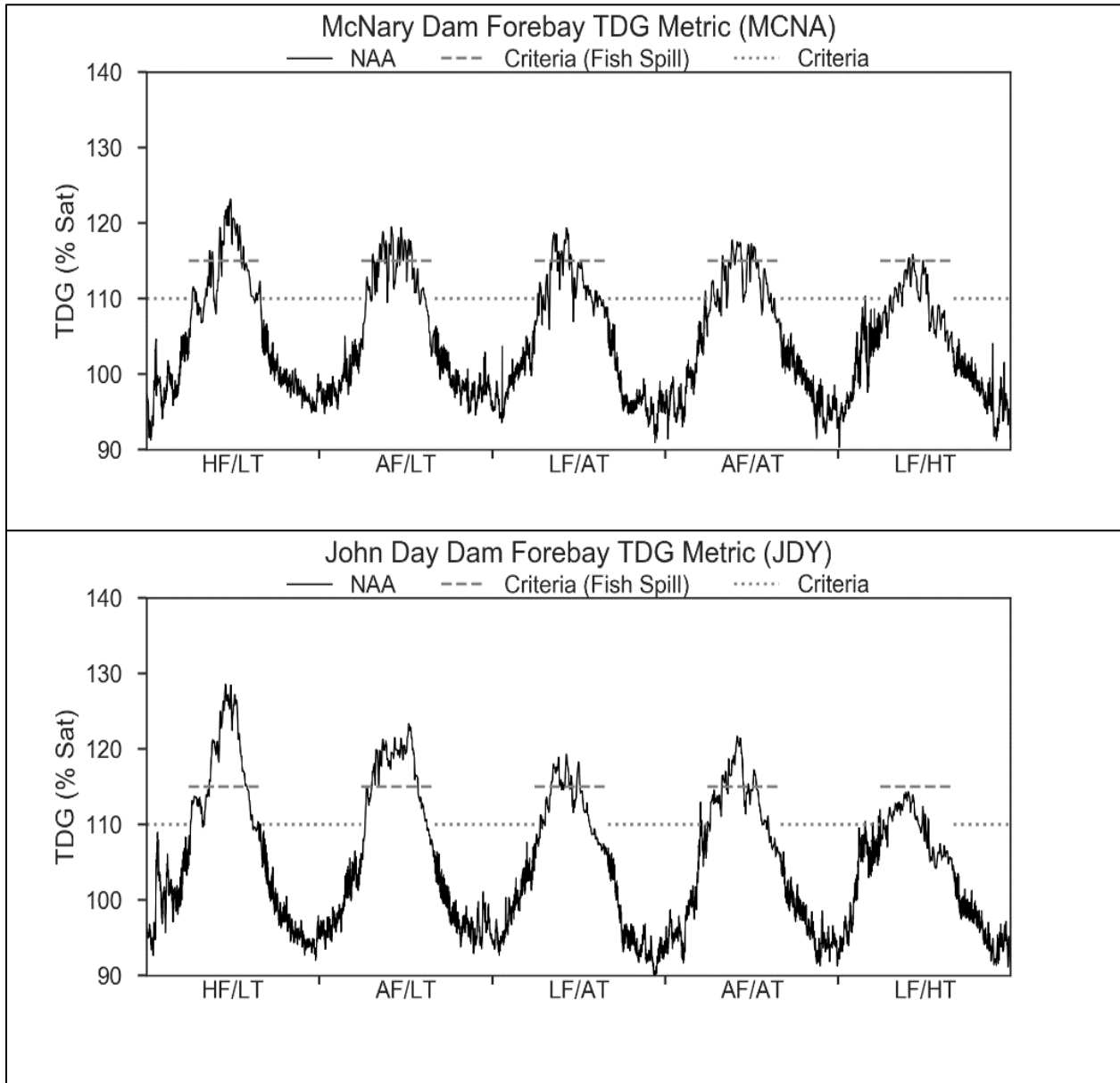
2291 Under the No Action Alternative, it is expected that juvenile downstream fish passage
2292 operations will continue to be implemented over the next 25 years. These operations are
2293 regionally supported as they have proved to be an important tool for safe downstream juvenile
2294 fish passage. In the future, it is unknown how impacts to water quality, namely TDG, may limit
2295 spill at the lower four Columbia River dams. There has been an increasing interest by some
2296 stakeholders to loosen constraints on TDG water quality state waivers and increase spill
2297 released from the lower Columbia River dams.

2298 Forebay TDG for the No Action Alternative at McNary, John Day, The Dalles, and Bonneville
2299 Dams were modeled under a 5-year range of river and meteorological conditions (Figure 3-25.).
2300 The modeled results show that forebay TDG saturations can exceed 115 percent at all four
2301 dams during most of the years and conditions presented. The only exception was for The Dalles
2302 Dam which had zero modeled forebay TDG exceedances in 2015, a year when river flows were
2303 lower than normal, and summer ambient air temperatures were higher. Maximum forebay TDG
2304 saturation would be higher during a year when river flows were higher than normal, and
2305 summer ambient air temperatures were lower (such as in 2011). The number of modeled
2306 forebay TDG exceedances within a particular year would be highest at Bonneville Dam, though
2307 the maximum modeled forebay TDG saturation would be observed at McNary or John Day
2308 Dam.

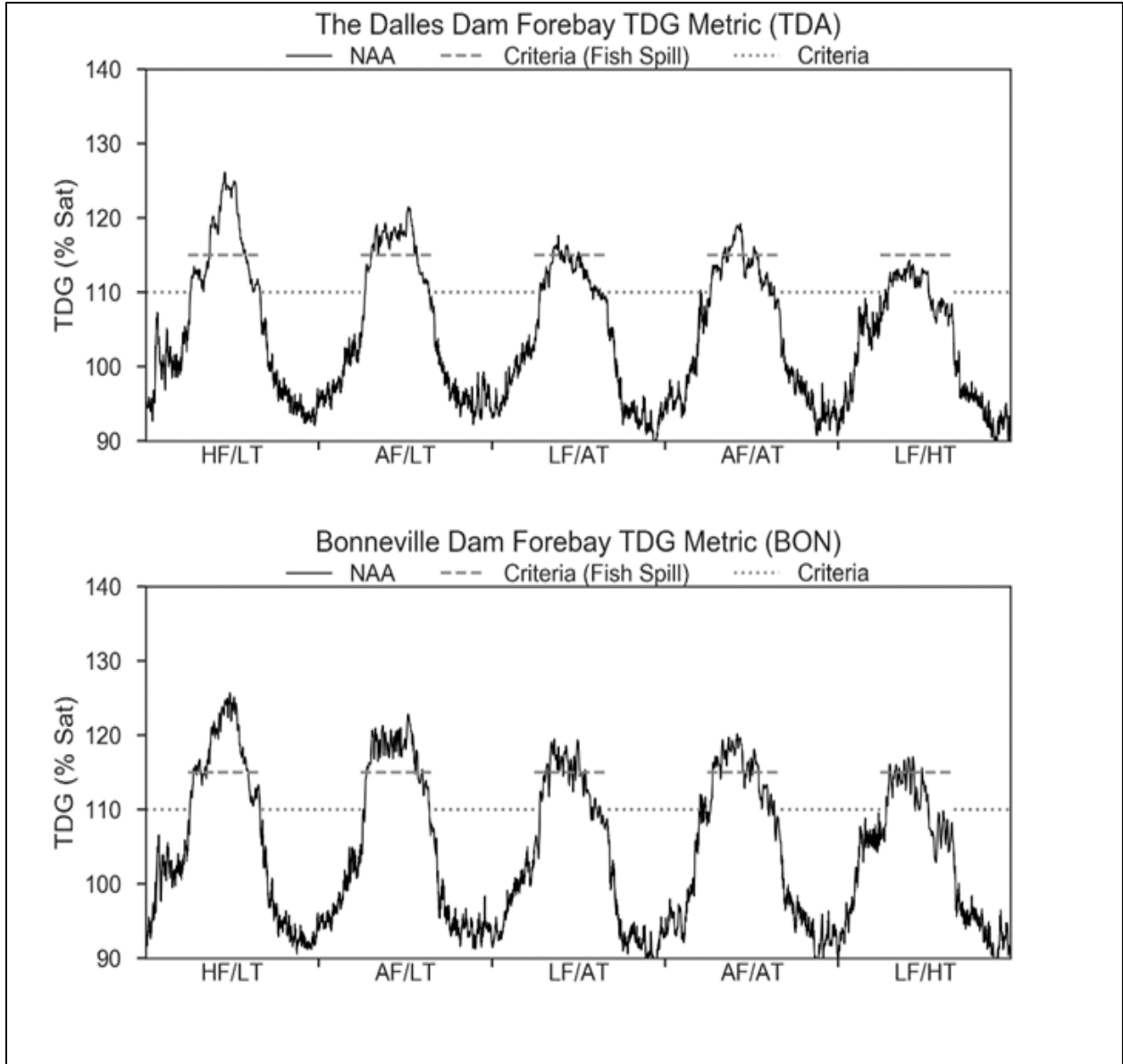
2309 Modeled results for tailwater TDG for the No Action Alternative (Figure 3-27.) show that
2310 tailwater TDG saturations can exceed 120 percent at all four dams depending on the years and
2311 conditions presented. Tailwater TDG exceedances would be expected at McNary and The Dalles
2312 Dams under all conditions except lower than normal flow and higher air temperature (such as
2313 in years 2011 to 2014). At John Day Dam, tailwater TDG exceedances would be expected only
2314 under high or average flow conditions and lower than normal air temperature (such as in years
2315 2011 to 2012). TDG exceedances would be expected in the Bonneville tailwater under the full
2316 range of modeled river and meteorological conditions. Generally, the number of expected
2317 exceedances decreases as flow decreases and air temperature increases. Maximum TDG
2318 saturations would be higher during a year when river flows were higher than normal, and
2319 summer ambient air temperatures were lower (such as in 2011). Under average and low flow
2320 conditions (such as in years 2012 to 2015), the maximum modeled tailwater TDG saturation
2321 would be observed at Bonneville Dam. Under high flow conditions (such as in year 2011), the

2322 maximum modeled tailwater TDG saturation would be highest at McNary Dam (though only
2323 slightly higher than at Bonneville Dam).

2324 In summary, the modeling results show that, under the No Action Alternative, TDG saturation
2325 exceedances can occur during spill season, but vary depending on inflow, meteorological
2326 conditions, and spill operations. This would be expected to continue into the future.

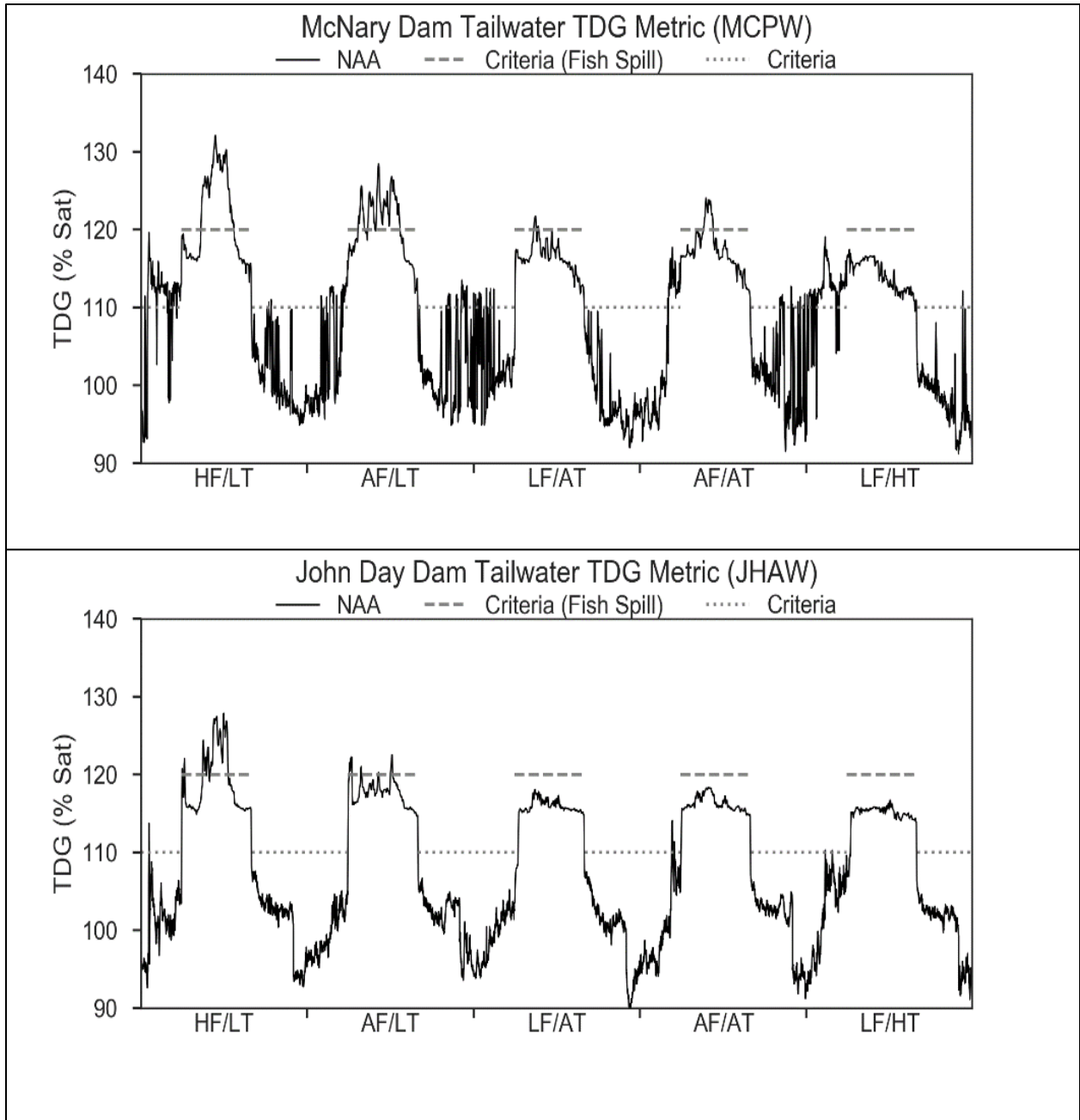


2327
2328 **Figure 3-25. Modeled Forebay Total Dissolved Gas for the No Action Alternative at McNary**
2329 **and John Day Dams Under a 5-Year Range of River and Meteorological Conditions**



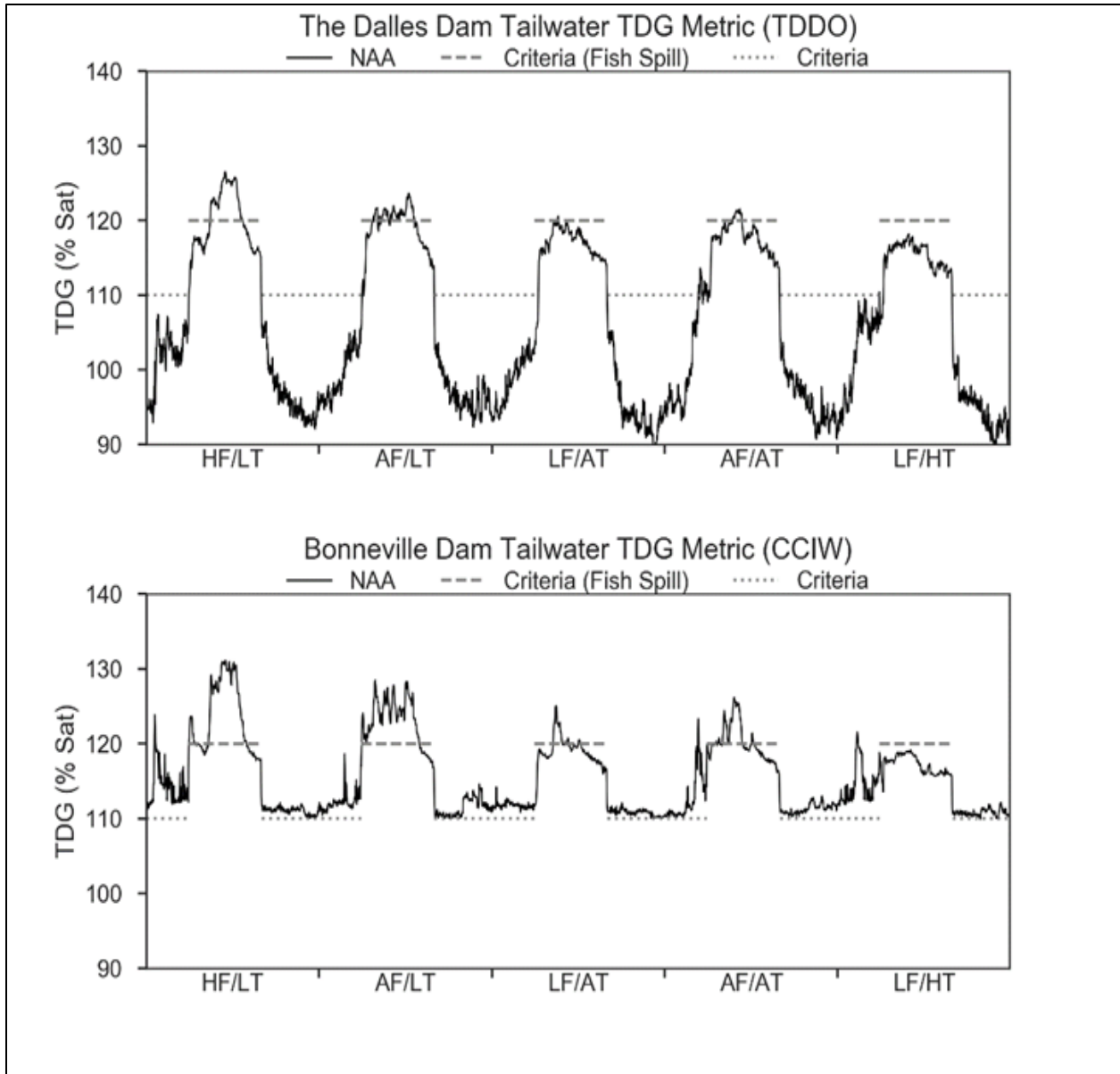
2330
2331
2332

Figure 3-26. Modeled Forebay Total Dissolved Gas for the No Action Alternative at The Dalles and Bonneville Dams Under a 5-Year Range of River and Meteorological Conditions



2333
2334
2335

Figure 3-27. Modeled Tailwater Total Dissolved Gas for the No Action Alternative at McNary, and John Day Dams Under a 5-Year Range of River and Meteorological Conditions



2336
2337 **Figure 3-28. Modeled Tailwater Total Dissolved Gas for the No Action Alternative at The**
2338 **Dalles and Bonneville Dams Under a 5-Year Range of River and Meteorological Conditions**

2339 **3.3.3 Other Physical, Chemical, and Biological Processes**

2340 Suspended solids concentrations and turbidity are generally highest when flow is also high,
2341 though both are rarely observed at levels of concern. At any given time, the concentrations of
2342 total and dissolved constituents, as well as Secchi disk depth, conductivity, and other physical
2343 parameters, are not markedly different from one end of the lower Columbia River System to
2344 the other. Water in the main channel is well oxygenated; rarely is dissolved oxygen below 7.5
2345 mg/L, but it is sometimes quite high (13-15 mg/L), likely due to photosynthetic activity. PH is
2346 typically a bit higher than neutral, varies spatially only minimally, and has no obvious temporal
2347 trend. Additionally, pH can be considered high at times as it has been measured above 8.5 at

2348 least once within the last 10 years in each of the reservoirs. High pH and/or dissolved oxygen in
2349 portions of the reach from The Dalles to Bonneville Dams resulted in the inclusion of these
2350 parameters in the Washington or Oregon 303(d) lists. Chlorophyll a is highly variable both
2351 spatially and temporally. Based on summer concentrations of total phosphorus, chlorophyll a,
2352 and transparency, each of the reservoirs is typically mesotrophic, though occasionally slightly
2353 oligotrophic or slightly eutrophic depending on the location. Phytoplankton and zooplankton
2354 data are limited to older, single datasets in each of the McNary and John Day Reservoirs; data
2355 from multiple sampling events in similar locations were not available to make temporal
2356 comparisons.

2357 Pollutants in the lower Columbia River are widely distributed and are derived from a variety of
2358 point and non-point sources. Some portions of all four reservoirs have TMDLs for dioxin and
2359 are included in the Washington or Oregon 303(d) lists for polychlorinated biphenyls (PCBs).
2360 Relatively high uranium concentrations, related to upstream activities, were present in all four
2361 reservoirs, though data was only available for one sampling event in 2009. Atmospheric
2362 deposition from urban areas also contributes pollutants to the lower river, such as mercury.
2363 Bonneville Lake and Lake Celilo (The Dalles and Bonneville Reservoirs) were included in the
2364 Oregon 303(d) list for mercury. The Oregon Health Authority recommends limiting the amount
2365 of resident fish species consumed from Ruckel Creek (about 1 mile upstream of Bonneville
2366 Dam) upstream to McNary Dam due to moderate levels of mercury and PCBs in fish tissue.
2367 Consumption of resident fish is not advised in this portion of the reach from Bonneville Dam to
2368 Ruckel Creek due to high levels of PCBs in fish tissue. Salmon, steelhead, lamprey and shad are
2369 not included in both of these fish advisories. Legacy pesticides from agricultural runoff have
2370 also been found in all lower Columbia River reservoirs, with higher concentrations found near
2371 tributary junctions.

2372 The introduction of pollutants and excess nutrients from farming and industrial activities as well
2373 as urban runoff and atmospheric deposition is expected to continue. Emerging contaminants
2374 such as pharmaceuticals and new pesticides will also likely become more prevalent. The lower
2375 Columbia River contains a wide variety of human-sourced compounds, including metals and
2376 organic compounds. This condition is expected to remain generally unchanged and, thus, it is
2377 expected that these impairments would continue under the No Action Alternative.

2378 **3.4 SEDIMENT THROUGHOUT THE SYSTEM**

2379 Upland sediment sources are expected to generally remain as they are currently identified in
2380 the Affected Environment. In-water processes that affect sediment movement, such as
2381 seasonally high flows, are expected to generally remain as well. Sediment erosion and accretion
2382 would continue following similar patterns with no great change in magnitude or extent since no
2383 major structures (dams, locks, or other large structures) are expected to be added or removed
2384 from the Columbia River under the No Action Alternative.

2385 **3.4.1 Upper Columbia River Basin**

2386 Libby Dam has greatly influenced the sediment transport in the Kootenai River. Lake Kooconusa
2387 is estimated to trap 94 to 97 percent of incoming sediments during average flow conditions and
2388 about 88 percent under peak flow conditions. Historical and current point source discharges of
2389 contaminants that may impact sediments in Lake Kooconusa and the Kootenai River exist in the
2390 watershed. Two major sources of sediment contamination in the watershed, an ammonium
2391 phosphate fertilizer plant and a kraft pulp mill, have been closed or substantially improved.
2392 However, coal mining operations have expanded in the watershed in British Columbia with a
2393 ten-fold increase in waste spoils. Studies have shown an increase in the loadings of selenium
2394 and nitrogen to Lake Kooconusa from coal mining operations.

2395 Sediment metals concentrations in both the Canadian portion of the reservoir and in Montana
2396 are low, with no metals concentrations exceeding the Pacific Northwest regional sediment
2397 screening levels, suggesting that adverse effects to the benthic community would not be
2398 expected. For most metals, concentrations in benthic sediments were significantly greater than
2399 corresponding shoreline sediments, suggesting that metals may be accumulating in Lake
2400 Kooconusa. Downstream of Libby Dam, sediment metals, organochlorine pesticides, polycyclic
2401 aromatic hydrocarbons (PAHs), PCBs, and asbestos concentrations are low. River sediment
2402 metal concentrations are similar to Lake Kooconusa, while PCBs were below laboratory
2403 detection limits, and PAHs were low. Concentrations of organochlorine pesticides detected in
2404 the river were very low, with most organochlorine pesticides (including DDT + metabolites) well
2405 below any Pacific Northwest regional sediment evaluation screening levels.

2406 Sixty-five percent of the watershed upstream of Hungry Horse Dam lies within a wilderness
2407 area and the rest of the basin is sparsely developed. The watershed is largely unaffected by
2408 human activities and there has been little concern for contaminant issues.

2409 Extensive mining has occurred in the Clark Fork-Pend Oreille watershed since the late 1800s.
2410 Elevated concentrations of metals such as cadmium, copper, lead, and zinc in sediments have
2411 been documented in the Clark Fork-Pend Oreille River watershed as far downstream as the
2412 Priest River, just upstream of Albeni Falls Dam. These data suggest that metal contamination
2413 from the Clark Fork River has been transported downstream through Lake Pend Oreille and into
2414 the Pend Oreille River. The limited amount of sediment organic contaminant data collected in
2415 the Clark Fork-Pend Oreille River system upstream of Albeni Falls Dam, suggests that little
2416 contamination is present. Downstream of Albeni Falls Dam, sediment metals concentrations for
2417 lead and zinc in the Lower Pend Oreille River were low to moderate and did not exceed the
2418 Pacific Northwest regional screening levels suggesting that adverse effects to the benthic
2419 community would not be expected. For most metals, concentrations measured in the lower
2420 Pend Oreille River were similar to or slightly lower than concentrations measured upstream of
2421 Albeni Falls Dam. Concentrations of organochlorine pesticides and PCBs measured in selected
2422 sediment samples were all below laboratory reporting limits.

2423 Grand Coulee Dam is an efficient sediment trap and little suspended material moves through
2424 the dam and downstream. Sediment eroded from the landscape washes into the river during

2425 naturally occurring landslides, although Lake Roosevelt drawdown operations can increase the
2426 possibility of anthropomorphically caused landslides. Lake Roosevelt water levels are closely
2427 managed to prevent landslides, and would continue to be in the future.

2428 Lake Roosevelt sediments are polluted from metals mining and smelting operations. From 1896
2429 to 1995, smelting waste products (primarily slag and wastewater) were discharged into the
2430 Columbia River a few miles north of the U.S.-Canada border, introducing zinc, mercury, arsenic,
2431 lead, and other metals and contaminants into the lake. Contaminated smelting wastewater
2432 continues to be discharged into the river. Some metals have bioaccumulated through the food
2433 chain of plants and animals in and surrounding the lake, with the greatest levels of
2434 bioaccumulation occurring closest to the location of smelting operations. Movement of slag,
2435 wastewater, and sediments that have been contaminated by these materials has not been
2436 sufficiently characterized. However, elevated surface water metal concentrations associated
2437 with wastewater releases have been reported near Grand Coulee Dam. Additionally, during
2438 high flow events, the surface waters of downstream Rufus Woods Lake can have elevated levels
2439 of zinc, suggesting that flow events can facilitate downstream movement of smelting
2440 wastewater contaminants. Sediment in Rufus Woods Lake contains elevated levels of metals
2441 such as zinc, lead, mercury, and cadmium. Elevated concentrations of metals can
2442 bioaccumulate and if concentrations are very high can kill aquatic organisms, and fish
2443 consumption advisories are made when levels of contaminants in fish tissue render their
2444 consumption a health hazard. Mobilization and exposure of contaminated bed sediments is
2445 affected by Lake Roosevelt drawdown depths and durations. Under the No Action Alternative,
2446 the management of Lake Roosevelt would largely be unaltered, and drawdown depths and
2447 durations would remain similar to those that already occur. Impacts to sediment transport and
2448 aquatic biota under the No Action Alternative would therefore be similar to those under
2449 current conditions.

2450 In addition to mining and smelting pollution originating north of the U.S.-Canada border, sites
2451 of historical mining operations on the Spokane River, which enters the Columbia River in Lake
2452 Roosevelt, are sources of contaminated sediments entering in to Lake Roosevelt. Levels of PCBs
2453 in the tissue of fish from the Spokane River have exceeded guidelines for human consumption.
2454 It is unknown at what rate PCBs are entering Lake Roosevelt from the Spokane River, but it is
2455 not anticipated to increase in the future as long as upstream land and dam management
2456 practices do not change.

2457 **3.4.2 Lower Snake River**

2458 This stretch includes the Clearwater River below Dworshak Dam downstream to the confluence
2459 with the Snake River, and the Snake River beginning at the Hells Canyon Complex downstream
2460 to Ice Harbor Dam. Based on the Programmatic Sediment Management Plan (Corps 2014), the
2461 majority of sediment entering the lower Snake River (into the Lower Granite Reservoir) comes
2462 from the upper Snake River – Hells Canyon area, with less material provided by the Clearwater
2463 River. There is some evidence that erosion and sediment inputs have increased over the several
2464 decades (Corps 2014), which has been attributed to wildfires and agricultural practices.

2465 Wildfires occur at unpredictable intervals, and can denude forested areas leaving them
2466 susceptible to erosion from rainfall and snowmelt runoff.

2467 The Snake River runs along the Idaho-Oregon border and the watershed extends far into Idaho.
2468 Idaho has a Nonpoint Source Management Plan which discusses nonpoint source categories
2469 and nonpoint source pollution prevention. (Idaho Department of Environmental Quality [IDEQ]
2470 2015) Nonpoint source pollution categories include agriculture, livestock grazing, natural
2471 resource extraction (mining), timber/silviculture management, urban and suburban
2472 development, and transportation. The Idaho plan includes the implementation of best
2473 management practices and pollution abatement practices as methods for meeting nonpoint
2474 goals. Sedimentation/siltation and total suspended solids are pollutant categories that are
2475 identified in the Idaho 303d integrated report as causing stream impairments (IDEQ 2014). A
2476 statewide implementation of nonpoint pollution controls could reduce human-induced
2477 sediment loading to streams, especially sediment sources related to land uses. Similarly, the
2478 Corps has committed to coordinating with the local sediment management group and other
2479 land managing agencies to explore opportunities to implement additional upland sediment
2480 reduction projects when feasible (Corps 2014).

2481 Below Lower Granite Dam, the Snake River receives much less sediment input due to the flatter
2482 terrain and generally lower precipitation. (Corps 2014) Several tributaries provide sediment to
2483 the various reservoirs, but at a much lower rate than the input to Lower Granite Reservoir. Land
2484 uses include some suburban population areas as well as agriculture and grasslands; these are
2485 potential sources of sediment and pollutants due to point and non-point discharges. The
2486 sediment is generally considered to be affected by pesticides as evidenced by the 303d listings
2487 for fish tissue impairments. USGS tracks pesticide occurrence in major rivers; see for example
2488 Williamson (1998) and similar publications for information on pesticides in the Columbia River
2489 Basin. Pesticide occurrence is expected to continue similar longterm (increasing) trends as
2490 those identified by Ryberg and Gilliom (2015).

2491 **3.4.3 Lower Columbia River**

2492 The lower Columbia River includes the Columbia River below the middle reach non-Federal
2493 dams and the Snake River below the Ice Harbor Dam, extending to Bonneville Dam (the
2494 downstream limit of this project). The bed of the main channel is composed of fine and medium
2495 grained sands (0.125 to 0.500 millimeter). Between 80 to 90 percent of the sediment
2496 transported through the lower Columbia River is composed of suspended fine-grained
2497 sediment. The natural riverbanks consist of 10 to 20 feet of clay-silt, overlying much deeper
2498 sand deposits. At the downstream end (below Bonneville Dam), sandy beaches occur where
2499 dredged material has been placed along the shore.

2500 The lower Columbia River drainage area is more heavily populated than the upper watershed,
2501 with several larger population centers (e.g., Kennewick). In general, land use transitions from
2502 rural and agricultural to urban/suburban downstream (approaching Portland) although large
2503 tracts of protected and forested lands exist. The downstream end (Bonneville Dam area) has
2504 experienced numerous wildfires, including the 2017 Eagle Creek fire. Burned land is more

2505 erodible due to the lack of vegetation and other changes in the surface soil. For example, post-
2506 fire flood flows on Eagle Creek are expected to increase by 412 percent and the rate of soil
2507 erosion is projected to increase from essentially zero before the fire to over 4 tons per acre.
2508 (U.S. Forest Service 2017) The general pattern of increasing erosion would be expected to occur
2509 throughout the basin after major fires.

2510 Sediment pollutants in the lower Columbia River are widely distributed and derived from a
2511 variety of point and non-point sources. The Hanford site is a well-known active remediation
2512 area. Urban and agricultural runoff is the source of a variety of pollutants. Atmospheric
2513 deposition also contributes pollutants from urban areas; notably mercury. In general, the lower
2514 Columbia River contains a wide variety of anthropogenic compounds including metals and
2515 organic compounds. This condition is expected to remain generally unchanged. As with
2516 sediment in the rest of the basin, pollutants would be expected to remain and to be toxic to
2517 some benthic organisms (MacDonald et al. 2012). Bioaccumulation of some compounds, as
2518 demonstrated in fish advisories and 303d listings, would also be expected to continue for the
2519 future.

2520 **3.4.4 Chemicals of Concern**

2521 Major land uses throughout the watershed include agriculture, forest/timber, and industrial
2522 and urban/suburban development. Over the next 25 years, the general land use is expected to
2523 remain largely the same partly due to the large tracts of publicly held lands that are not
2524 available for development. Population growth is concentrated mostly in the metropolitan
2525 counties of the state (Washington Office of Financial Management 2018). The current patterns
2526 of predominately agricultural land use, agriculture and forest product manufacture, and
2527 navigation would continue, driving the need for future sediment management in navigation
2528 channels. It is anticipated that pesticides – the specific compounds, the patterns of use, and the
2529 quantity of applied materials – would change over time as additional experience is gained with
2530 currently used chemicals and as new commercially available options are developed. Older
2531 pesticides would cease to be used, resulting in a slow change to the composition of chemical
2532 contaminants found in the sediment. However, deeply shoaled materials, such as those
2533 immediately behind the dams, would continue to be a reservoir of historical pesticides and
2534 pesticide degradation products.

2535 Current chemicals of concern would remain concerns. This includes metals, PAHs, volatile
2536 organic compounds, pesticides and pesticide degradation products, PCBs, dioxins,
2537 radionuclides, and nutrients (ammonia). Existing pollution that has accumulated would not
2538 completely biodegrade or chemically react, although some compounds would at least start to
2539 break down (the now banned pesticide DDT would slowly become the degradation products
2540 DDE or DDD, for example). Metals do not biodegrade and would remain in the sediment.
2541 Ongoing research is likely to identify new sediment contaminants that would be regulated, such
2542 as current work on the occurrence of trace pharmaceuticals (Nilsen et al. 2014). The presence
2543 of these compounds in sediment is not well studied, but it is anticipated that new chemicals of

2544 concern may be identified. Future sediment quality may reflect changes in environmental
2545 regulation on water discharges.

2546 Sediment management and dredging under the No Action Alternative is the same as the
2547 sediment management for the affected environment. Where re-occurring dredging is needed
2548 (such as at the confluence of the Snake and Clearwater Rivers), it is assumed that dredged
2549 materials would continue to be of sufficient quality for either in-water or upland beneficial use,
2550 for habitat creation, or as upland fill. Sediment characterization following the Sediment
2551 Evaluation Framework (RSET 2018), or other applicable guidance, would continue to be
2552 required for any new dredging or sediment related projects.

2553 **3.5 WATER AND SEDIMENT QUALITY CONCLUSIONS**

2554 Under the No Action Alternative, reservoir and hydropower operations are assumed to
2555 continue in essentially the same manner as current operations.

2556 **CHAPTER 4 - MULTIPLE OBJECTIVE ALTERNATIVE 01**

2557 Multiple Objective Alternative 1 (MO1) was developed with the goal to benefit or avoid adverse
2558 effects to congressionally-authorized purposes while also benefiting ESA-listed fish species
2559 relative to the No Action Alternative. To meet multiple objectives, a wide array of measures are
2560 included in this alternative. The large number of measures would be implemented throughout
2561 the project study area. See Chapter 2 of the main EIS report for a complete description of MO1.

2562 **4.1 UPPER COLUMBIA RIVER BASIN**

2563 **4.1.1 Water Temperature**

2564 In general, water temperature response at the Libby and Hungry Horse Dams are expected to
2565 be similar to the No Action Alternative. However, slight changes in water temperatures
2566 downstream of Libby Dam could occur due to the *December Libby Target Elevation* and
2567 *Modified Draft at Libby* measures.

2568 **4.1.1.1 Libby and Hungry Horse Dams and Reservoirs**

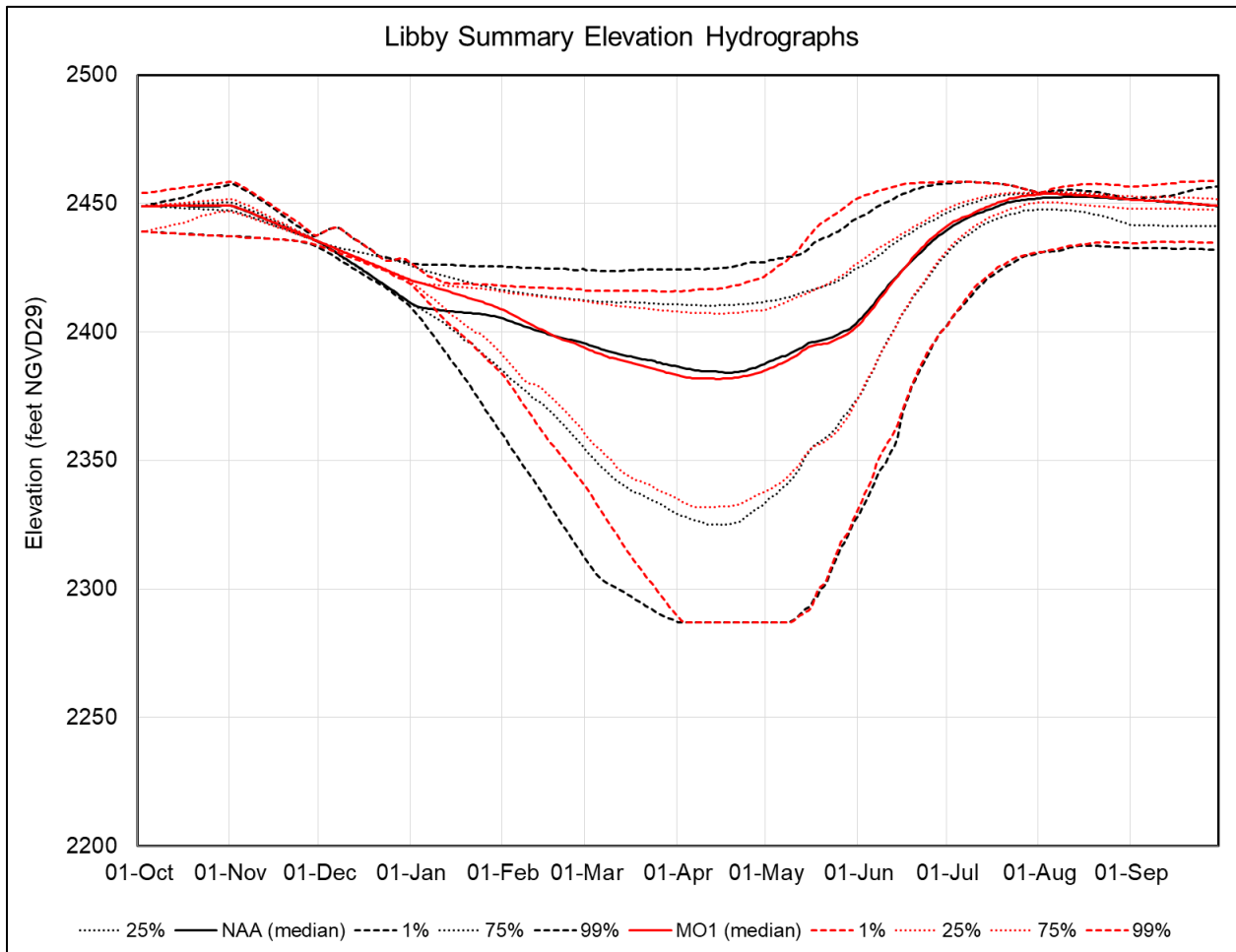
2569 Under MO1, Libby Dam’s draft and refill operations will be modified. The end of December
2570 sliding scale variable draft will be eliminated and replaced with a single draft target, and a
2571 summer sliding scale draft will be implemented. In general, MO1 would result in higher water
2572 elevations in Lake Koocanusa for most of the year, but the draft would be deeper for those
2573 years with a drier water forecast in April. It should be noted that these changes do vary by
2574 water year, water forecast, and time of year. A summary hydrograph for Lake Koocanusa,
2575 representing the probability of the reservoir elevation on any given day under MO1 and the No
2576 Action Alternative is shown in Figure 4-1.. Based on the median, MO1 Lake Koocanusa
2577 elevations are similar to No Action Alternative elevations from October through the end of
2578 November, and held higher from December through the middle of February. MO1 median
2579 elevations are drafted slightly deeper in the spring from March through the end of May, held
2580 similar during June and July, and generally held higher by about 1 to 4 feet in August through
2581 September. In years with high water supply forecasts (represented by 75 percent and 99
2582 percent in Figure 4-1.) draft rates are similar but generally delayed by a couple of weeks. In
2583 years with low water supply forecasts (25 percent and 1 percent in Figure 4-1.), MO1 drafts are
2584 deeper than the No Action Alternative.

2585 Historical temperature data suggests that holding the pool higher in the winter results in colder
2586 spring and summer reservoir temperatures and difficulty for the SWS to achieve downstream
2587 temperatures objectives. When the pool is drafted deeper in the winter, the pool volume is
2588 less, thereby allowing for greater warming in the spring from warmer inflows and warming air
2589 temperatures.

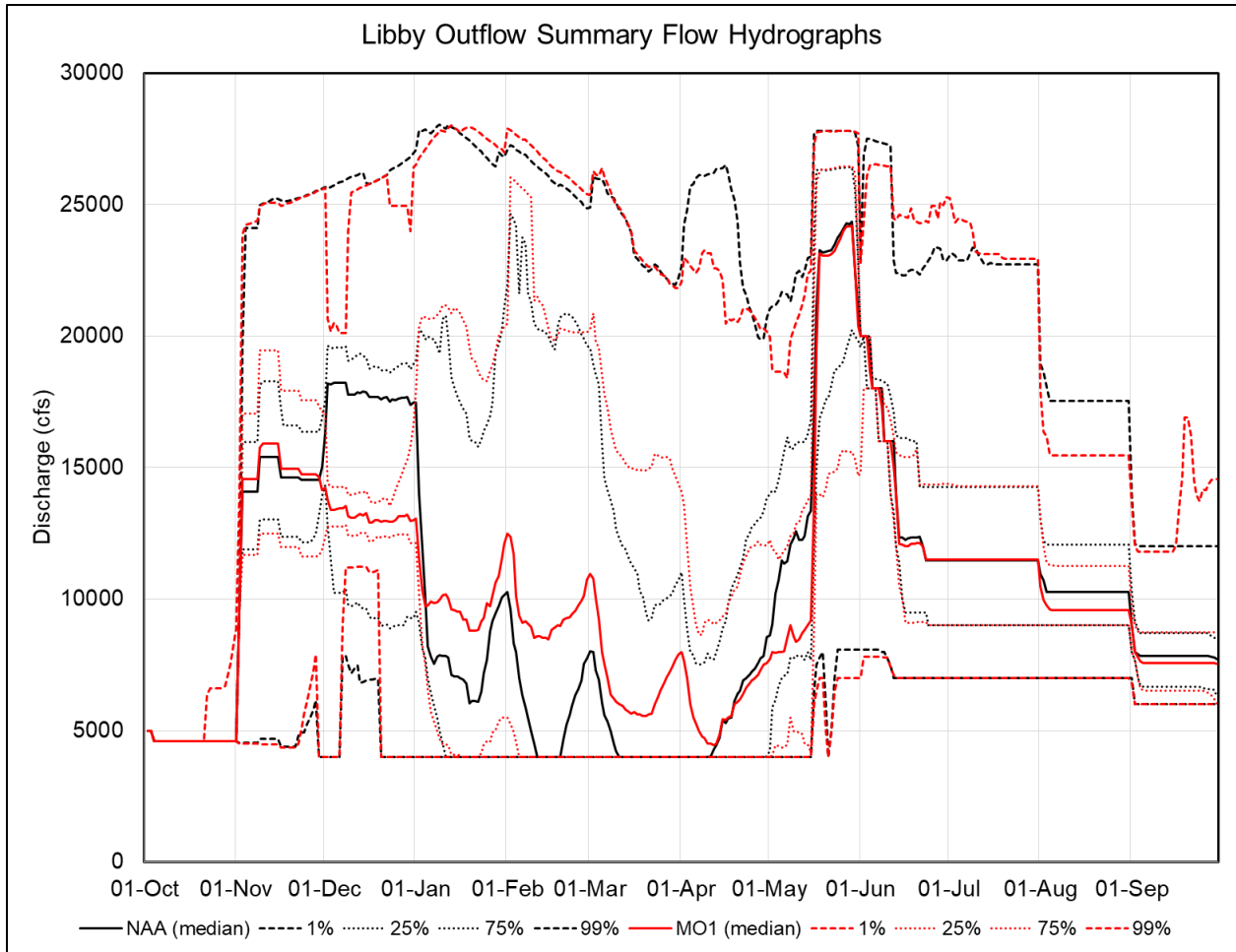
2590 In general, MO1 largely impacts Libby Dam outflows and Kootenai River flows in the winter and
2591 spring. Modeled outflows presented in Figure 4-2 show the greatest difference between MO1
2592 and No Action Alternative flows from December through May. In this figure, the 1 percent

2593 exceedance represents the highest flows and the 99 percent the lowest flows. Modeling results
 2594 showed that for the median flows, MO1 releases are expected to be similar in October and
 2595 November, lower in December, higher from January through March, and relatively similar from
 2596 April through August. High and low outflows follow a similar pattern with the exception that in
 2597 June and July, there is an increase in the highest releases under MO1, which translates to an
 2598 increase in spill from 1 to 2 percent under MO1.

2599 Changes in downstream temperatures from Libby Dam to Bonners Ferry may be a result of
 2600 MO1 increasing the median monthly flows in January through March to draft the pool at a more
 2601 aggressive rate. During the cold winter months, Kootenai River water can cool by several
 2602 degrees between Libby Dam and Bonners Ferry if flows are held low. By increasing the flows to
 2603 draw the pool down aggressively in the winter, MO1 may prevent the natural cooling of the
 2604 river as it moves downstream. These higher winter temperatures in the Kootenai River may be
 2605 detrimental for certain fish species, such as burbot, which require near freezing river
 2606 temperatures (<35°F or <2°C) to spawn.



2607
 2608 **Figure 4-1. Libby Dam-Lake Kocanusa Summary Forebay Elevations for Multiple Objective**
 2609 **Alternative 1 Versus No Action Alternative**



2610
2611 **Figure 4-2. Libby Dam-Lake Koocanusa Summary Outflows for Multiple Objective Alternative**
2612 **1 Versus No Action Alternative**

2613 Libby Dam’s SWS provides some ability to manipulate where in the water column water
2614 entering the powerhouse penstocks is drawn from. The range of the SWS bulkheads are from
2615 elevation 2,409 feet to 2,200 feet. Because SWS protocol maintains at least 30 feet of
2616 submergence over the top row of the bulkheads for hydraulic stability, the SWS has the ability
2617 to perform under the full range of possible MO1 drawdown operations with a similar efficiency
2618 as under the No Action Alternative. Modeled forebay elevations under MO1 are predicted to be
2619 slightly different than under the No Action Alternative but within the operating range of the
2620 SWS and similar to the ranges observed in historical years. As such, use of the SWS to manage
2621 downstream water temperatures seen under the No Action Alternative is expected to continue
2622 under MO1.

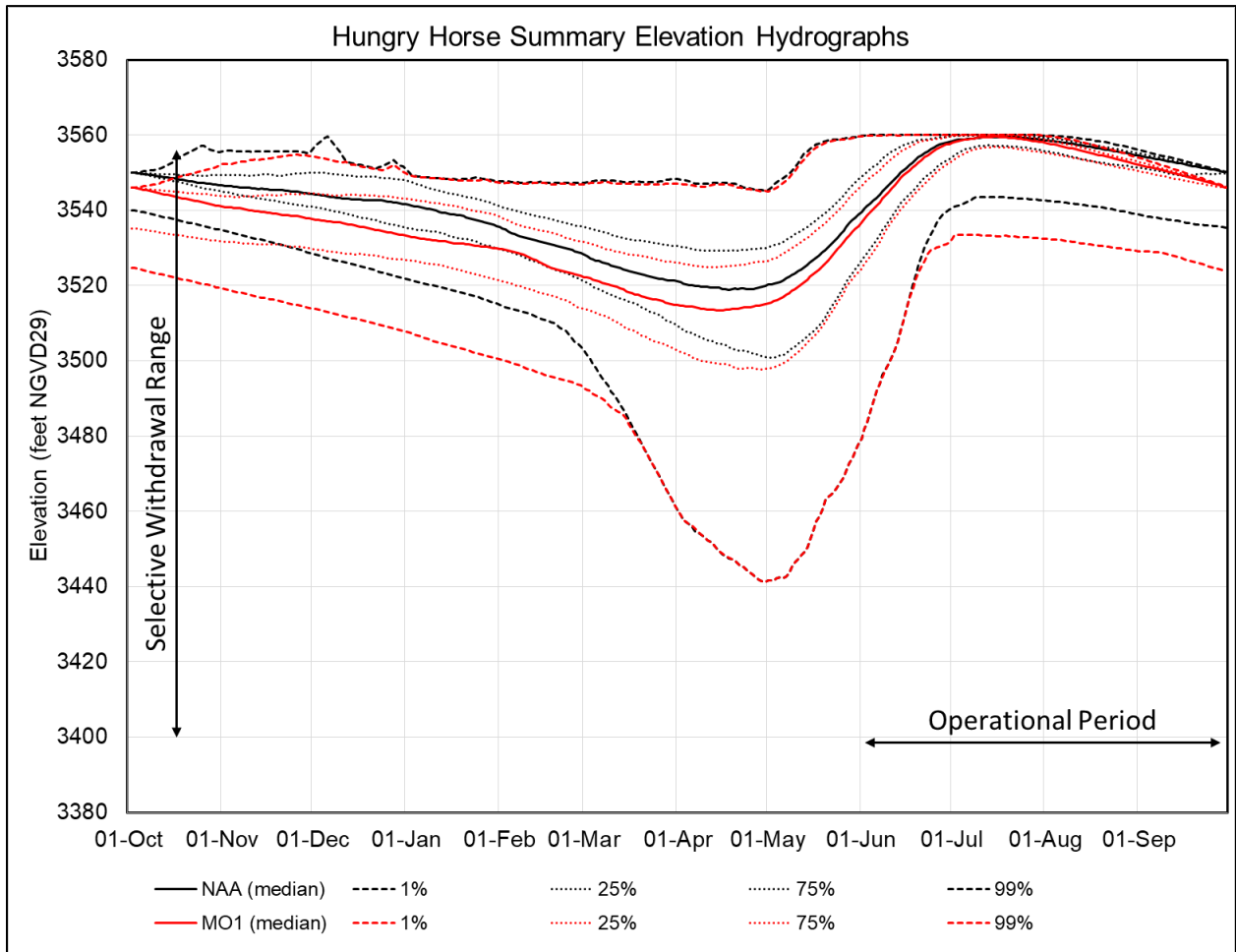
2623 The ability of the SWS to manage downstream water temperatures under a variety of
2624 drawdown and inflow conditions will continue under MO1. However, under the No Action
2625 Alternative, downstream river temperatures during the fall and winter are generally several
2626 degrees warmer than pre-dam Kootenai River conditions, while water released from the dam
2627 during the spring and summer is generally several degrees cooler than natural river conditions

2628 (See Figure 3-1.). The limitations of the SWS that exist for the No Action Alternative are
2629 expected to continue for MO1.

2630 Under MO1, modeled water temperatures in the South Fork Flathead River below Hungry
2631 Horse Dam would be similar to conditions expected under the No Action Alternative. Only two
2632 operational measures in MO1 apply to Hungry Horse:

- 2633 • Sliding Scale at Libby and Hungry Horse
- 2634 • Hungry Horse Additional Water Supply

2635 These measures would implement a sliding scale draft and allow for the additional release of 90
2636 kaf of stored water from April 1 to October 30. Since water temperature in the downstream
2637 river is managed through the use of a SWS, neither of these operational measures would likely
2638 have an impact on meeting downstream water temperature objectives (Figure 4-3.).



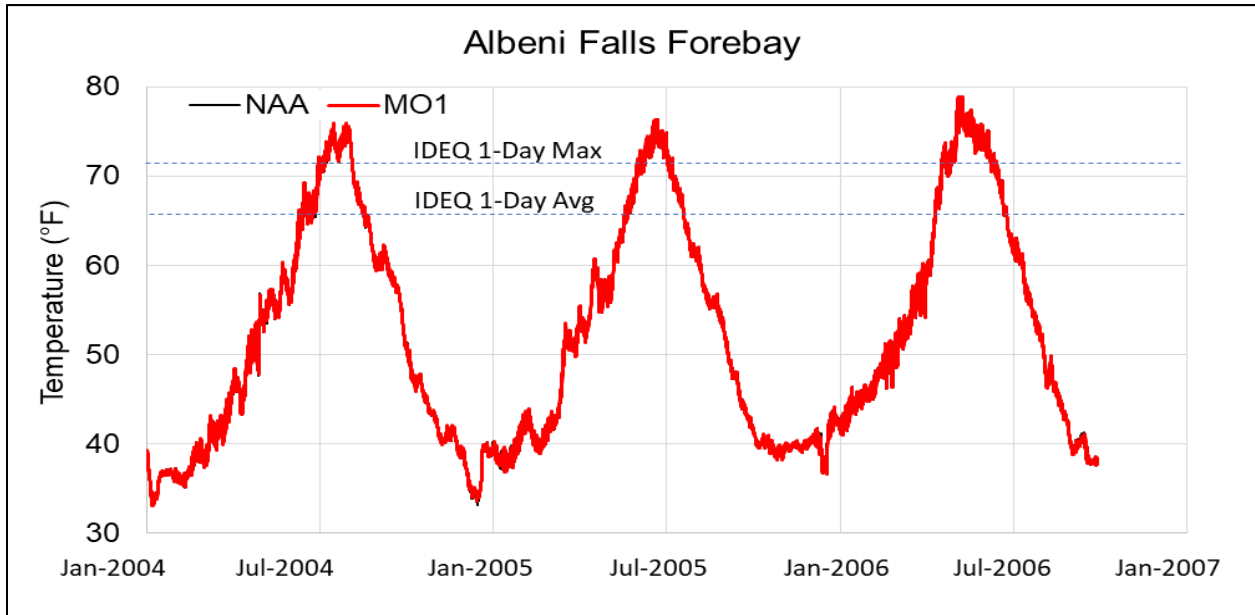
2639 **Figure 4-3. Hungry Horse Summary Forebay Elevations for Multiple Objective Alternative 1**
2640 **Versus No Action Alternative Showing the Operational Range of the Selective Withdrawal**
2641 **Structure.**
2642

2643 Hungry Horse Reservoir thermally stratifies in the summer and can provide some downstream
2644 water temperature management through use of the SWS. The SWS at Hungry Horse Dam is
2645 operated from approximately June to end of September. The SWS can be made/modified to
2646 operate over a pool elevation range from full (3,560 feet) down 160 feet (3,400 feet), with the
2647 lower operating position providing for a control gate submergence of 20 feet. However, major
2648 modification to the structure(s) is required to enable function over the lower 60 feet of this
2649 range, including removal of the upper and intermediate stationary gates. The ability of the SWS
2650 to manage discharge temperatures under a variety of drawdown and inflow conditions will
2651 continue under all of the Multiple Objective Alternatives. Similar to Libby, the SWS relies on the
2652 thermal stratification of the reservoir for downstream water temperature management. The
2653 onset of thermal stratification is difficult to predict and can vary from year to year because of
2654 reasons such as inflow volumes, inflow temperatures, reservoir drawdown elevation, discharge
2655 volumes and weather conditions. Historical temperature data suggests that holding the pool
2656 higher results in colder reservoir temperatures and difficulty meeting downstream water
2657 temperatures in the spring. When the pool is drafted deeper, the pool volume is less, thereby
2658 allowing for greater warming in the spring and summer from warmer inflows and warming air
2659 temperatures.

2660 The change in drawdown elevations under MO1 are not likely substantial enough to result in a
2661 significant change in forebay temperatures and thermal stratification compared to the No
2662 Action Alternative. The limitations of the SWS that exist for the No Action Alternative are
2663 expected to continue for all of the Multiple Objective Alternatives.

2664 **4.1.1.2 Albeni Falls Dam and Reservoir**

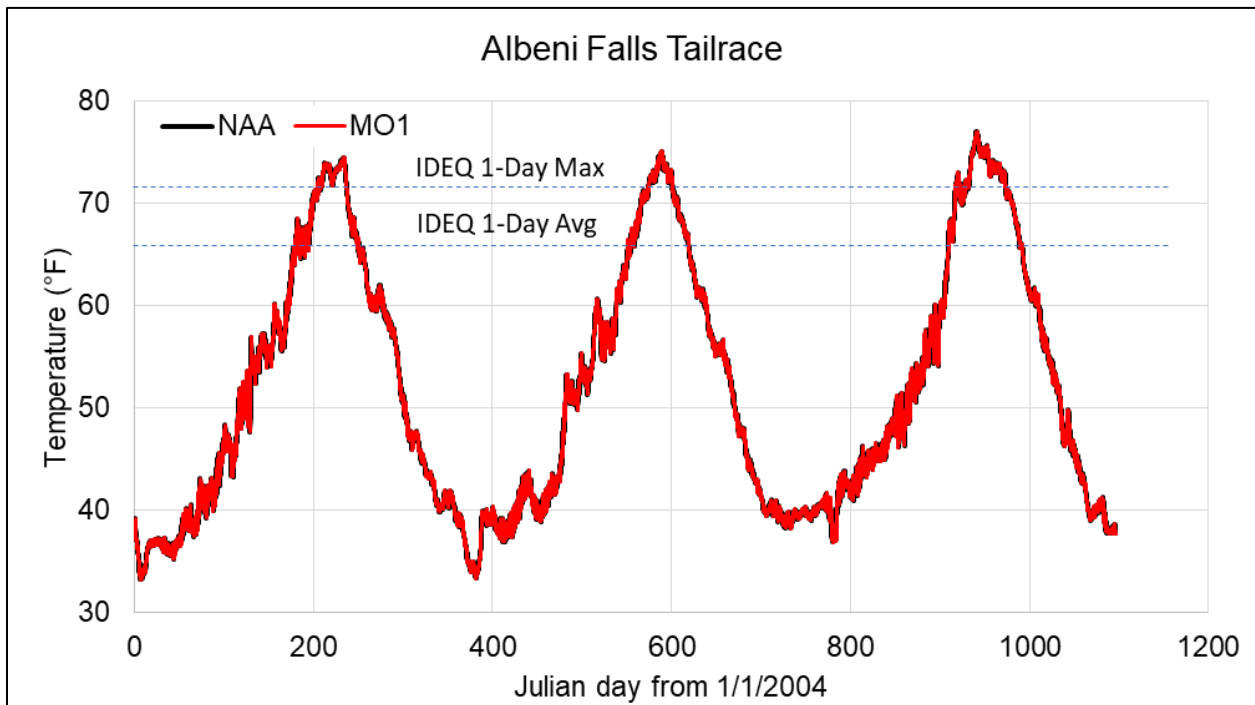
2665 Under MO1, there are no changes to operations at Albeni Falls Dam. Any changes in flow from
2666 Hungry Horse Dam under MO1 that move downstream through the basin are diluted and
2667 become small by the time they enter the Pend Oreille River Basin. As such, there are no
2668 expected changes in Lake Pend Oreille elevations or Pend Oreille River flows between MO1 and
2669 the No Action Alternative. Model results show little change in temperature at Albeni Falls Dam
2670 between MO1 and No Action Alternative with the majority of temperature differences between
2671 the two alternatives of about ± 0.35 degree Fahrenheit (± 0.2 degree Celsius) (Figure 4-4. and
2672 Figure 4-5.). Modeled temperatures under both MO1 and the No Action Alternative would
2673 continue to exceed the IDEQ Pend Oreille River temperature criteria (1-Day Maximum of 71.6°F
2674 and 1-Day Average of 66.2°F) during the summer.



2675
2676
2677
2678
2679

Figure 4-4. Modeled Forebay Temperatures for the No Action Alternative and Multiple Objective Alternative 1 at Albeni Falls from 2004 to 2006

Note: IDEQ 1-Day Maximum temperature standard of 22°C and 1-Day Average standard of 19°C are shown for comparison.



2680
2681
2682
2683
2684

Figure 4-5. Modeled Tailwater Temperatures for the No Action Alternative and Multiple Objective Alternative 1 at Albeni Falls from 2004 to 2006

Note: IDEQ 1-Day Maximum temperature standard of 22°C and 1-Day Average standard of 19°C are shown for comparison.

2685 **4.1.1.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

2686 Under MO1, five operational measures apply to changes in management at Grand Coulee Dam
2687 as compared to the No Action Alternative:

- 2688 • *Update System Flood Risk Management (FRM) Calculation;*
- 2689 • *Grand Coulee Maintenance Operations;*
- 2690 • *Planned Draft Rate at Grand Coulee;*
- 2691 • *Winter System FRM Space, and;*
- 2692 • *Lake Roosevelt Additional Water Supply.*

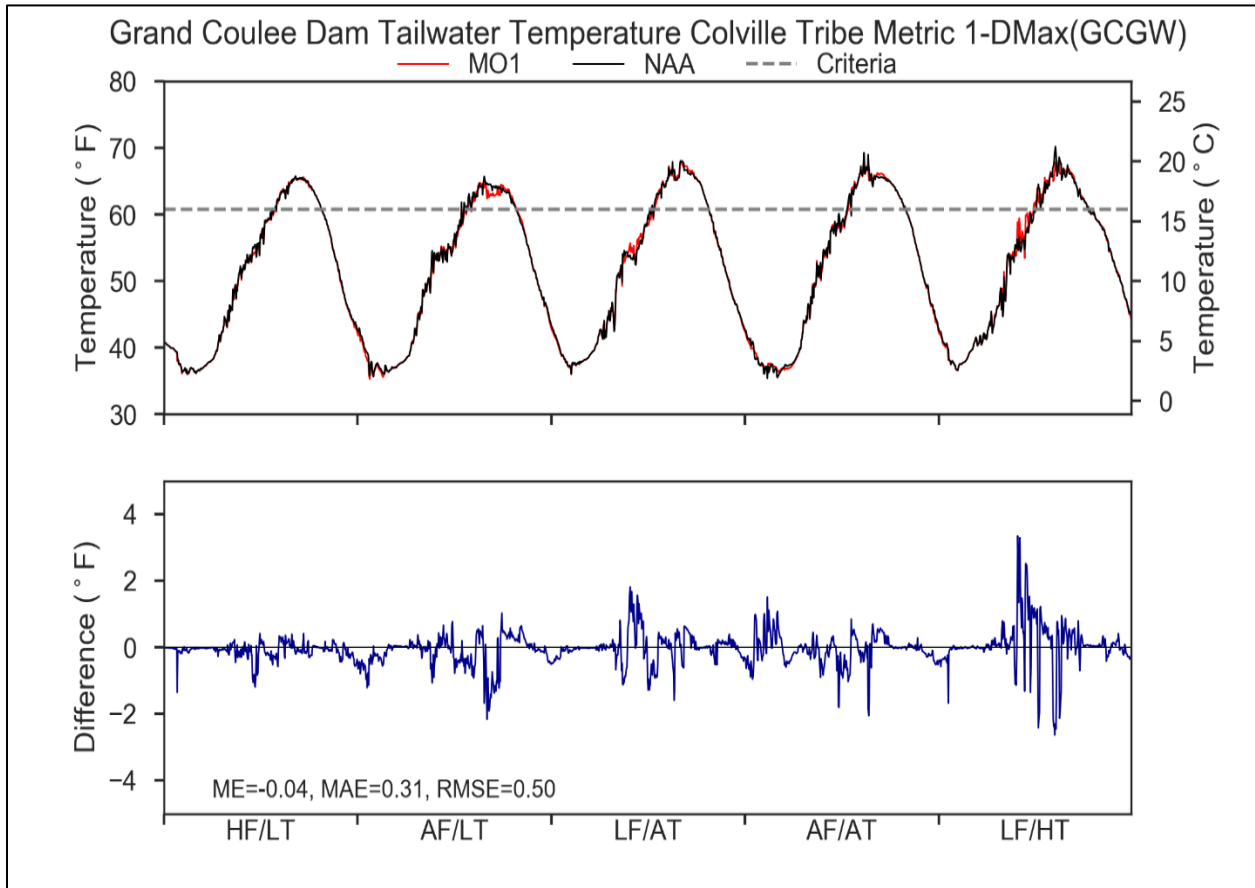
2693 Combined, these measures would result in Lake Roosevelt being drafted 650,000 acre-feet
2694 deeper in December, combining with other FRM measures to be deeper than the No Action
2695 Alternative January through March, and a removal of an additional 1.15 Maf of water (about
2696 1.5 percent of total average inflow into Lake Roosevelt from April to October) from the
2697 reservoir for water supply purposes.

2698 Overall, temperatures in the reservoir are predicted to remain largely the same as the No
2699 Action Alternative. The changes that do occur are short in duration or low in magnitude. In
2700 general, impacts are greatest at Grand Coulee Dam and are reduced toward the U.S.-Canada
2701 border wherein the impacts from MO1 are almost unnoticeable at Hall Creek.

2702 Figure 4-6. shows predicted water temperatures below Grand Coulee Dam under MO1 as
2703 compared to the No Action Alternative. Water temperatures are similar under both
2704 alternatives, but model results suggest there would be a slight increase in water temperatures,
2705 particularly in the spring, under MO1 in the LF/HT type years. For the LF/HT type years, the
2706 modeled water temperature downstream of Grand Coulee Dam during the spring/early
2707 summer months is approximately 0.3 degree Fahrenheit warmer (for the period from May
2708 through July) than the No Action Alternative, but releases range from plus or minus several
2709 degrees. The temperature differences are likely due to a combination of the water year type
2710 (extreme low flow year with high temperatures susceptible to changes in operations),
2711 operational changes resulting in reduced outflows (FRM and water supply measures), and
2712 potentially simplifying assumptions in the modeling. An additional factor influencing spring and
2713 summer temperatures in some years may be winter and spring operations that decrease
2714 storage during that period, which would potentially reduce the cold water mass that would
2715 influence the inflowing temperature signal from upstream.

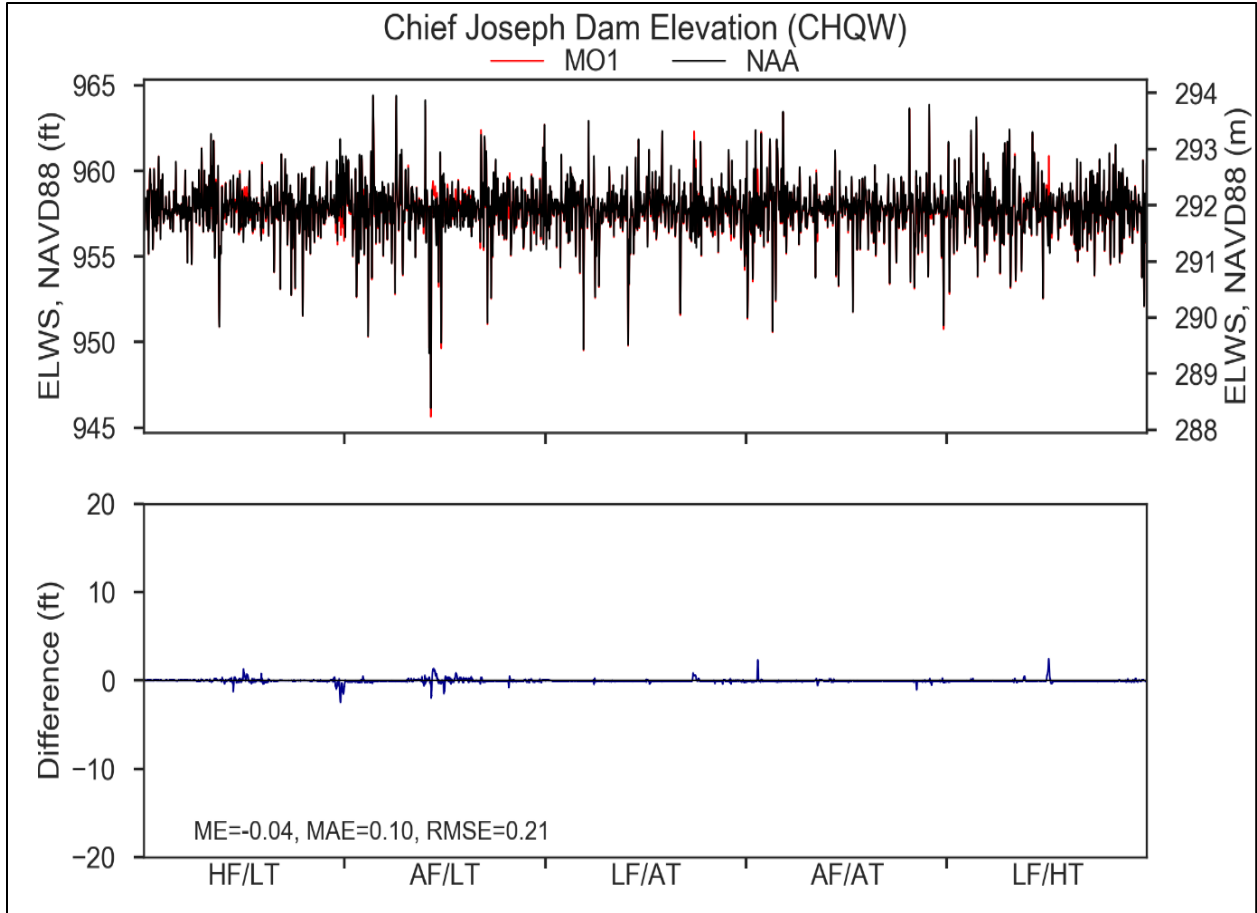
2716 Model results predict little change in Rufus Woods Lake forebay elevations for MO1 when
2717 compared to the No Action Alternative (Figure 4-7.). Consequently, modeled temperatures
2718 under MO1 at Chief Joseph Dam tailwater are similar to the No Action Alternative with the
2719 majority of temperature differences in the ± 1 degree Fahrenheit range (Figure 4-8.). In general,
2720 temperatures modeled for MO1 are similar or slightly cooler than the No Action Alternative for
2721 most river and climate conditions. An exception is for the low flow scenarios (LF/AT and LF/HT)

2722 where river temperatures in the spring are expected to be up to 1 degree Fahrenheit greater
 2723 under the MO1 alternative. Tailwater temperatures under both the MO1 and No Action
 2724 Alternative are predicted to exceed the Washington State standard of 63.5F (17.5°C) as
 2725 measured by the 7-day average of the daily maximum temperature in August and September.
 2726 Similar to the No Action Alternative, there is little difference in temperature between Grand
 2727 Coulee Dam (Figure 4-6.) and Chief Joseph Dam (Figure 4-8.) under MO1 showing that water
 2728 temperatures released from Lake Roosevelt are passed through Rufus Woods Lake unchanged.



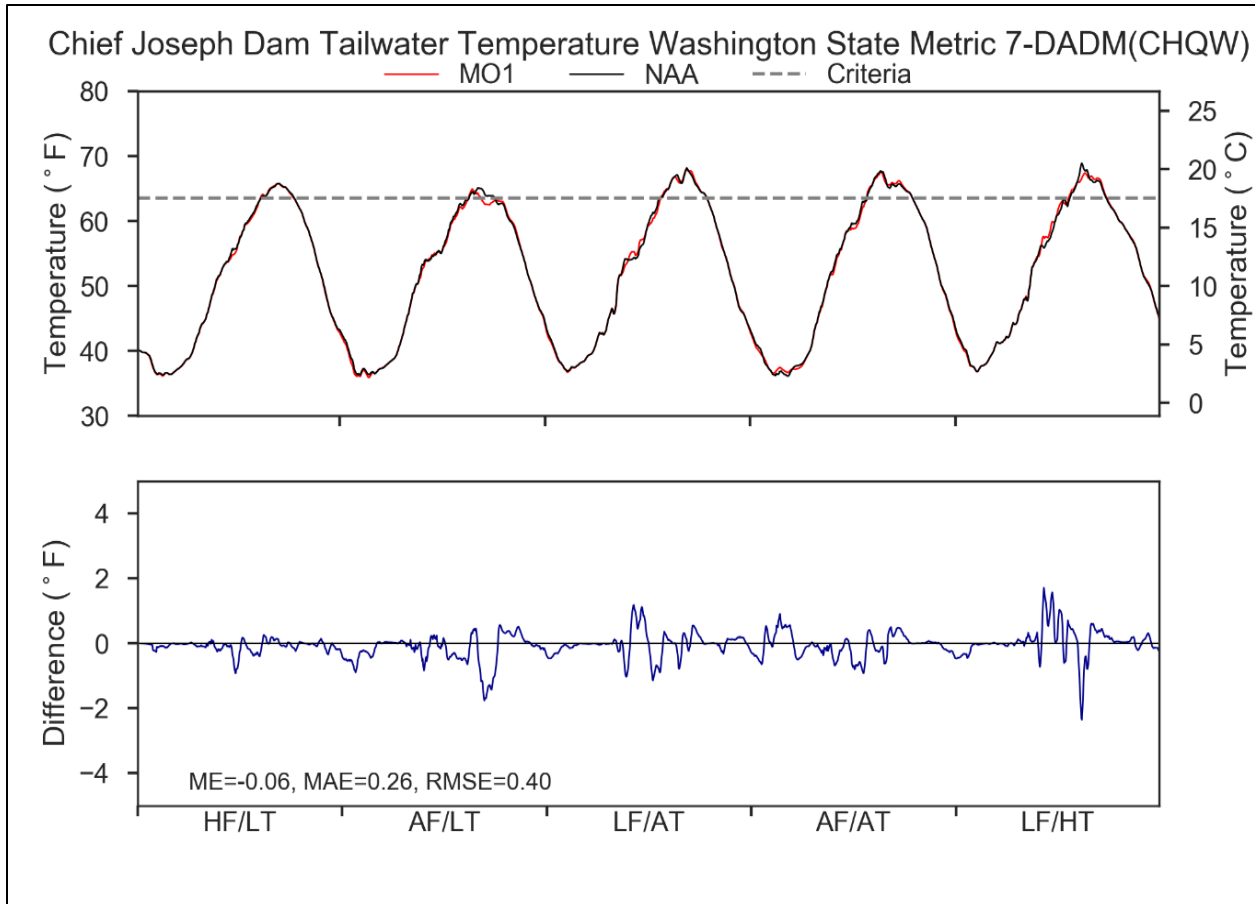
2729 **Figure 4-6. Modeled Tailwater Temperature for the No Action Alternative and Multiple**
 2730 **Objective Alternative 1 at Grand Coulee Dam Under a 5-year Range of River and**
 2731 **Meteorological Conditions Compared to the Confederated Colville Tribe 1-D Maximum Water**
 2732 **Quality Standard**
 2733

2734 Note: HF/LT = high flow/low air temperature; AF/LT = average flow/low air temperature; LF/AT= low flow/average
 2735 air temperature; AF/AT = average flow/average air temperature; and LF/HT = low flow/ high air temperature.



2736
2737
2738

Figure 4-7. Chief Joseph Dam-Rufus Woods Lake Forebay Elevations Multiple Objective Alternative 1 Versus No Action Alternative



2739
 2740 **Figure 4-8. Modeled Tailwater Temperature for the No Action Alternative and Multiple**
 2741 **Objective Alternative 1 at Chief Joseph Dam Under a 5-Year Range of River and**
 2742 **Meteorological Conditions**

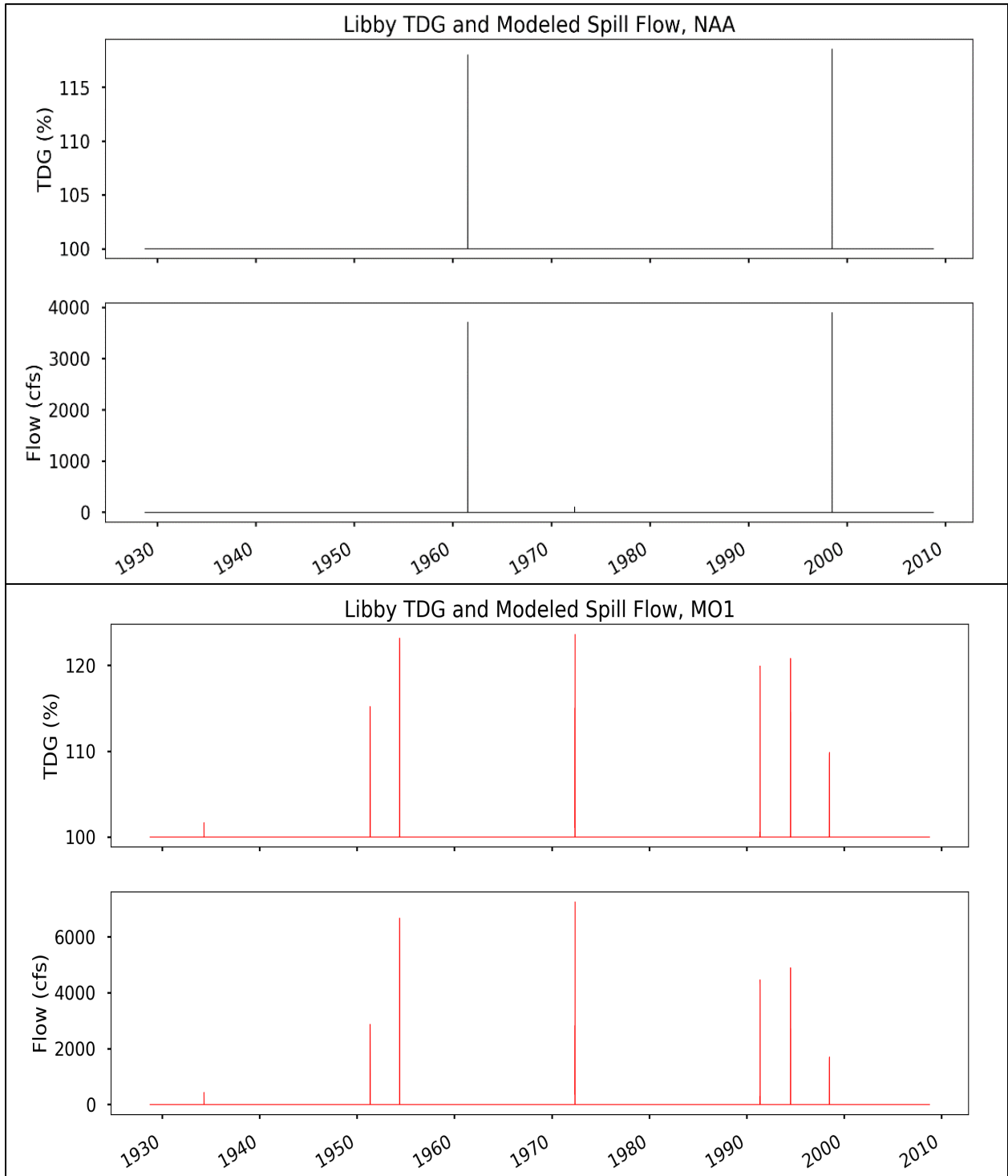
2743 **4.1.2 Total Dissolved Gas**

2744 There are a few measures within MO1 that could change TDG produced by the operation of the
 2745 upper basin dams. These changes are most noticeable at Grand Coulee, as discussed below.

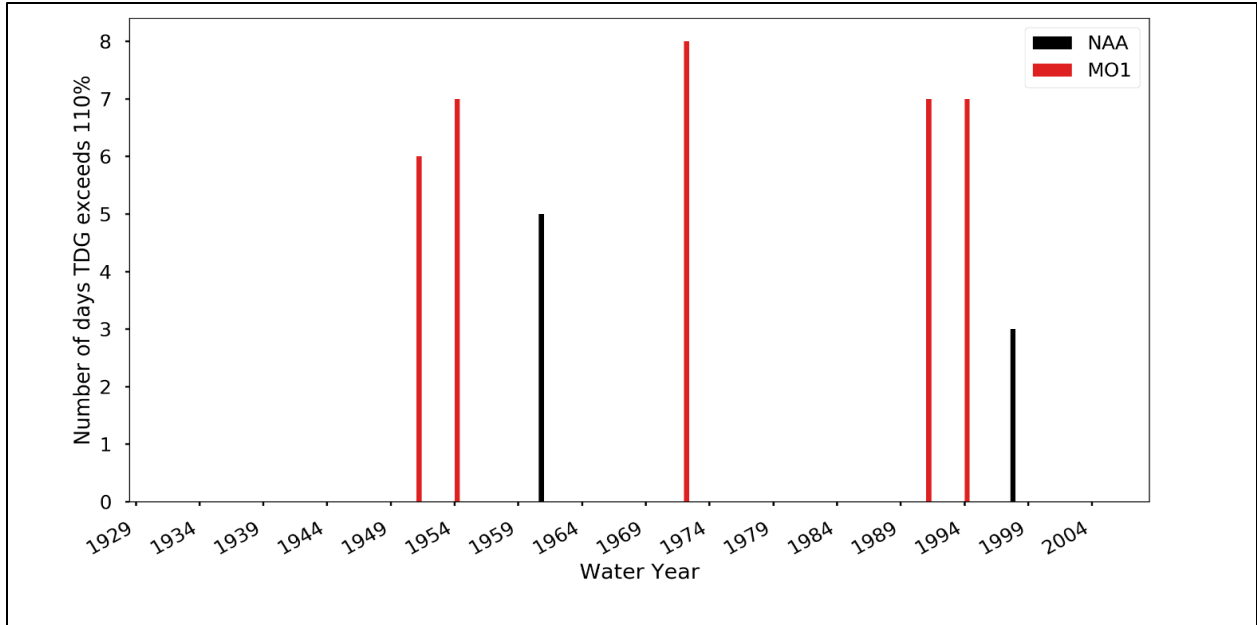
2746 **4.1.2.1 Libby and Hungry Horse Dams and Reservoirs**

2747 Libby Dam is operated to minimize spill. Under MO1, Libby Dam’s draft and refill operations will
 2748 be modified resulting in an increase in the highest releases from the dam. This operational
 2749 change is predicted to increase the chance of spill at Libby Dam from about 1 to 2 percent. The
 2750 MO1 and No Action Alternative ResSim modeled flows for the 80-year period from 1928 to
 2751 2008 are presented in Figure 4-9.. The model predicts six years with spill for MO1 versus only
 2752 three years with spill for the No Action Alternative over the 80-year period. Under the No
 2753 Action Alternative, the maximum TDG saturation is about 118 percent while under MO1, the
 2754 maximum TDG saturation is predicted to be about 124 percent. The number of days exceeding
 2755 the State of Montana 110 percent TDG criteria increased from 8 days for the No Action

2756 Alternative to 35 days for MO1 (Figure 4-10.). Although spill from Libby Dam for the 80-year
2757 model period are predicted to increase under MO1, the frequency of spill is still very small.

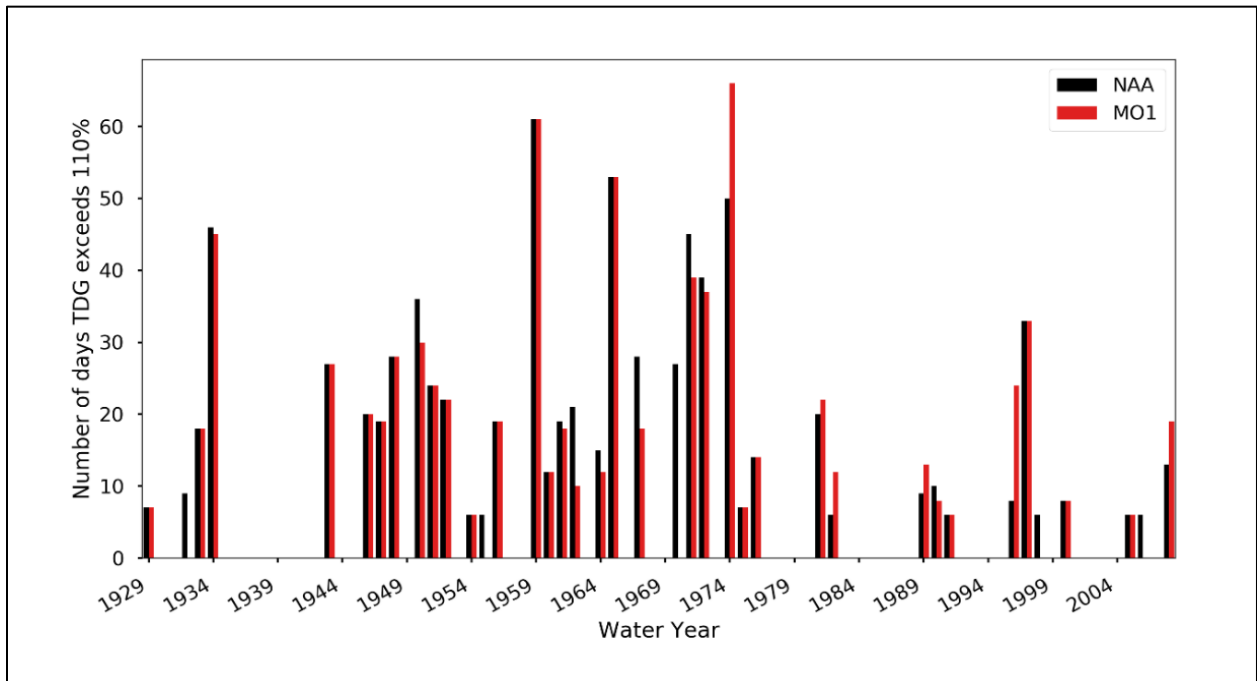


2758 **Figure 4-9. Modeled Tailwater Total Dissolved Gas and Spillway Flows for the No Action**
2759 **Alternative and Multiple Objective 1 at Libby Dam over an 80-Year Period**
2760



2761
 2762 **Figure 4-10. Modeled Tailwater Total Dissolved Gas 110 Percent Exceedance Days for the No**
 2763 **Action Alternative and Multiple Objective Alternative 1 at Libby Dam over an 80-Year Period**

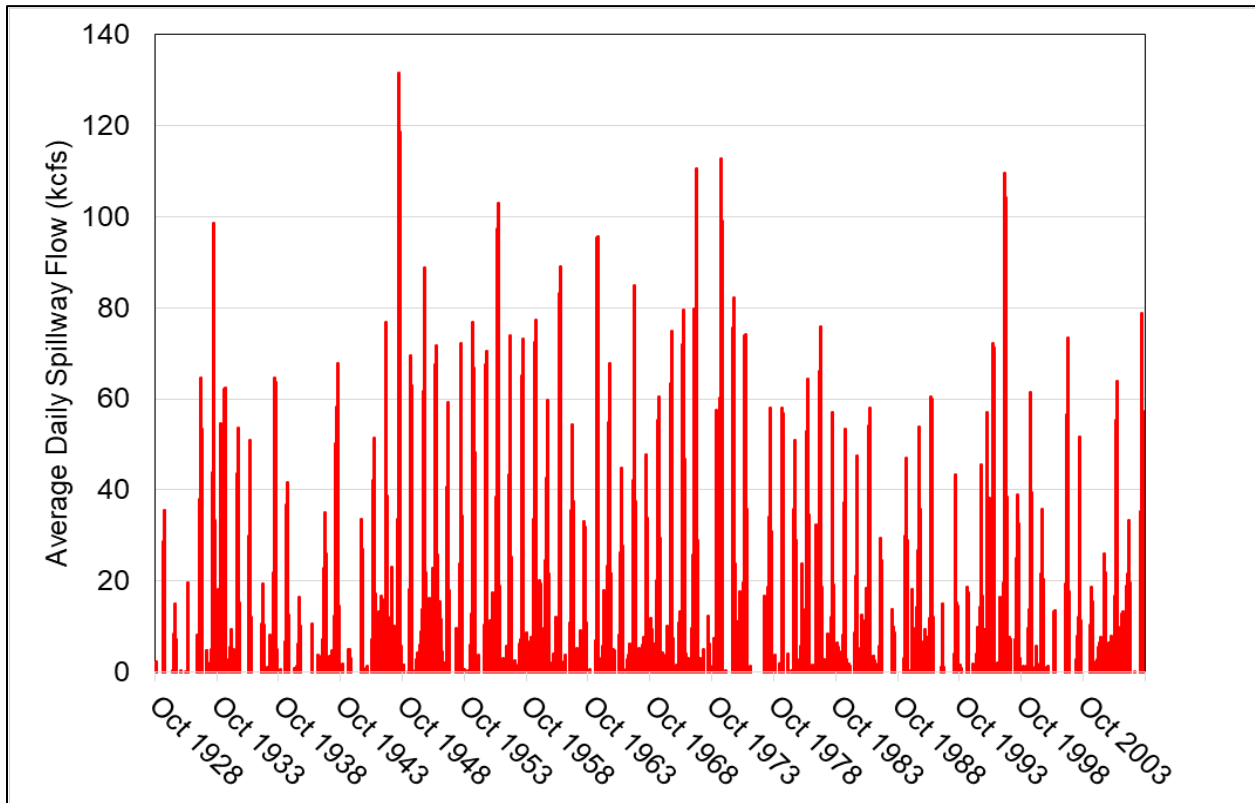
2764 Figure 4-11. shows the number of days that TDG is anticipated to exceed 110 percent below
 2765 Hungry Horse Dam under MO1. As shown, spill releases and some violations in the State of
 2766 Montana water quality standard would be similar to the No Action Alternative.



2767
 2768 **Figure 4-11. Number of Days that Total Dissolved Gas is Above the 110 Percent State Water**
 2769 **Quality Standard Under the No Action Alternative and Multiple Objective Alternative 1 at**
 2770 **Hungry Horse Dam**

2771 **4.1.2.2 Albeni Falls Dam and Reservoir**

2772 During high flow spring runoff periods, TDG in the Pend Oreille River upstream of Albeni Falls
2773 Dam can be greater than 110 percent largely because of spillway releases from Cabinet Gorge
2774 Dam located on the Clark Fork River about 55 miles upstream of Albeni Falls Dam. In general,
2775 when spill is spread evenly across the spillway, spillway discharges up to about 10 kcfs can
2776 increase TDG saturations over forebay levels by about 1 to 2 percent. Spillway discharges
2777 between about 10 to 50 kcfs can increase TDG saturations by about 5 to 9 percent below Albeni
2778 Falls Dam. However, when flows in the Pend Oreille River exceed about 50 to 60 kcfs, the Albeni
2779 Falls dam powerhouse operations are suspended and the spillway gates are raised, allowing the
2780 river to flow relatively un-impounded across the dam. Under these high flow conditions, Albeni
2781 Falls Dam produces no TDG as the river is essentially free flowing. Spillway flows at Albeni Falls
2782 Dam were modeled under MO1 and the No Action Alternative for the 80 year period from 1928
2783 to 2008 using the ResSim model (Figure 4-12.). In general, there was no difference in spillway
2784 flows under MO1 and the No Action Alternative. For both alternatives, spillway flows were
2785 predicted to range between 1 and 50 kcfs in nearly every year at Albeni Falls Dam, with many
2786 years having spill exceed 60 kcfs resulting in free-flowing conditions. These similar spillway
2787 flows under MO1 and the No Action Alternative are expected to produce nearly identical TDG
2788 saturations downstream of Albeni Falls Dam.



2789 **Figure 4-12. Modeled Tailwater Spillway Flows for the No Action Multiple Objective**
2790 **Alternative 1 at Albeni Falls Dam over an 80-Year Period**
2791

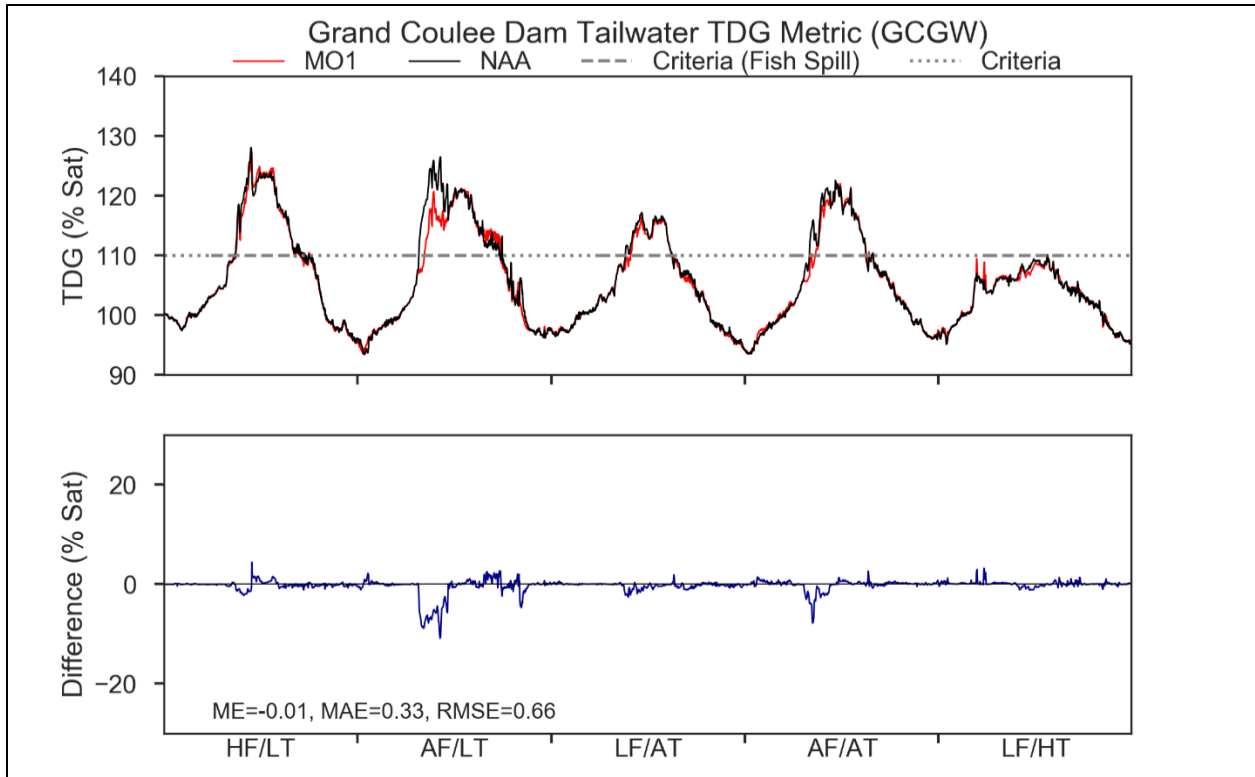
2792 Note: Free-flowing is point where powerhouse operations are suspended and the spillway gates are raised,
2793 representing no spill.

2794 **4.1.2.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

2795 MO1 operational measures, specific to Grand Coulee Dam, include the *Update System FRM*
2796 *Calculation, Grand Coulee Maintenance Operations, Planned Draft Rate at Grand Coulee*
2797 *measure, Winter System FRM Space measure, and the Lake Roosevelt Additional Water Supply*
2798 *measure*. In addition to these, changes in operations of upstream projects result in changes to
2799 inflows at Grand Coulee, which may have minor impacts on inflowing TDG but are not captured
2800 by the system modeling. These changes to inflow also impact Grand Coulee outflows.

2801 During average to above-average water years, the additional storage may reduce the need to
2802 spill water at the dam between mid-December to March, reducing the associated downstream
2803 TDG. The *Grand Coulee Maintenance Operations* and *Lake Roosevelt Additional Water Supply*
2804 *measure* could also affect TDG concentrations below Grand Coulee Dam. *Grand Coulee*
2805 *Maintenance Operations* could create additional spill due to a decrease in power plant capacity
2806 from turbine maintenance. This could increase TDG from April to July due to a reduction in the
2807 number of turbines available to pass water. On the other hand, the *Lake Roosevelt Additional*
2808 *Water Supply* measure could decrease potential spill during this same timeframe. Starting in
2809 March, the increase in water withdrawal (0.6 kcfs) from Lake Roosevelt under operational
2810 measure Lake Roosevelt Additional Water Supply also decreases outflows and spill from Grand
2811 Coulee; however, this influence is not significant until April (3.2 kcfs increase in pumping and
2812 decrease in outflows) and continues through the summer period. As shown in Figure 4-13., the
2813 measures partially offset each other in the analysis of the overall alternative, and in some cases
2814 create a reduction in TDG. Under MO1, TDG concentrations tend to be slightly lower,
2815 particularly in the average water years.

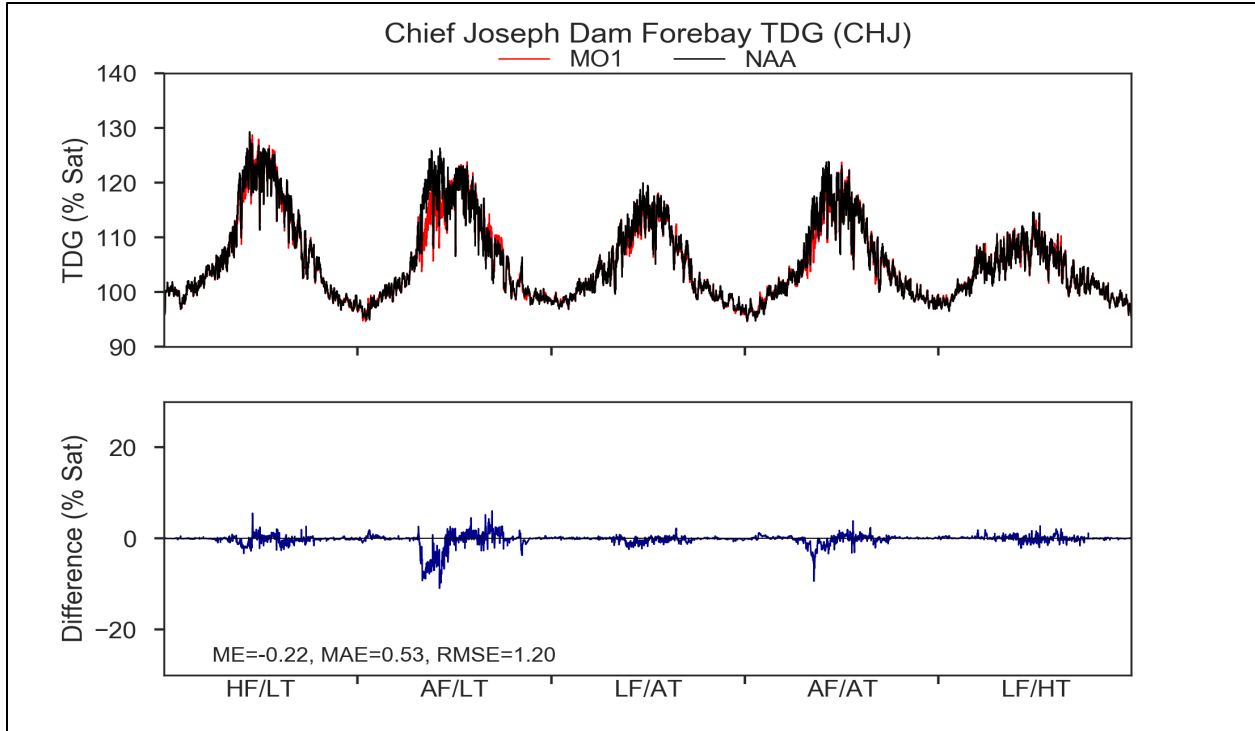
2816 As stated above, the operational measure for *Grand Coulee Maintenance Operation* has the
2817 potential to increase spill through the reduction in the hydraulic capacity of the powerhouse at
2818 Grand Coulee. The *Grand Coulee Maintenance Operation* in isolation could result in significant
2819 increases in spill and TDG, in some cases producing TDG in excess of 130 percent; however, this
2820 effect is largely offset in the spring and early summer by the other measures. An additional
2821 impact expected from the *Grand Coulee Maintenance Operation* measure is the potential for
2822 slightly deeper spill over the drum gates (when the forebay elevation is greater than 1,267 feet,
2823 MSL). Information to assess the magnitude of water quality impacts directly related to this
2824 measure is unavailable but would likely result in small increases in TDG. In wet conditions, it is
2825 anticipated that potential maintenance activities could be delayed in advance of spill to allow
2826 spill over more gates. Another factor not considered in the analysis is that as maintenance
2827 occurs, there would be an increase to hydraulic capacity as more units become available. This
2828 would result in reduced spill and TDG in some cases; however, the other actions would have a
2829 larger impact on outflows and associated spill.



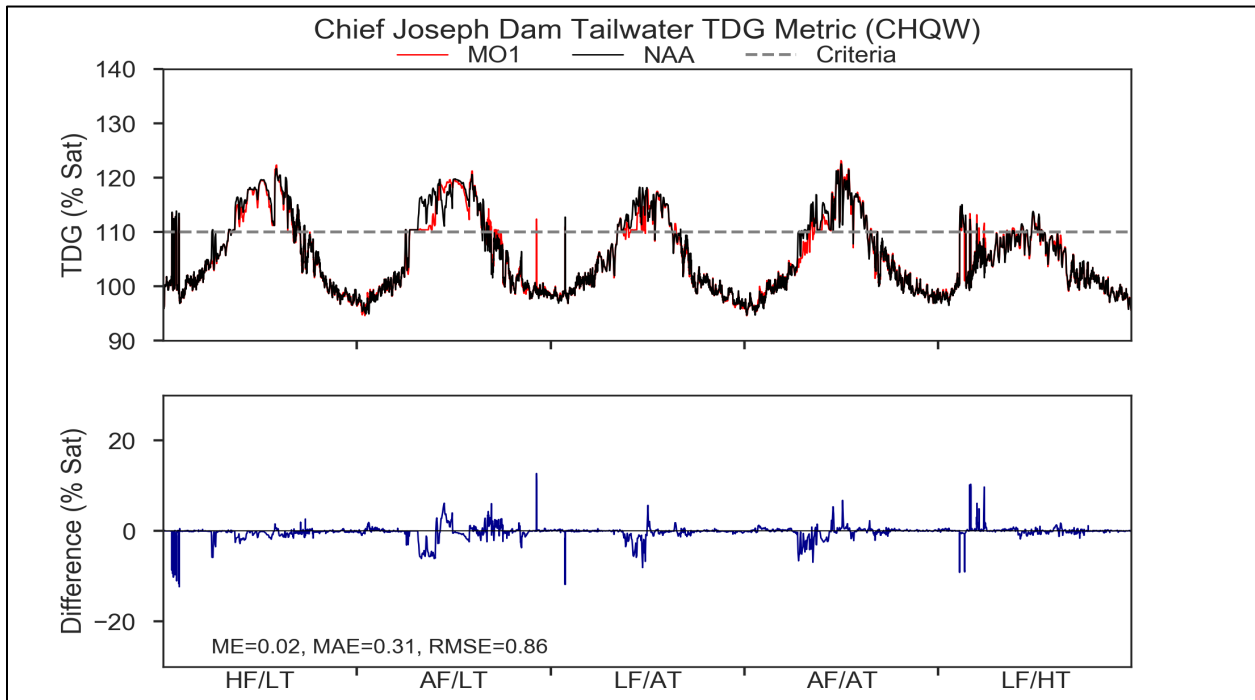
2830
 2831 **Figure 4-13. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and**
 2832 **Multiple Objective Alternative 1 at Grand Coulee Dam Under a 5-Year Range of River and**
 2833 **Meteorological Conditions**

2834 TDG at the forebay of Chief Joseph Dam is largely a function of the TDG saturations released
 2835 upstream from Lake Roosevelt and Grand Coulee Dam because little degassing occurs in Rufus
 2836 Woods Lake. High spill volumes via the outlet tubes at Grand Coulee Dam can increase TDG
 2837 saturations in Rufus Woods Lake at the Chief Joseph Dam forebay to over 130 percent. In
 2838 addition, during high flows, TDG saturations entering Lake Roosevelt from Canada can be
 2839 elevated to greater than 120 percent. During these high TDG periods, spill at Chief Joseph Dam
 2840 over the deflectors can degas supersaturated conditions discharged by Grand Coulee Dam.
 2841 Spilling at Chief Joseph Dam when incoming TDG levels are above 120 percent can reduce
 2842 downstream system TDG loading. Therefore, Chief Joseph Dam is often used to help manage
 2843 overall system TDG production in the mainstem Columbia River. In addition, to avoid spilling
 2844 through the outlet tubes at Grand Coulee Dam, spill is often shifted from Grand Coulee to Chief
 2845 Joseph to take advantage of the lower TDG produced by spilling over the deflectors. This
 2846 operational strategy is expected to continue under MO1.

2847 Chief Joseph Dam TDG saturations predicted at the forebay and tailwater were modeled under
 2848 MO1 and compared to the No Action Alternative (Figure 4-15.). In general, predicted forebay
 2849 and tailwater TDG levels under MO1 operations are similar to or less than under No Action
 2850 Alternative operations. It is expected that under MO1, Chief Joseph Dam would continue to
 2851 decrease TDG during high flow years when elevated TDG saturations occur in the forebay.



2852
2853 **Figure 4-14. Modeled Forebay Total Dissolved Gas Saturations for the No Action Alternative**
2854 **and Multiple Objective Alternative 1 at Chief Joseph Dam Under a 5-Year Range of River and**
2855 **Meteorological Conditions**



2856
2857 **Figure 4-15. Modeled Tailwater Total Dissolved Gas Saturations for the No Action Alternative**
2858 **and Multiple Objective Alternative 1 at Chief Joseph Dam Under a 5-Year Range of River and**
2859 **Meteorological Conditions**

2860 **4.1.3 Other Physical, Chemical and Biological Processes**

2861 **4.1.3.1 Libby and Hungry Horse Dams and Reservoirs**

2862 There are no known sources of contamination in Hungry Horse Reservoir or in the South Fork
2863 Flathead River. Additionally, there is insufficient information to determine if Hungry Horse
2864 Reservoir, and the South Fork Flathead River downstream of the dam, would experience any
2865 significant impacts to physical, chemical, or biological processes compared to the No Action
2866 Alternative. Although operational measure *Sliding Scale at Libby and Hungry Horse* and *Hungry*
2867 *Horse Additional Water Supply* could result in deeper drafts and lower reservoir elevations,
2868 stratification and thermocline depths in the reservoir are not expected to change.

2869 Water level fluctuations in reservoirs may increase methyl-mercury concentrations in the
2870 waterbody as seasonally inundated areas of a reservoir have higher rates of methylation
2871 activity when compared to permanently inundated areas of a reservoir (Willacker et al. 2016).
2872 Studies suggest that methyl-mercury has a greater probability of entering the food web during
2873 the spring and summer growing seasons (January through July) (Willacker et al. 2016). Under
2874 MO1, the measures don't change the cyclic occurrence of inundation and exposure but do
2875 result in earlier and longer exposure of sediments that may have some impact on mercury
2876 methylation in Hungry Horse Reservoir. However, unlike other downstream locations such as
2877 Lake Roosevelt, mercury has not been recorded as a concern at Hungry Horse Reservoir as the
2878 only likely mercury input at this location is through airborne pollution.

2879 MO1 modifies operations at Libby Dam resulting in changes in the drafting depth and water
2880 elevations of Lake Kootenai that may impact physical, chemical, and biological water quality
2881 parameters when compared to existing conditions and the No Action Alternative. MO1
2882 reservoir elevations and outflows during average water supply years will be relatively similar to
2883 existing conditions and the No Action Alternative, and water quality changes are not
2884 anticipated. However, for high water supply forecast years, the reservoir would be drafted
2885 shallower, meaning there would be a greater volume of water in Lake Kootenai during the
2886 spring runoff. Conversely, for low water supply years, the reservoir would be drafted deeper,
2887 meaning there would be a lesser volume of water in Lake Kootenai during the spring runoff.

2888 Retention time, which is the inverse of the flushing rate, refers to the length of time water
2889 remains in a waterbody. Lake volume, inflow, and outflow are important factors in determining
2890 the overall retention time in a waterbody. In general, shorter retention times allow for the
2891 rapid exchange and movement of inflow chemical constituents through the lake. Longer
2892 retention times allow for the accumulation and transformations of inflow chemical constituents
2893 in sediments and lake water, and their cycling through the ecosystem. For a long, narrow, deep
2894 waterbody like Lake Kootenai, shorter retention times may allow certain chemical
2895 constituents in inflowing waters, such as total phosphorus, to move farther down reservoir
2896 toward the forebay before settling out or transforming.

2897 Water quality chemical and biological parameters of concern in Lake Kootenai that may be
2898 impacted by MO1 changes in the reservoir elevation and retention times include nutrients,

2899 metals such as selenium, and phytoplankton such as cyanobacteria and diatoms. It is likely that
2900 winter drawdown elevation and the corresponding reservoir volume, as well as spring runoff
2901 volume and the corresponding suspended sediment/total phosphorus concentrations, are all
2902 factors in determining how far down-reservoir suspended sediments/total phosphorus reaches.
2903 Historical data show that Lake Kootenai is a sink for phosphorus, with little inflow
2904 sediment/phosphorus moving down-reservoir past Libby Dam. Conversely, Lake Kootenai
2905 does not appear to be a sink for nitrogen, and most of the inflowing nitrate passes down-
2906 reservoir to the forebay and Kootenai River regardless of reservoir elevations and retention
2907 times. Increased nitrate loadings to Lake Kootenai, largely due to coal mining operations in
2908 British Columbia, and low phosphorus concentrations have created a large imbalance in the
2909 nitrogen-to-phosphorus ratio, with the ratio often exceeding 100:1 at the forebay, resulting in
2910 strong phosphorus limitation.

2911 Despite rising nitrate concentrations in Lake Kootenai, phytoplankton blooms appear to have
2912 been kept in check by the strong phosphorus limitation under existing conditions and the No
2913 Action Alternative. However, these conditions also indicate that the lake could be susceptible to
2914 increased phytoplankton blooms if phosphorus concentrations increase in the future or if there
2915 are further changes in the nitrogen-to-phosphorus ratio. It is possible that the operational
2916 changes proposed for MO1 may impact the nutrient dynamics in Lake Kootenai, which could
2917 result in seasonal changes in phytoplankton densities and functional types. Shorter retention
2918 times for low water supply years may result in greater total phosphorus concentrations while
2919 longer retention times for high water years may result in lower phosphorus concentrations.
2920 However, these operational changes in retention times are small and only occur during more
2921 extreme water years (high/low water supply), which likely would reduce potential nutrient and
2922 phytoplankton impacts from MO1 at Libby Dam.

2923 Increasing selenium concentrations and other associated metals (cadmium and lead) in Lake
2924 Kootenai from coal mining operations in British Columbia are a concern for existing conditions
2925 and the No Action Alternative. The USGS has estimated that increased coal mining in the
2926 Kootenai River watershed above Libby Dam have increased selenium loading to Lake Kootenai
2927 fivefold over the past 20 years. Over the next 25 years, it is expected that coal production in the
2928 Kootenai River watershed will continue to increase. Although there does not yet appear to be
2929 an increasing trend in water column selenium concentrations in the reservoir, there is concern
2930 that the continued selenium loadings to Lake Kootenai may lead to additional selenium
2931 contamination. It is possible that the changes in reservoir elevation, flow, and retention time
2932 under MO1 may alter the movement, cycling, and transformation of selenium and other
2933 associated metals (cadmium and lead) in the reservoir and downstream in the Kootenai River,
2934 possibly resulting in water and sediment quality impacts. However, such operational changes
2935 would only occur during more extreme high/low water supply years.

2936 **4.1.3.2 Albeni Falls Dam and Reservoir**

2937 Under MO1, there are no changes to operations at Albeni Falls Dam. The physical, chemical,
2938 and biological water quality of Lake Pend Oreille and the Pend Oreille River described under the
2939 No Action Alternative are expected to remain unchanged.

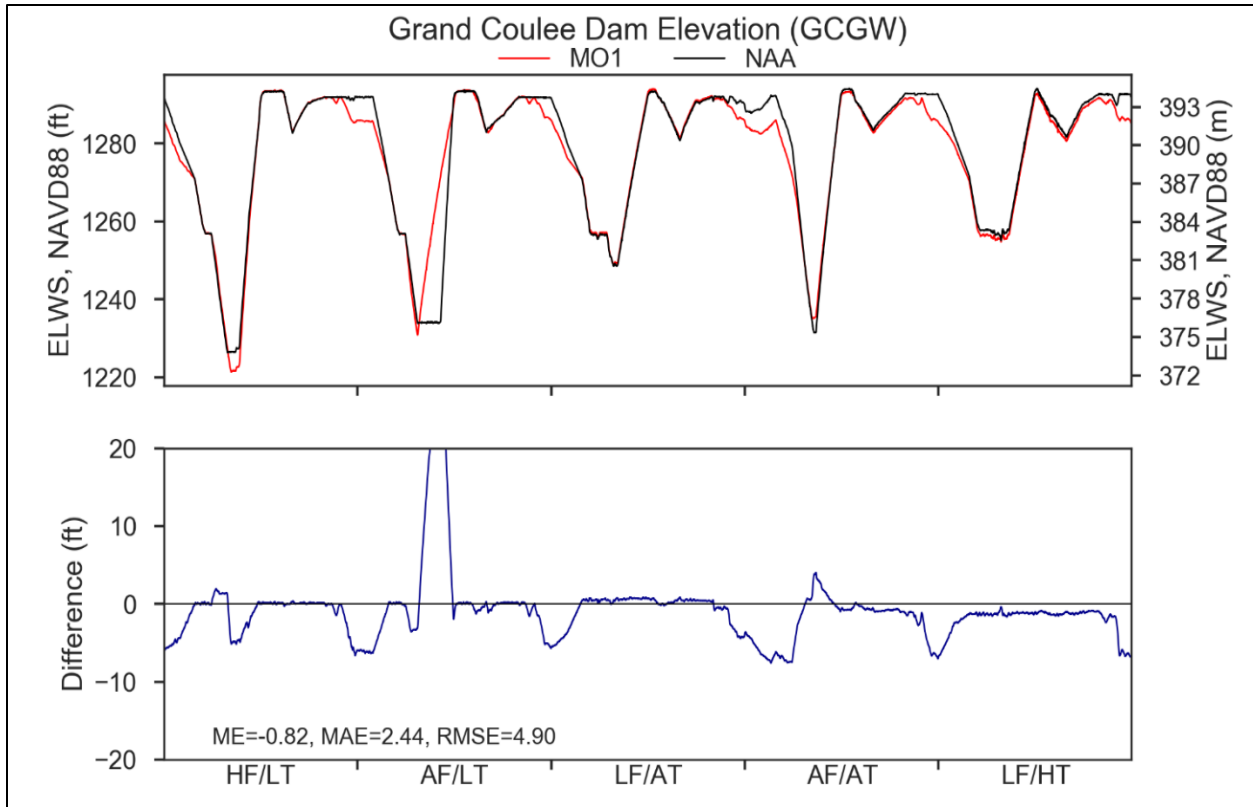
2940 **4.1.3.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

2941 Under MO1, model results indicate that flow through Lake Roosevelt would slightly decrease
2942 from March through May; however, retention time would largely remain unchanged during the
2943 rest of the year, with the exception of slightly shorter retention time in the winter, partially due
2944 to the winter draft for Winter System FRM Space (Figure 4-16.). In general, Lake Roosevelt
2945 tends to display relatively low primary productivity throughout the year. With similar or shorter
2946 retention times, changes in primary productivity are not expected.

2947 The *Planned Draft Rate At Grand Coulee* measure changes the planning drawdown rate (as
2948 depicted in the storage reservation diagram [SRD]) from 1.0 foot per day to a target of 0.8 feet
2949 per day. Mass wasting, such as small local landslides within Lake Roosevelt, has been related to
2950 the rate of drawdown at Grand Coulee Dam. Decreases in these mass wasting events that
2951 introduce sediment in pulses to the reservoir should result in decreases in turbidity under MO1.

2952 Water level fluctuations in Lake Roosevelt may have an impact on mercury cycling within the
2953 reservoir, especially when the lowest lake levels occur from April through July. Water level
2954 fluctuations in reservoirs may increase methyl-mercury concentrations in the waterbody as
2955 seasonally inundated areas of a reservoir have higher rates of methylation activity when
2956 compared to permanently inundated areas of a reservoir (Willacker et al. 2016). Studies suggest
2957 that methyl-mercury has a greater probability of entering the food web during the spring and
2958 summer growing seasons (January through July) (Willacker et al. 2016). Due to the deeper
2959 winter draft proposed by MO1, a larger variation of water elevation is anticipated in the spring,
2960 which may promote a higher rate of mercury cycling. The lower panel of Figure 4-16. shows
2961 that, under MO1, average reservoir elevations are expected to remain about 7 feet lower than
2962 the No Action Alternative. Therefore, MO1 may slightly increase the rate of mercury cycling
2963 within Lake Roosevelt.

2964 MO1 includes modified operations at Grand Coulee Dam that could result in some changes in
2965 monthly outflows to Rufus Woods Lake and Chief Joseph Dam. However, only minor changes to
2966 operational conditions at Chief Joseph Dam are expected. Reservoir elevations and river flows
2967 will be relatively similar between the No Action Alternative and MO1. As such, the physical,
2968 chemical, and biological water quality of Rufus Woods Lake and the Columbia River
2969 downstream of Chief Joseph Dam under MO1 are expected to remain relatively unchanged
2970 from the No Action Alternative. The harmful algae blooms at this location described under the
2971 affected environment and the No Action Alternative would continue in the future under MO1.



2972
 2973 **Figure 4-16. Modeled Forebay Elevations for the No Action Alternative and Multiple Objective**
 2974 **1 at Grand Coulee Dam Under a 5-Year Range of River and Meteorological Conditions**

2975 **4.2 LOWER SNAKE RIVER BASIN**

2976 The timing of summer releases from Dworshak Dam would change under MO1 from the
 2977 *Modified Dworshak Summer Draft* measure, which would alter not only the timing of outflow
 2978 from Dworshak Dam, but in the lower Snake River as well. The intent would be to begin drafting
 2979 the reservoir June 20 rather than July 1, continue releasing water to the 110 percent spill cap
 2980 through July, reduce outflow by about 48 percent in August, and then increase the median
 2981 September outflow by approximately 37 percent. There would be minimal changes to outflow
 2982 during the remainder of the year. Flows in the lower Snake River would increase by 2 and 8
 2983 percent in July and September, and decrease by about 16 percent in August.

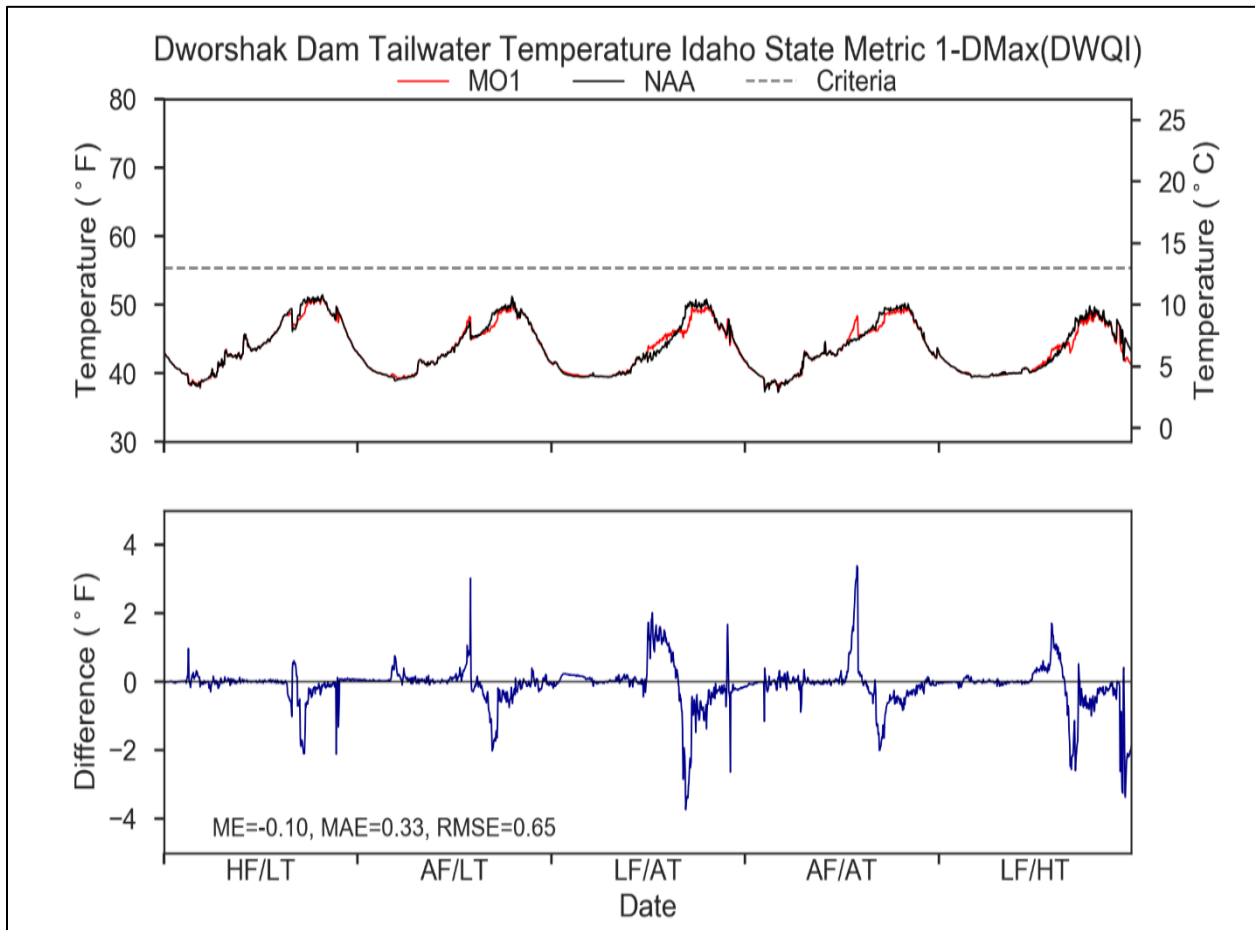
2984 **4.2.1 Water Temperature**

2985 It is not anticipated that fish ladder water temperature improvements at Lower Monumental
 2986 and Ice Harbor Dams (the *Lower Snake Ladder Pumps* measure) would have any meaningful
 2987 impact to downstream river water temperatures. These structural changes are anticipated to
 2988 affect fish ladder conditions only.

2989 The *Modified Dworshak Summer Draft* measure is likely to change water temperatures that
 2990 would occur during the summer and early fall months in the lower Snake River. Details are
 2991 described below.

2992 **4.2.1.1 Dworshak Dam and Reservoir**

2993 The temperature changes that would occur with implementation of MO1 relative to the No
2994 Action Alternative are shown in Figure 30. The primary shifts would occur in July, August,
2995 September, and October under most of the flow/temperature conditions. Median increases
2996 ranging from 0.3 to 1.3 degrees Fahrenheit would occur under MO1 for the AF/LT, LF/AT,
2997 AF/AT, and LF/HT conditions between July 1 and August 10. No temperature changes would
2998 occur during this time period for the HF/LT conditions. Median MO1 temperature decreases
2999 that would occur during the September/October time frame range from 0.2 degree Fahrenheit
3000 for the HF/LT condition to 0.9 degree Fahrenheit for the LF/AT condition. The maximum daily
3001 decrease would occur for the LF/AT condition at 3.7 degrees Fahrenheit and range from 2.0 to
3002 2.6 degrees Fahrenheit for the other conditions. However, the model results for the five
3003 representative conditions show that tailwater temperatures would continue to be less than the
3004 State of Idaho’s COLD/SS standard of 55.4°F (Figure 4-17.).

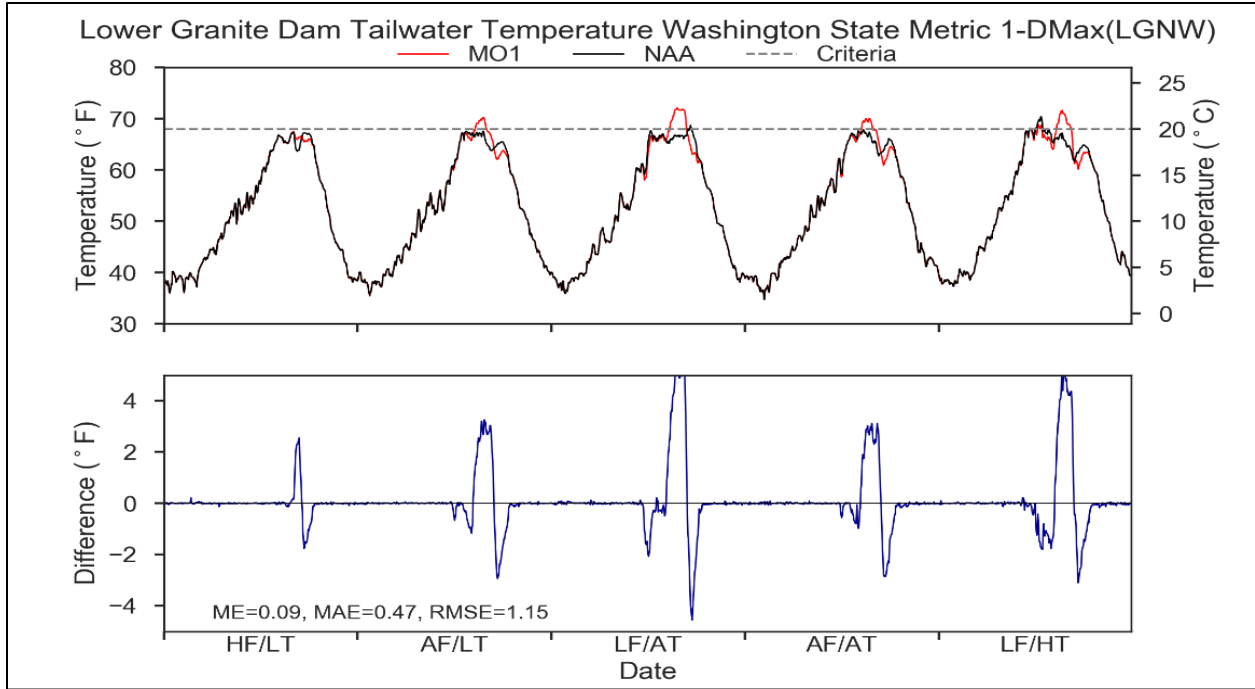


3005 **Figure 4-17. Modeled Tailwater Temperature for the No Action Alternative and Multiple**
3006 **Objective Alternative 1 at Dworshak Dam Under a 5Year Range of River and Meteorological**
3007 **Conditions**
3008

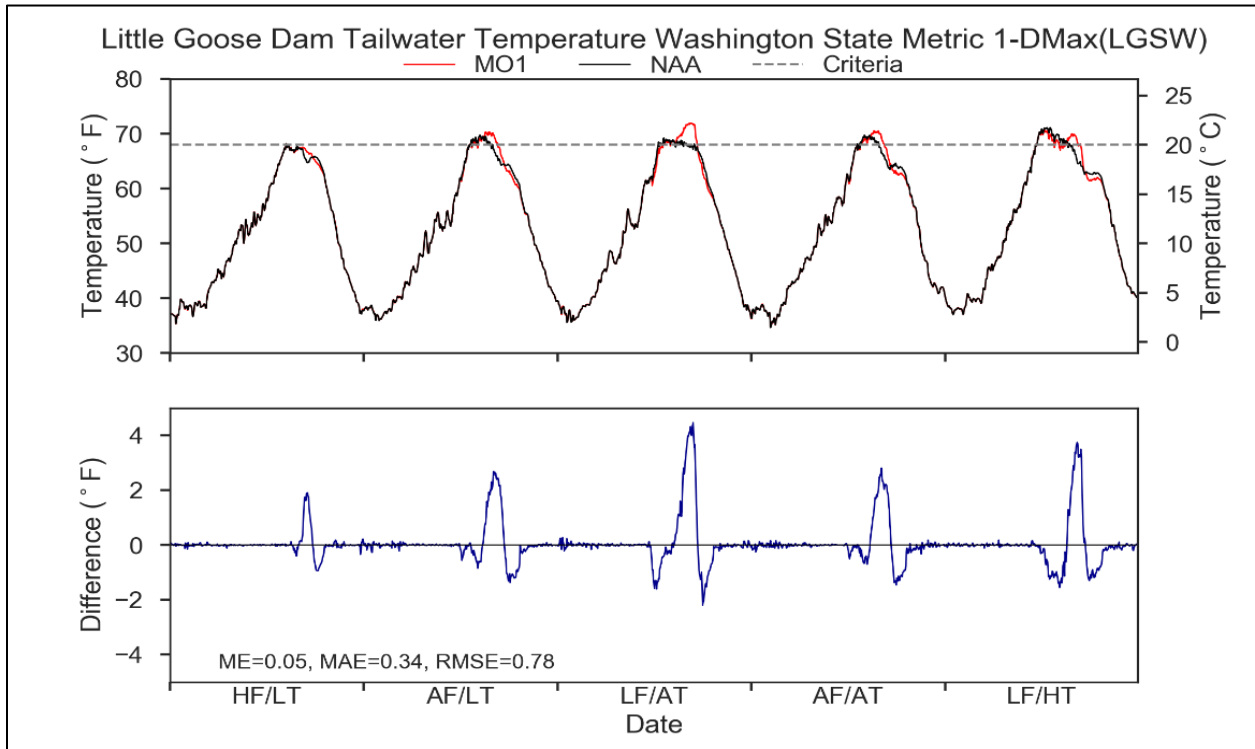
3009 **4.2.1.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
3010 **Reservoirs**

3011 Tailwater temperatures would increase, primarily during August, to varying degrees at the four
3012 lower Snake River projects under MO1 relative to the No Action Alternative (Figure 4-18. -
3013 Figure 4-21.). The least amount of change would occur during HF/LT conditions when there would
3014 be approximately 12 to 13 additional days when water temperatures would increase over No
3015 Action Alternative conditions by more than 1 degree Fahrenheit at the three upstream projects
3016 (Figure 4-22.). There would only be three additional days downstream from Ice Harbor Dam when
3017 temperatures would increase by the same amount. For the remaining four flow/temperature
3018 conditions, it is anticipated there would be 32 to 37 additional days when temperatures would be
3019 greater than 1 degree Fahrenheit over No Action Alternative conditions at Lower Granite Dam
3020 and decrease toward Ice Harbor Dam, where there would be 22 to 30 additional days.

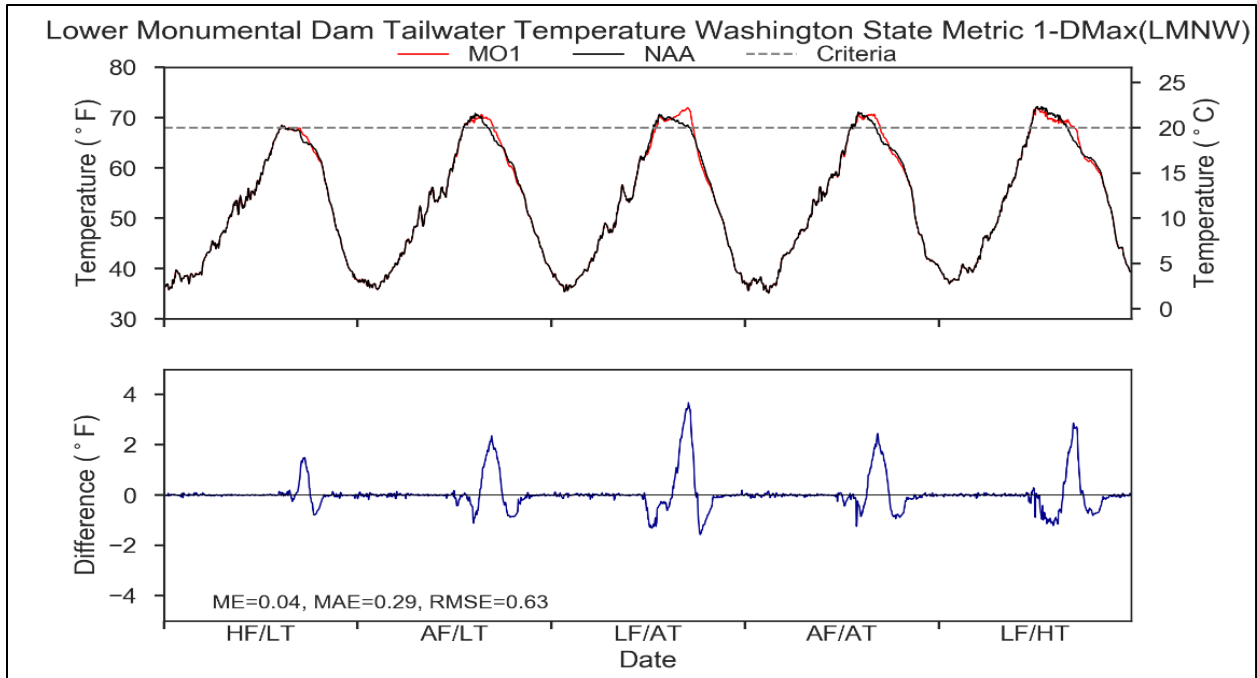
3021 Similarly, Washington's 68°F temperature standard would be exceeded more often at Lower
3022 Granite Dam for most of the flow/temperature conditions than at the other lower Snake River
3023 projects (Figure 4-23.). This is due to changes in Dworshak operations under MO1 and the direct
3024 effect that the *Modified Dworshak Summer Draft* measure has on Lower Granite Reservoir and
3025 tailwater temperatures. The influence of the Dworshak operations lessen as water moves
3026 downstream, with the least amount of change in water temperatures (between MO1 and No
3027 Action Alternative) at Ice Harbor Dam. The model results indicate there would be 21 to 27
3028 additional days when the criteria would be exceeded at Lower Granite Dam, with water
3029 temperatures of 70°F to 73°F and 2 to 8 days at Ice Harbor Dam (maximum temperatures ranging
3030 from 71°F to 74°F during the AF/LT, LF/AT, AF/AT, and LF/HT conditions). Additional exceedances
3031 at the Little Goose and Lower Monumental projects would generally be intermediate, ranging
3032 from 2 to 14 days for the same conditions, but daily maximum temperatures would still range
3033 from 70°F to 73°F. The HF/LT conditions would not lead to additional days of elevated
3034 temperatures at Lower Granite and Little Goose dams, and only 2 to 3 days at the Lower
3035 Monumental and Ice Harbor projects, which is within the models margin of error.



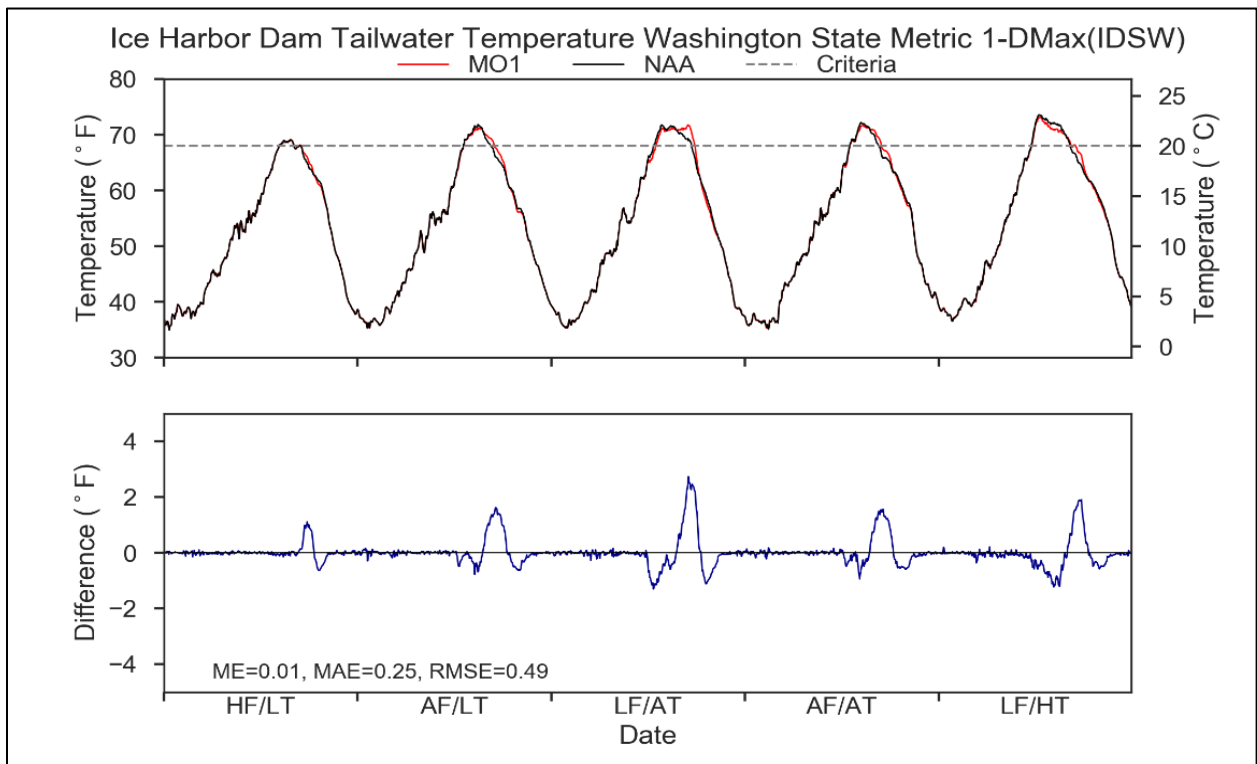
3036
 3037 **Figure 4-18. Modeled Tailwater Temperatures for the No Action Alternative and Multiple**
 3038 **Objective Alternative 1 at Lower Granite Dam Under a 5Year Range of River and**
 3039 **Meteorological Conditions**



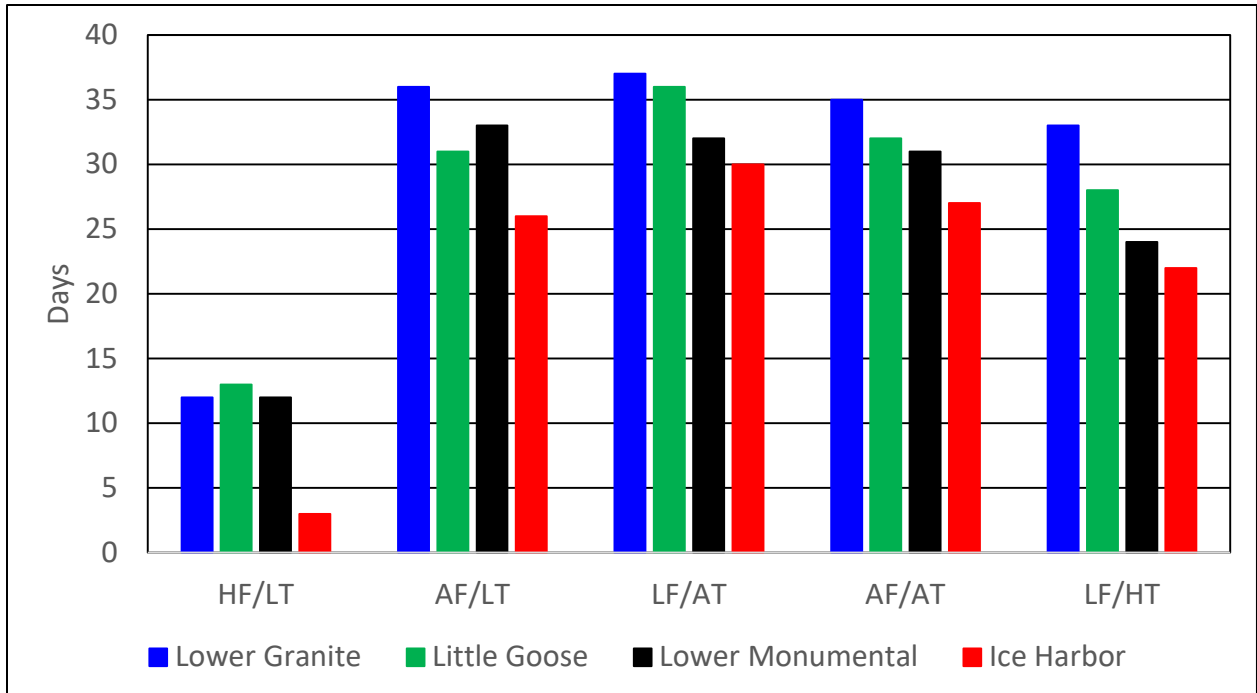
3040
 3041 **Figure 4-19. Modeled Tailwater Temperatures for the No Action Alternative and Multiple**
 3042 **Objective Alternative 1 at Little Goose Dam Under a 5Year Range of River and Meteorological**
 3043 **Conditions**



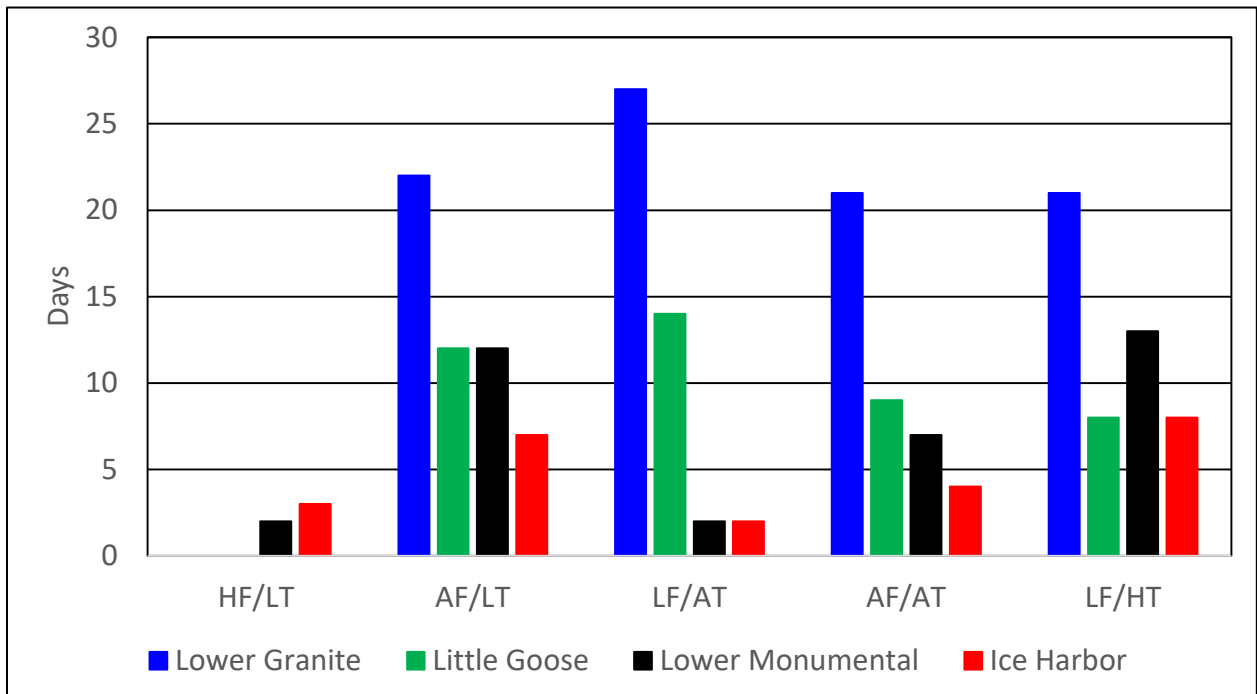
3044
 3045 **Figure 4-20. Modeled Tailwater Temperatures for the No Action Alternative and Multiple**
 3046 **Objective Alternative 1 at Lower Monumental and Ice Harbor Dams Under a 5-Year Range of**
 3047 **River and Meteorological Conditions**



3048
 3049 **Figure 4-21. Modeled Tailwater Temperatures for the No Action Alternative and Multiple**
 3050 **Objective Alternative 1 at Lower Monumental and Ice Harbor Dams Under a 5-Year Range of**
 3051 **River and Meteorological Conditions**



3052
 3053 **Figure 4-22. Number of Days During the Year when There Would be Greater than One Degree**
 3054 **Temperature Increase at the Four Lower Snake River Dam Tailwater Locations Under Multiple**
 3055 **Objective Alternative 1 Relative to the No Action Alternative**



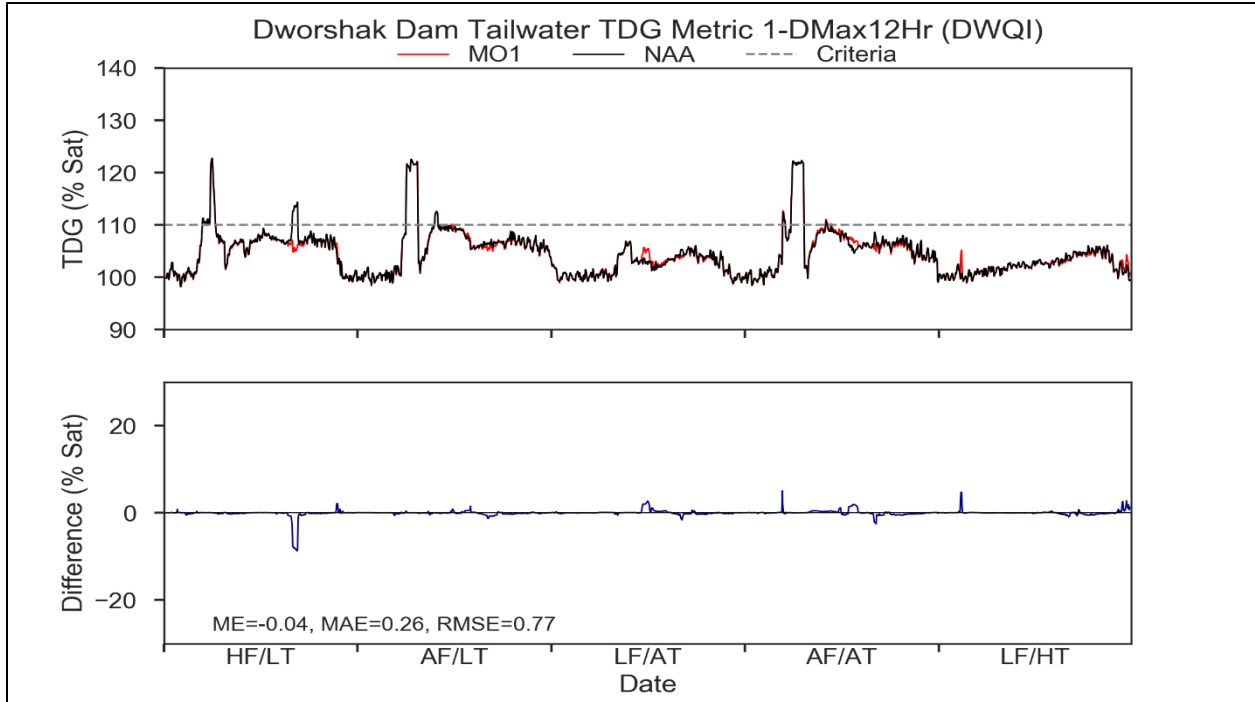
3056
 3057 **Figure 4-23. Number of Additional Days During the Year when the Washington 68 °F**
 3058 **Temperature Standard Would be Exceeded at the Four Lower Snake River Dam**
 3059 **Locations Under Multiple Objective Alternative 1 relative to the No Action Alternative**

3060 **4.2.2 Total Dissolved Gas**

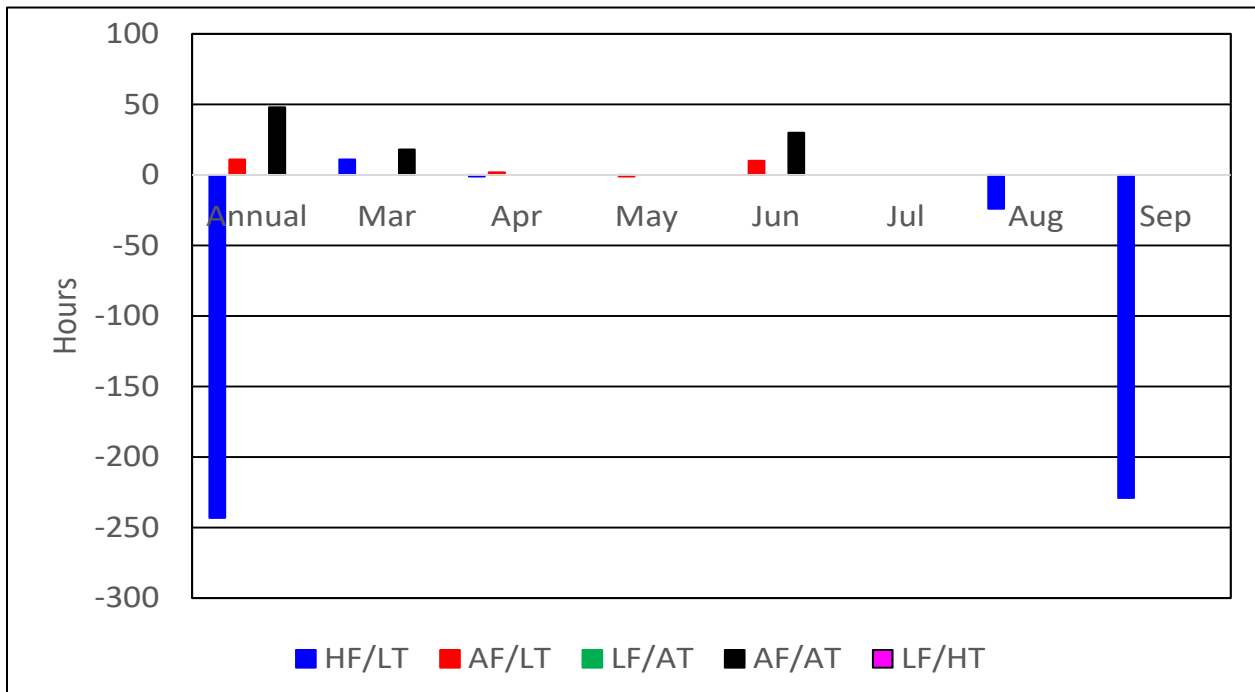
3061 There are two measures within MO1 that modify juvenile fish passage spill operations in the
3062 lower Snake River (the *Block Spill Test* and the *Summer Spill Stop Trigger* measures); no fish spill
3063 operations are included in MO1 for Dworshak Dam. The *Block Spill Test* measure calls for a spill
3064 test to evaluate the latent mortality hypothesis; spill operations switch between performance
3065 (base) spill and a test spill operation within a given season. The *Spill Stop Trigger* measure calls
3066 for the modification, or early end to summer juvenile fish passage spill operations at the lower
3067 Snake River projects. Ending dates vary from August 6 to August 21, depending on the dam.
3068 Due to the within-season switch between operations, in conjunction with an assumed higher
3069 amount of lack of market spill in the No Action Alternative, model results do not show a notable
3070 differences in TDG in MO1 as compared to the No Action Alternative. Details are described
3071 below.

3072 **4.2.2.1 Dworshak Dam and Reservoir**

3073 The predicted TDG saturation in the Dworshak Dam tailwater under MO1 would be similar to
3074 No Action Alternative, with a few exceptions (Figure 4-24.). The highest gas saturation would
3075 still occur during spring releases. Increases would range from 11 to 18 hours during March for
3076 the HF/LT and AF/AT conditions, respectively, under MO1 (Figure 4-25.). June increases would
3077 range from 10 to 30 hours for AF/LT and AF/AT conditions, respectively. All of these changes
3078 would be minimal since they only account for approximately one to four percent of the time in
3079 any of the months. A more notable change would occur during September during HF/LT
3080 conditions when a reduction of 229 hours above the standard would be expected—equivalent
3081 to a 32 percent decrease for the month.



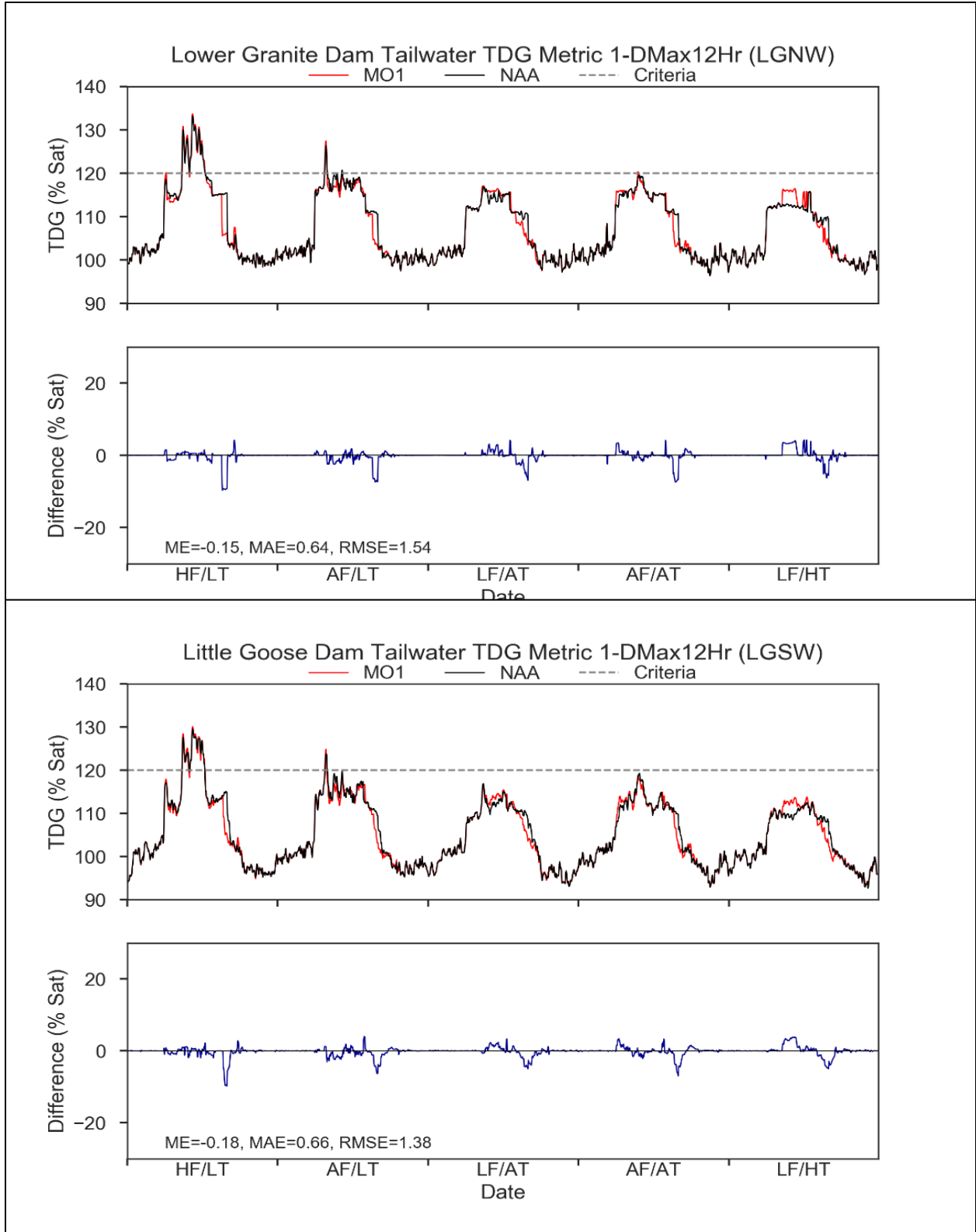
3082
 3083 **Figure 4-24. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and**
 3084 **Multiple Objective Alternative 1 at Dworshak Dam Under a 5-Year Range of River and**
 3085 **Meteorological Conditions**



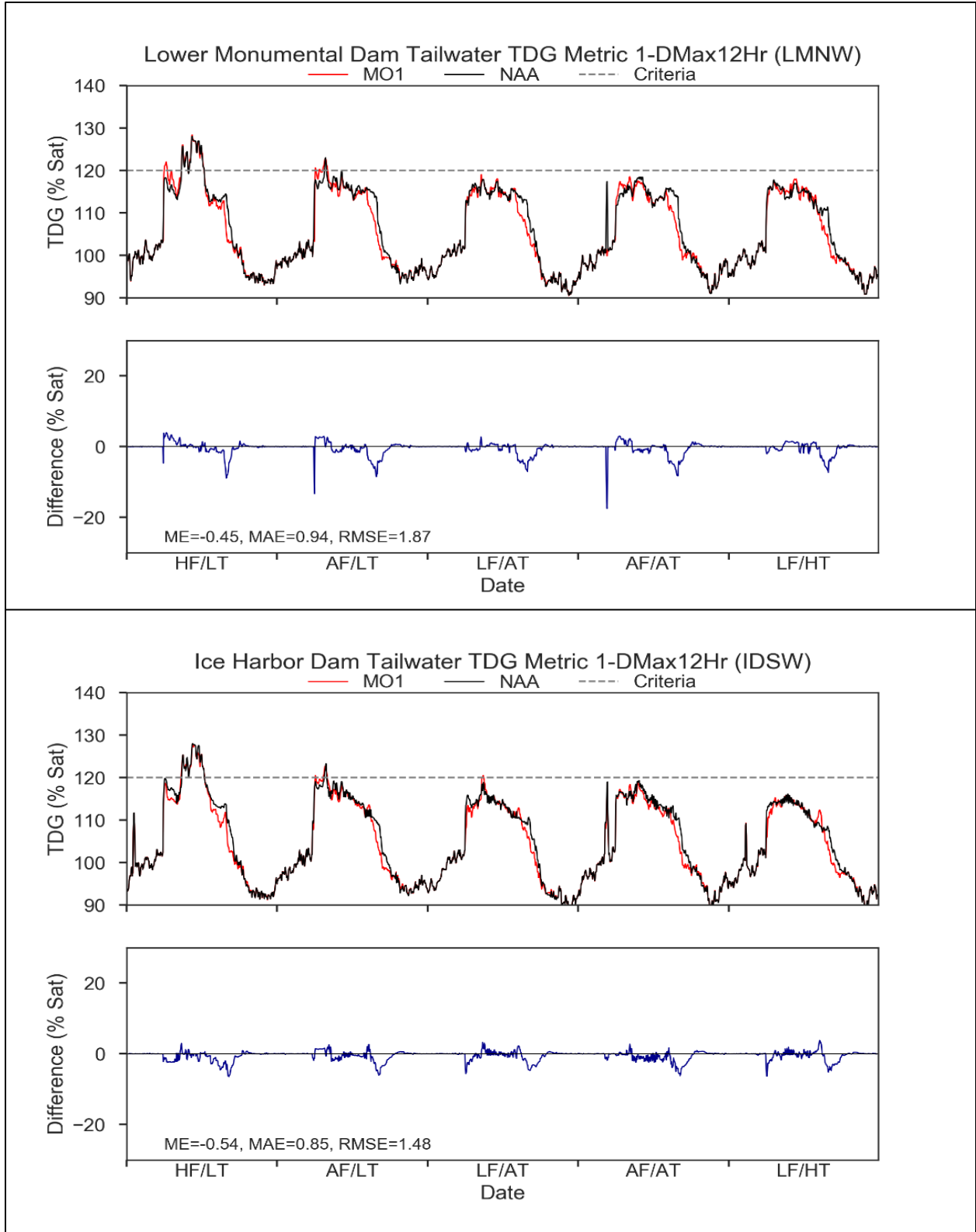
3086
 3087 **Figure 4-25. Increases and Decreases in the Number of Hours the Idaho 110 Percent Total**
 3088 **Dissolved Gas Standard Would be Met at the Dworshak Dam Tailwater Location for Each**
 3089 **Flow/Temperature Condition Under Multiple Objective Alternative 1 Relative to the No**
 3090 **Action Alternative**

3091 **4.2.2.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
3092 **Reservoirs**

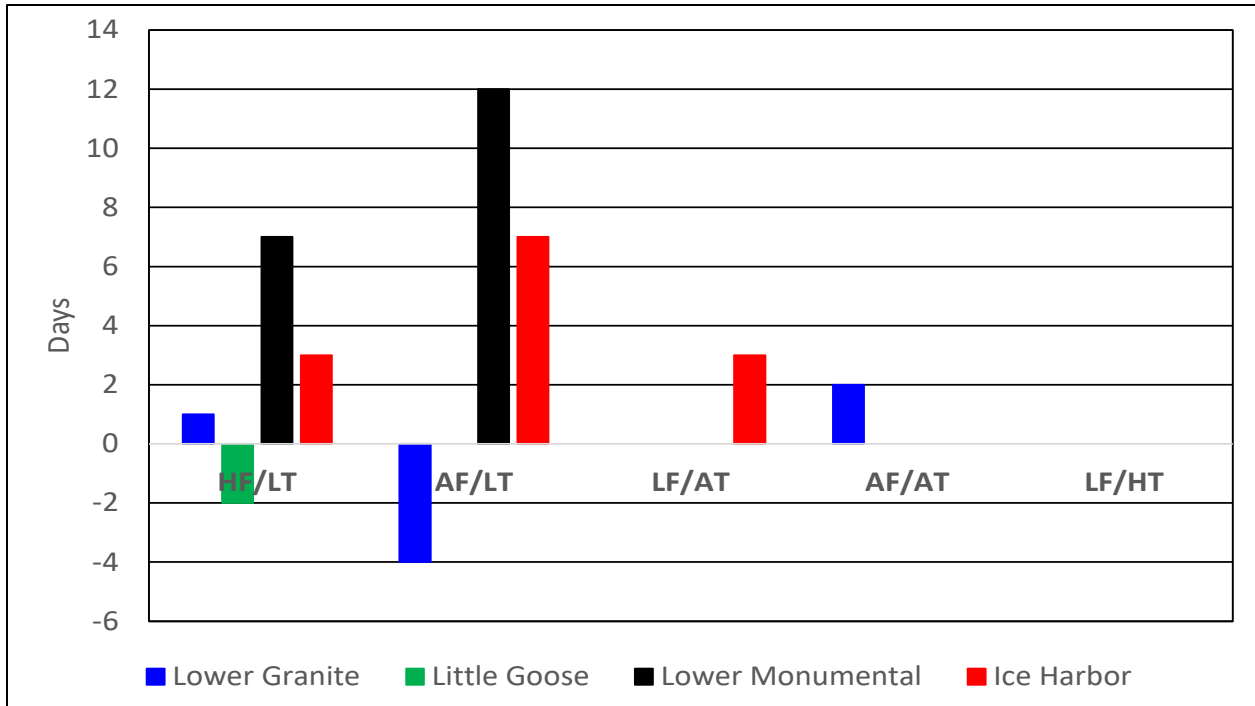
3093 Total gas saturation at the tailwater stations of the four lower Snake River dams under MO1
3094 would be similar to the No Action Alternative with a few exceptions (Figure 4-26. and
3095 Figure 4-27.). April through August TDG would be less than the Washington 120 percent waiver
3096 for the LF/AT, AF/AT, and LF/HT conditions. The only possible exceptions are the additional 3
3097 days at Ice Harbor Dam during LF/AT conditions and 2 days at Lower Granite Dam during AF/AT
3098 conditions (Figure 4-28.). However, both of these are within the margin of error for the model.
3099 Larger changes would occur during HF/LT and AF/LT conditions at Lower Monumental Dam
3100 when an additional 7 and 12 days, respectively, would exceed the standard. TDG exceedances
3101 at the Ice Harbor Dam tailwater location would also increase by 7 days under the AF/LT
3102 condition.



3103
 3104 **Figure 4-26. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and**
 3105 **Multiple Objective Alternative 1 at Lower Granite and Little Goose Dams Under a 5-Year**
 3106 **Range of River and Meteorological Conditions**

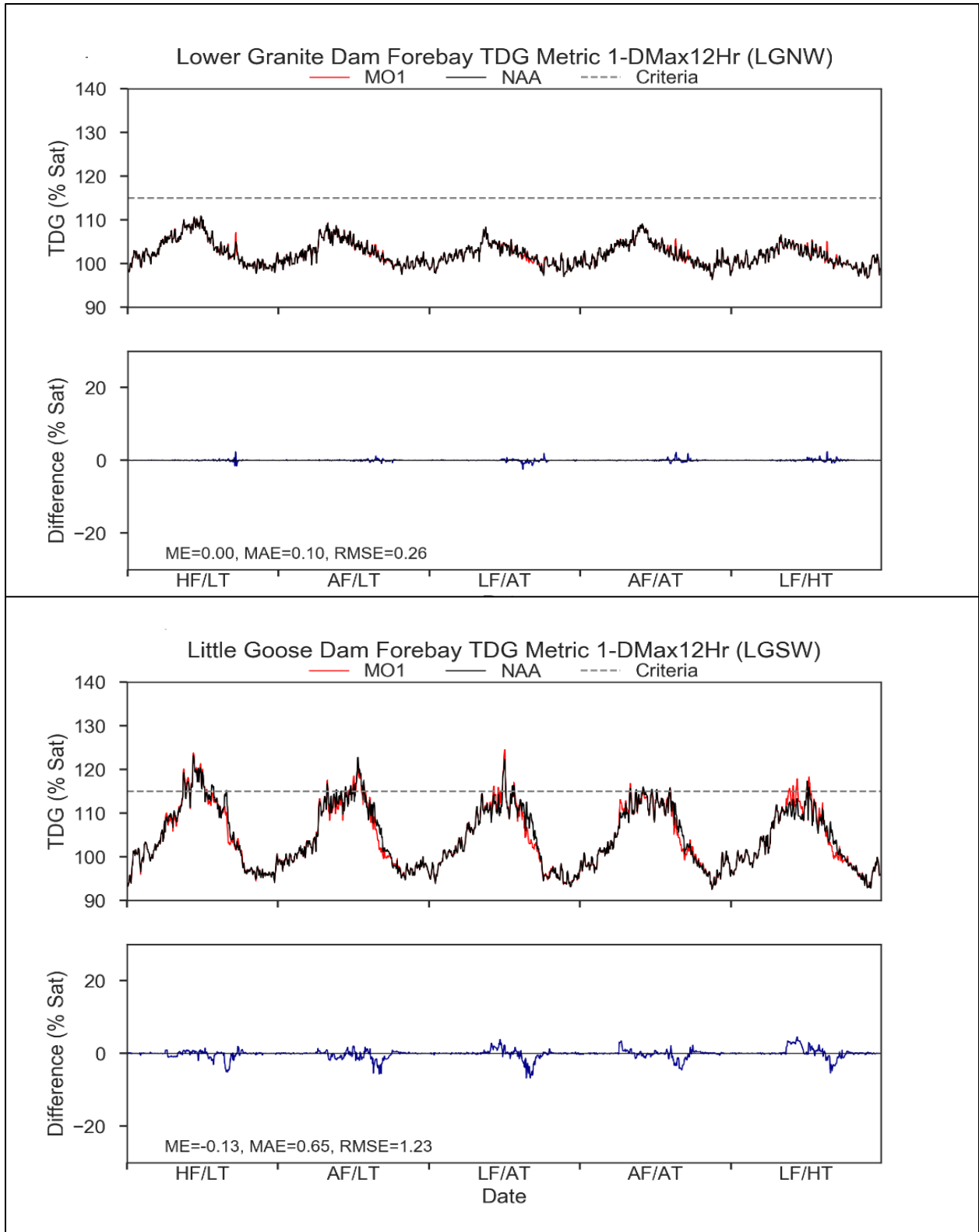


3107
 3108 **Figure 4-27. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and**
 3109 **Multiple Objective Alternative 1 at Lower Monumental and Ice Harbor Dams Under a 5-Year**
 3110 **Range of River and Meteorological Conditions**



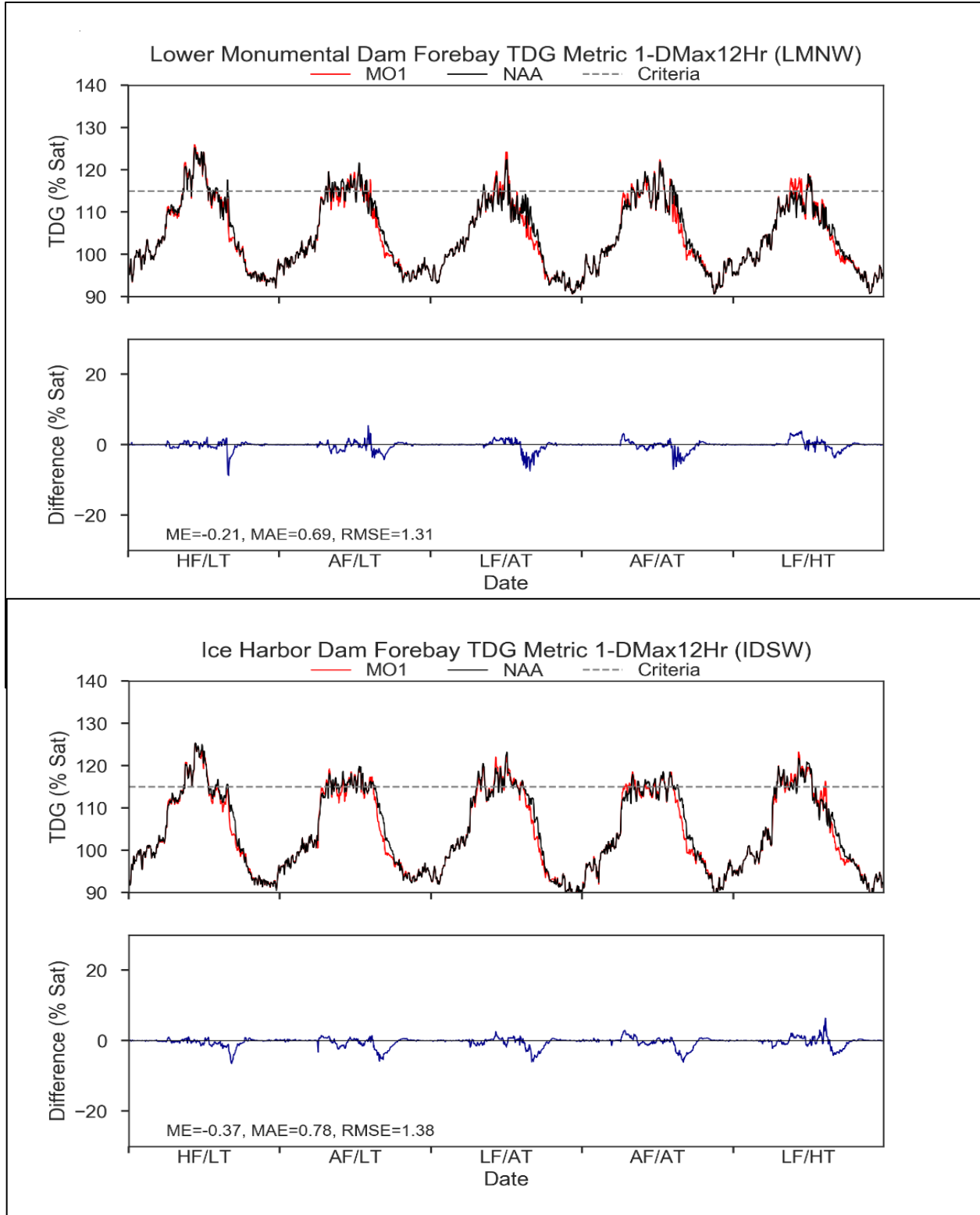
3111
 3112 **Figure 4-28. Increases and Decreases in the Number of Days the Washington 120 Percent**
 3113 **Total Dissolved Gas Standard Would be Met at the Lower Snake River Dam Tailwater**
 3114 **Locations for each Flow/Temperature Condition Under Multiple Objective Alternative 1**
 3115 **Relative to the No Action Alternative**

3116 The model results for forebay TDG at the four lower Snake River dams under MO1 are in many
 3117 ways similar to the previous results for the No Action Alternative (Figure 4-29. and
 3118 Figure 4-30.). TDG saturation at Lower Granite Dam would remain below Washington’s April
 3119 through August 115 percent waiver during each flow/temperature condition. The number of
 3120 days that the standard would be exceeded would decrease by one to 11 days at Little Goose,
 3121 Lower Monumental, and Ice Harbor dams during HF/LT, AF/LT, and AF/AT conditions
 3122 (Figure 4-31.). Increases in forebay TDG would be greatest under MO1 at Little Goose and
 3123 Lower Monumental dams under a LF/HT condition.

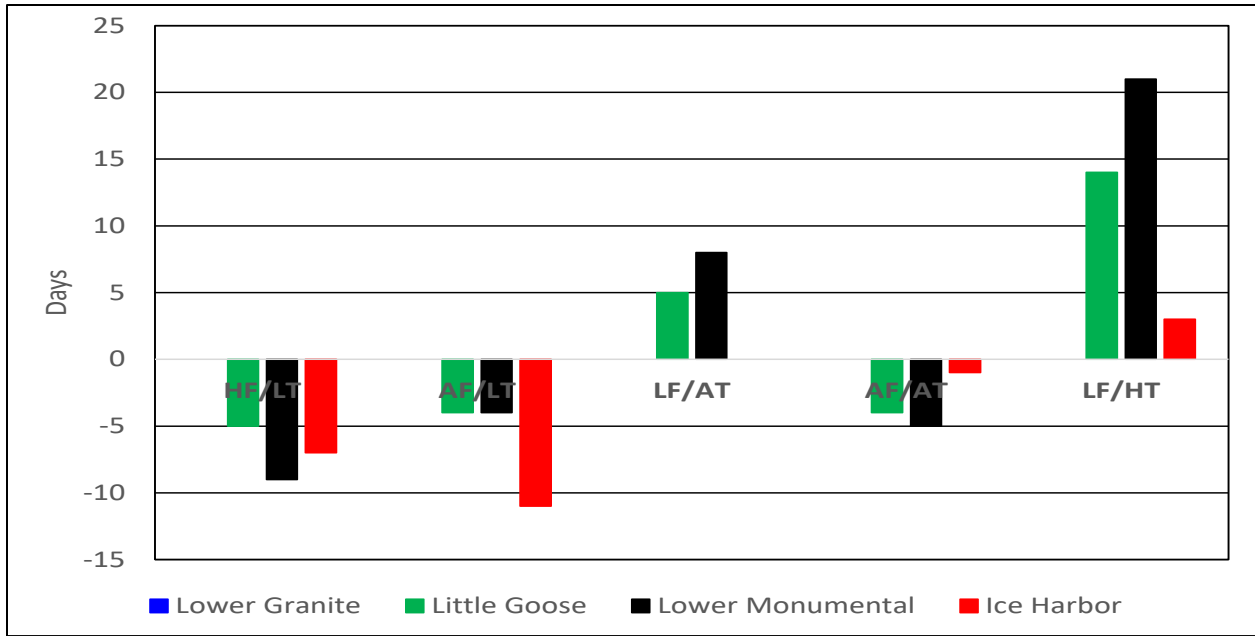


3124
 3125
 3126
 3127

Figure 4-29. Modeled Forebay Total Dissolved Gas for the No Action Alternative and Multiple Objective Alternative 1 at Lower Granite and Little Goose Dams Under a 5-Year Range of River and Meteorological Conditions



3128
 3129 **Figure 4-30. Modeled Forebay Total Dissolved Gas for the No Action Alternative and Multiple**
 3130 **Objective Alternative 1 at Lower Monumental and Ice Harbor Dams Under a 5-Year Range of**
 3131 **River and Meteorological Conditions**



3132
3133 **Figure 4-31. Increases and Decreases in the Number of Days the Washington 115 Percent**
3134 **Total Dissolved Gas Standard Would be Met at the Lower Snake River Dam Forebay Locations**
3135 **for each Flow/Temperature Condition Under Multiple Objective Alternative 1 Relative to the**
3136 **No Action Alternative**

3137 **4.2.3 Other Physical, Chemical, and Biological Processes**

3138 **4.2.3.1 Dworshak Dam and Reservoir**

3139 Reduced outflow during August would increase the hydrologic residence time of the reservoir
3140 during that month which could lead to an increase in phytoplankton growth, including
3141 cyanobacteria (blue-green algae). However, since the nutrient fertilization program that adds
3142 liquid nitrogen to modify the nitrogen to phosphorus ratio would continue, adjustments to the
3143 application rate would be made to mitigate formation of these blooms in most of the reservoir.
3144 Other parameters such as Secchi disk depth and chlorophyll a concentrations would remain
3145 within normal inter-annual variability.

3146 **4.2.3.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
3147 **Reservoirs**

3148 The reduced outflows from Dworshak Dam during August would lead to higher water
3149 temperatures, an increase in hydrologic residence times, and higher concentrations of nutrients
3150 due to a greater contribution of total flow from the middle Snake River. These conditions could
3151 promote increased primary production, including nuisance growth of aquatic algae or
3152 cyanobacteria. These effects might be especially pronounced where waters are more quiescent
3153 and where contact recreation is common, such as swimming areas or sheltered boat launches.
3154 However, such effects are highly uncertain and cannot be confidently predicted with available
3155 information.

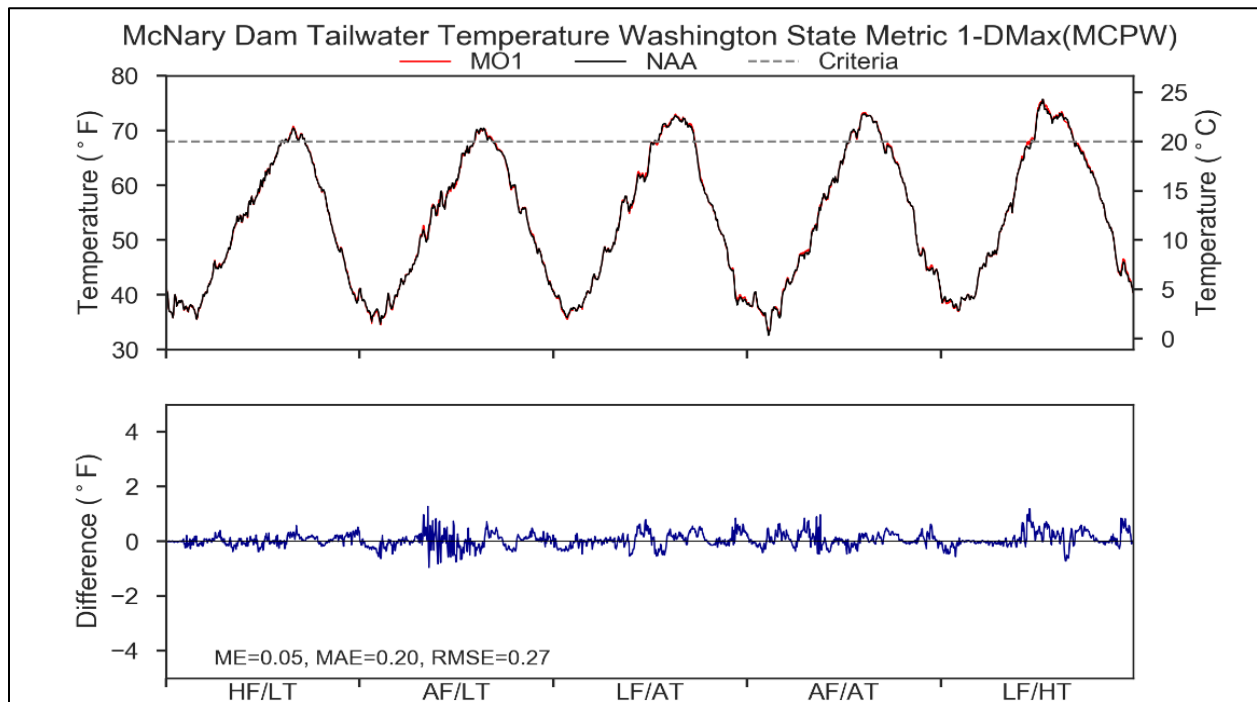
3156 **4.3 LOWER COLUMBIA RIVER**

3157 **4.3.1 Water Temperature**

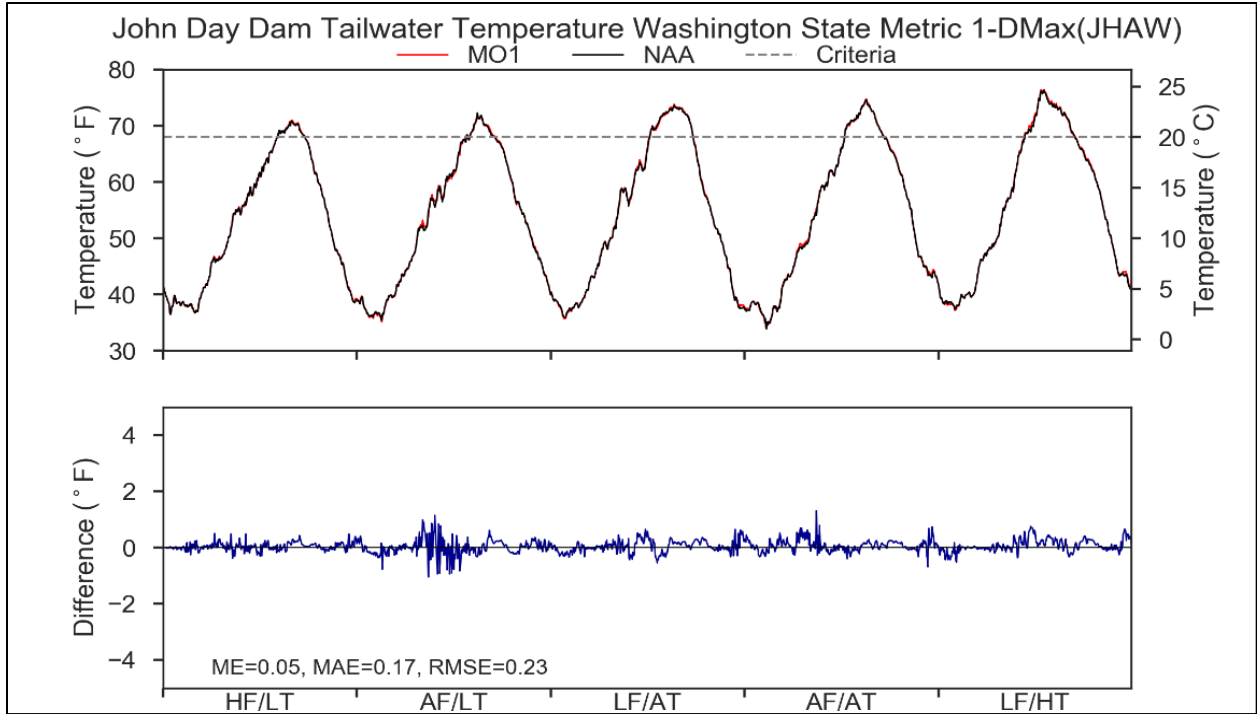
3158 There are no specific structural or operational measures in MO1 that are expected to influence
3159 water temperatures in the lower Columbia River. Details are provided below.

3160 **4.3.1.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

3161 The tailwater temperatures for MO1 at McNary, John Day, The Dalles, and Bonneville Dams
3162 were modeled under a 5-year range of river and meteorological conditions, and compared to
3163 the modeled results for the No Action Alternative (Figure 4-32. through Figure 4-35.). Just as
3164 with the No Action Alternative model results, the MO1 model results show that tailwater
3165 temperatures can exceed 68°F at all four dams during any of the years and conditions
3166 presented, and maximum water temperatures and the frequency of water temperature
3167 exceedances of state water quality standards would be higher during a year when river flows
3168 were lower than normal and summer ambient air temperatures were higher (as in LF/HT). The
3169 shift in the timing of releases from Dworshak Dam to provide cooler water both earlier and
3170 later in the summer to the lower Snake River appears to have little or no effect on water
3171 temperatures in the lower Columbia River. The average frequency of water temperature
3172 exceedances to the State water quality standards would be nearly identical for the No Action
3173 Alternative and MO1 for all four lower Columbia River dams (Figure 4-36.). Generally, there
3174 would not be a significant difference in tailwater temperatures under the No Action Alternative
3175 and MO1.

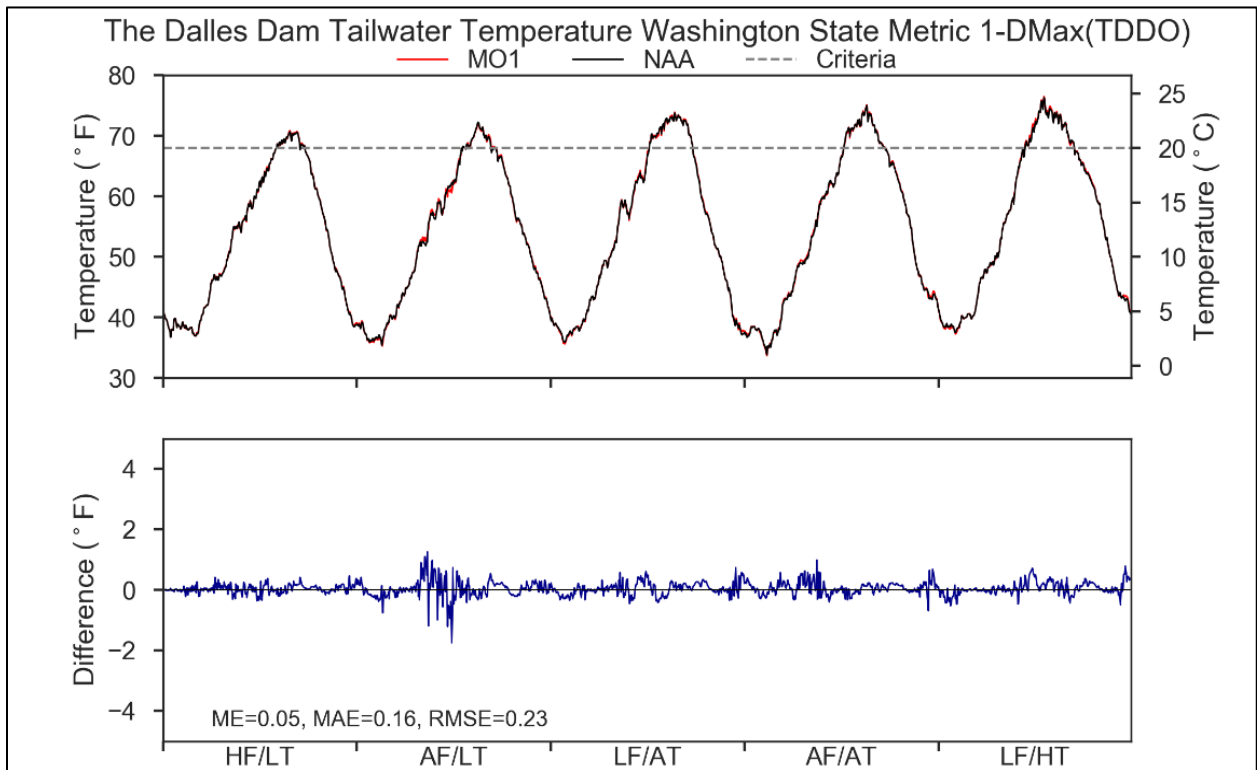


3176 **Figure 4-32. Modeled Tailwater Temperature for Multiple Objective Alternative 1 at McNary**
3177 **Dam Under a 5-Year Range of River and Meteorological Conditions**
3178



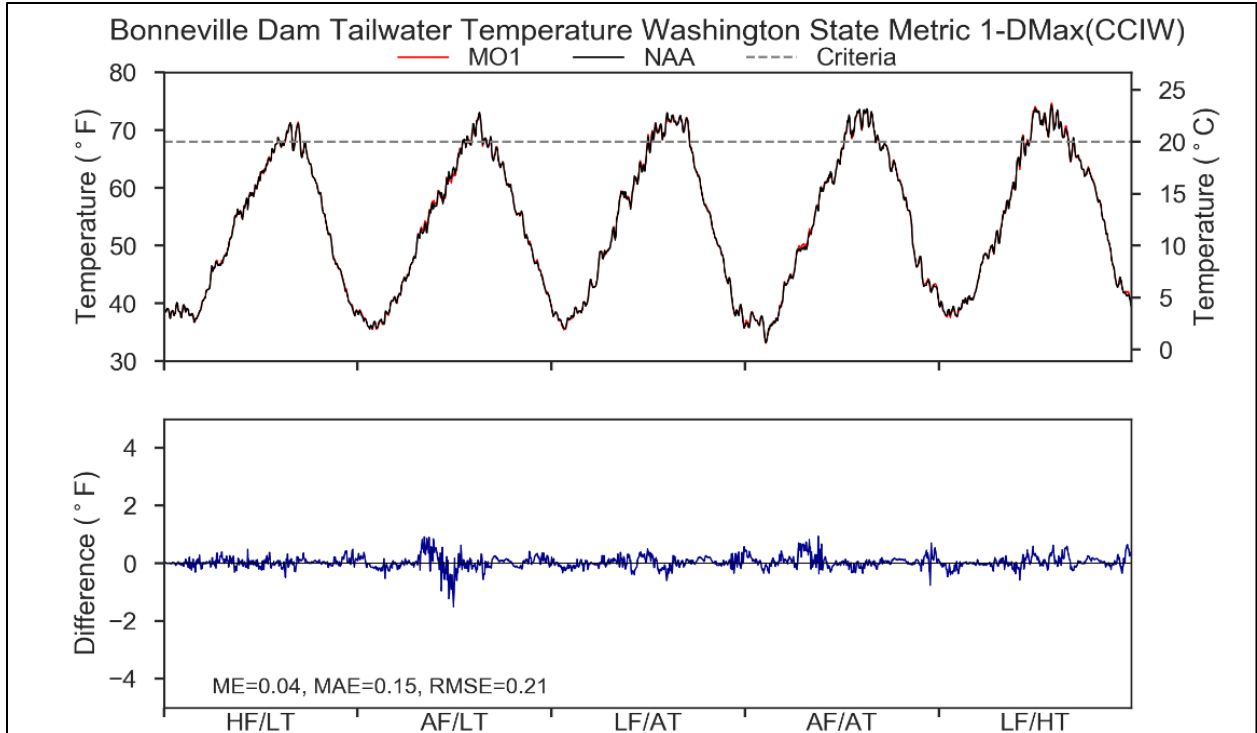
3179
 3180
 3181

Figure 4-33. Modeled Tailwater Temperature for Multiple Objective Alternative 1 at John Day Dam Under a 5-Year Range of River Meteorological Conditions



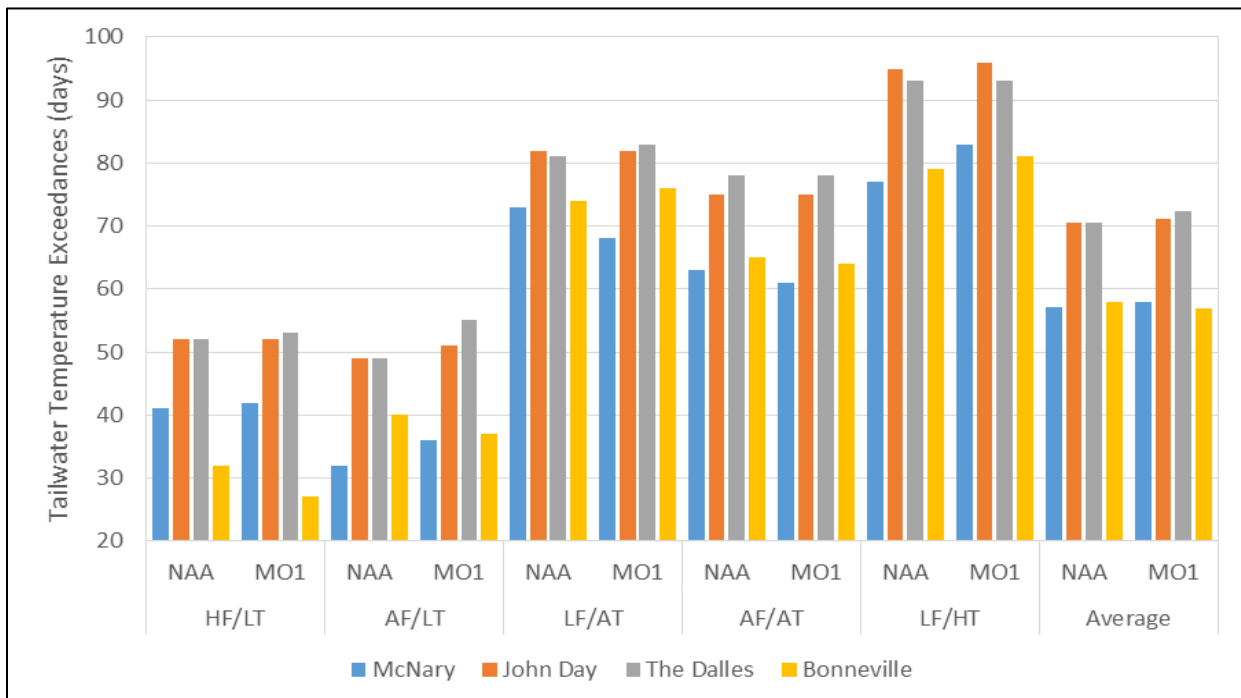
3182
 3183
 3184

Figure 4-34. Modeled Tailwater Temperature for Multiple Objective Alternative 1 at The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions



3185
 3186
 3187

Figure 4-35. Modeled Tailwater Temperature for Multiple Objective Alternative 1 at Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions



3188
 3189
 3190
 3191
 3192

Figure 4-36. Frequency of Modeled Tailwater Temperature Violations of State Water Quality Standards for the No Action Alternative and Multiple Objective Alternative 1 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-Year Range of River and Meteorological Conditions

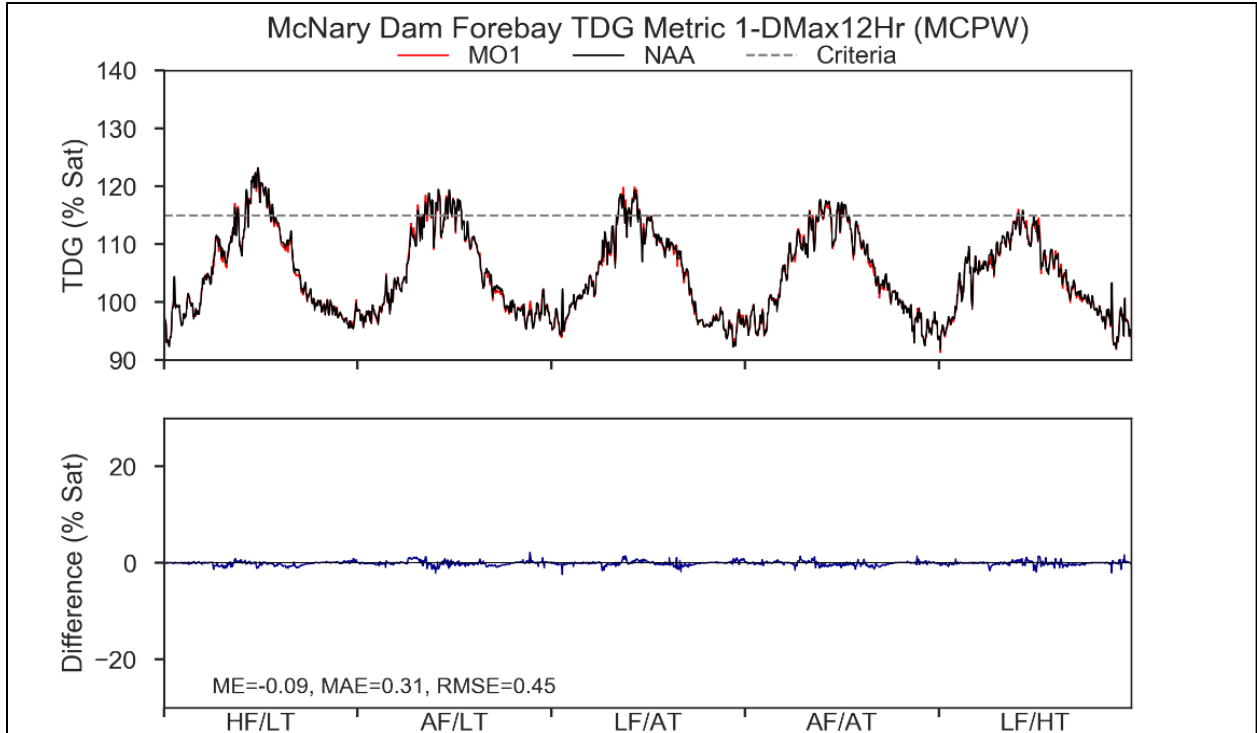
3193 **4.3.2 Total Dissolved Gas**

3194 The *Block Spill Test* measure calls for a spill test to evaluate the latent mortality hypothesis in
3195 the lower Columbia River. Under this measure, spill operations switch between performance
3196 (base) spill and a test spill operation within a given season. Due to the within season switch
3197 between operations, in conjunction with an assumed higher amount of lack of market spill in
3198 the No Action Alternative, model results do not show a notable difference in TDG in MO1 as
3199 compared to the No Action Alternative. Details are described below.

3200 **4.3.2.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

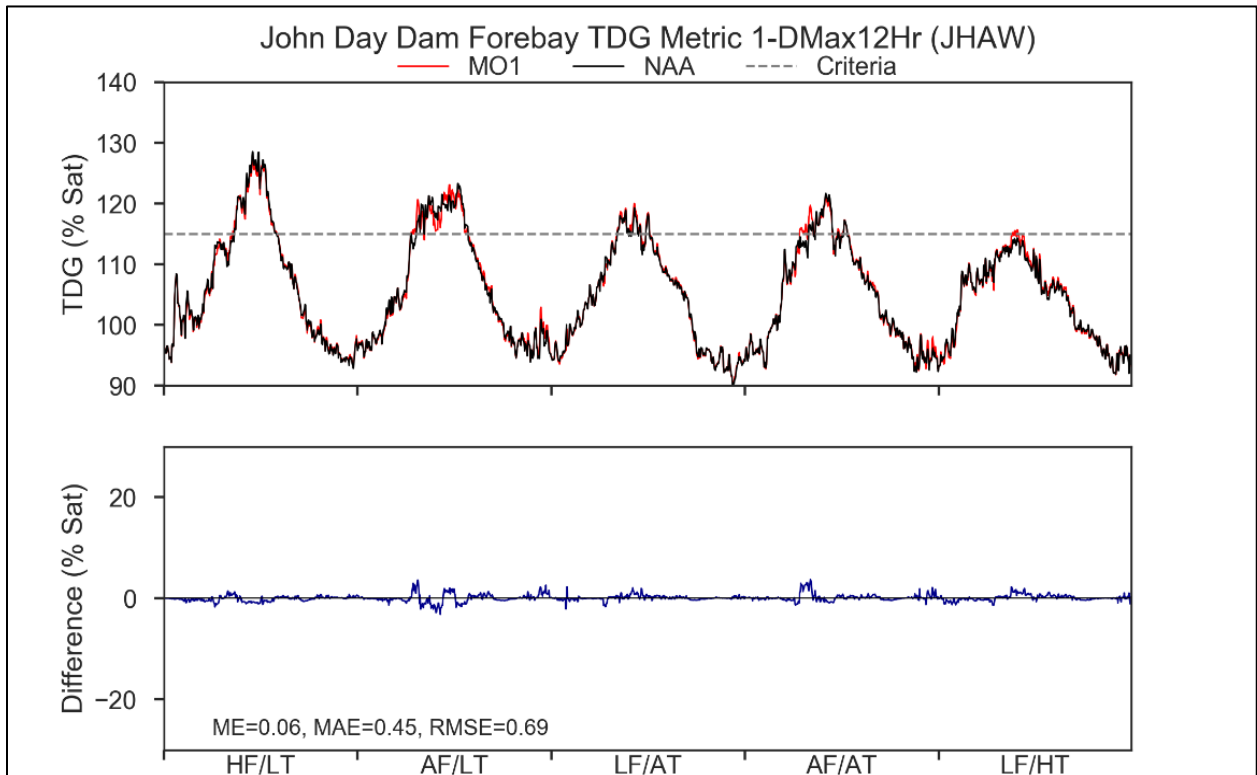
3201 Forebay TDG saturations for MO1 at McNary, John Day, The Dalles, and Bonneville Dams were
3202 modeled under a 5-year range of river and meteorological conditions and compared to the
3203 modeled results for the No Action Alternative (Figure 4-37. through Figure 4-40.). The MO1
3204 model results show that forebay TDG saturations can exceed 115 percent at all four dams
3205 during all of the years and conditions presented. Maximum forebay TDG saturation would be
3206 higher during a year when river flows were higher than normal and summer ambient air
3207 temperatures were lower (as in 2011). Forebay TDG saturations would be similar in MO1 as
3208 compared to No Action Alternative for all four dams. Differences between the No Action
3209 Alternative and MO1 exceedance frequencies for TDG would be minor (Figure 4-41).

3210 MO1 model results show that tailwater TDG saturations can exceed 120 percent at all four
3211 dams depending on the river and meteorological conditions, though there are conditions where
3212 exceedances do not occur for McNary and John Day Dams (Figure 4-42. through Figure 4-45.).
3213 Maximum tailwater TDG saturation would be higher during a year when river flows were higher
3214 than normal and summer ambient air temperatures were lower (HF/LT). Tailwater TDG
3215 saturations in MO1 as compared to the No Action Alternative are fairly similar for all four dams.
3216 The differences in frequencies of tailwater TDG exceedances for all four dams are minor
3217 (Figure 4-46.).



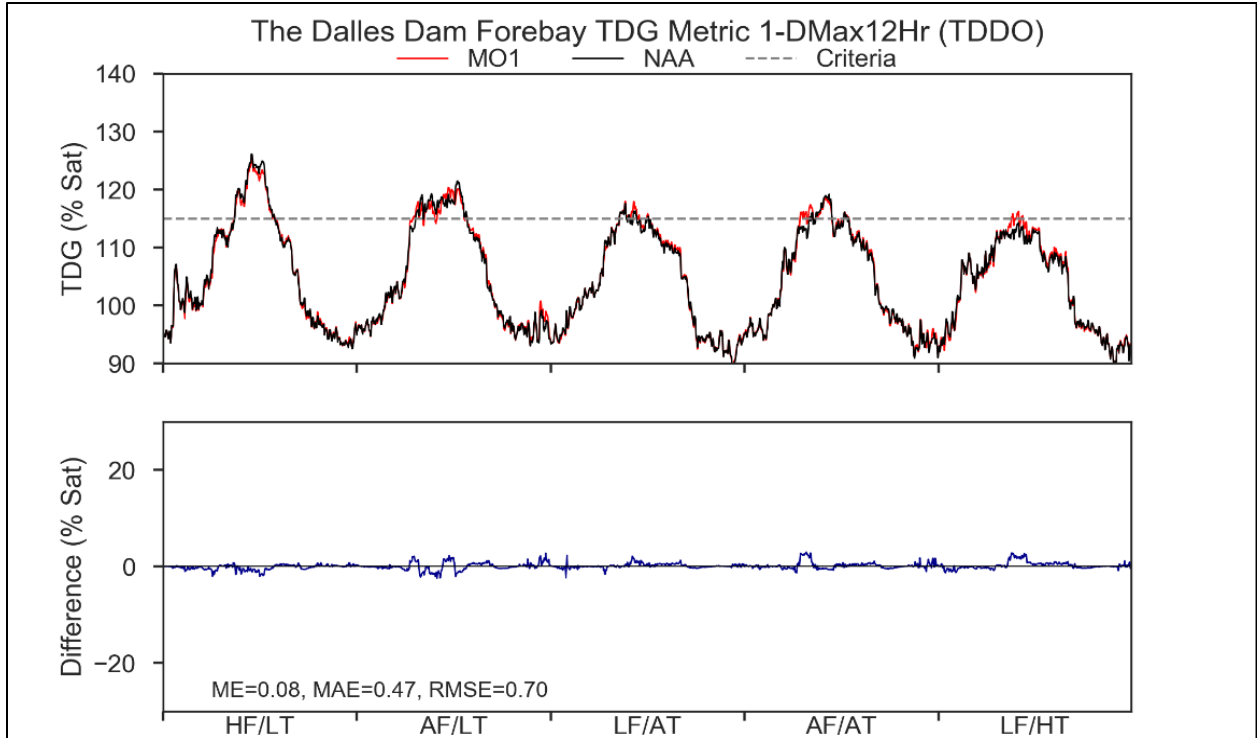
3218
 3219
 3220

Figure 4-37. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 1 at McNary Dam Under a 5-Year Range of River and Meteorological Conditions



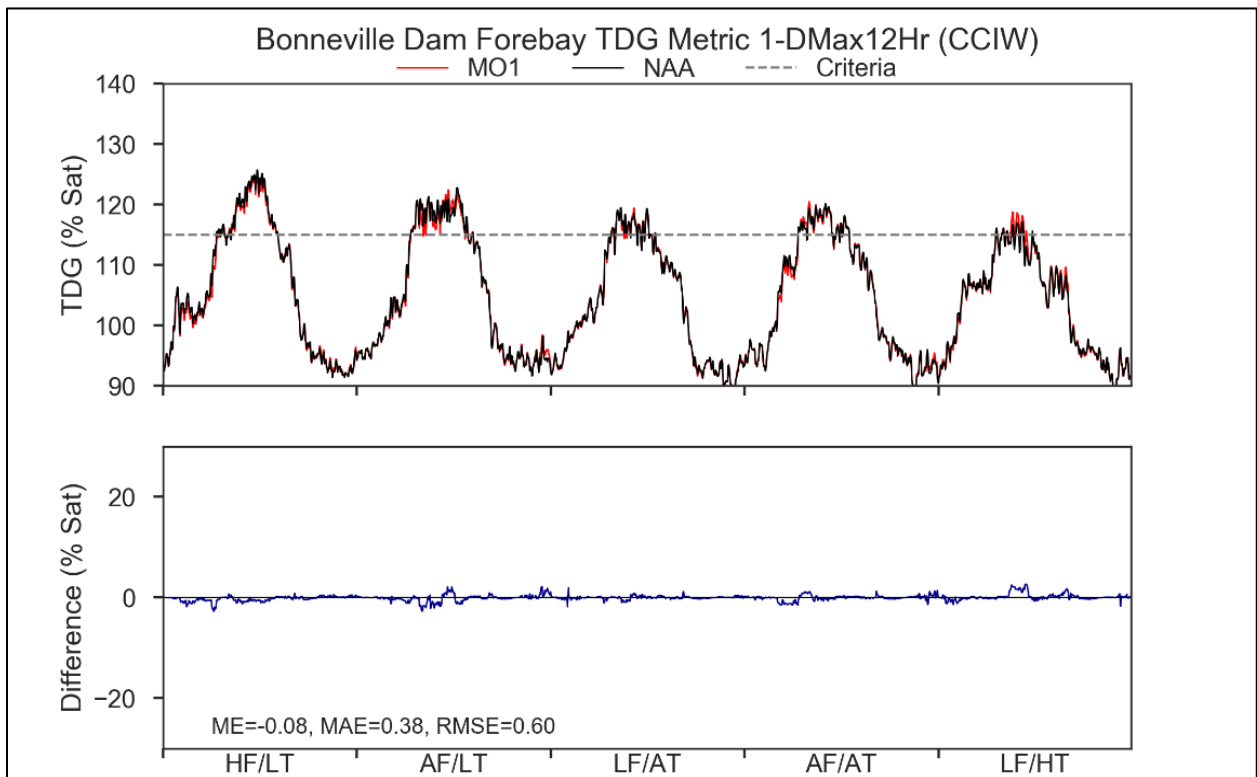
3221
 3222
 3223

Figure 4-38. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 1 at John Day Dam Under a 5-Year Range of River and Meteorological Conditions



3224
 3225
 3226

Figure 4-39. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 1 at The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions



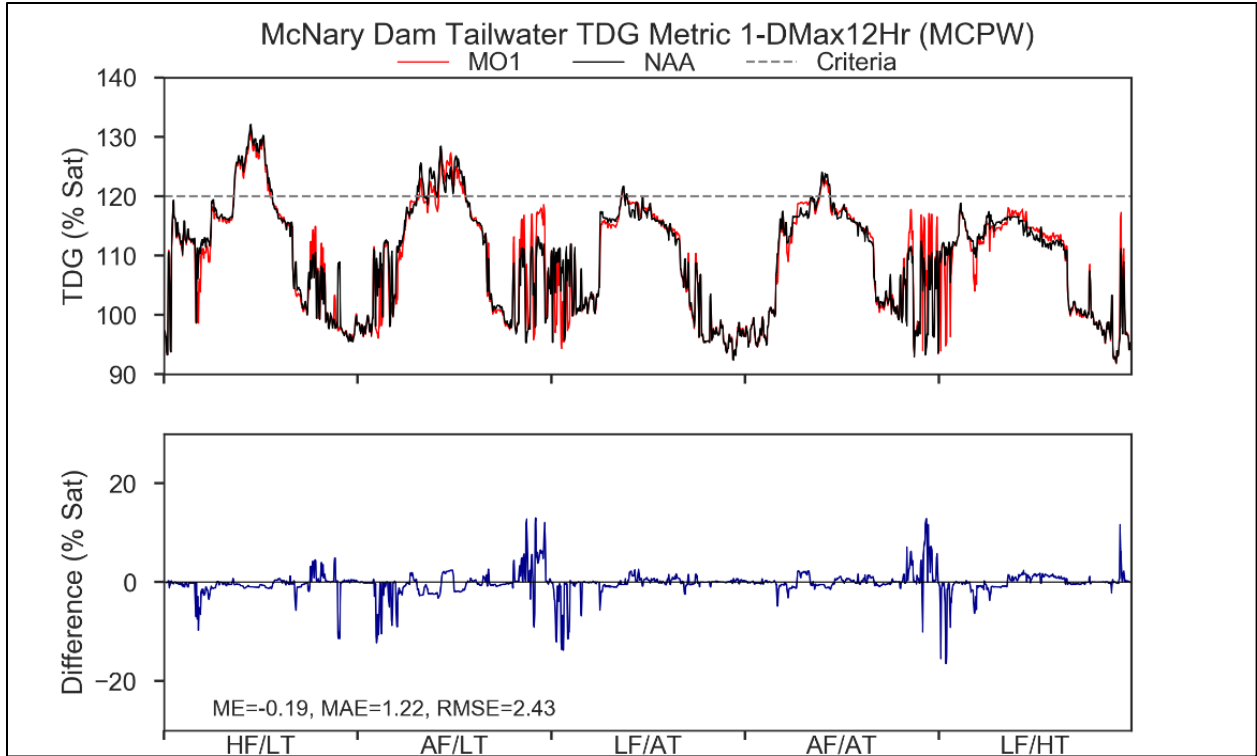
3227
 3228
 3229

Figure 4-40. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 1 at Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions

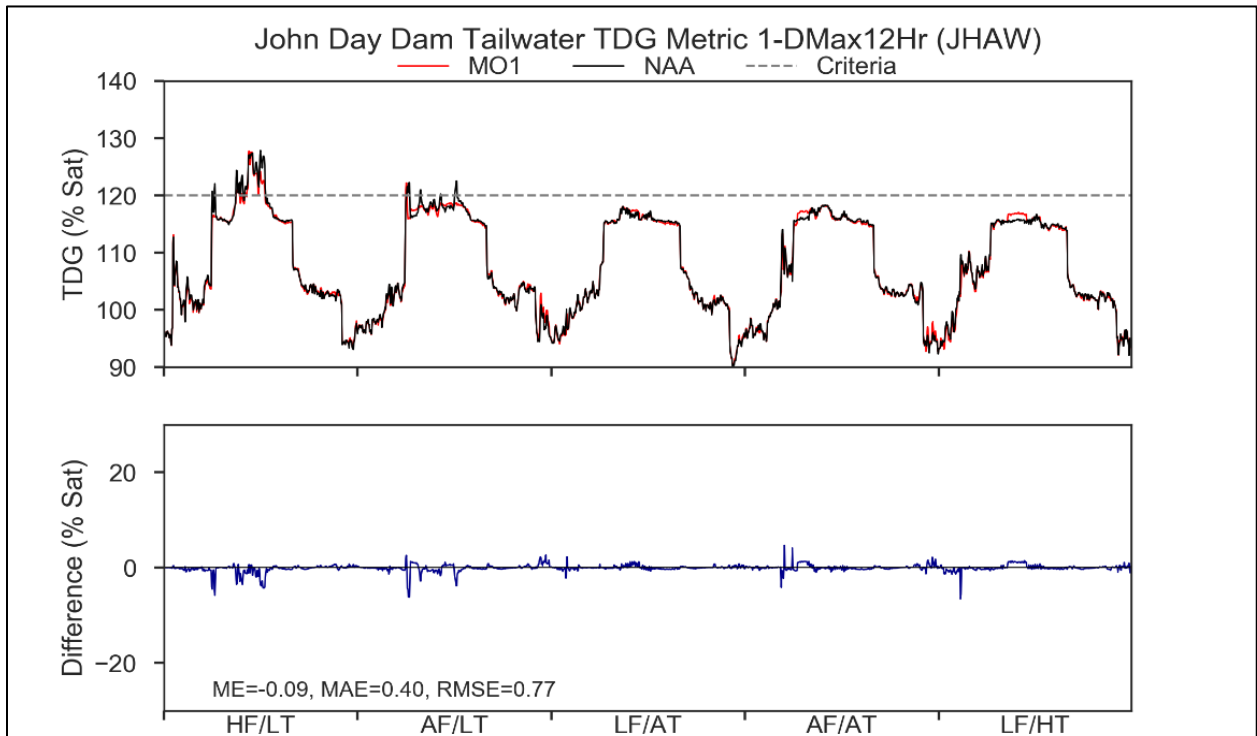


3230
 3231
 3232
 3233

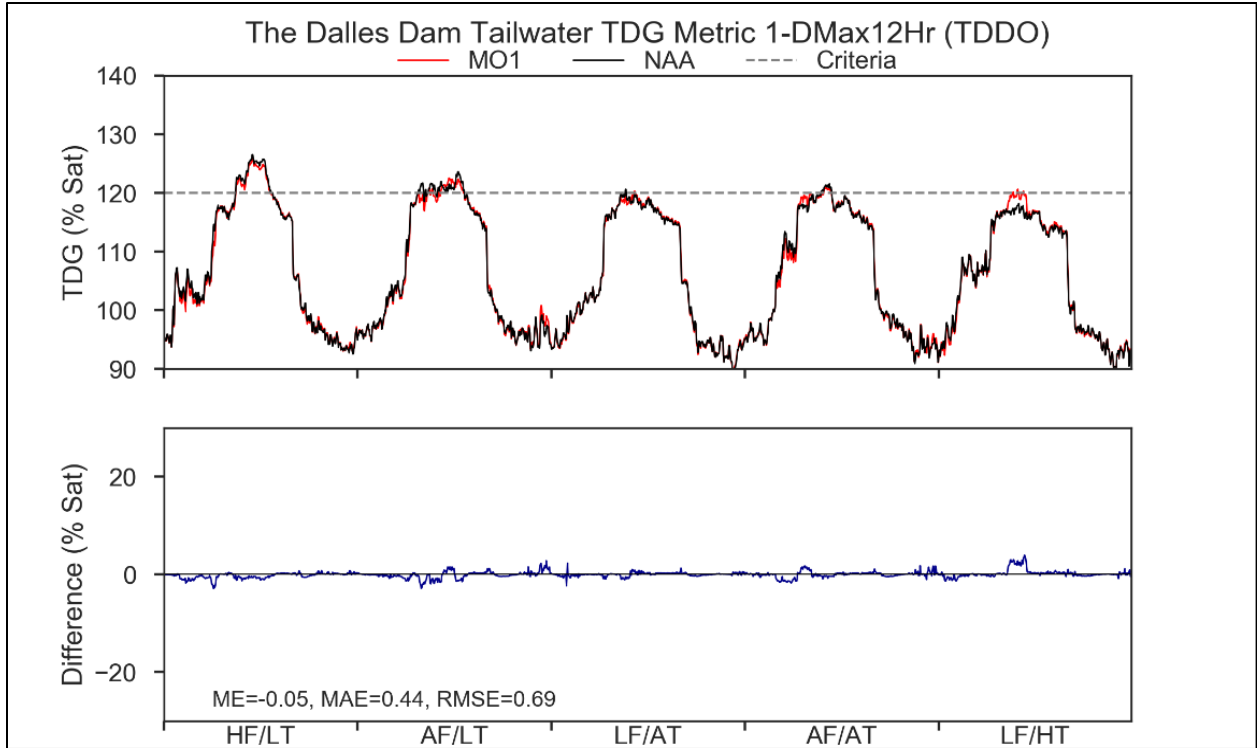
Figure 4-41. Frequency of Modeled Forebay Total Dissolved Gas for the No Action Alternative and Multiple Objective Alternative 1 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-Year Range of River and Meteorological Conditions



3234
 3235 **Figure 4-42. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 1 at**
 3236 **McNary Dam Under a 5-Year Range of River and Meteorological Conditions**

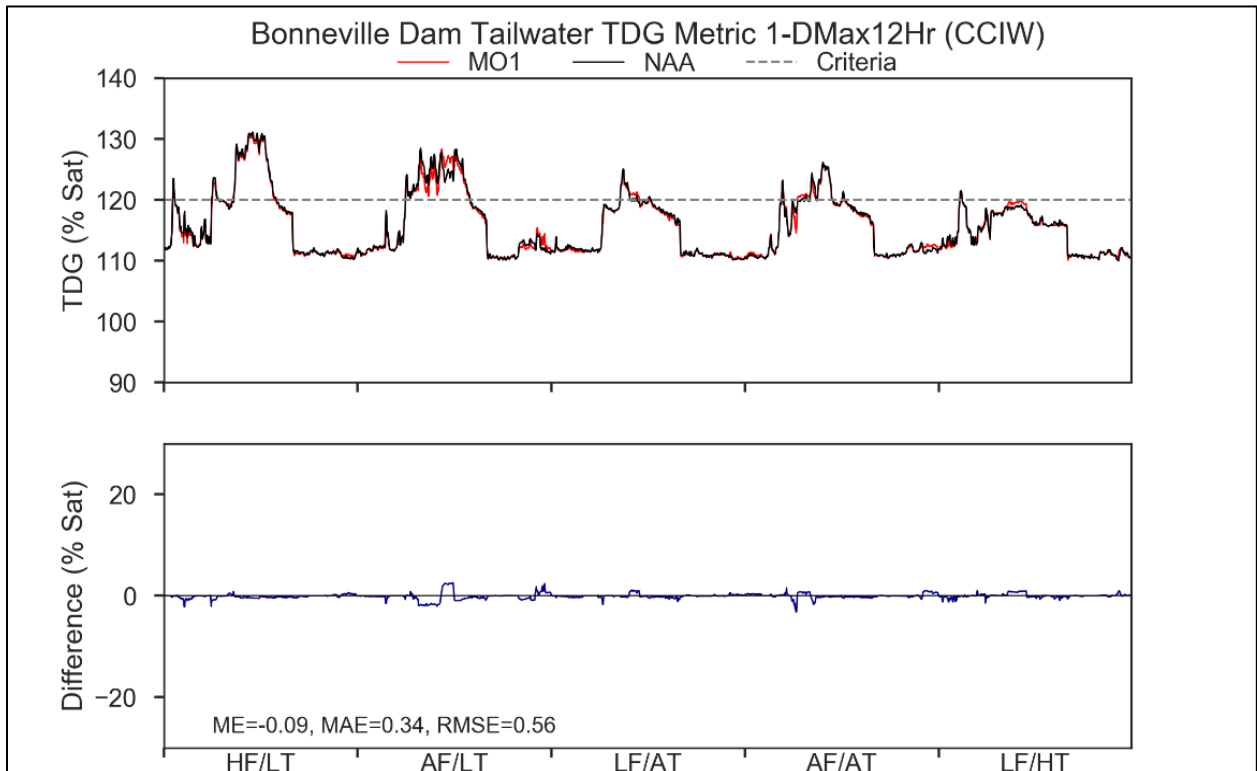


3237
 3238 **Figure 4-43. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 1 at**
 3239 **John Day Dam Under a 5-Year Range of River and Meteorological Conditions**



3240
3241
3242

Figure 4-44. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 1 at The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions



3243
3244
3245

Figure 4-45. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 1 at Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions



3246
 3247
 3248
 3249

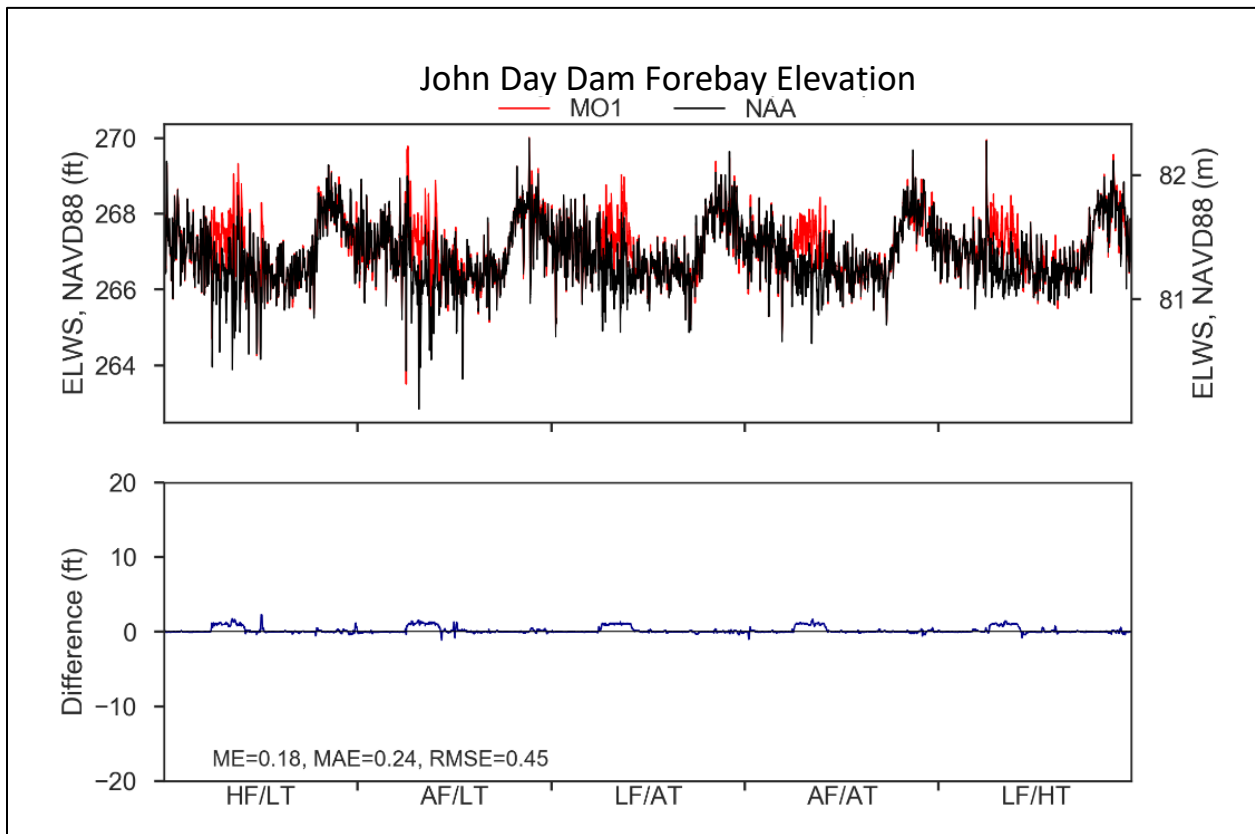
Figure 4-46. Frequency of Modeled Tailwater Total Dissolved for the No Action Alternative and Multiple Objective Alternative 1 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-Year Range of River and Meteorological Conditions

3250 **4.3.3 Other Physical, Chemical, and Biological Processes**

3251 **4.3.3.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

3252 Under the MO1 *Predator Disruption Operations* measure, the John Day Reservoir elevation
3253 would be manipulated (raised and maintained) during April and May to disrupt juvenile
3254 salmonid predator reproduction success (Figure 4-47.). Raising the water level could lead to a
3255 minor increase in total suspended solids (TSS) and associated impacts (turbidity, light
3256 attenuation, and/or chemicals that may be associated with TSS like nutrients, metals, and
3257 organics). However, the impact is expected to be negligible in the large John Day Reservoir.

3258 Otherwise, the introduction of pollutants and excess nutrients from farming and industrial
3259 activities, as well as urban runoff, is expected to continue under MO1. As with the No Action
3260 Alternative, emerging contaminants such as pharmaceuticals and new pesticides will also likely
3261 become more prevalent. The lower Columbia River contains a variety of human-sourced
3262 compounds, including metals and organic contaminants. This condition is expected to remain
3263 generally unchanged, and it is expected that current water quality impairments would continue.



3264 **Figure 4-47. Modeled Forebay Elevation for Multiple Objective Alternative 1 at John Day Dam**
3265 **Under a 5-Year Range of River and Meteorological Conditions**
3266

3267 **4.4 SEDIMENT PROCESSES**

3268 **4.4.1 Sediment Sources**

3269 Operational changes at Libby Dam under MO1 are not expected to affect sediment movement
3270 downstream in the Kootenai River when compared to existing conditions and the No Action
3271 Alternative; the same can be said for Hungry Horse Dam. MO1 does not impact Albeni Falls
3272 Dam operations and will not affect sediment sources or movement compared to existing
3273 conditions and the No Action Alternative. Some additional mobilization of sediment and
3274 shoreline erosion is expected within Lake Roosevelt Reservoir due to changes in elevations
3275 under MO1. However, it is not anticipated that additional sediment will pass the dam; expected
3276 impacts would occur within reservoir. MO1 flow changes at Chief Joseph Dam are minor, and
3277 no impacts to sediment sources or movement are expected.

3278 MO1 includes structural changes aimed at improving fish passage in the lower Columbia River
3279 Basin; these proposed measures would not affect sediment sources or movement. The
3280 proposed operational changes generally have a goal of improving flexibility in operation and of
3281 improving in-stream (flow and temperature) conditions for fish; changing the timing of flows or
3282 the temperature characteristics does not affect sediment sources. MO1 is not expected to
3283 affect land use throughout the basin, including upland recreation, flood management,
3284 agricultural, timber, or mining activities, and it is not expected to change population growth
3285 patterns in the area of any of the affected reservoirs. Overall, MO1 is not expected to affect
3286 sediment movement within the system.

3287 **4.4.2 Chemicals of Concern**

3288 No change is predicted to the list of sediment chemicals of concern throughout the basin,
3289 compared to the existing conditions and No Action Alternative. The contaminants of concern
3290 would remain metals, polycyclic aromatic hydrocarbons, volatile organic compounds, pesticides
3291 and pesticide degradation products, PCBs, dioxins, and nutrients (ammonia—the form of
3292 nitrogen typically found in anoxic or anaerobic sediment). Due to changes in reservoir
3293 operation, changes to water levels could affect the mobility and bioavailability of some
3294 pollutants such as mercury (Willacker et al. 2016).

3295 **4.5 CONCEPTUAL SITE MODEL**

3296 MO1 is not expected to affect sediment movement patterns, so the conceptual site model for
3297 sediment/dredging is the same as the conceptual site model(s) for the existing conditions and
3298 No Action Alternative. Portions of the basin that are currently not dredged (Chief Joseph
3299 Reservoir) would not be dredged in the future. Areas of the basin that are currently maintained
3300 by dredging (such as at the confluence of the Snake River and Clearwater River) would continue
3301 to require periodic dredging. Sediment characterization following the Sediment Evaluation
3302 Framework (RSET 2018) or other applicable guidance would continue to be required for
3303 dredging or sediment related projects.

3304 **4.6 WATER AND SEDIMENT QUALITY CONCLUSIONS**

3305 The most notable MO1 measures that affect water quality include:

- 3306 • *Block Spill Test* measure: This spill test is to evaluate latent mortality hypothesis (flip-flop
3307 between base and test spring spill operations).
- 3308 • *Summer Spill Stop Trigger* measure: This measure modifies summer juvenile fish passage
3309 spill operations (ends spill on lower Snake River early).
- 3310 • *Modified Draft at Libby, December Libby Target Elevation, Update System FRM Calculation,*
3311 *Planned Draft Rate at Coulee, Grand Coulee Maintenance Operations, Winter System FRM*
3312 *Space & Sliding Scale at Libby and Hungry Horse* measures: These measures maximize
3313 operating flexibility and improve overall systems operations including winter FRM at Libby
3314 and Grand Coulee Dams.
- 3315 • *Lake Roosevelt Additional Water Supply & Hungry Horse Additional Water Supply* measures:
3316 These measures modify operations to meet existing contractual water supply obligations.
- 3317 • *Modified Dworshak Summer Draft* measure: This measure modifies the timing of Dworshak
3318 Dam releases to provide cold water earlier (June 21 to August 1) and later (September 1 to
3319 September 30).

3320 **4.6.1 Multiple Objective Alternative 1 Results–Water Temperature**

3321 In general, MO1 would result in little to no change in water temperature conditions at Hungry
3322 Horse, Albeni Falls, Grand Coulee, and Chief Joseph dams and reservoirs, as compared to the
3323 No Action Alternative. Due to higher winter reservoir elevations at Libby Dam, resulting from
3324 the *December Libby Target Elevation* measure, followed by higher outflows (aggressive
3325 drafting) in late winter/early spring from the *Modified Draft at Libby* measure, water
3326 temperatures could be warmer in the winter and colder in the early spring and summer as
3327 compared to the No Action Alternative. This could result in minor negative impacts to resident
3328 fish species. Overall impacts to water temperature in Regions A and B are negligible.

3329 Under MO1, the *Modified Dworshak Summer Draft* measure, which calls for the modified
3330 timing of Dworshak Dam releases to provide cold water earlier (June 21 to August) and later
3331 (September 1 to September 30), would result in notable changes to Dworshak project outflows,
3332 but only slight changes in water temperature. Water temperature effects would be more
3333 pronounced downstream, with decreased water temperatures expected in the lower Snake
3334 River (Lower Granite – Ice Harbor Dams) in July and September, and warmer water
3335 temperatures and frequent exceedances to 68°F water temperature target set in the Lower
3336 Granite tailrace, expected in August. Average overall water temperature effects would be
3337 considered moderate in the lower Snake River, with major impacts expected downstream of
3338 Lower Granite Dam and negligible impacts downstream of Ice Harbor Dam (Section 2.6 and
3339 Chapter 9). Little to no change in water temperatures would be expected in the lower Columbia
3340 River at McNary, John Day, The Dalles, and Bonneville dams and reservoirs.

3341 **4.6.2 Multiple Objective Alternative 1 Results–Total Dissolved Gas**

3342 In general, MO1 would have little to no impact on TDG conditions below Libby, Hungry Horse,
3343 and Albeni Falls as compared to the No Action Alternative. Downstream of Grand Coulee Dam,
3344 major reductions in overall TDG may be possible in the spring/early summer due to the measures
3345 that call on more operational flexibility for FRM (*Update System FRM Calculation, Planned Draft*
3346 *Rate at Grand Coulee, Grand Coulee Maintenance Operations, and Winter System FRM Space*
3347 *measures*), and the water supply measure (*Lake Roosevelt Additional Water Supply*). The major
3348 maintenance measure (*Grand Coulee Maintenance Operations*), is expected to temporarily
3349 reduce the powerhouse capacity of Grand Coulee Dam and increase the magnitude of spill and
3350 TDG in some situations; but, when combined with other modifications to operations, effects
3351 seemed to balance and actually reduce TDG based on water quality results. TDG effects
3352 anticipated at Grand Coulee are expected to be carried downstream into Rufus Woods Lake.
3353 During high flow years, however, the spillway deflectors at Chief Joseph Dam would provide
3354 some degassing of elevated TDG generated from upstream Canadian dam and Grand Coulee Dam
3355 operations. TDG effects downstream of Chief Joseph Dam are negligible.

3356 Slight differences to TDG could occur downstream of the lower Snake River projects due to the
3357 modification of spring and summer juvenile downstream fish passage spill as called for in the
3358 *Block Spill Test* and *Summer Spill Stop Trigger* measures, respectively; however, overall effects are
3359 expected to be negligible. No changes to lower Columbia River TDG are anticipated to occur
3360 under MO1.

3361 **4.6.3 Multiple Objective Alternative 1 Results –Other Water Quality Impacts**

3362 In general, MO1 would result in little to no change in other water quality parameters at Libby
3363 Hungry Horse, Albeni Falls, and Chief Joseph dams and reservoirs, as compared to the No Action
3364 Alternative. At Grand Coulee, the increased reservoir elevation fluctuations, associated with FRM
3365 measures including the *Update System FRM Calculation, Winter System FRM Space, and Lake*
3366 *Roosevelt Additional Water Supply*, could lead to increased mercury methylation, while the
3367 measure *Planned Draft Rate At Grand Coulee*, which slows the reservoir draft rate to 0.8 feet per
3368 day, could result in a decrease in bank erosion, sloughing, and overall turbidity in the reservoir.

3369 In the lower Snake River, anticipated warmer water temperatures in August, due to the *Modified*
3370 *Dworshak Summer Draft* measure, could result in increased cyanotoxin blooms and associated
3371 water quality issues such as increased epilimnetic dissolved oxygen, reduced hypolimnetic
3372 dissolved oxygen, etc. Little to no change in other water quality parameters would be expected in
3373 the lower Columbia River at McNary, John Day, The Dalles, and Bonneville dams and reservoirs as
3374 compared to No Action Alternative.

3375 **4.6.4 Multiple Objective Alternative 1 Results –Sediment Quality**

3376 MO1 is not expected to affect land use throughout the basin, including upland recreation, flood
3377 management, agricultural, timber, or mining activities, and it is not expected to change
3378 population growth patterns in the area of any of the affected reservoirs. Overall, MO1 is not
3379 expected to affect sediment movement within the system.

3380

CHAPTER 5 - MULTIPLE OBJECTIVE ALTERNATIVE 2

3381 Multiple Objective Alternative 2 (MO2) was developed with the goal to increase hydropower
3382 production and reduce regional greenhouse gas emissions while avoiding or minimizing
3383 negative impacts to other authorized project purposes. Refer to the complete alternative
3384 description located in Chapter 2 of the main EIS document.

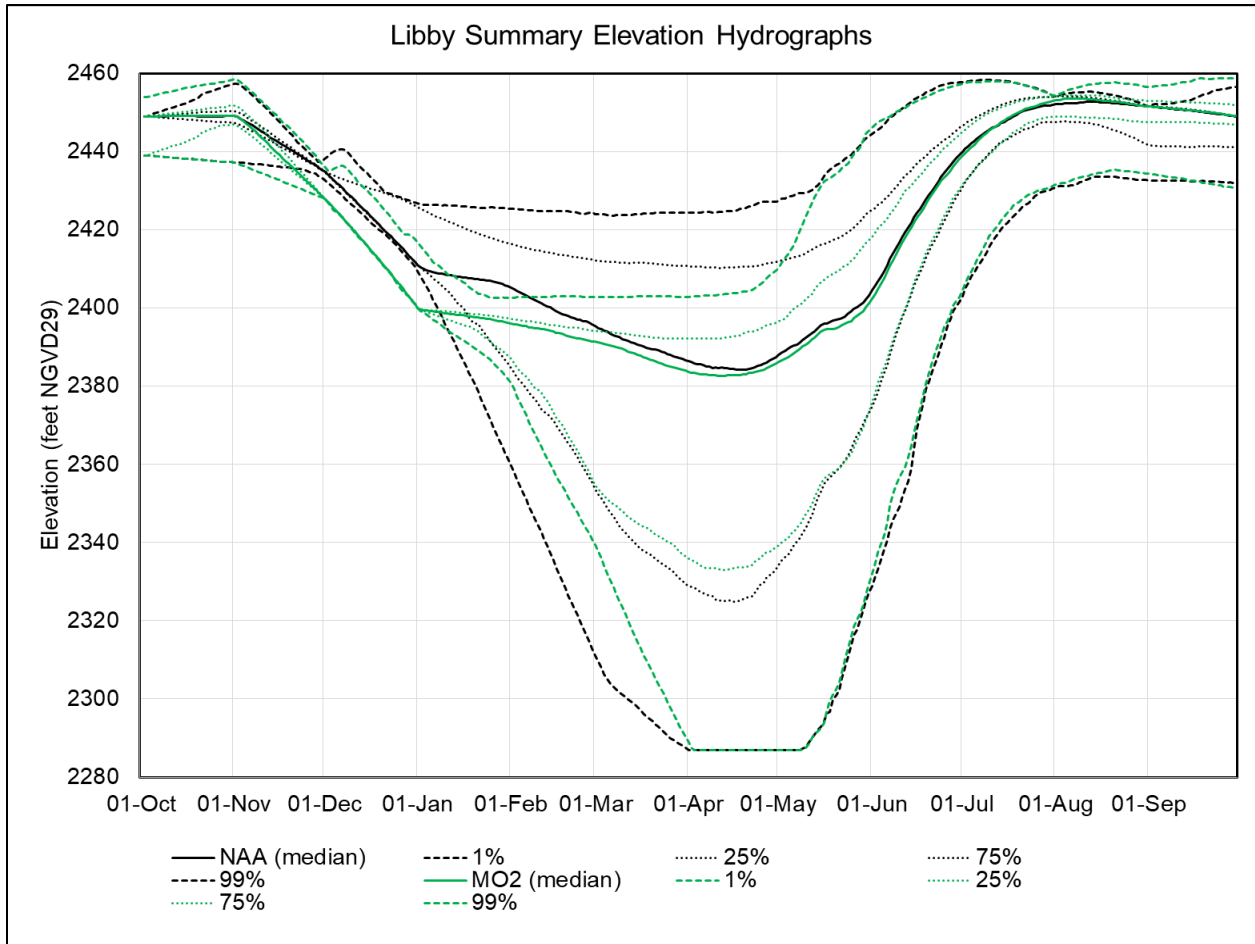
3385 **5.1 UPPER COLUMBIA RIVER BASIN**

3386 **5.1.1 Water Temperature**

3387 **5.1.1.1 Libby and Hungry Horse Dams and Reservoirs**

3388 For Libby Dam, MO2 is similar to Multiple Objective Alternative (MO3) and includes operational
3389 changes that could result in changes to draft and refill operations when compared to the No
3390 Action Alternative, as shown in the summary hydrograph (Figure 5-1.). For the majority of MO2
3391 years, the end of November draft elevation target is 8 feet lower than the No Action Alternative
3392 to facilitate a lower end of December target elevation of 2,400 feet NGVD29, which is about 11
3393 feet lower than the majority of No Action Alternative years. January and February draft
3394 elevations are typically deeper under MO2 largely because of the prolonged impacts of the
3395 deeper November and December drafts for hydropower operations as well as for adjusted draft
3396 targets (measures *Slightly Deeper Draft For Hydropower* and *Sliding Scale At Libby*,
3397 respectively). The final end-of-April draft elevation for the median and wettest quarter of years
3398 are similar to the No Action Alternative. However, for the driest 40 percent of years, the end-of-
3399 April draft is about 11 to 19 feet deeper than the No Action Alternative. Reservoir refill and
3400 summer pool elevations are improved over the No Action Alternative with the reservoir
3401 reaching the end of July full pool about 6 percent more often than under the No Action
3402 Alternative. August and September reservoir elevations under MO2 are about 1 to 4 feet higher
3403 than under the No Action Alternative. In general, the MO2 drafting changes would result in
3404 lower water elevations in Lake Kootenai from November through April, with substantially
3405 lower end-of-April water elevations (11 to 19 feet) in the driest 40 percent of years. It should be
3406 noted that these changes do vary by water year, water forecast, and time of year. A summary
3407 hydrograph for Lake Kootenai, representing the probability of the reservoir elevation on any
3408 given day under MO2 and the No Action Alternative is shown in Figure 5-1..

3409 MO2 largely impacts Libby Dam outflows and Kootenai River flows from about November
3410 through April (Figure 5-2.). When compared to the No Action Alternative, median average MO2
3411 outflows are about 14 to 34 percent greater in November and December, 11 to 42 percent less
3412 from January through April, and about 5 to 9 percent less from May through September.
3413 Outflows are decreased in late April and May due to increased refill. For the median condition,
3414 sturgeon pulses remain the same. The increased outflow from Libby Dam in November and
3415 December results in an increase in median monthly river water elevations of 1.3 to 1.8 feet in
3416 the free-flowing reach below Libby Dam and about 1.6 feet at Bonners Ferry. Decreased
3417 January through May flows result in a decrease in median monthly Kootenai River water
3418 elevations below Libby Dam by as much as 2.1 feet.

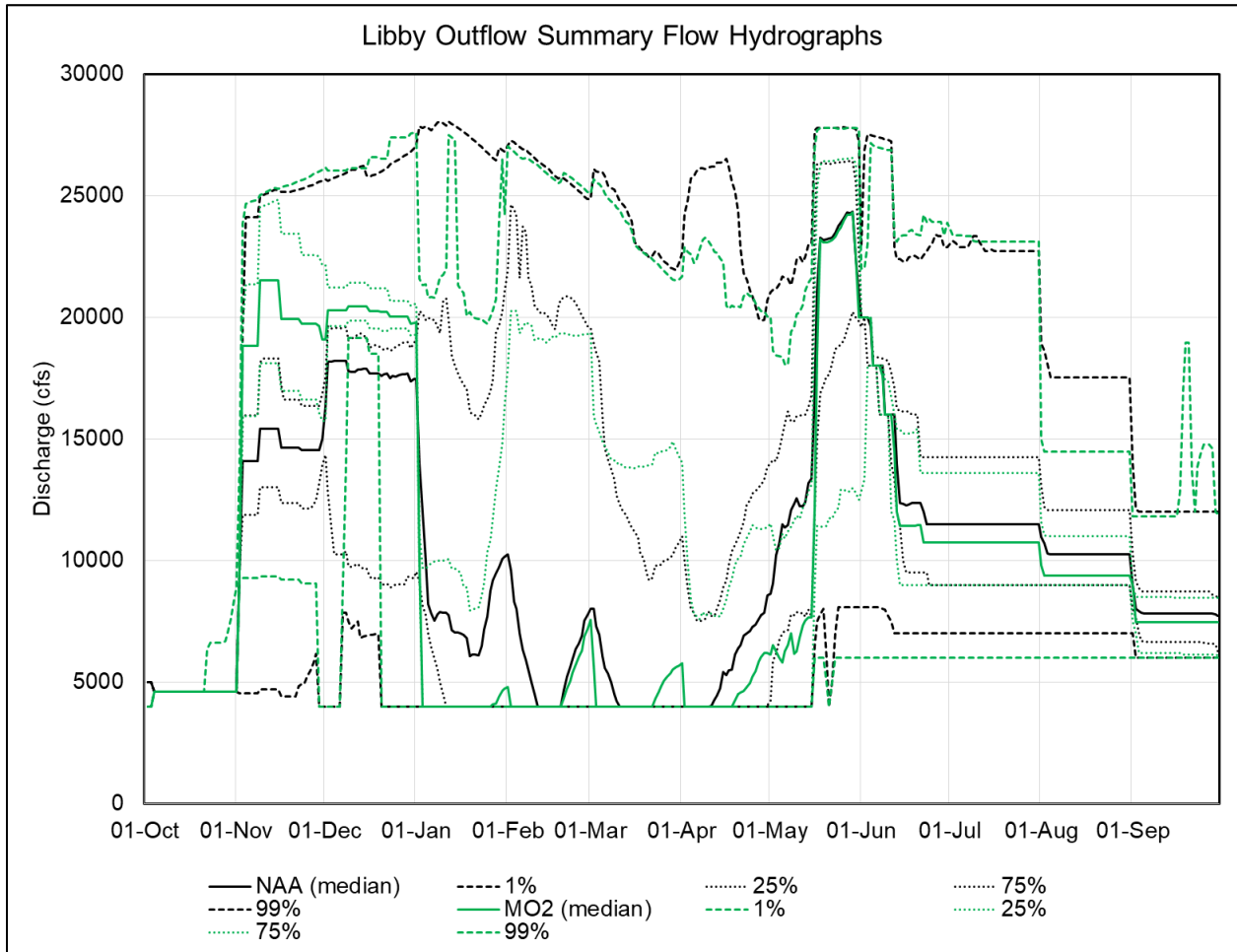


3419
 3420 **Figure 5-1. Libby Dam-Lake Koocanusa Summary Forebay Elevations for Multiple Objective**
 3421 **Alternative 2 Versus the No Action Alternative**

3422 Similar to the No Action Alternative, Libby Dam’s SWS provides some ability to adjust where in
 3423 the water column water is drawn from. The range of the SWS bulkheads are from elevation
 3424 2,409 feet to 2,200 feet NGVD29. Because SWS protocol maintains at least 30 feet of
 3425 submergence over the top row of the bulkheads for hydraulic stability, the SWS has the ability
 3426 to perform under the full range of possible MO2 drawdown operations with a similar efficiency
 3427 as under the No Action Alternative. Modeled forebay elevations under MO2 are predicted to be
 3428 well within the operating range of the SWS and similar to the ranges observed in historical
 3429 years.

3430 The ability of the SWS to manage discharge temperatures under a variety of drawdown and
 3431 inflow conditions would continue under MO2. However, thermal stratification must be present
 3432 in the forebay for the SWS to achieve temperatures as close as possible to the temperature rule
 3433 curve developed by the Corps and Montana Fish, Wildlife, and Parks and described in Section
 3434 3.1.1.1 of the No Action Alternative. The onset of thermal stratification is difficult to predict and
 3435 can vary from year to year due to reasons such as inflow volumes, inflow temperatures,
 3436 reservoir drawdown elevation, discharge volumes, and weather conditions. Historical
 3437 temperature data suggests that holding the pool higher results in colder reservoir temperatures

3438 and difficulty for the SWS to achieve temperatures within the rule curve. When the pool is
 3439 drafted deeper, the pool volume is less thereby allowing for greater warming in the spring and
 3440 summer from warmer inflows and warming air temperatures.



3441
 3442 **Figure 5-2. Libby Dam-Lake Kootenai Summary Outflows for Multiple Objective Alternative**
 3443 **2 Versus the No Action Alternative**

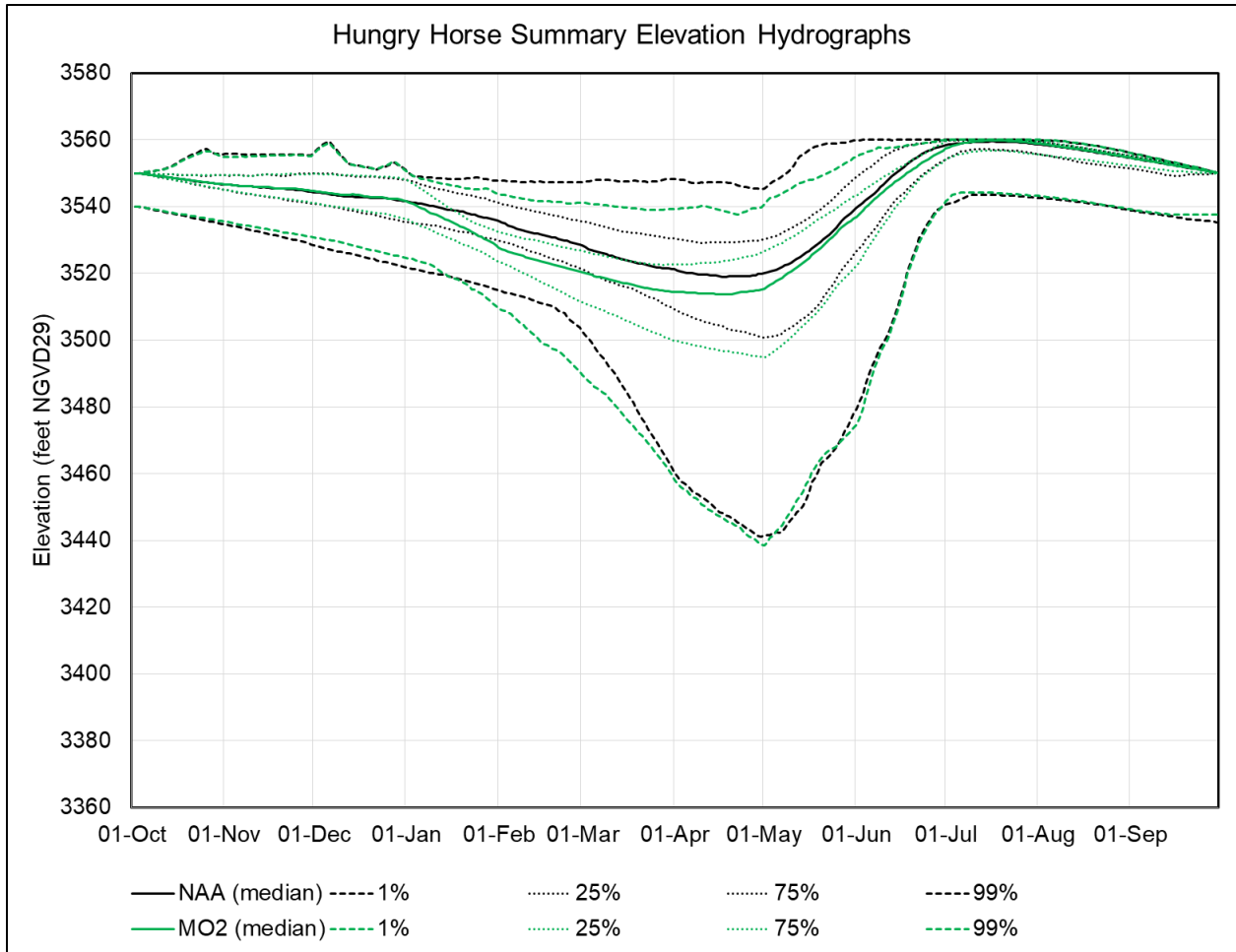
3444 The lower reservoir elevations under MO2 for the driest 40 percent of years are likely
 3445 substantial enough to result in a change in forebay temperatures and thermal stratification
 3446 compared to the No Action Alternative. These lower reservoir elevations should result in
 3447 slightly warmer reservoir temperatures and earlier thermal stratification during the spring and
 3448 summer resulting in a greater ability for the SWS to achieve downstream temperatures within
 3449 the rule curve when compared to the No Action Alternative. It should be noted that under the
 3450 No Action Alternative, downstream river temperatures during the fall and winter are generally
 3451 several degrees warmer than pre-dam Kootenai River conditions, while water released from the
 3452 dam during the spring and summer is generally several degrees cooler than natural river
 3453 conditions. The limitations of the SWS that exist for the No Action Alternative are expected to
 3454 continue for MO2.

3455 Changes in downstream temperatures from Libby Dam to Bonners Ferry may result from MO2
3456 increasing the median average monthly flows in November and December and decreasing the
3457 median monthly flows in January through April. During the cold winter months, Kootenai River
3458 water can cool by several degrees between Libby Dam and Bonners Ferry if flows are held low.
3459 Therefore, by increasing November and December flows, downstream temperatures may
3460 increase during these months under MO2. Conversely, by decreasing flows from January
3461 through April, MO2 may decrease temperatures by allowing the natural cooling of the river as it
3462 moves downstream. It is uncertain how increasing early winter temperatures and then
3463 decreasing late winter temperatures in the Kootenai River would impact winter spawning fish
3464 species, such as burbot, which require near-freezing river temperatures (<35°F or <2°C) to
3465 spawn.

3466 Under MO2, three operational measures apply to Hungry Horse:

- 3467 • *Sliding Scale at Libby And Hungry Horse*
- 3468 • *Ramping Rates for Safety*
- 3469 • *Slightly Deeper Draft for Hydropower*

3470 These operational measures lift all ramping rate limitations when restrictions are not for safety,
3471 partially lift pool elevation restrictions to allow use of storage for hydropower generation, and
3472 offer a sliding scale draft for summer flow augmentation. Implementing the operational
3473 measure *Slightly Deeper Draft for Hydropower* would result in lower reservoir elevations in
3474 winter and spring under MO2, which are likely substantial enough to result in a change in
3475 forebay temperatures and thermal stratification compared to the No Action Alternative
3476 (Figure 5-3.). These lower reservoir elevations should result in slightly warmer reservoir
3477 temperatures and earlier thermal stratification during the spring and summer resulting in a
3478 greater ability for the SWS to achieve the best possible downstream temperatures when
3479 compared to the No Action Alternative.



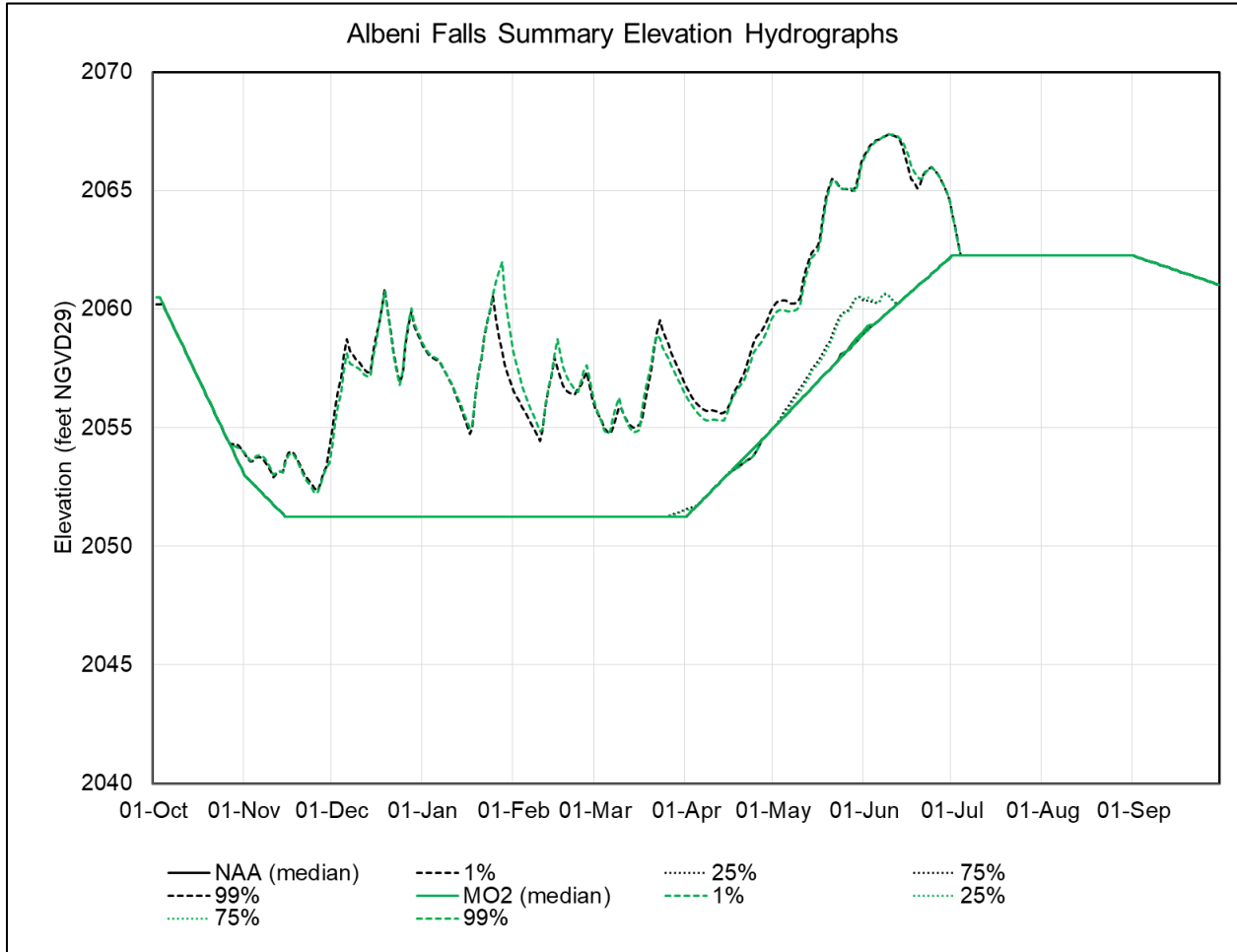
3480
3481 **Figure 5-3. Hungry Horse Reservoir Summary Elevation Hydrograph for Multiple Objective**
3482 **Alternative 2 Versus the No Action Alternative**

3483 **5.1.1.2 Albeni Falls Dam and Reservoir**

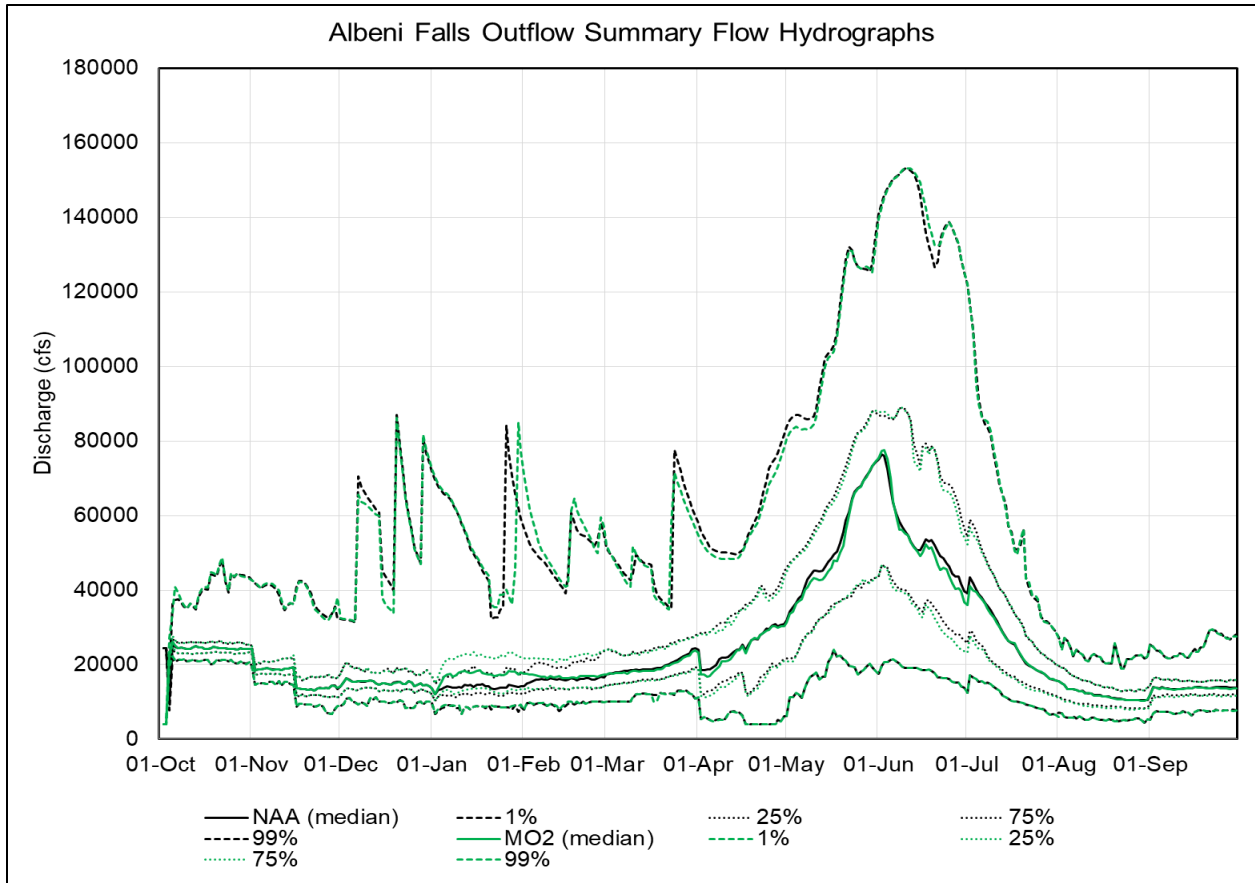
3484 Under MO2, Albeni Falls Dam operations will change little compared to the No Action
3485 Alternative. However, MO2 operational changes at Hungry Horse will result in flow changes in
3486 the Flathead River that will be evident downstream through Lake Pend Oreille and the Pend
3487 Oreille River. In particular, increases of 108 percent in the average January outflows out of
3488 Hungry Horse translates to an increase of about 20 percent in the Pend Oreille River at Albeni
3489 Falls Dam. Decreases of 8 to 37 percent in the average monthly March through June flows from
3490 Hungry Horse translate to about a 3 to 4 percent decrease in Pend Oreille River flows at Albeni
3491 Falls. Similar to other alternatives, flow reductions for Hungry Horse under MO2 can be seen
3492 through the Pend Oreille River Basin, but they are increasingly diluted moving downstream. As
3493 such, under MO2 Lake Pend Oreille and the Pend Oreille River will see only a small hydrological
3494 change compared to the No Action Alternative (Figure 5-4.).

3495 Water temperatures in the Pend Oreille River upstream and downstream of Albeni Falls Dam
3496 were modeled using W2 for the period 2004 through 2006. W2 model results indicate little

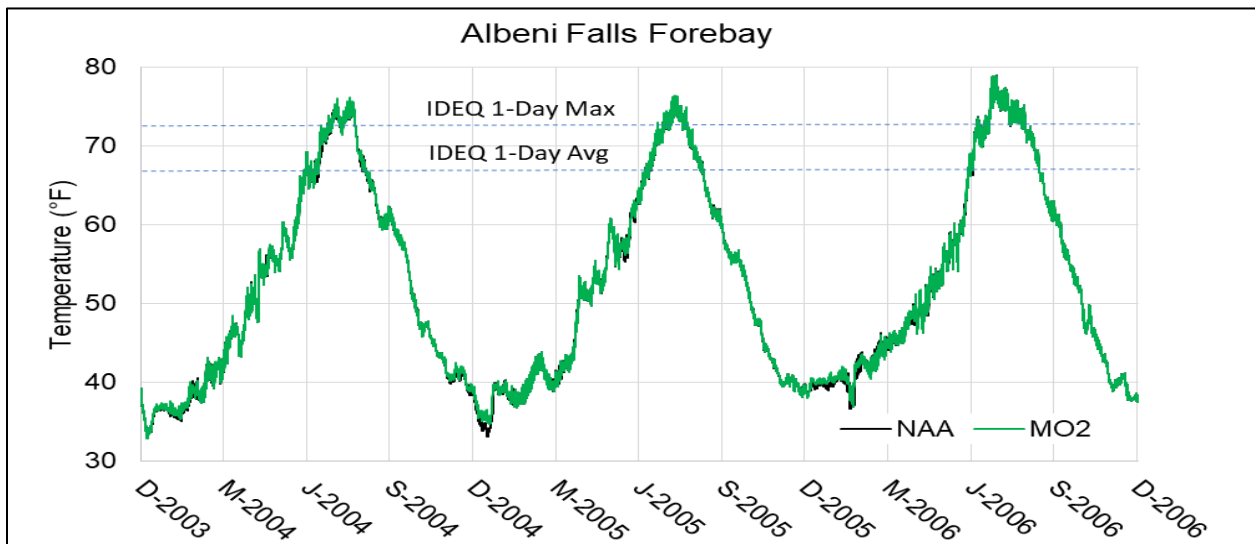
3497 change in water temperatures upstream and downstream of Albeni Falls Dam. In general,
 3498 temperature changes between MO2 and the No Action Alternative are small, ranging from
 3499 about 32.9°F to 34.7°F (-0.5 to 1.5°C). Temperature differences were greatest during the winter
 3500 months (January and February) with MO2 slightly increasing river temperatures (up to 1.5
 3501 degrees Celsius) possibly due to the higher flows moving through the Pend Oreille River System
 3502 from Hungry Horse operational changes (Figure 5-4.). Temperature differences between MO2
 3503 and No Action Alternative during the mid-June to mid-September summer period are minimal
 3504 and range from about ± 32.9°F to 33.8°F (0.5 to 1.0°C).



3505 **Figure 5-4. Albeni Falls Dam Summary Elevation Hydrograph for Multiple Objective**
 3506 **Alternative 2 Versus the No Action Alternative**
 3507

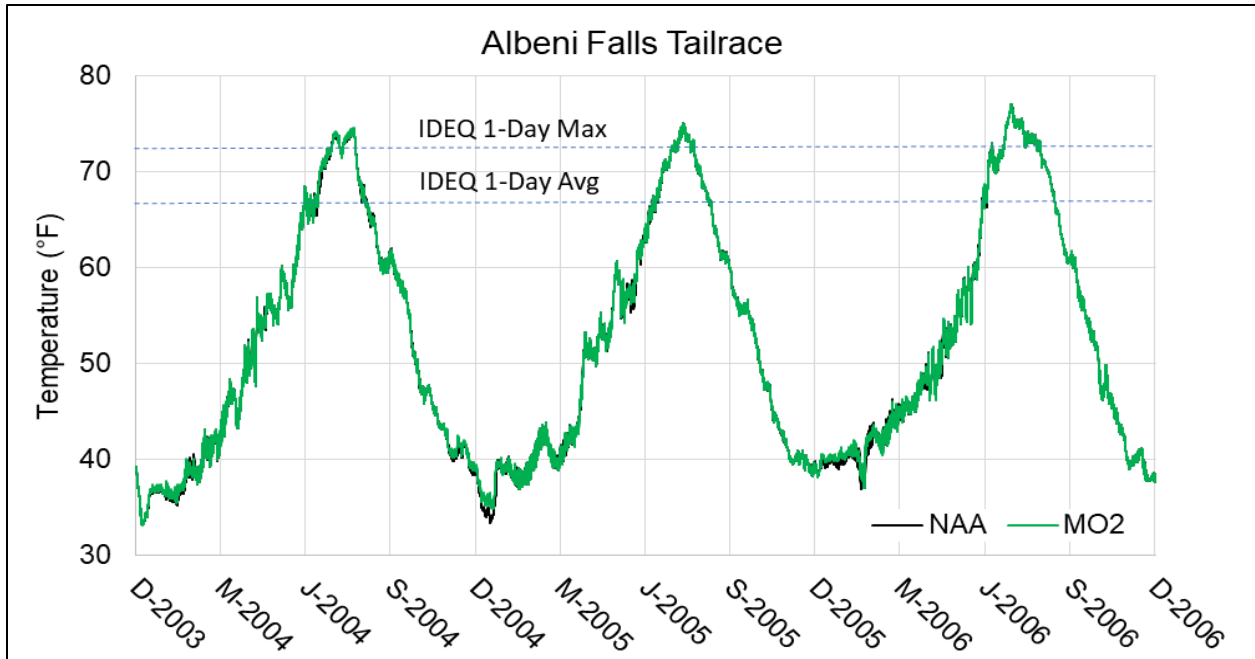


3508
 3509 **Figure 5-5. Albeni Falls Dam Summary Outflows for Multiple Objective Alternative 2 Versus**
 3510 **the No Action Alternative**



3511
 3512 **Figure 5-6. Modeled Forebay Temperatures for the No Action Alternative and Multiple**
 3513 **Objective Alternative 2 at Albeni Falls from 2004 to 2006**

3514 Note: IDEQ 1-Day Maximum temperature standard of 71.6°F (22°C) and 1-Day Average standard of 66.2°F (19°C)
 3515 are shown for comparison.



3516
3517 **Figure 5-7. Modeled Tailwater Temperatures for the No Action Alternative and Multiple**
3518 **Objective Alternative 2 at Albeni Falls from 2004 to 2006**

3519 Note: IDEQ 1-Day Maximum temperature standard of 71.6°F (22°C) and 1-Day Average standard of 66.2°F (19°C)
3520 shown for comparison.

3521 **5.1.1.3 Chief Joseph Dams and Reservoirs**

3522 Under MO2, the operations of Grand Coulee Dam and Lake Roosevelt above the dam are
3523 altered by five operational measures:

- 3524 • Update System FRM Calculation
3525 • Grand Coulee Maintenance Operations
3526 • Planned Draft Rate at Grand Coulee
3527 • Winter System FRM Space
3528 • *Slightly Deeper Drafts for Hydropower*

3529 Lake Roosevelt water temperature could be impacted under MO2 through implementation of
3530 these multiple measures, and additionally by changes to inflows from measures targeting
3531 projects upstream. Many of these measures impact winter and spring storage and outflows;
3532 however, they are not expected to impact temperatures significantly.

3533 The Grand Coulee Maintenance Operations would address operational constraints for the
3534 ongoing maintenance of the power plants. This measure would reduce the hydraulic capacity
3535 through the power plants and increase the likelihood of spill. This measure, however, is largely
3536 offset by the other measures that impact spring flows. Operational measure Winter System
3537 FRM Space increases the draft space available for winter operations starting in December, and

3538 in addition, measure Slightly Deeper Draft for Hydropower allows deeper draft, especially in the
3539 winter, for more power generation. A more in-depth discussion of these operational measures
3540 and their effects can be found in [Section H&H-MO2].

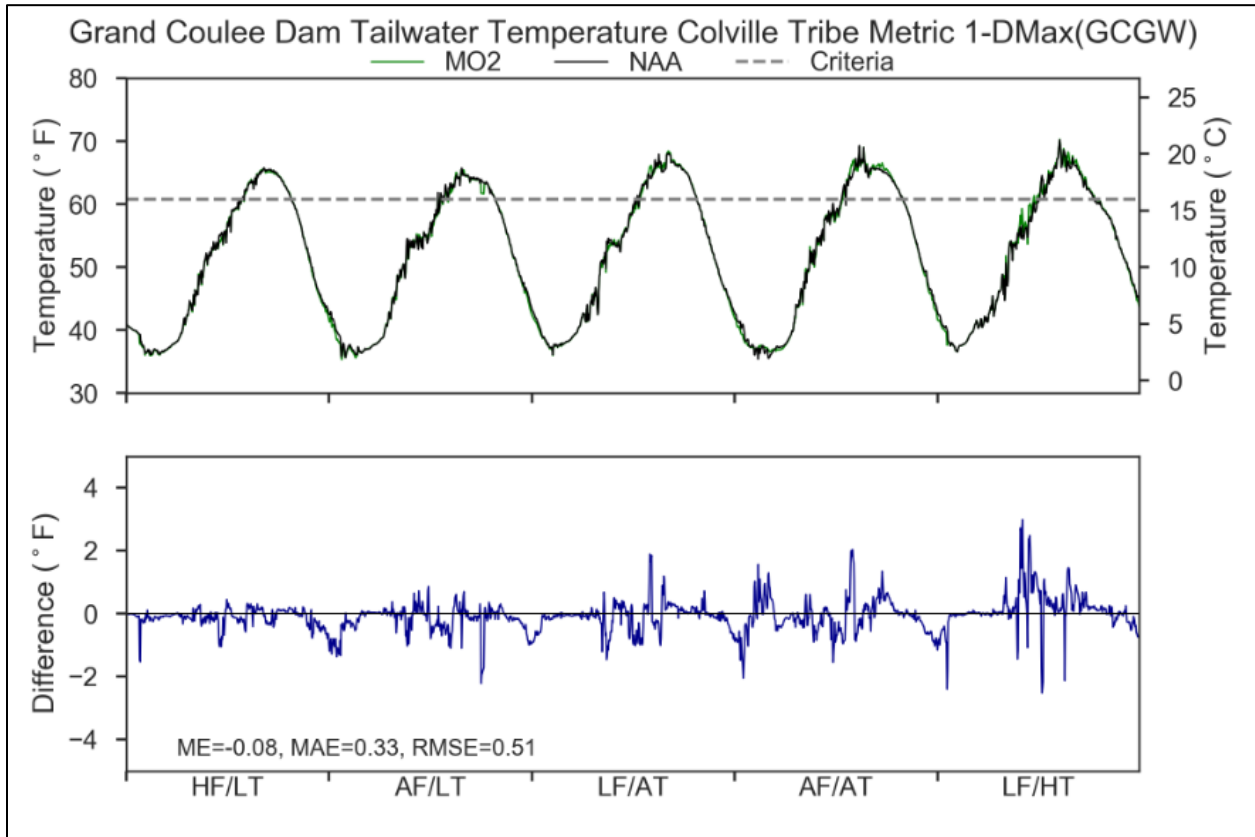
3541 On average, MO2 water temperatures are nearly identical to conditions under the No Action
3542 Alternative in Lake Roosevelt and the Columbia River downstream. The changes that do occur
3543 are short in duration or low in magnitude. In general, impacts are greatest at Grand Coulee
3544 Dam and are reduced toward the U.S.-Canada border wherein the impacts from MO2 are
3545 almost unnoticeable at Hall Creek. Overall, an increase of temperature at depth in the fall,
3546 overall all years, is the most pronounced difference from the No Action Alternative in the lower
3547 reservoir. This is partially due to some modeling assumptions which warrants further
3548 investigation. An additional factor influencing spring and summer temperatures in some years
3549 may be winter and spring operations that decrease storage, which could potentially reduce the
3550 cold-water mass that influences the inflowing temperature signal from upstream.

3551 The downstream temperatures vary slightly year to year from the No Action Alternative;
3552 generally they are very similar with changes well less than a degree on a monthly average. The
3553 modeled water temperatures below Grand Coulee Dam for MO2 result in a few more days
3554 above the 61°F temperature standard (Colville Tribe Class I Temperature TMDL) on average as
3555 compared to the No Action Alternative in all years except low flow years. Figure 5-8. shows
3556 predicted water temperatures below Grand Coulee Dam under MO2 compared to the No
3557 Action Alternative.

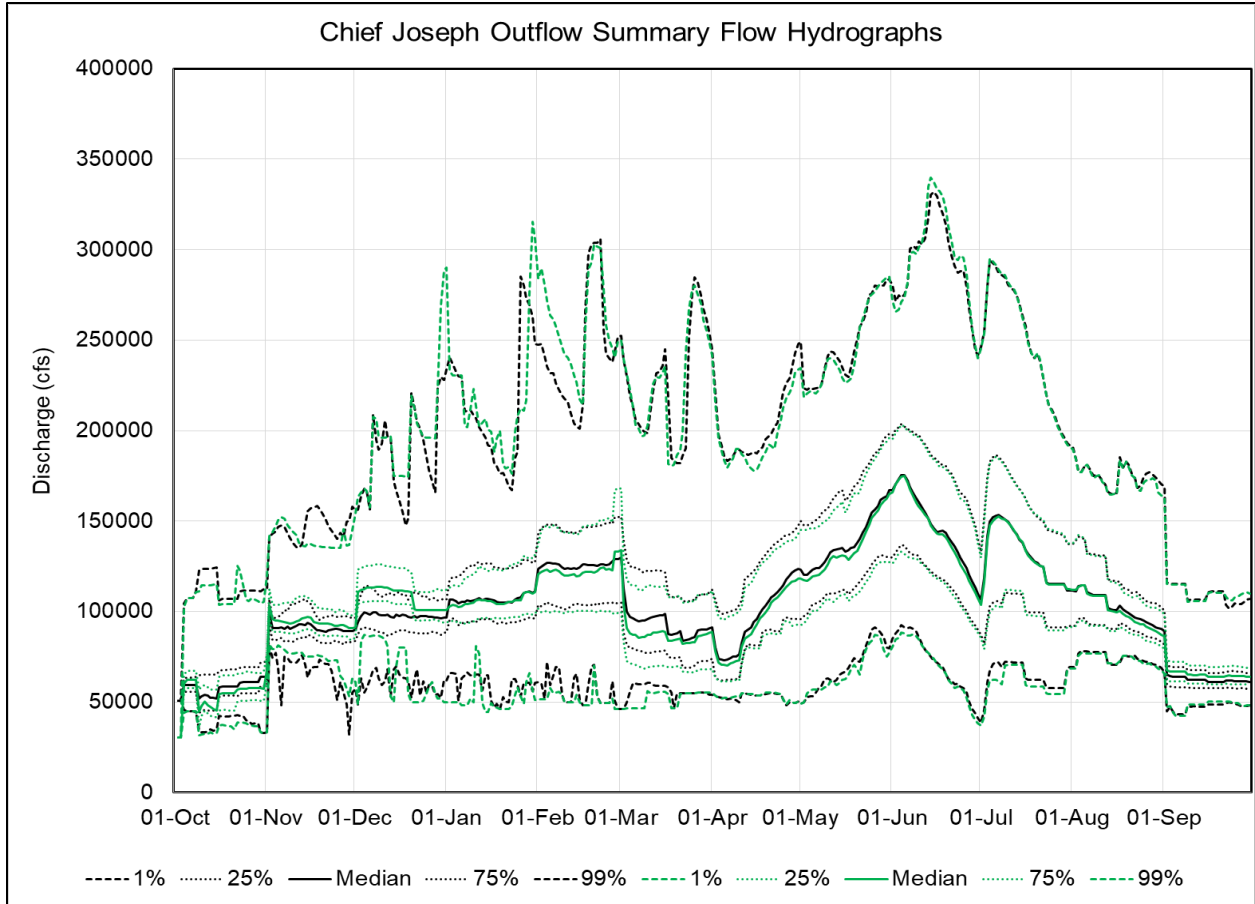
3558 Under MO2, reservoir elevation changes and corresponding project outflow changes predicted
3559 at Grand Coulee Dam would carry downstream through Rufus Woods Lake and Chief Joseph
3560 Dam. In general, average monthly outflows out of Chief Joseph Dam would be greater in
3561 November and December (3 and 12 percent, respectively), and lower from about January
3562 through August (range of -1 to -6 percent). Changes in winter Columbia River flows below
3563 Grand Coulee Dam are largely due to MO2 operational measures at Grand Coulee Dam and
3564 from flow changes at Libby Dam (Figure 5-9.). Since Chief Joseph Dam is a run-of-river project,
3565 little change to forebay elevations would occur for MO2 when compared to the No Action
3566 Alternative (Figure 5-10.). Tailwater temperatures under both MO2 and the No Action
3567 Alternative are predicted to exceed the Washington State and tribal water quality standards
3568 regardless of water year type or meteorological condition.

3569 Water temperatures under MO2 at Chief Joseph Dam tailwater are similar to or slightly cooler
3570 than the No Action Alternative with the majority of temperature differences in the ±1 to 2
3571 degrees Fahrenheit range (Figure 5-11.). In general, temperatures modeled for MO2 are similar
3572 to or slightly cooler than the No Action Alternative for most river and meteorological
3573 conditions. Exceptions are for the AF/AT and LF/HT scenarios where river temperatures in the
3574 spring and early summer are expected to be 1 to 2 degrees Fahrenheit warmer under MO2.
3575 Tailwater temperatures under both MO2 and the No Action Alternative are predicted to exceed
3576 the Washington State standard of 63.5°F (17.5°C) as measured by the 7-day average of the daily
3577 maximum temperature in August and September. Similar to the No Action Alternative, there is

3578 little difference between Grand Coulee Dam tailwater (Figure 5-8.) and Chief Joseph Dam
3579 tailwater (Figure 5-11.) temperatures under MO2, showing that water temperatures released
3580 from Lake Roosevelt are passed through Rufus Woods Lake unchanged.

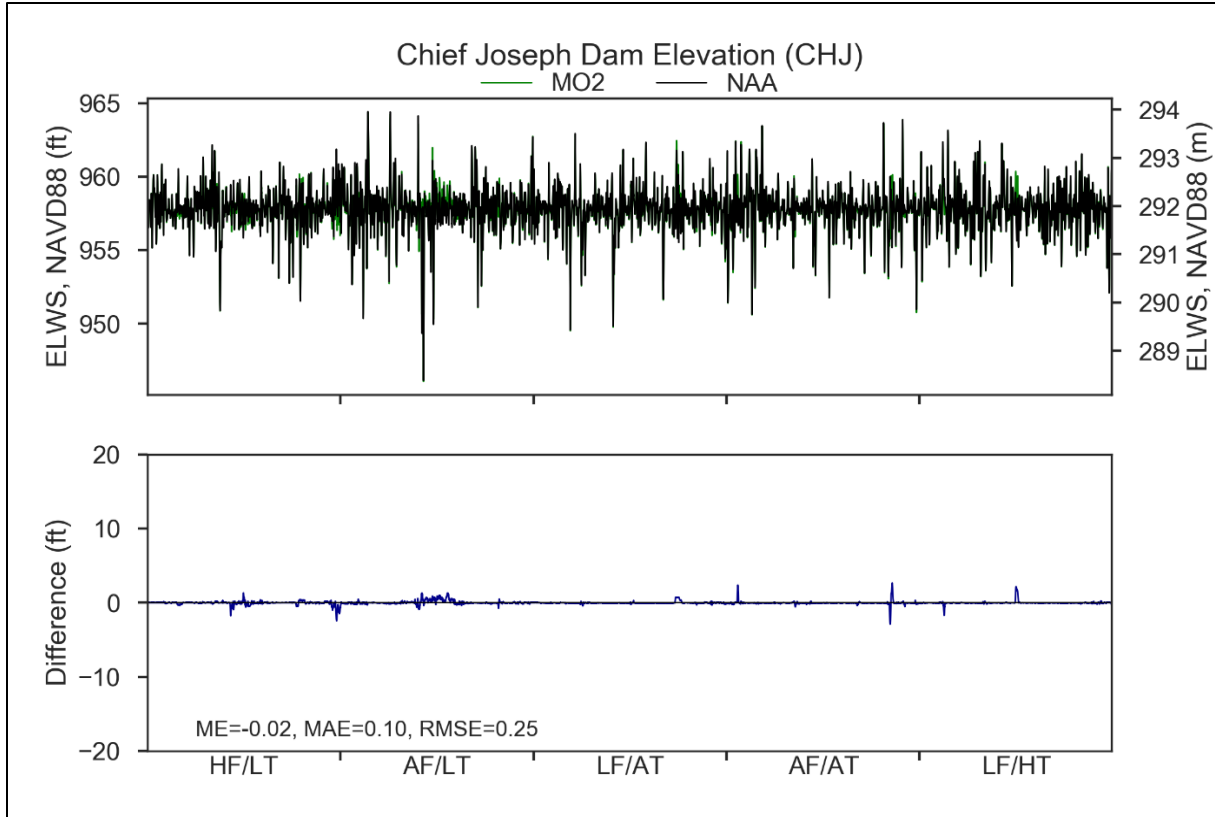


3581
3582 **Figure 5-8. Modeled Tailwater Temperatures for the No Action Alternative and Multiple Objective**
3583 **Alternative 2 at Grand Coulee Dam Under a 5-Year Range of River and and Meteorological**
3584 **Conditions Compared to the Confederated Colville Tribe 1-D Maximum Water Quality Standard**



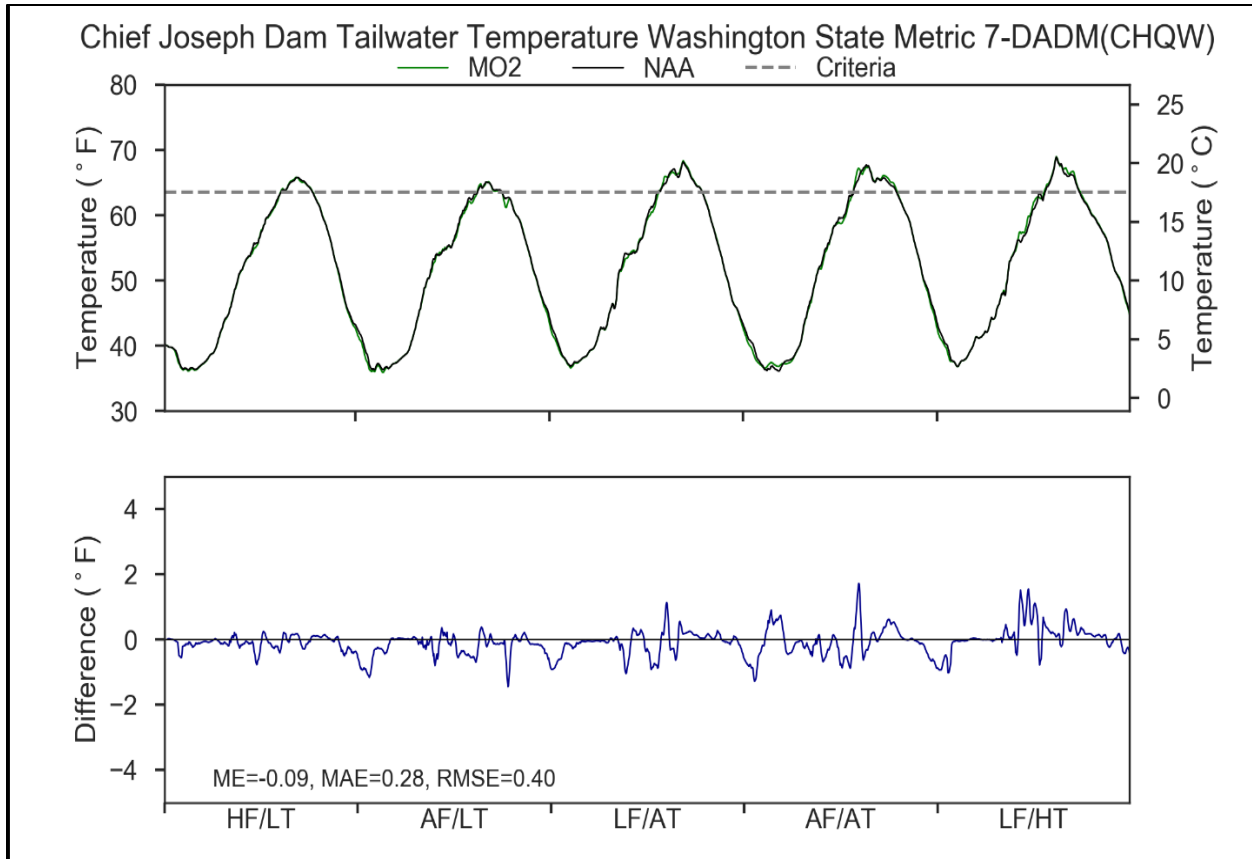
3585
 3586
 3587

Figure 5-9. Chief Joseph Dam-Rufus Woods Lake Outflows for Multiple Objective Alternative 2 Versus the No Action Alternative



3588
3589
3590

Figure 5-10. Chief Joseph Dam-Rufus Woods Lake Forebay Elevations for Multiple Objective Alternative 2 Versus the No Action Alternative

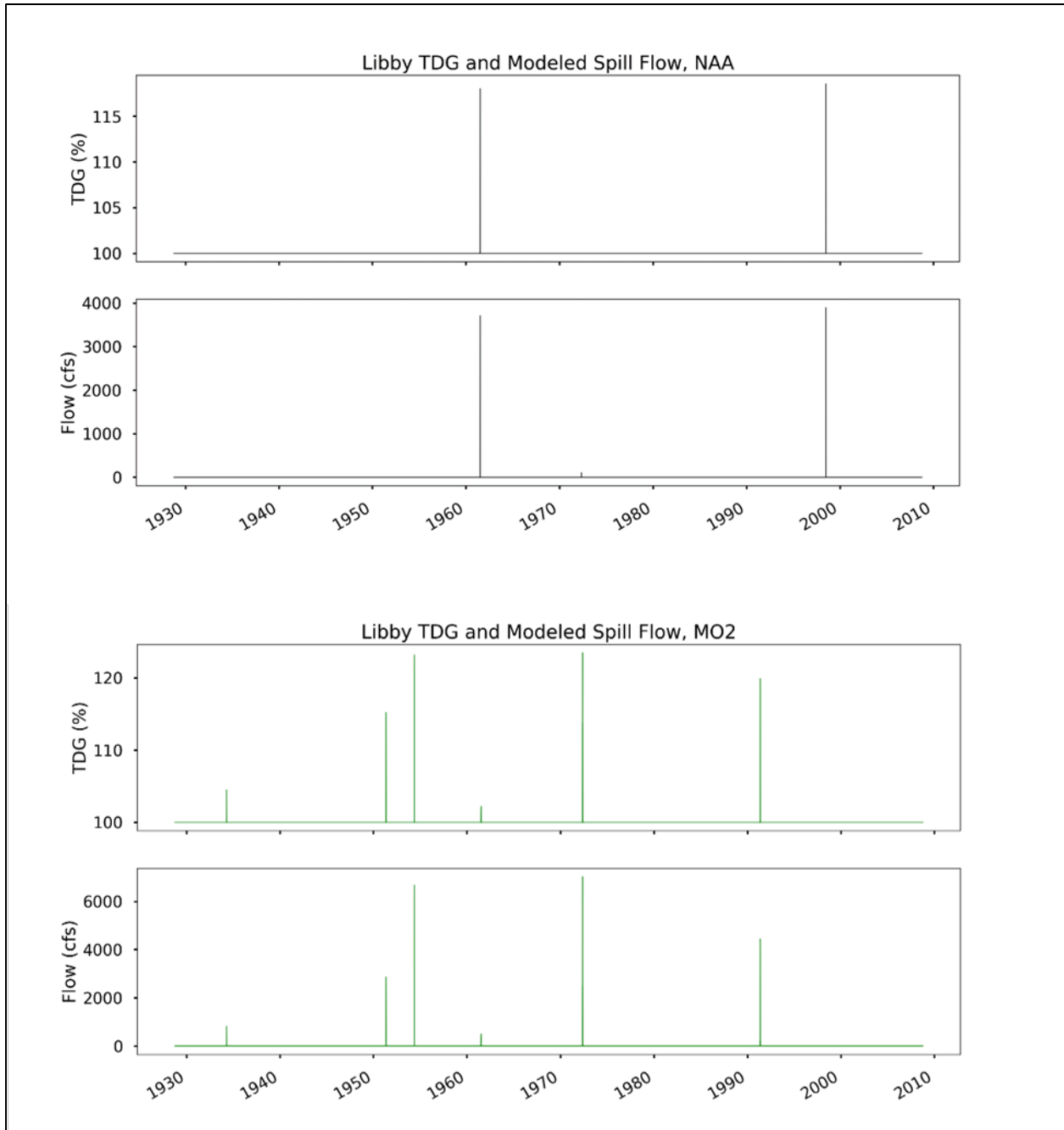


3591
 3592 **Figure 5-11. Modeled Tailwater Temperature for the No Action Alternative and Multiple**
 3593 **Objective Alternative 2 at Chief Joseph Dam Under a 5-Year Range of River and**
 3594 **Meteorological Conditions**

3595 **5.1.2 Total Dissolved Gas**

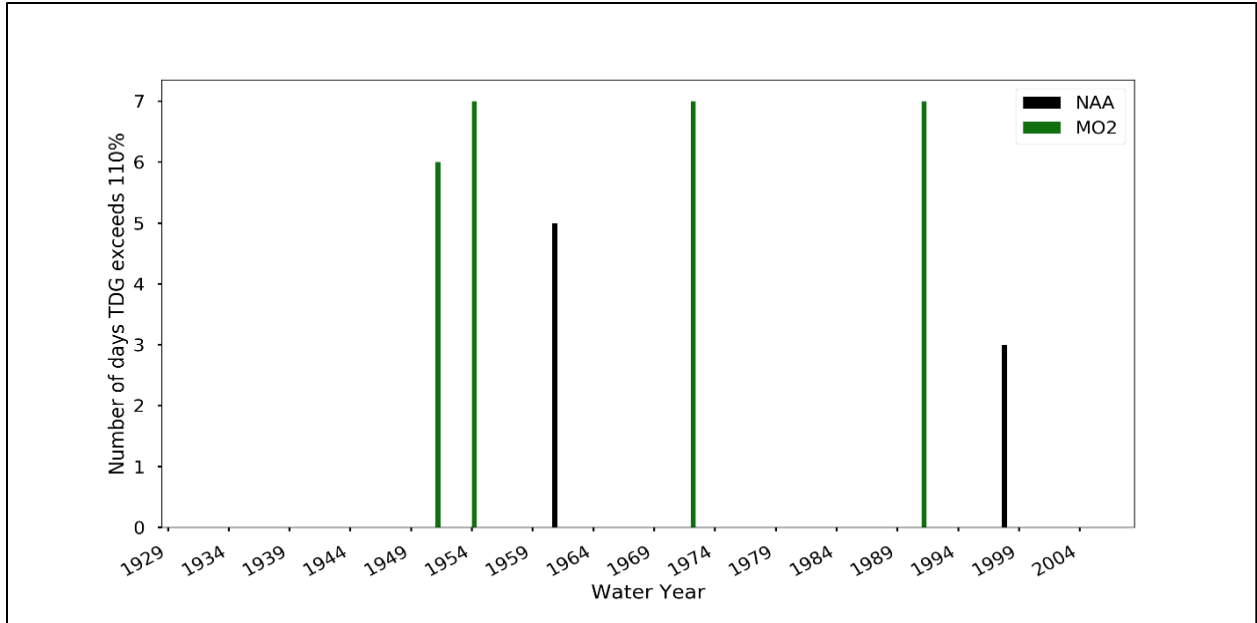
3596 **5.1.2.1 Libby and Hungry Horse Dams and Reservoirs**

3597 Libby Dam is typically operated to minimize spill due to associated water quality concerns such
 3598 as elevated TDG. Under MO2, Libby Dam’s draft and refill operations will be modified resulting
 3599 in an increase in the highest releases from the dam. This operational change is predicted to
 3600 increase the chance of spill at Libby Dam. The 80-year period of record flows (1928 to 2008)
 3601 were used to predict TDG, as presented in Figure 5-12.. This shows that the number of years
 3602 where spill could occur increases from three years under the No Action Alternative to 6 years
 3603 under MO2. The number of days exceeding the State of Montana 110 percent criteria would
 3604 increase as well, from 8 days for the No Action Alternative to 27 days for MO2 (Figure 5-13.).
 3605 Although spill from Libby Dam for the 80-year model period is predicted to increase under
 3606 MO2, the frequency of spill is still negligible.



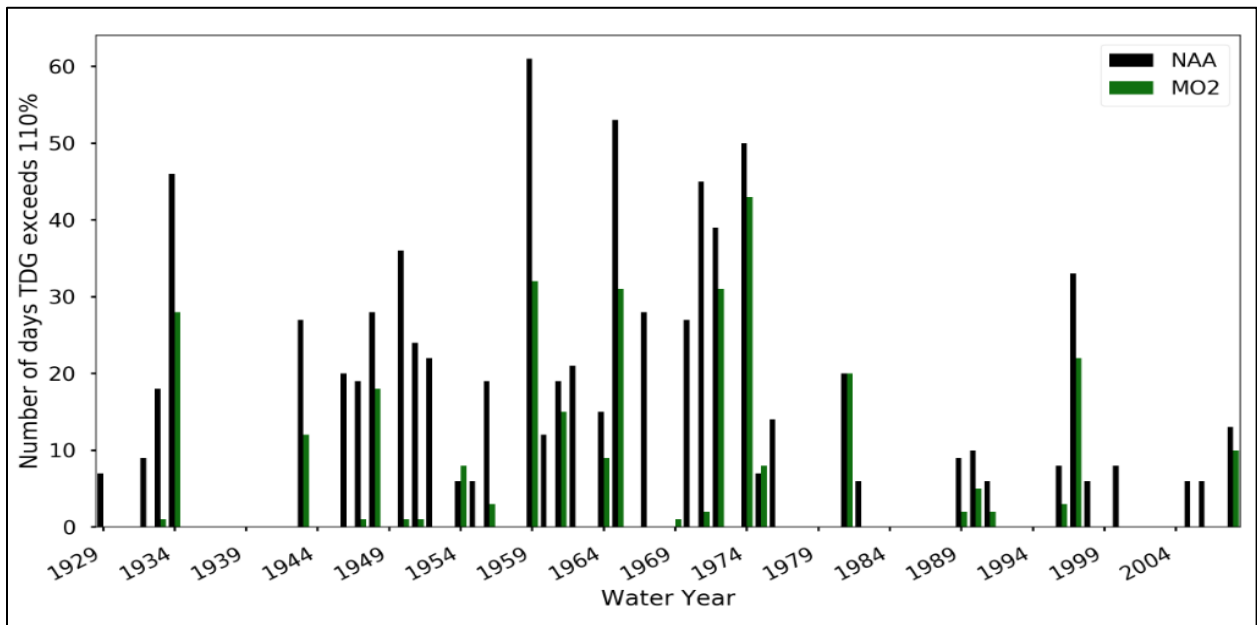
3607
 3608 **Figure 5-12. Modeled Tailwater Total Dissolved Gas and Spillway Flows for the No Action**
 3609 **Alternative and Multiple Objective Alternative 2 at Libby Dam over an 80Year Period**

3610 The Additional Draft for Hydropower measure results in additional winter outflows and a
 3611 deeper draft (reservoir drawdown) in January. This reduces spring outflows and spill in some
 3612 situations at Hungry Horse Dam, which could reduce the elevated TDG concentrations in the
 3613 spring. The anticipated Hungry Horse Dam flow and spill changes under MO2 would reduce the
 3614 number of days TDG is exceeded in most years. The Sliding Scale at Libby and Hungry Horse
 3615 measure does not significantly change the summer storage in comparison to the No Action
 3616 Alternative and does not appear to affect spill and TDG at Hungry Horse Dam.



3617
 3618 **Figure 5-13. Number of Days Modeled Tailwater Total Dissolved Gas Exceeds the 110 Percent**
 3619 **State Water Quality Standards for the No Action Alternative and Multiple Objective**
 3620 **Alternative 2 at Libby Dam over an 80- Year Period**

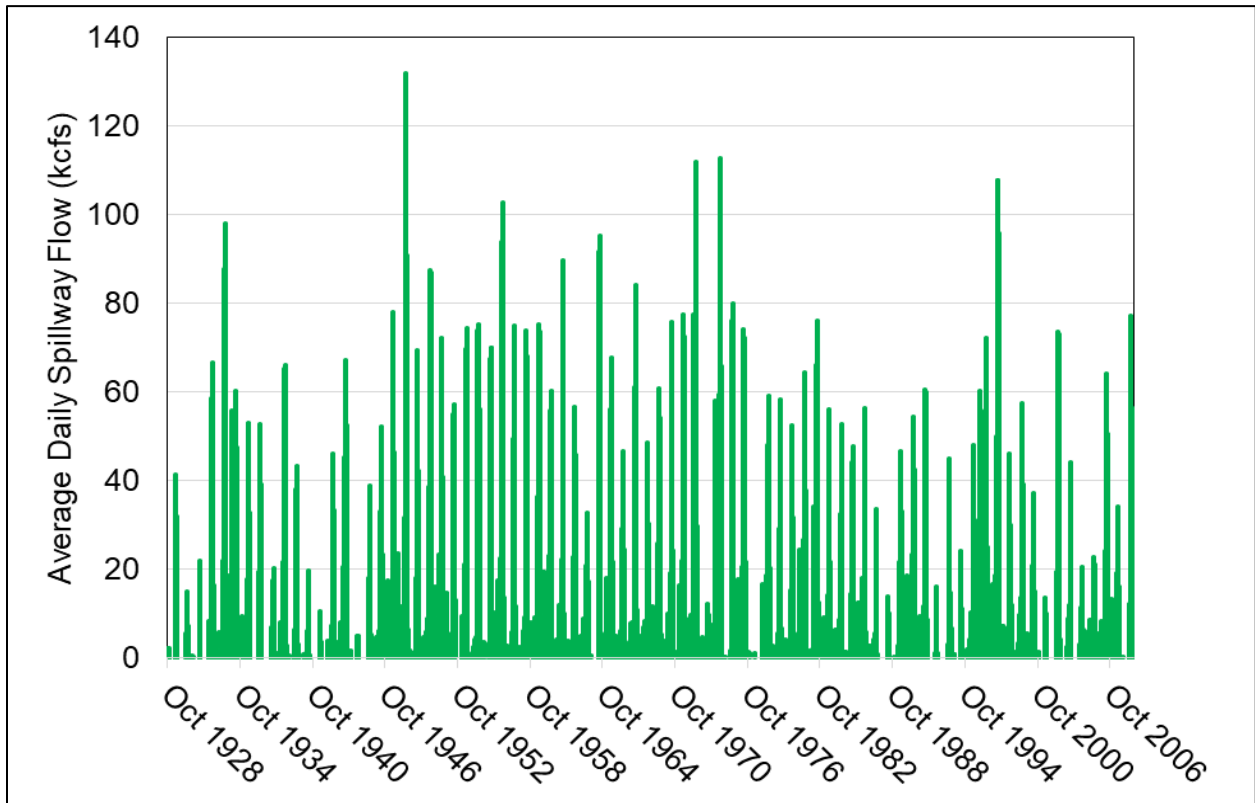
3621 Figure 5-14. shows the number of days that TDG is anticipated to exceed 110 percent below
 3622 Hungry Horse Dam under the MO2 that was modeled from 1929 through 2008. The number of
 3623 days that the State water quality standard is exceeded is notably less under MO2 as compared
 3624 to the No Action Alternative.



3625
 3626 **Figure 5-14. Number of Days that Total Dissolved Gas is Above the 110 Percent State Water**
 3627 **Quality Standard Under the No Action Alternative and Multiple Objective Alternative 2 at**
 3628 **Hungry Horse Dam**

3629 **5.1.2.2 Albeni Falls Dam and Reservoir**

3630 TDG in the Pend Oreille River upstream of Albeni Falls Dam can be greater than the State of
3631 Montana 110 percent criteria largely because of spillway releases from Cabinet Gorge Dam,
3632 located on the Clark Fork River about 55 miles upstream of Albeni Falls Dam. During most years,
3633 Albeni Falls Dam spills during high flow spring runoff. In general, spillway discharges up to
3634 about 10 kcfs can increase TDG saturations over forebay levels by about 1 to 2 percent, while
3635 spill between 10 to 50 kcfs can increase TDG saturations downstream of Albeni Falls by about 5
3636 to 9 percent. When Pend Oreille River flows exceed about 50 to 60 kcfs, Albeni Falls Dam
3637 powerhouse operations are suspended and the spillway gates are raised, allowing the river to
3638 flow relatively un-impounded across the dam. Under these high flow conditions, Albeni Falls
3639 Dam produces no TDG as the river is essentially free flowing. Spillway flows at Albeni Falls Dam
3640 were modeled under the MO2 and No Action Alternative for the 80-year period from 1928 to
3641 2008 using the ResSim model (Figure 5-15.). There was little difference in spillway flows
3642 between MO2 and the No Action Alternative. For both alternatives, spillway flows were
3643 predicted to range between 1 and 50 kcfs in nearly every year at Albeni Falls Dam, with many
3644 years having spill exceed about 60 kcfs, resulting in free-flowing conditions. These similar
3645 spillway flows under MO2 and the No Action Alternative are expected to result in no change in
3646 TDG saturations downstream of Albeni Falls Dam.



3647 **Figure 5-15. Modeled Tailwater Spillway Flows for the No Action Alternative and Multiple**
3648 **Objective Alternative 2 at Albeni Falls Dam over an 80-Year Period**
3649

3650 **5.1.2.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

3651 There are five MO2 operational measures specific to Grand Coulee Dam that would impact
3652 TDG:

- 3653 • *Deeper Drafts for Hydropower*
- 3654 • *Update System FRM Calculation*
- 3655 • *Planned Draft Rate at Grand Coulee*
- 3656 • *Grand Coulee Maintenance Operations*
- 3657 • *Winter System FRM Space*

3658 A more in-depth discussion of these operational measures and their effects can be found in
3659 [Section H&H-MO2]. None of these operational measures in MO2 would affect TDG levels
3660 within Lake Roosevelt, which are largely influenced by upstream dams that are outside the
3661 scope of this analysis. In addition to the measures listed above, changes in operations of
3662 upstream projects (from the *Deeper Drafts for Hydropower* measure and other modifications)
3663 could result in changes to inflows at Grand Coulee, which may have minor impacts on inflowing
3664 TDG but are not captured by the system modeling.

3665 Increased outflows from Grand Coulee from November to January are a result of winter space
3666 requirements for rain-induced flooding (*Winter System FRM Space and Deeper Draft for*
3667 *Hydropower* measures). The *Grand Coulee Maintenance Operations* measure could increase
3668 spill by reducing the hydraulic capacity through the power plants during any period of the year
3669 when outflows exceed power plant capacity. Operational measure *Planned Draft Rate at Grand*
3670 *Coulee* would result in a slightly earlier draft in Lake Roosevelt in wetter years; while the *Update*
3671 *System FRM Calculation* measure determines the deepest draft point for Grand Coulee in the
3672 spring, and in some years this measure results in a deeper draft than in the No Action
3673 Alternative. Despite the increase in winter outflows, TDG is not anticipated to increase
3674 significantly as 98 percent of the time the project does not spill in December, and when spill
3675 does occur, it is likely that pool elevations during this time of year allow for spill over the drum
3676 gates. Overall, MO2 operational measures would result in higher Columbia River flows below
3677 the dam from December to February, when TDG is generally below the 110 percent
3678 Washington State and Colville Tribes standard.

3679 The increase in winter outflows and deeper pool elevations result in a decrease in outflow April
3680 through July. The reduced outflows, and spill in some cases, during the spring months result in
3681 decreased TDG. This is most pronounced in May and June. Under MO2, average TDG
3682 concentrations are slightly lower (0.3 percent), resulting in about 4 days less violations to
3683 Washington State water quality per year. Additionally, TDG might be reduced in May and June
3684 under MO2, but above the Washington State TDG standard for about 90 hours more during
3685 high-flow years (Figure 5-16.).

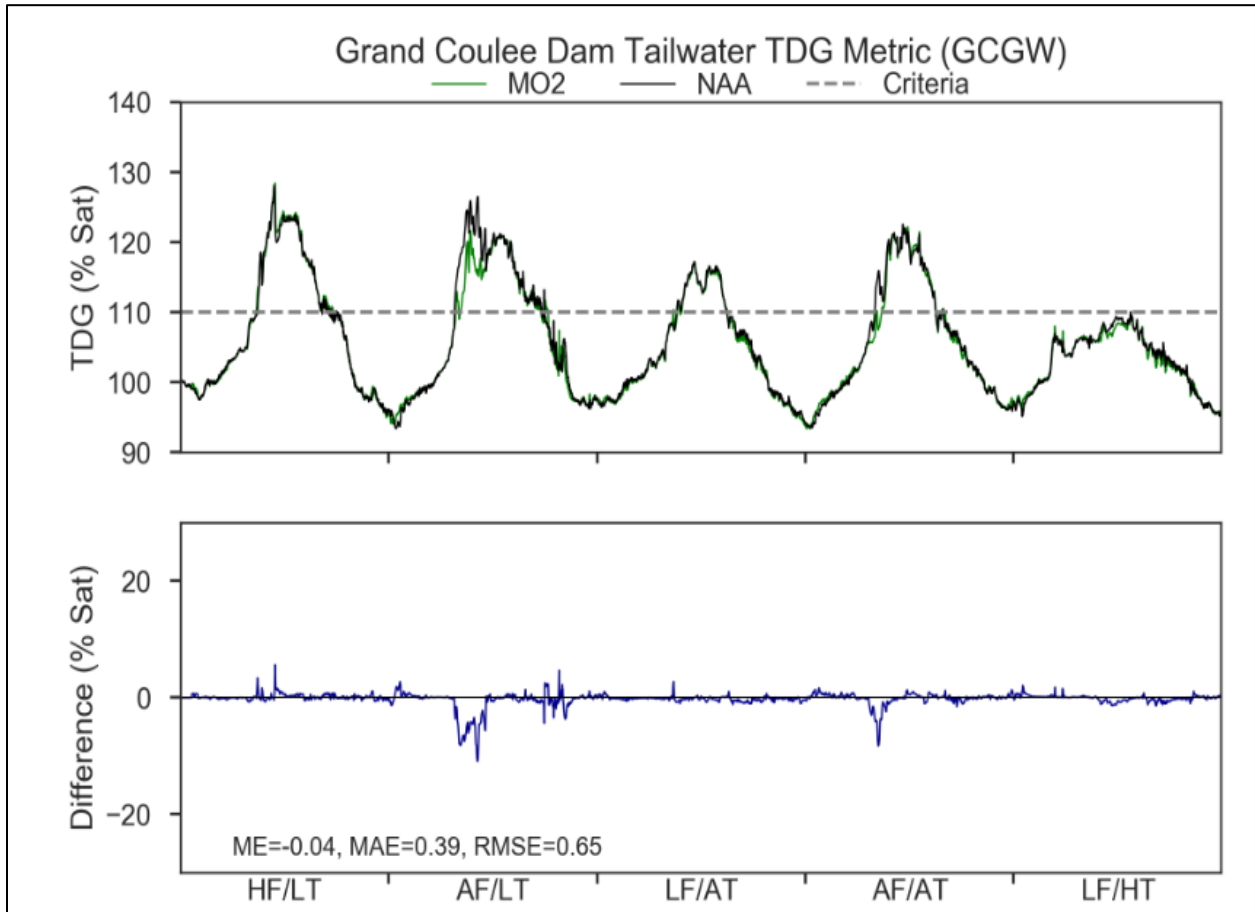
3686 As stated above, the operational measures for *Grand Coulee Maintenance Operations* have the
3687 potential to increase spill through the reduction in the hydraulic capacity of the powerhouse at
3688 Grand Coulee. The Grand Coulee Maintenance Operations in isolation could result in significant
3689 increases in spill and TDG, in some cases producing TDG in excess of 130 percent for limited
3690 duration; however, this effect is largely offset in the spring and early-summer by the other
3691 measures. An additional impact expected from *Grand Coulee Maintenance Operations* is the
3692 potential for slightly deeper spill over the drum gates (when the forebay elevation is greater
3693 than 1,267 feet, NGVD29). Information to assess the magnitude of water quality impacts
3694 directly related to Grand Coulee Maintenance Operations is unavailable but would likely result
3695 in small increases in TDG. In wet conditions, it is anticipated that potential maintenance
3696 activities could be delayed in advance of spill to allow spill over more gates. Another factor not
3697 considered in the analysis is that as maintenance occurs, there would be an increase to
3698 hydraulic capacity as more units become available. This would result in reduced spill and TDG in
3699 some cases; however, the other actions have a larger impact on outflows and associated spill.

3700 As shown in Figure 5-17., the combination of these particular operational measures tend to
3701 offset each other in the analysis of the overall alternative and, in some cases, result in a
3702 reduction in TDG. The shaded area in the figure shows the entire range of TDG predicted by the
3703 MO2 and No Action Alternative models. The models indicate significant reductions in the early
3704 months compared to the No Action Alternative in high water years. Therefore, compared to the
3705 No Action Alternative, MO2 could somewhat reduce TDG but the number of daily Washington
3706 State water quality violations in the Columbia River below the dam will mostly remain the
3707 same.

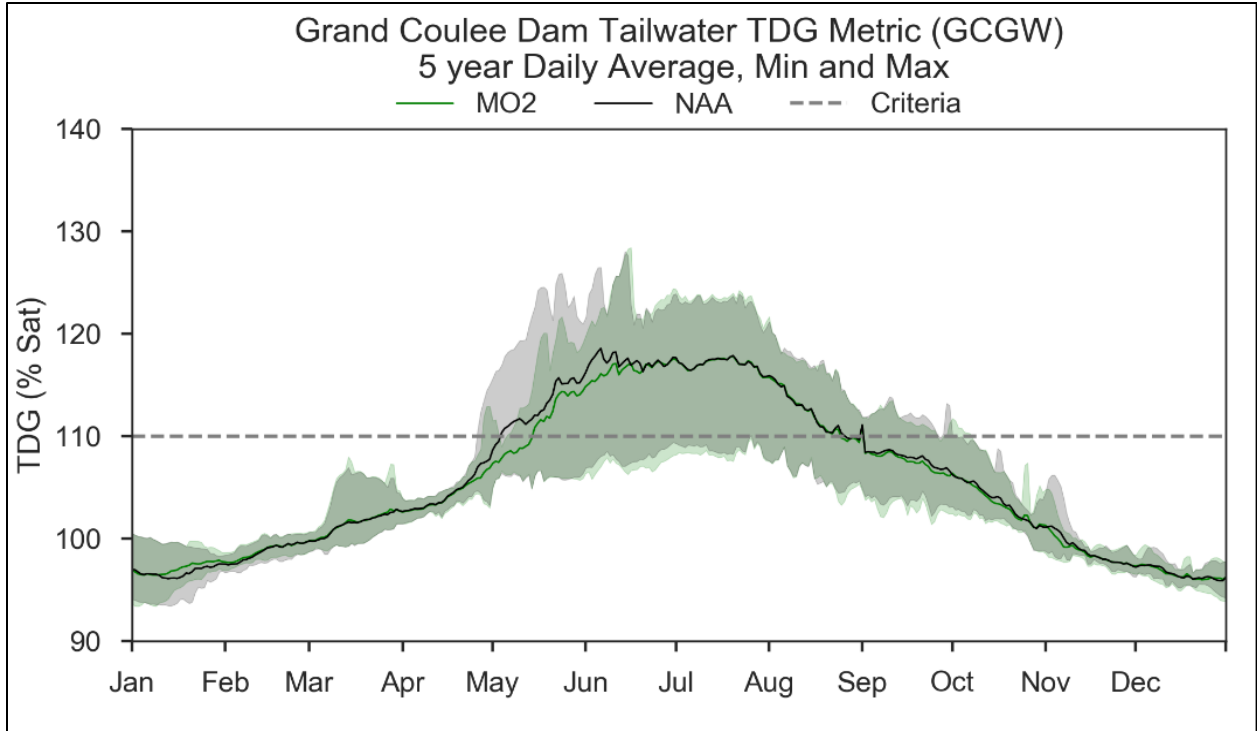
3708 TDG at the forebay of Chief Joseph Dam is largely a function of the TDG released upstream from
3709 Lake Roosevelt and Grand Coulee Dam because little degassing occurs in Rufus Woods Lake.
3710 High inflow TDG saturations to Lake Roosevelt from Canada, as well as spill from Grand Coulee
3711 Dam via the outlet tubes, can increase TDG saturations in Rufus Woods Lake at the Chief Joseph
3712 Dam forebay to over 130 percent. During periods when incoming TDG levels are above
3713 approximately 120 percent, spilling at Chief Joseph Dam over the spillway deflectors can degas
3714 the water and reduce downstream system TDG loading. Therefore, Chief Joseph Dam is often
3715 used to help manage overall system TDG production in the mainstem Columbia River. In
3716 addition, to avoid spilling through the outlet tubes at Grand Coulee Dam, spill is often shifted
3717 from Grand Coulee Dam to Chief Joseph Dam to take advantage of the lower TDG produced by
3718 spilling over the deflectors. These operational strategies are expected to continue under MO2.

3719 Chief Joseph Dam TDG saturations at the forebay and tailwater modeled under MO2 were
3720 compared to the No Action Alternative (Figure 5-18). In general, MO2 forebay TDG saturations
3721 are predicted to be similar to or slightly less than the No Action Alternative under a wide range
3722 of flow and air temperature conditions. Tailwater TDG saturations under MO2 are predicted to
3723 be both lower and higher than the No Action Alternative depending on flow and meteorological
3724 conditions. The number of days the tailwater exceeds the 110 percent TDG criteria is predicted
3725 to be slightly lower under MO2 for all flow and meteorological conditions (Figure 5-19.).
3726 Decreased TDG saturations between the forebay and tailwater during higher spill years such as

3727 2011 (HF/LT) and 2012 (AF/LT) modeled under the No Action Alternative would continue under
3728 MO2. It is expected that under MO2, Chief Joseph Dam would continue to decrease TDG during
3729 high spill years when TDG saturations greater than about 120 percent occur in the forebay.

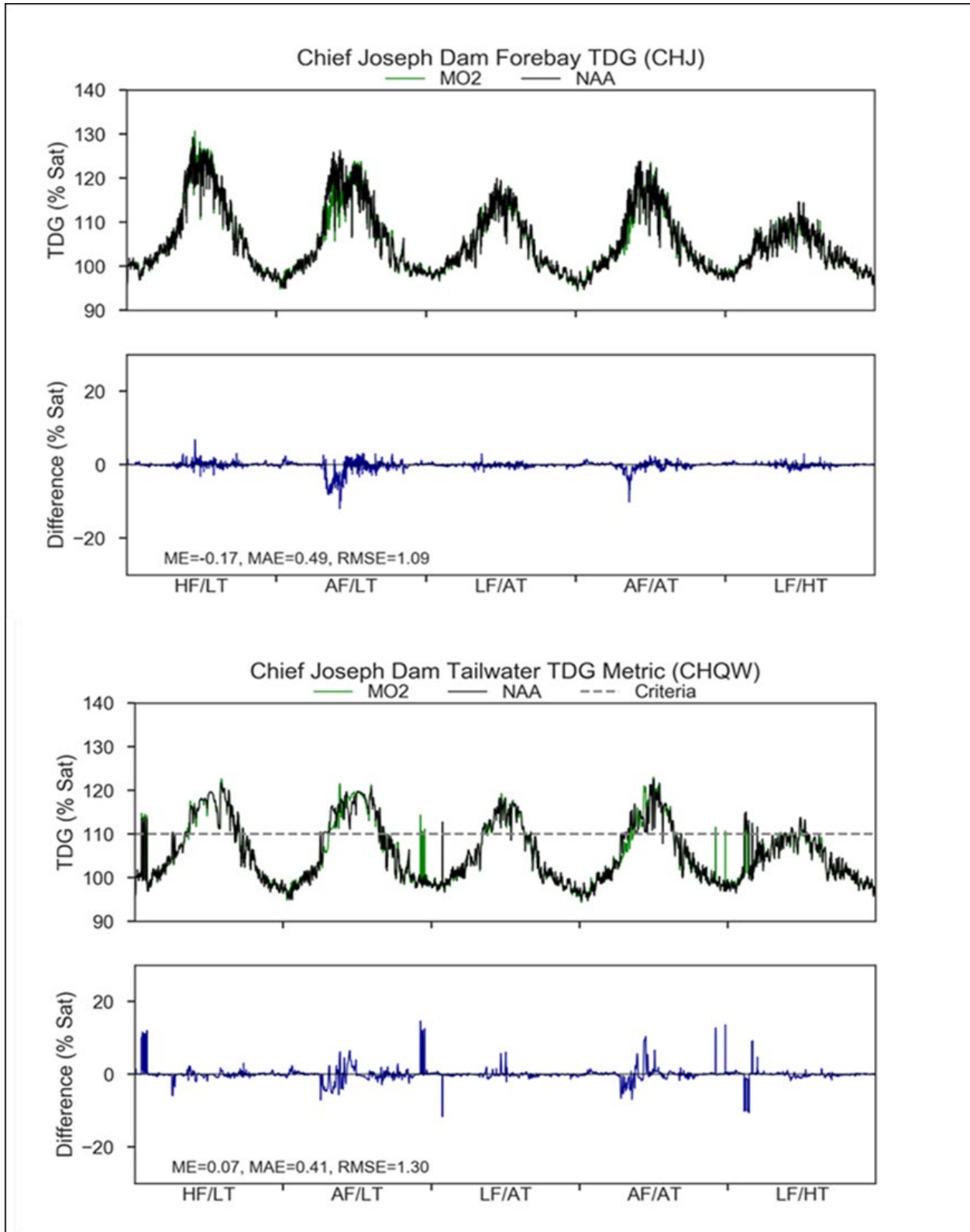


3730
3731 **Figure 5-16. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and**
3732 **Multiple Objective Alternative 2 at Grand Coulee Dam Under a 5-Year Range of River and**
3733 **Meteorological Conditions**



3734
3735
3736
3737

Figure 5-17. Modeled Range of Tailwater Total Dissolved Gas for the No Action Alternative and Multiple Objective Alternative 2 at Grand Coulee Dam Under a 5-Year Range of River and Meteorological Conditions



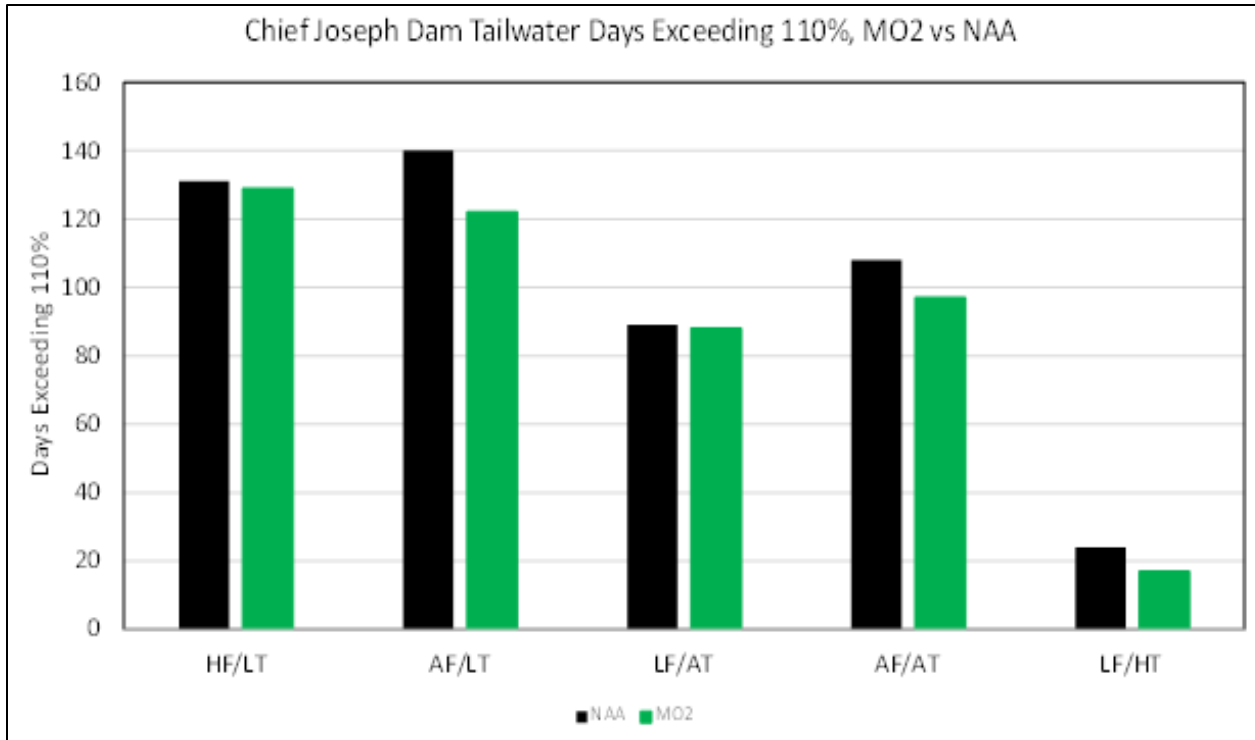
3738

3739

3740

3741

Figure 5-18. Modeled Forebay and Tailwater Total Dissolved Gas Saturations for the No Action Alternative and Multiple Objective Alternative 2 at Chief Joseph Dam Under a 5-Year Range of River and Meteorological Conditions



3742
 3743 **Figure 5-19. Days Exceeding the 110 Percent Total Dissolved Gas Criteria for the No Action**
 3744 **Alternative and Multiple Objective Alternative 2 at Chief Joseph Dam Tailwater Under a 5-**
 3745 **Year Range of River and Meteorological Conditions**

3746 **5.1.3 Other Physical, Chemical, and Biological Processes**

3747 **5.1.3.1 Libby and Hungry Horse Dams and Reservoirs**

3748 MO2 would modify operations at Libby Dam resulting in changes in the drafting depth and
 3749 water elevations of Lake Kooconusa that may impact physical, chemical, and biological water
 3750 quality parameters when compared to existing conditions and the No Action Alternative. In
 3751 general, MO2 results in lower water elevations in Lake Kooconusa from November through
 3752 April, with substantially lower end-of-April water elevations (11 to 19 feet) in the driest 40
 3753 percent of years. Reservoir refill and summer pool elevations are improved over the No Action
 3754 Alternative with the reservoir reaching full pool by the end of July and maintaining higher
 3755 elevations, of about 1 to 4 feet in August and September. For water quality concerns, of
 3756 particular interest are the 11- to 19-foot lower end-of-April water elevations because they
 3757 equate to less volume of water in Lake Kooconusa during the spring runoff and a shorter water
 3758 retention time in Lake Kooconusa.

3759 Water quality chemical and biological parameters of concern in Lake Kooconusa that may be
 3760 impacted by changes in the reservoir elevation and retention times, under MO2, include
 3761 suspended sediments, nutrients such as phosphorus and nitrogen, metals such as selenium, and
 3762 phytoplankton such as cyanobacteria and diatoms. For a long, narrow, deep waterbody like
 3763 Lake Kooconusa, shorter retention times may allow certain chemical constituents in inflowing

3764 waters to move farther down-reservoir toward the forebay and outflow before settling out or
3765 transforming.

3766 It is likely that the end-of-April drawdown elevation and the corresponding reservoir volume, as
3767 well as spring runoff volume and the corresponding phosphorus and sediment concentrations,
3768 are all factors in determining how far down-reservoir total phosphorus and suspended
3769 sediments reach. Historical data show that Lake Koochanusa is a sink for phosphorus and
3770 sediments, with little inflow concentrations moving down-reservoir past Libby Dam. A recent
3771 study by Yassien and Ward (2018) concluded that from 2014 through 2017, the total
3772 phosphorus retention in the reservoir ranged from 80 to 93 percent. Under MO2, the lower
3773 reservoir elevations for the driest 40 percent of years would likely allow sediments and total
3774 phosphorus from the inflow to move farther down-reservoir before settling out.

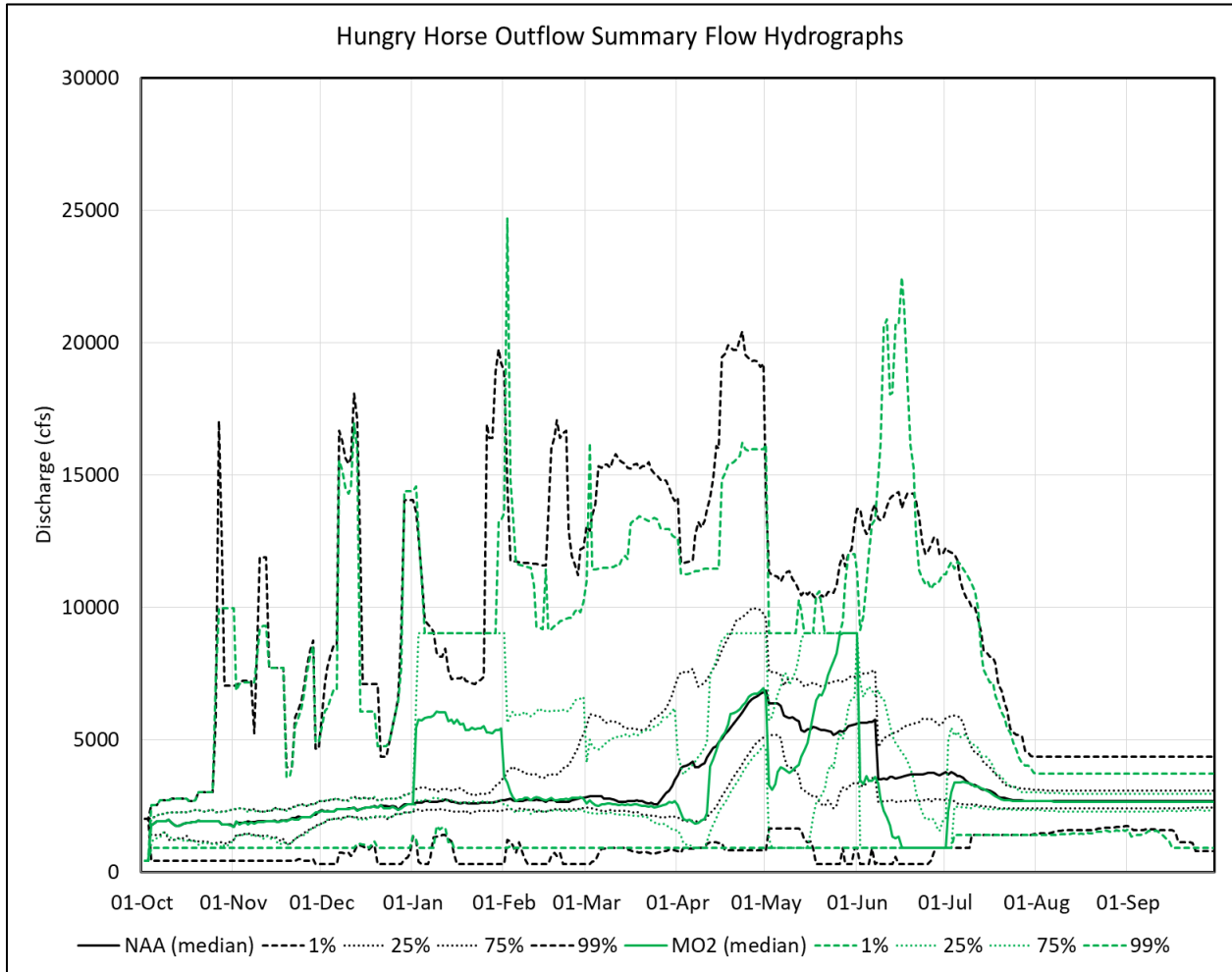
3775 Lake Koochanusa does not appear to be a sink for nitrogen and most of the inflow nitrate passes
3776 down-reservoir to the forebay and Kootenai River regardless of reservoir elevations and
3777 retention times. Increased nitrate loadings to Lake Koochanusa, largely due to coal mining
3778 operations in British Columbia and together with low phosphorus concentrations, have created
3779 a large imbalance in the nitrogen-to-phosphorus ratio, with the ratio often exceeding 100:1 at
3780 the forebay, resulting in strong phosphorus limitation. Despite rising nitrate concentrations in
3781 Lake Koochanusa, algal blooms appear to have been kept in check by the strong phosphorus
3782 limitation under existing conditions and the No Action Alternative. However, it is possible that
3783 the operational changes proposed for MO2 may increase total phosphorus concentrations in
3784 Lake Koochanusa, which could result in changes in phytoplankton densities and functional types.

3785 Increasing selenium concentrations in Lake Koochanusa from coal mining operations in British
3786 Columbia are a concern and were previously discussed for MO1 and the No Action Alternative.
3787 Over the next 25 years, it is expected that coal production in the Kootenai River watershed will
3788 **continue to increase**. Although there does not yet appear to be an increasing trend in water
3789 column selenium concentrations in the reservoir, there is concern that without water quality
3790 treatment, the continued selenium loadings to Lake Koochanusa may lead to additional selenium
3791 contamination. It is possible that the lower end-of-April reservoir elevations for the driest 40
3792 percent of years under MO2 may alter the movement, cycling, and transformation of selenium
3793 in the reservoir and downstream in the Kootenai River, possibly resulting in water and sediment
3794 quality impacts.

3795 Median reservoir elevations under MO2 would be lower during the spring, potentially flushing
3796 some early food sources from Libby Reservoir; however, during the growing season, mid-June
3797 through September, reservoir elevations would be similar as compared to the No Action
3798 Alternative. As such, Lake Koochanusa should not experience major changes to the physical,
3799 chemical, or biological processes compared to the No Action Alternative. Additionally, changes
3800 in the median average monthly outflows from Libby Dam during the mid-June through
3801 September time frame are relatively minor (reduction of 5 to 9 percent when compared to the
3802 No Action Alternative), which result in only a 0.3-foot decrease in median monthly elevation in

3803 the Kootenai River downstream of Libby Dam, and should not greatly impact the variability of
3804 (periodically wetted) zone productivity.

3805 Hungry Horse median reservoir elevations are expected to be lower under MO2 as compared to
3806 the No Action Alternative, particularly in early spring and summer (Figure 5-3.). These
3807 elevations combined with higher outflows (Figure 5-20.) in late spring/early summer could
3808 reduce in-lake productivity and food availability for resident fish species (ISAB 1997, Fraley et. al
3809 1989).



3810
3811 **Figure 5-20. Hungry Horse Dam Outflows for Multiple Objective Alternative 2 Versus the No**
3812 **Action Alternative**

3813 Water level fluctuations in reservoirs may increase methyl-mercury concentrations in the
3814 waterbody as seasonally inundated areas of a reservoir have higher rates of methylation
3815 activity when compared to permanently inundated areas of a reservoir (Willacker et al. 2016).
3816 Studies suggest that methyl-mercury has a greater probability of entering the food web during
3817 the spring and summer growing seasons (January through July) (Willacker et al. 2016). Under
3818 MO2, the measures don't change the cyclic occurrence of inundation and exposure but do
3819 result in earlier and longer exposure of sediments that may have some impact on mercury

3820 methylation in Hungry Horse Reservoir. However, unlike other downstream locations such as
3821 Lake Roosevelt, mercury has not been recorded as a concern at Hungry Horse Reservoir as the
3822 only likely mercury input at this location is through airborne pollution. Additionally, even this
3823 input is likely minor due to the relatively high air quality in the region.

3824 **5.1.3.2 Albeni Falls Dam and Reservoir**

3825 Under MO2, there are minor changes to operations at Albeni Falls Dam. The physical, chemical,
3826 and biological water quality of Lake Pend Oreille and the Pend Oreille River described under the
3827 No Action Alternative are expected to remain unchanged.

3828 **5.1.3.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

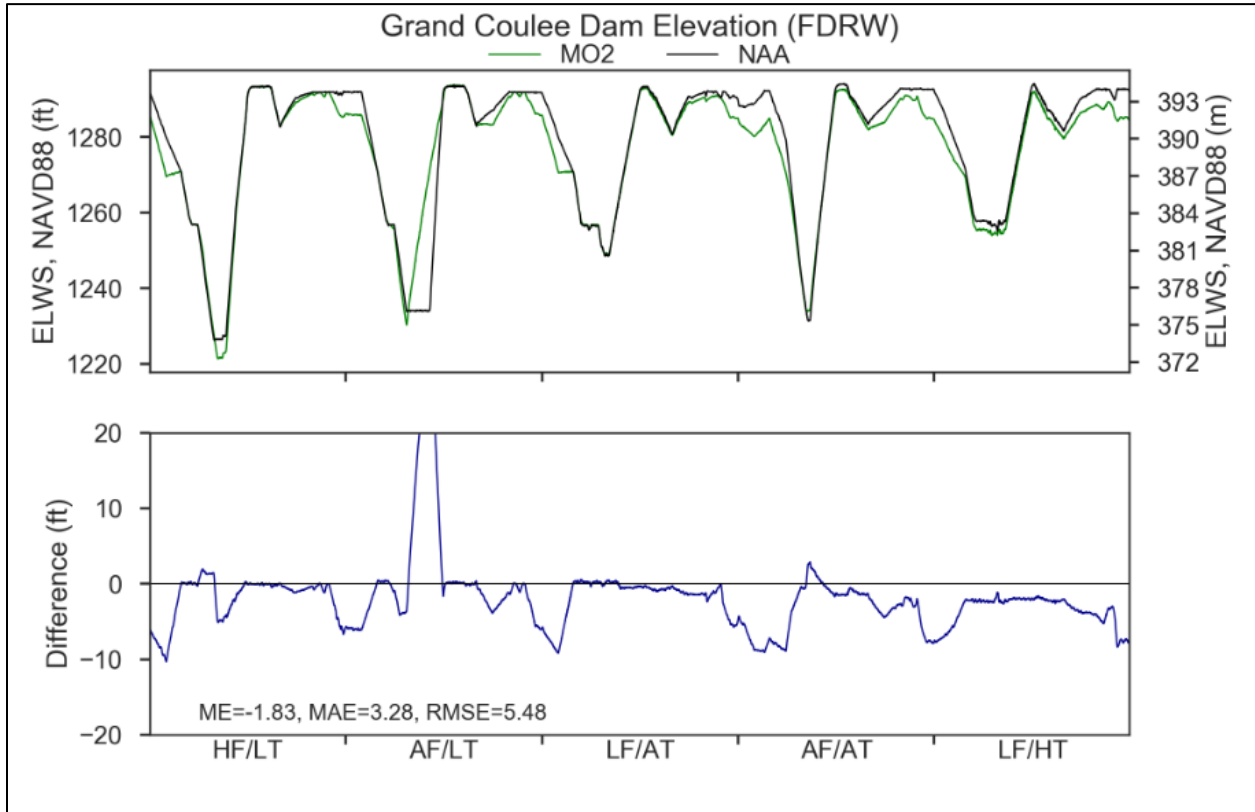
3829 Under MO2, retention time of water in the reservoir could decrease slightly from March
3830 through May; however, retention time would largely remain unchanged during the rest of the
3831 year, as compared to the No Action Alternative (Figure 5-21.). Lake Roosevelt tends to display
3832 relatively low primary productivity throughout the year. However, with slightly longer water
3833 retention times, some locations of the reservoir may experience primary productivity blooms.
3834 These blooms have the potential to increase pH and decrease dissolved oxygen when they
3835 decay. In the part of Lake Roosevelt where the Spokane River enters, in the LF/HT year, there is
3836 a greater portion of the water column that is anoxic; this may be related to water retention
3837 time and temperature conditions in this year.

3838 The *Planned Draft Rate at Grand Coulee* measure changes the planning drawdown rate (as
3839 depicted in the SRD) from 1.0 foot per day to a target of 0.8 feet per day. Mass wasting, such as
3840 small local landslides within Lake Roosevelt, has been related to the rate of drawdown at Grand
3841 Coulee Dam. Decreases in these mass wasting events that introduce sediment in pulses to the
3842 reservoir should result in decreases in turbidity under MO2.

3843 Water level fluctuations in reservoirs may increase methyl-mercury concentrations in the
3844 waterbody as seasonally inundated areas of a reservoir have higher rates of methylation
3845 activity when compared to permanently inundated areas of a reservoir (Willacker et al. 2016).
3846 Studies suggest that methyl-mercury has a greater probability of entering the food web during
3847 the spring and summer growing seasons (January to July) (Willacker et al. 2016). Under MO2,
3848 the measures don't change the cyclic occurrence of inundation and exposure but do result in
3849 earlier and longer exposure of sediments that may have some impact on mercury methylation
3850 in Lake Roosevelt. The lower panel of Figure 5-21. shows the difference in Lake Roosevelt water
3851 elevation throughout the year between MO2 and the No Action Alternative. Modeling indicates
3852 that the average draft is expected to remain about 7 feet lower under this alternative. MO2
3853 may very slightly increase the rate of mercury cycling within Lake Roosevelt.

3854 MO2 includes modified operations at Grand Coulee Dam that result in some changes in
3855 monthly outflows to Rufus Woods Lake and Chief Joseph Dam. However, only minor changes to
3856 operational conditions at Chief Joseph Dam are expected. As such, the physical, chemical, and
3857 biological water quality of Rufus Woods Lake and the Columbia River downstream of Chief

3858 Joseph Dam under MO2 are expected to remain relatively unchanged from the No Action
 3859 Alternative.



3860
 3861 **Figure 5-21. Modeled Forebay Elevations for the No Action Alternative and Multiple Objective**
 3862 **Alternative 2 at Grand Coulee Dam Under a 5-Year Range of River and Meteorological**
 3863 **Conditions**

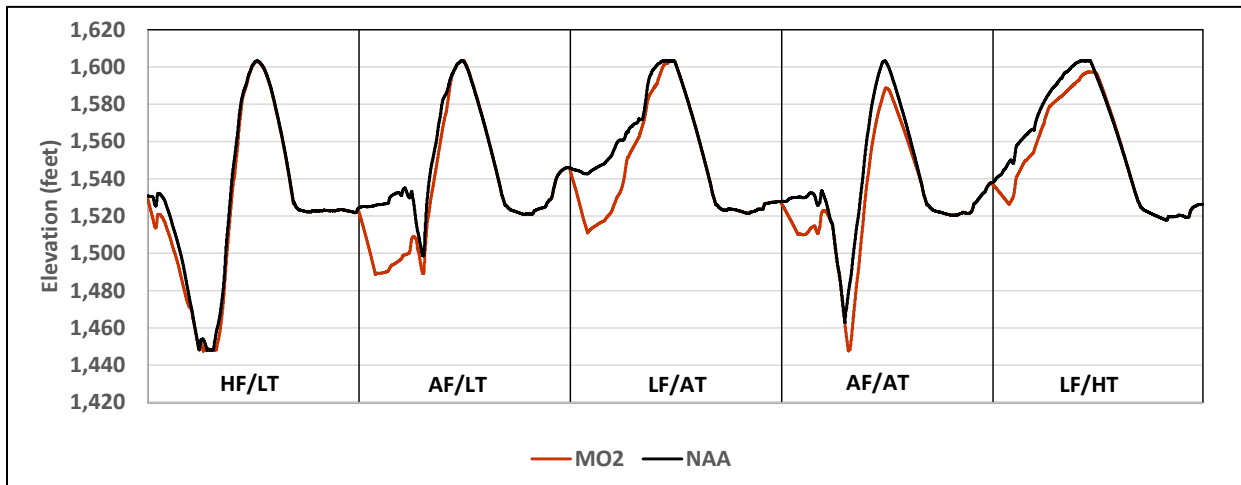
3864 **5.2 LOWER SNAKE RIVER BASIN**

3865 The two operational measures included as part of MO2 that would have the largest impact on
 3866 water quality in the lower Snake River Basin are operational measures *Spill to 110% TDG* and
 3867 *Slightly Deeper Draft for Hydropower*. The *Spill to 110% TDG* measure would limit juvenile fish
 3868 passage spill at the four lower Snake River projects to 110 percent in the tailraces and
 3869 downstream forebays. Exceptions would include times when spill is needed for the powerhouse
 3870 surface passage routes, for the spillway weirs, adult attraction, and during high flow or flood
 3871 events. Juvenile fish passage spill would begin annually on April 3 and end at midnight on July
 3872 31.

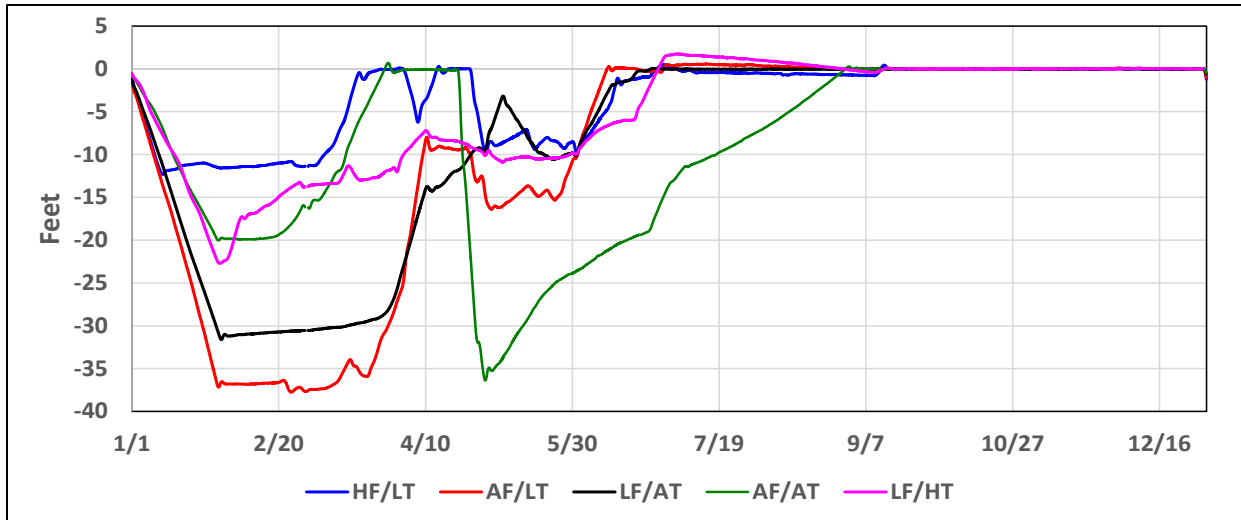
3873 The *Slightly Deeper Draft for Hydropower* measure would result in deeper drafts and slower
 3874 refill of Dworshak Reservoir during most of the five flow and meteorological conditions
 3875 modeled (Figure 5-22.). This measure would use current forecasts in the winter to draft
 3876 Dworshak 10 feet below its April draft target. If the forecast continued to become drier, it's
 3877 possible that draft target could be missed by more than 10 feet. Due to time constraints

3878 ResSim logic was not able to capture all of the desired logic in the modeling of the measure,
3879 which caused Dworshak to miss refill by more than expected. However, some reduction in refill
3880 seems probable due to the nature of forecast error in reservoir operations.

3881 For the model rule set evaluated, the two deepest drafts would occur during HF/LT and AF/AT
3882 conditions when the pool elevation would be less than 1,450 feet, NGVD29 during April. The
3883 anticipated MO2 minimum pool elevation during HF/LT conditions is, at most, 6 feet lower than
3884 it would be under the No Action Alternative (Figure 5-23.). During AF/AT conditions, the late-
3885 April MO2 elevation would be up to 36 feet lower than during the No Action Alternative.
3886 Additional drafting would also occur under MO2 between January and March during each flow
3887 and meteorological condition. The largest differences between MO2 and the No Action
3888 Alternative during this part of the year would occur during LF/AT and AF/LT conditions when
3889 the pool elevation would be approximately 30 feet and 35 feet lower, respectively. Refill would
3890 also occur later in the year during average and low-flow years and not reach full pool of 1,600
3891 feet, NGVD29 during AF/AT and LF/HT conditions.



3892
3893 **Figure 5-22. Dworshak Reservoir Pool Elevations for Multiple Objective Alternative 2 and No**
3894 **Action Alternative for the 5-Year Range of Flow and Meteorological Conditions Modeled**



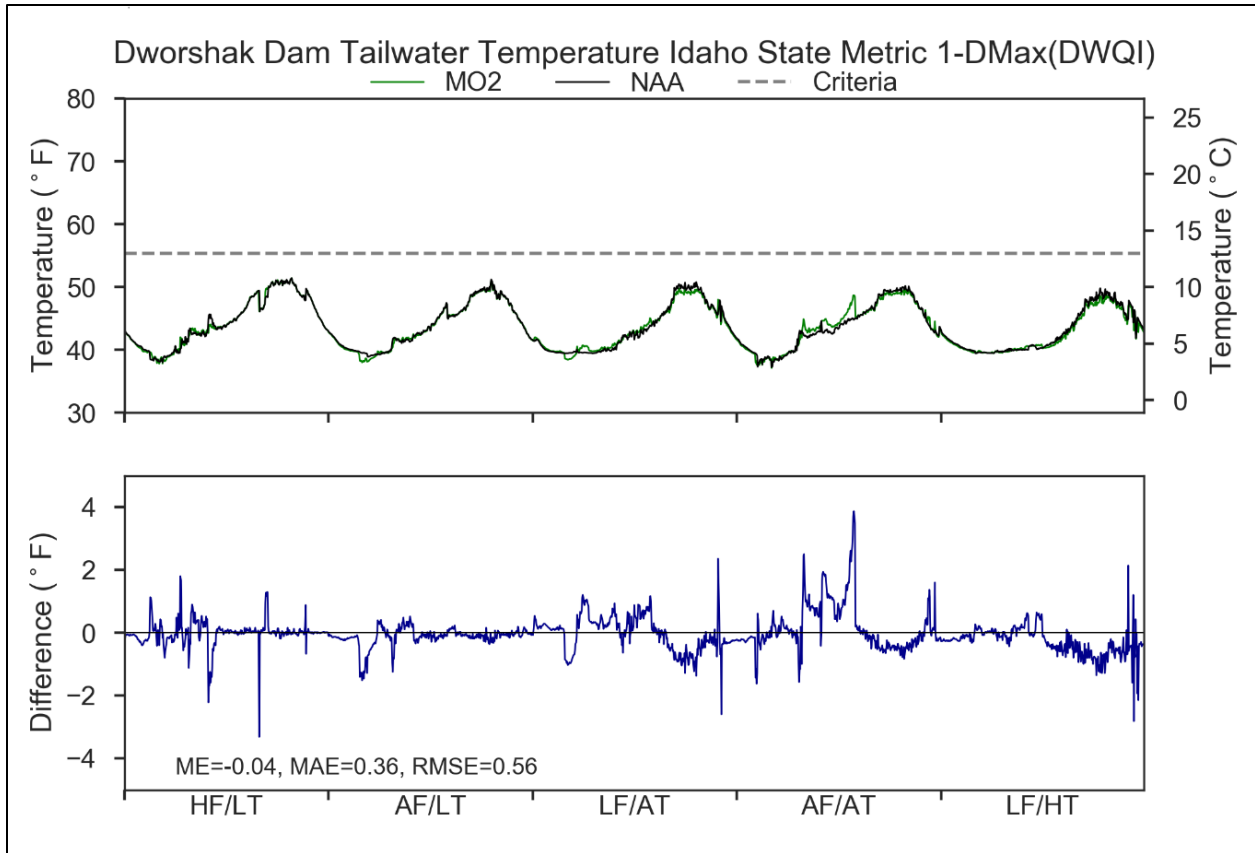
3895
3896 **Figure 5-23. Differences Between Dworshak Reservoir Pool Elevations for Multiple Objective**
3897 **Alternative 2 and the No Action Alternative for the 5-Year Range of Flow and Meteorological**
3898 **Conditions Modeled**

3899 **5.2.1 Water Temperature**

3900 **5.2.1.1 Dworshak Dam and Reservoir**

3901 Dworshak MO2 outflow temperatures would be very similar to No Action Alternative conditions
3902 and remain less than 52°F throughout the year (Figure 5-24.). The primary differences between
3903 the two alternatives occur during May, June, and July during AF/AT conditions (Table 5-1.). The
3904 largest average temperature increases during July would be higher by 1.6 degrees Fahrenheit
3905 but still only reach a daily maximum of 48.7°F. The average difference between MO2 and the
3906 No Action Alternative for June during the same conditions would be 1.2 degrees Fahrenheit,
3907 with a maximum daily temperature of 44.9°F. Average temperature decreases of -0.5 degrees
3908 Fahrenheit could also occur during September with low-flow conditions, but these differences
3909 are small and within the margin of modeling error.

3910 As modeled, water temperatures in the lower Snake River under MO2 showed some
3911 differences as compared the No Action Alternative for most of the year (Figure 5-25. and
3912 Figure 5-26.). However, the modeling assumptions resulted in misleading conclusions, in the
3913 lower Snake River. ResSim modeling assumptions did not represent the intended operations
3914 and instead showed the reservoir would have a decreased refill probability, refilling to within
3915 0.5 feet of the normal full reservoir elevation in about 48 percent of years (Chapter 3, Section
3916 3.2, *Hydraulics & Hydrology*). It is likely that in real-time operations, the refill probability for
3917 Dworshak Reservoir under MO2 would be higher than shown in modeled results, and more
3918 closely aligned to the No Action Alternative. Therefore, effects to water temperatures are
3919 considered negligible (Figure 5-27).



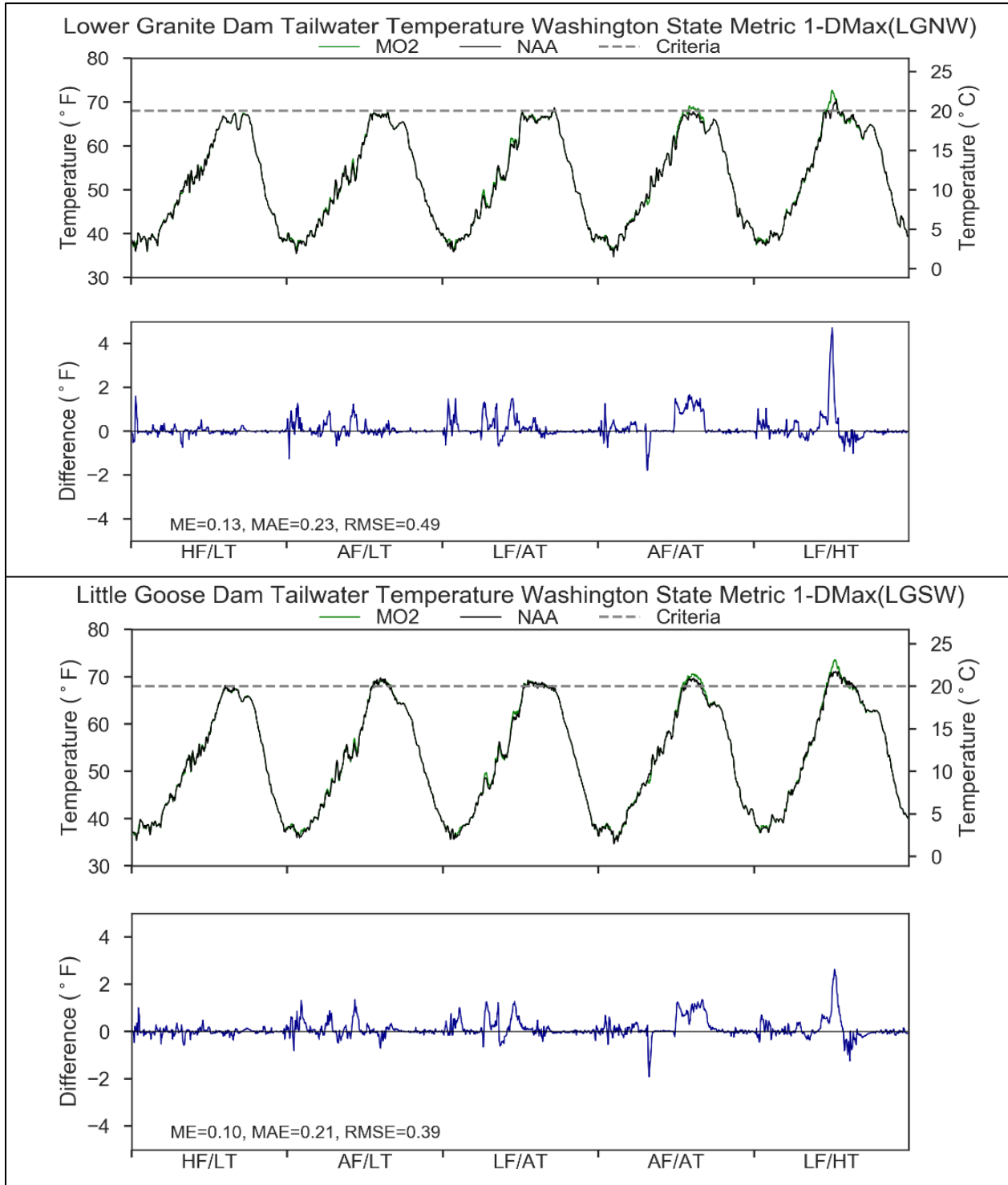
3920
 3921 **Figure 5-24. Modeled Tailwater Temperature for the No Action Alternative and Multiple**
 3922 **Objective Alternative 2 at Dworshak Dam Under a 5-Year Range of River and Meteorological**
 3923 **Conditions**

3924 **Table 5-1. Monthly Average Temperature Differences Between Multiple Objective Alternative**
 3925 **2 and the No Action Alternative Model Results at Dworshak Dam Outflow for Five Flow and**
 3926 **Meteorological Conditions**

Month	Flow and Air Temperature Conditions				
	HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
April	0.0	-0.1	0.5	-0.1	-0.1
May	0.3	0.2	0.4	0.8	0.0
June	-0.3	-0.1	0.2	1.2	0.4
July	0.0	-0.1	0.6	1.6	-0.3
August	-0.1	0.0	0.0	0.0	-0.4
September	0.2	-0.1	-0.5	-0.4	-0.5

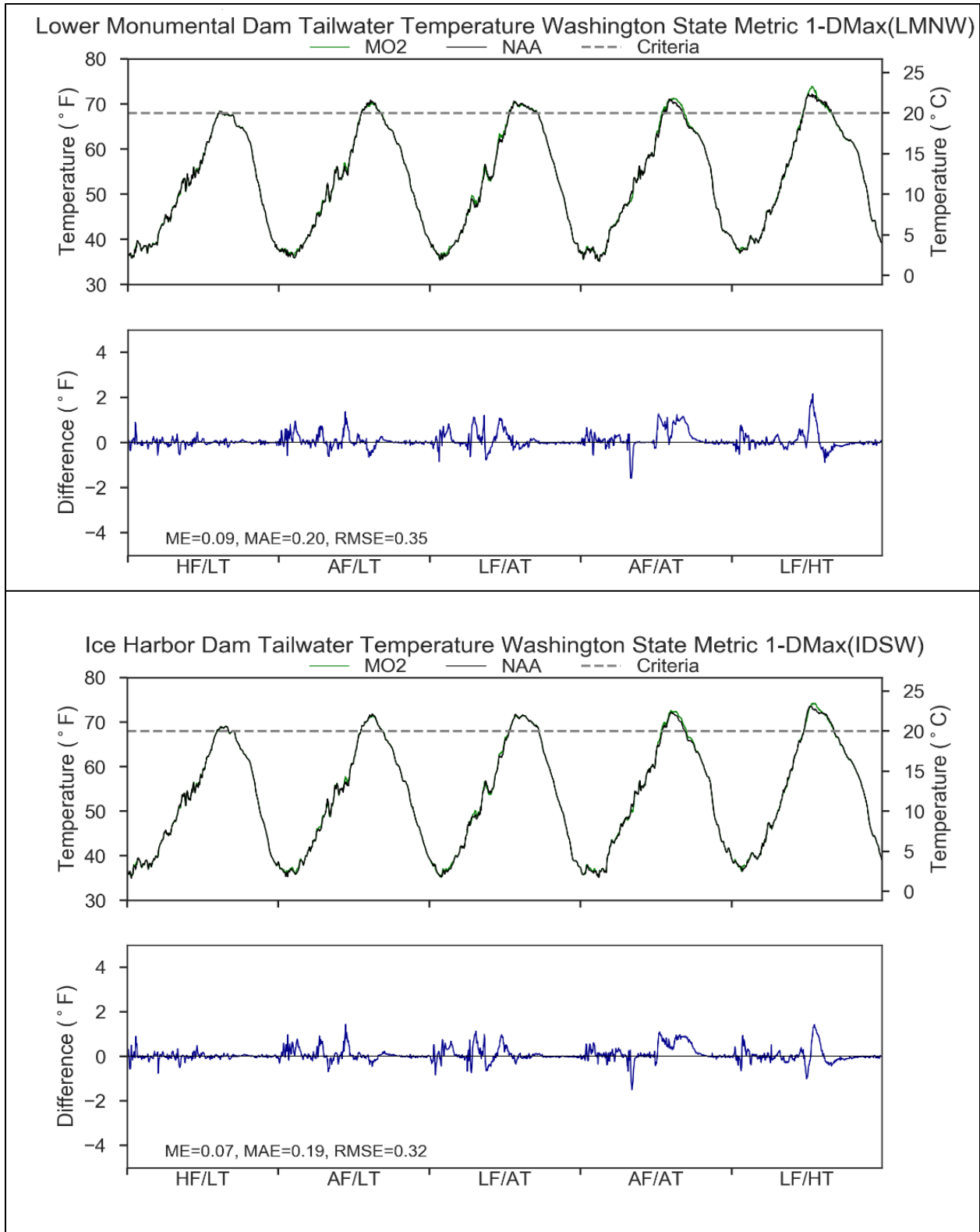
3927
 3928

5.2.1.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and Reservoirs



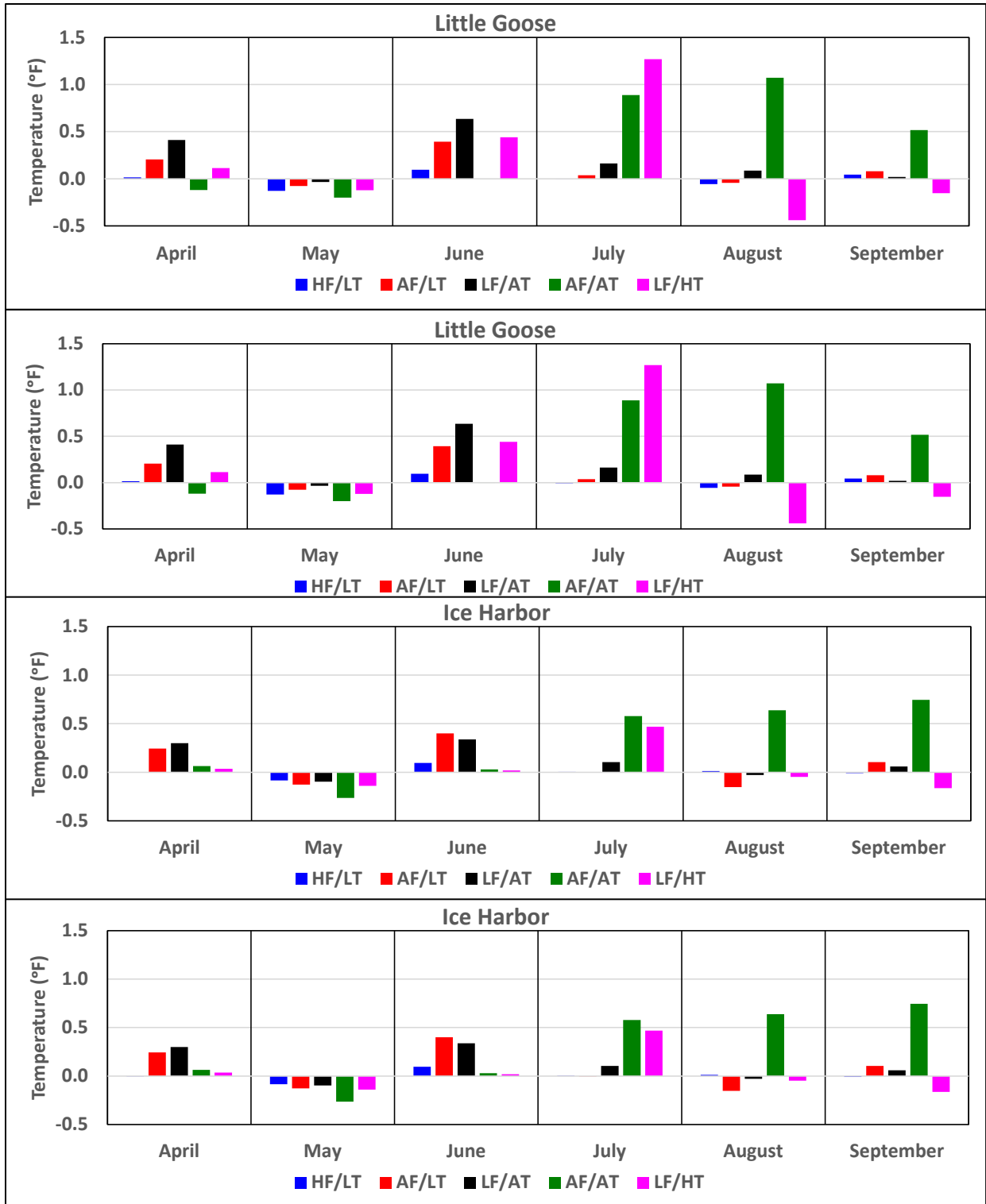
3929
 3930
 3931
 3932

Figure 5-25. Modeled Tailwater Temperatures for the No Action Alternative and Multiple Objective Alternative 2 at Lower Granite and Little Goose Dams Under a 5-Year Range of River and Meteorological Conditions



3933
 3934
 3935
 3936

Figure 5-26. Modeled Tailwater Temperatures for the No Action Alternative and Multiple Objective Alternative 2 at Lower Monumental and Ice Harbor Dams Under a 5-Year Range of River and Meteorological Conditions



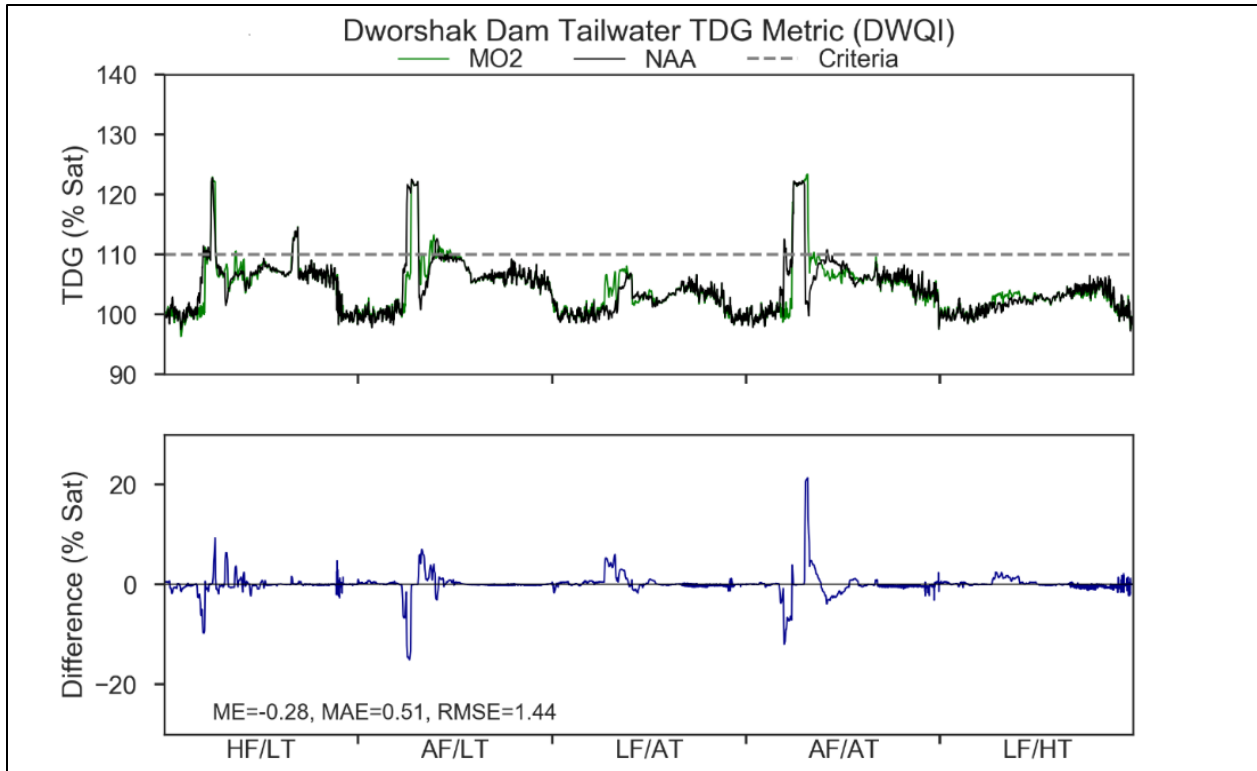
3937
 3938 **Figure 5-27. Differences to the Temperature that Would Occur Within Selected Ranges if**
 3939 **Multiple Objective Alternative 2 is Implemented when Compared to the No Action**
 3940 **Alternative at the Four Lower Snake River Dam Tailwater Locations Under a 5-Year Range of**
 3941 **River and Meteorological Conditions**

3942 **5.2.2 Total Dissolved Gas**

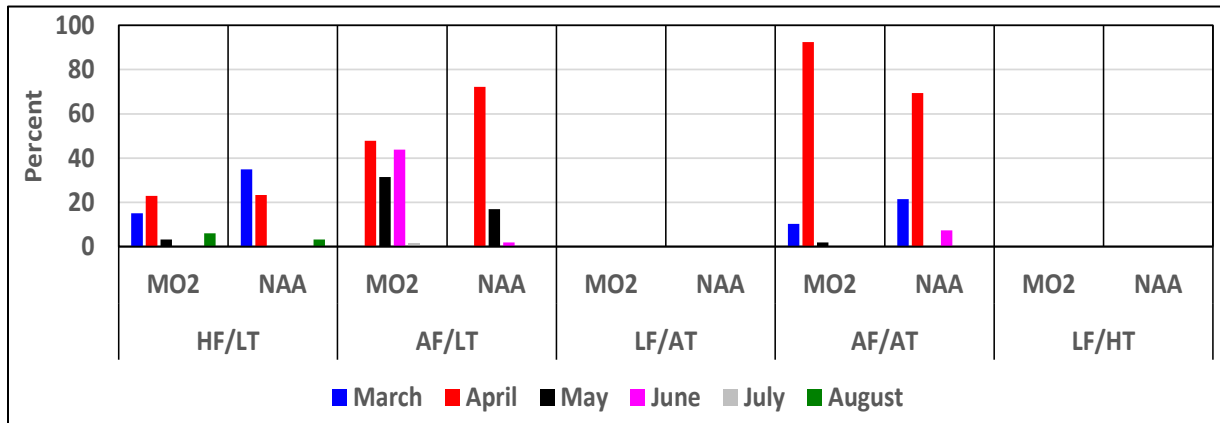
3943 **5.2.2.1 Dworshak Dam and Reservoir**

3944 Total gas saturation downstream from Dworshak Dam in the North Fork Clearwater River could
3945 increase during some months if MO2 was implemented (Figure 5-28.), however during realtime
3946 implementation of this measure, this would be avoided so as not to violate water quality TDG
3947 standards. Model results show that the operational rule set modeled for MO2 would create the
3948 largest increase in TDG during April with AF/AT conditions when 93 percent of the monthly TDG
3949 values would be greater than 110 percent saturation, and 88 percent would exceed 120 percent
3950 saturation. In comparison, 69 percent of the data would exceed the 110 percent standard for
3951 the same month under the No Action Alternative (Figure 5-29.). Notable increases would also
3952 occur under MO2 (as modeled) in May and June during AF/LT conditions. MO2 TDG saturations
3953 would be greater than 110 percent almost 32 percent of the time during May compared to 15
3954 percent of the time under the No Action Alternative. The June increase would be greater,
3955 reaching 44 percent of the time under MO2 compared to 2 percent of the time under the No
3956 Action Alternative.

3957 There are also a few instances when the TDG saturation would decrease if MO2 was
3958 implemented. Two of these instances would occur during March. During HF/LT conditions, the
3959 110 percent standard would be exceeded 15 percent of the time if MO2 was implemented
3960 compared to 35 percent for the time for the No Action Alternative. About 4 percent of the data
3961 would be greater than 120 percent for both alternatives. A similar reduction would occur during
3962 March with AF/AT conditions when the 110 percent standard would be exceeded about 10
3963 percent of the time under MO2 compared to 22 percent of the time under the No Action
3964 Alternative. Finally, during April of AF/LT conditions, the 110 percent criteria would be
3965 exceeded 48 percent of the time under MO2, down from 72 percent under the No Action
3966 Alternative. The percentage of time that the gas saturation would be greater than 120 percent
3967 would decrease from 63 percent for the No Action Alternative to 42 percent for MO2.



3968
 3969 **Figure 5-28. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and**
 3970 **Multiple Objective Alternative 2 at Dworshak Dam Under a 5-Year Range of River and**
 3971 **Meteorological Conditions**



3972
 3973 **Figure 5-29. Percent of the Monthly Total Dissolved Gas Data that is Greater than 110 Percent**
 3974 **for the Multiple Objective Alternative 2 and No Action Alternative Modeled for Dworshak**
 3975 **Dam Tailwater by Month for Five Meteorological Conditions**

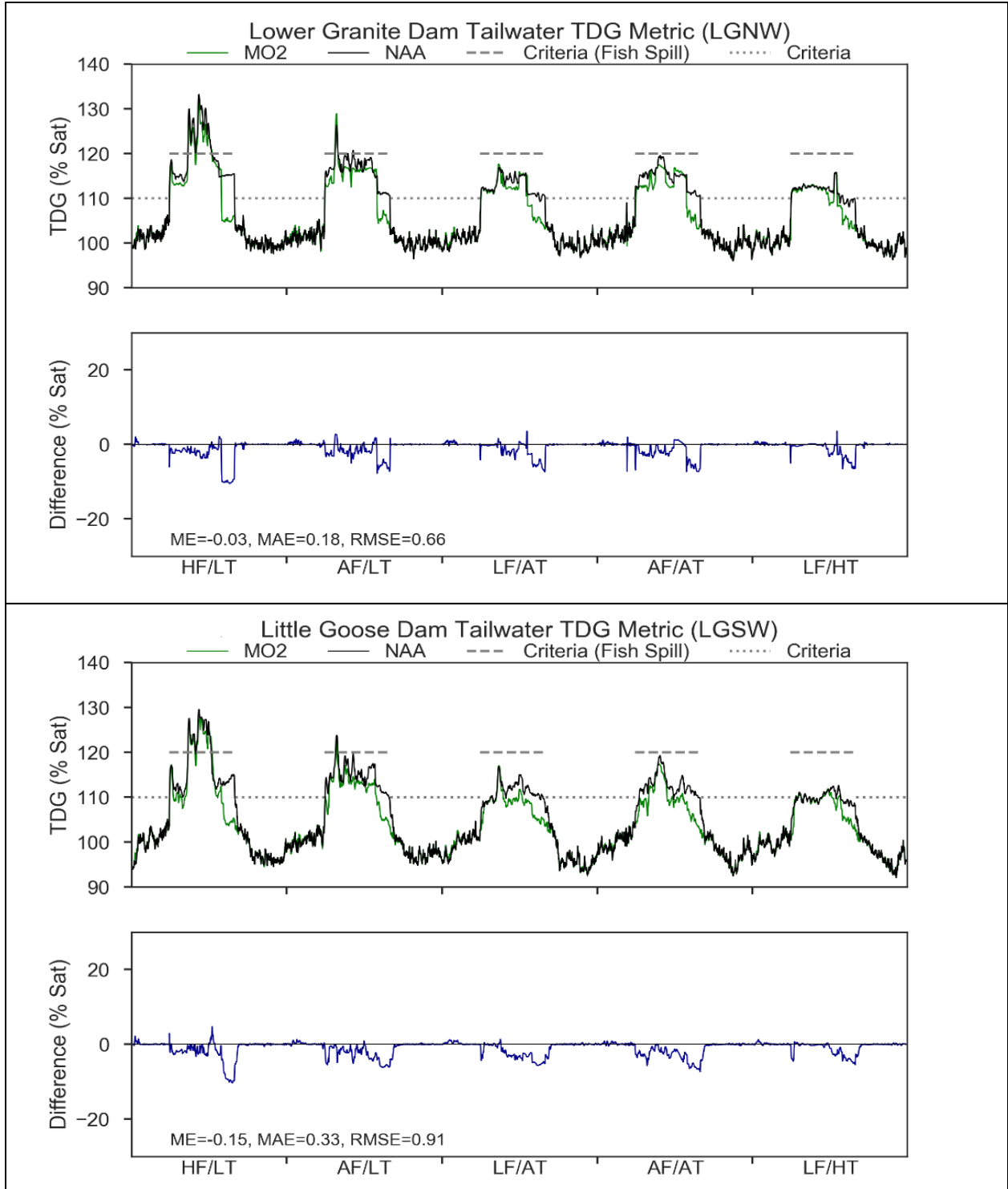
3976 **5.2.2.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
 3977 **Reservoirs**

3978 One of the operational measures within MO2 is to only spill for juvenile fish passage from April
 3979 through July while keeping the TDG saturation in the river at less than 110 percent (Figure 5-30).

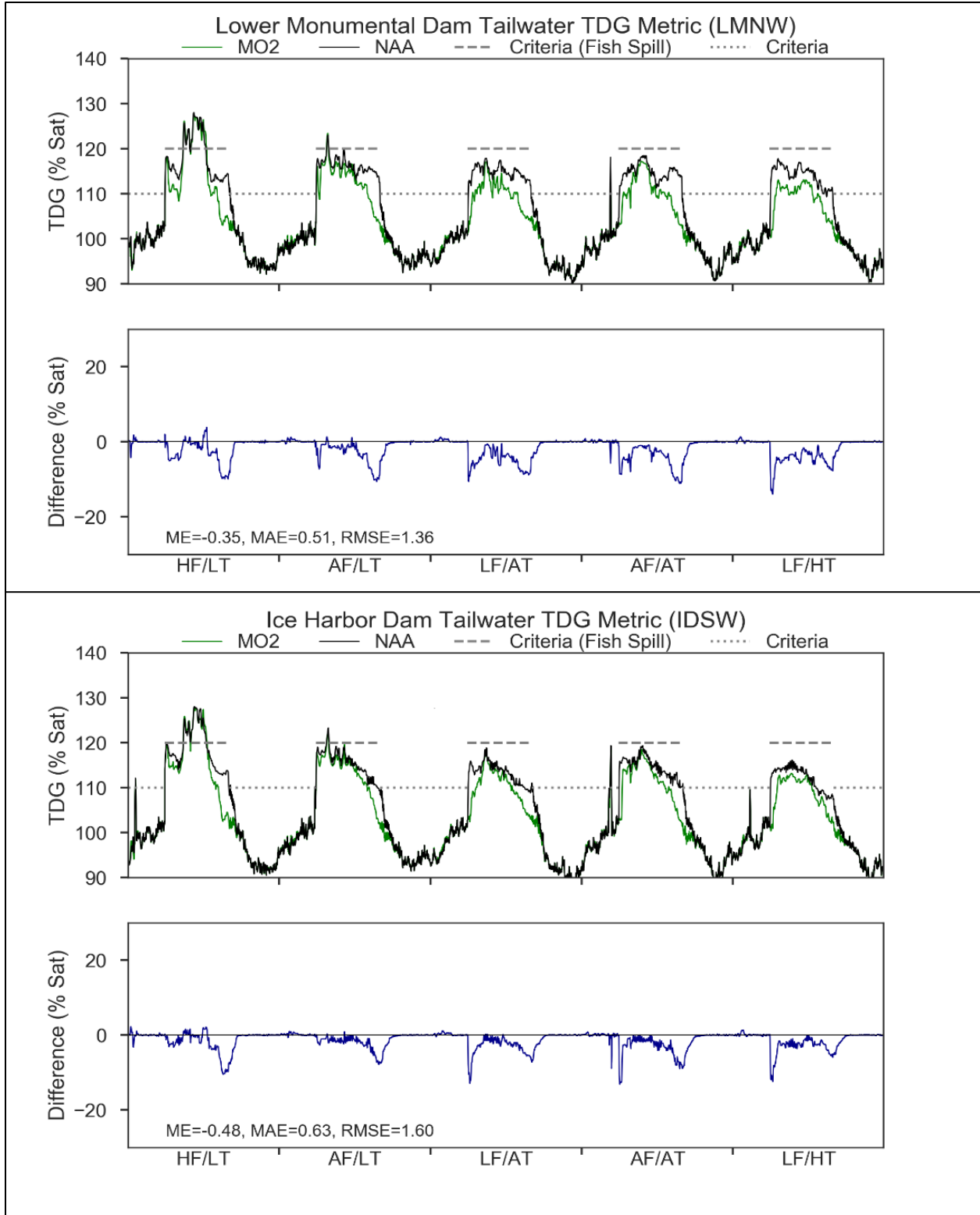
3980 and Figure 5-31.). Juvenile fish spill would not occur in August, but data for that month is
3981 included here to make comparisons with No Action Alternative model output. The combined
3982 April through August model data for each project tailwater location shows a shift toward a
3983 greater incidence of TDG saturation less than 110 percent at all projects (Figure 5-32.). Overall
3984 increases in the less than 110 percent category would range from about 12 percent at Little
3985 Goose Dam during LF/HT conditions to greater than 40 percent at both Little Goose and Lower
3986 Monumental projects during LF/AT and AF/AT conditions. Along with the greater amount of
3987 time that TDG would be less than 110 percent, there would be corresponding reductions in the
3988 higher TDG categories—typically the 110 to 115 percent and 115 to 120 percent ranges.

3989 The percent of time that tailwater TDG saturation would occur within specific ranges, from April
3990 through August, at each of the four lower Snake River projects are shown in Figure 5-33.
3991 through Figure 5-36.. There are several instances when no change, or a very small change,
3992 would occur. These were usually identified during LF/HT conditions at the Lower Granite and
3993 Little Goose Dams during April, May, June, and August, as well as at Ice Harbor Dam during June
3994 and August. May, and in some cases June, were the two months during the spill season when
3995 the differences between MO2 and the No Action Alternative were low compared to the other
3996 months, and that would be attributed to the higher river flows that occur during those months.
3997 The largest shifts to a lower TDG category would often occur in August because spill for fish
3998 would stop at the end of July under MO2.

3999 If implemented, maximum tailwater TDG saturation would exceed the 110 percent criteria at
4000 each of the four lower Snake River projects (Figure 5-37.) due to minimum spill requirements,
4001 lack of market conditions and involuntary spill. Maximum levels would remain below 120
4002 percent during most months and flow/meteorological conditions. The exceptions would occur
4003 during May, June, and July of HF/LT conditions when concentrations would exceed 125 percent
4004 at all four dams, and during April of AF/LT conditions when maximum gas saturations would
4005 range from 122 percent at Ice Harbor Dam to 125 percent at Lower Granite Dam. Maximum
4006 TDG levels during August would be less than 110 percent for almost all flow/meteorological
4007 conditions, the exceptions being Lower Monumental and Ice Harbor tailwaters during HF/LT
4008 conditions when gas saturation could reach 112 percent.

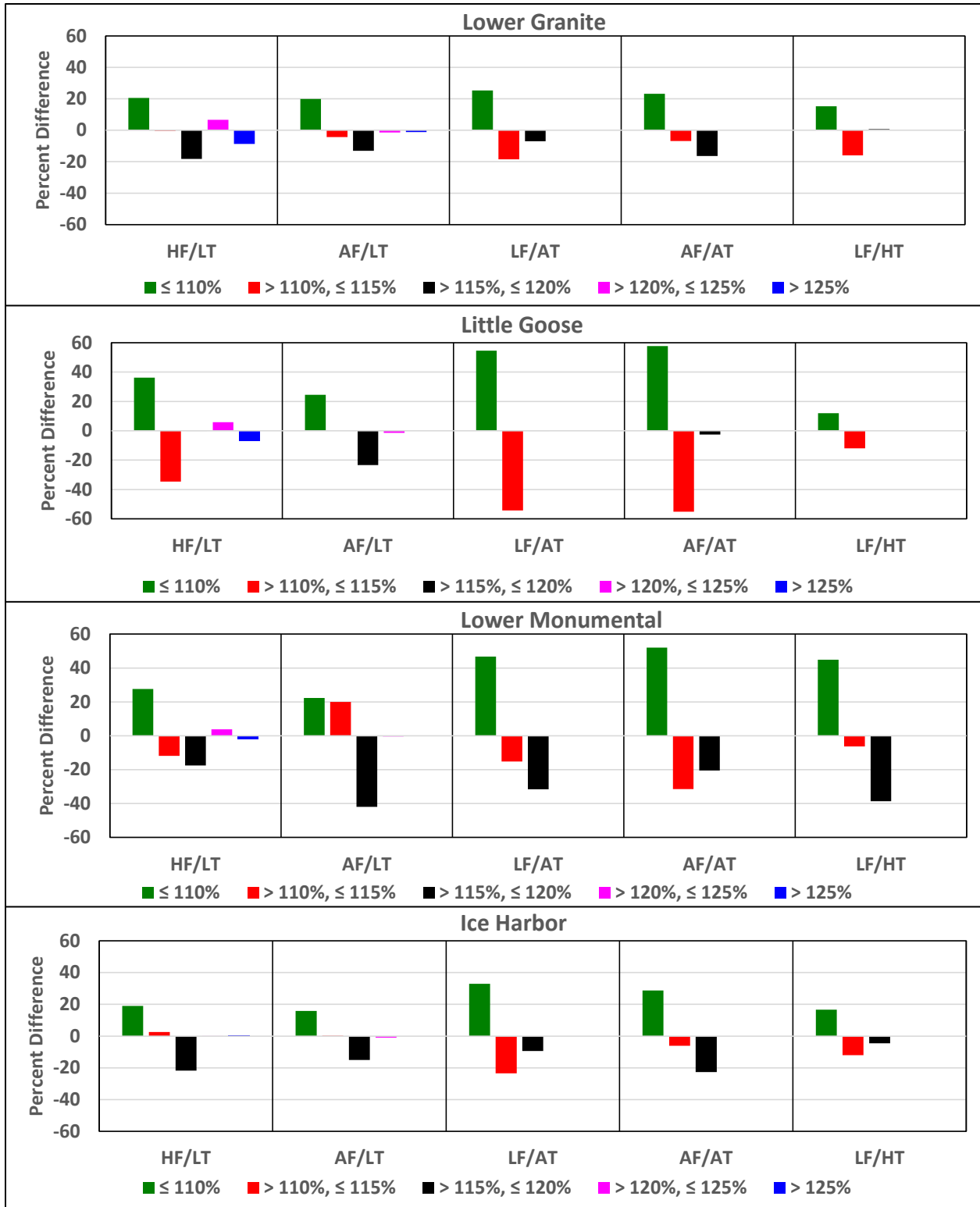


4009
 4010 **Figure 5-30. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and**
 4011 **Multiple Objective Alternative 2 at Lower Granite and Little Goose Dams Under a 5-Year**
 4012 **Range of River and Meteorological Conditions**



4013
 4014
 4015
 4016

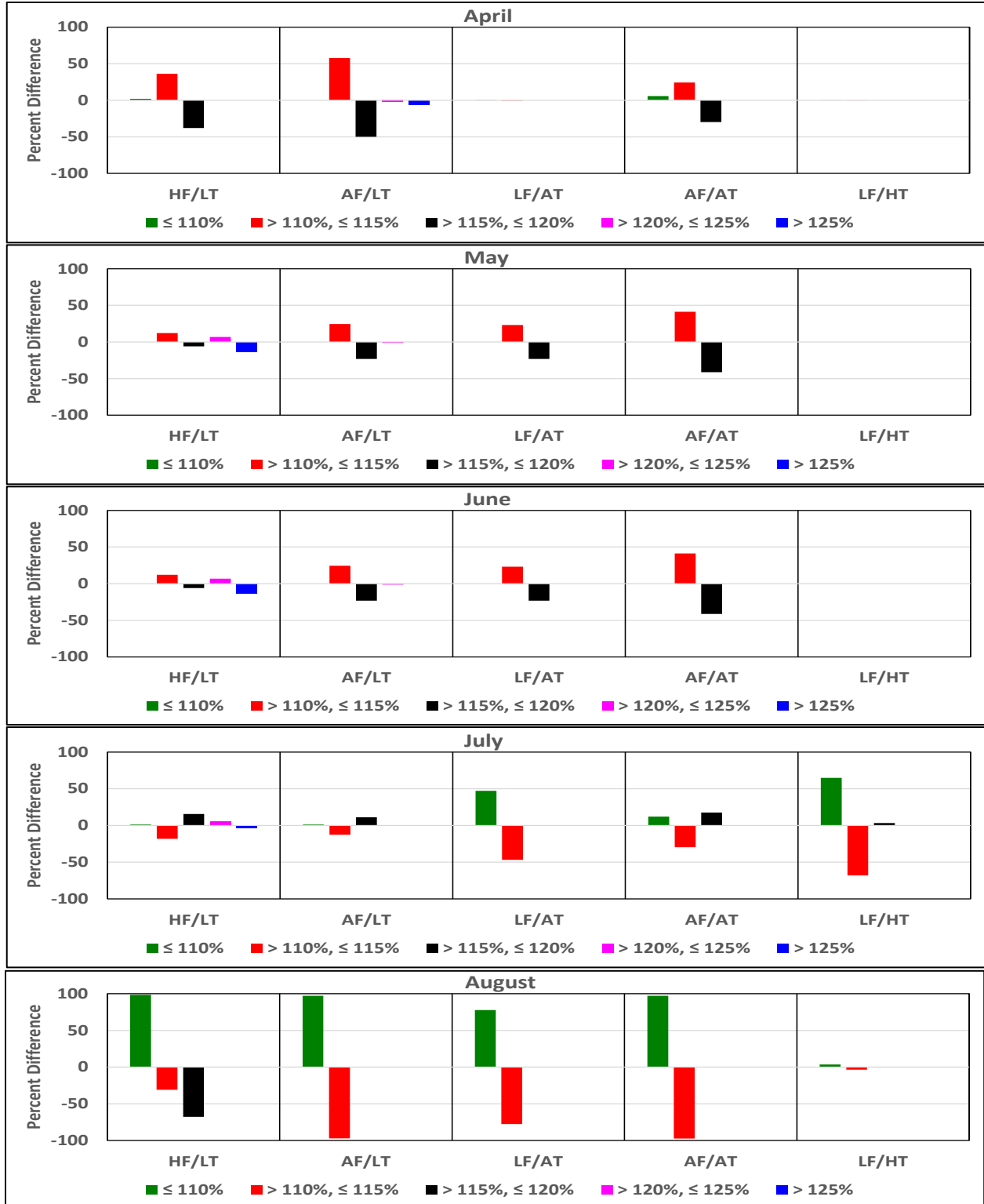
Figure 5-31. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and Multiple Objective Alternative 2 at Lower Monumental and Ice Harbor Dams Under a 5-year Range of River and Meteorological Conditions



4017
 4018
 4019
 4020
 4021

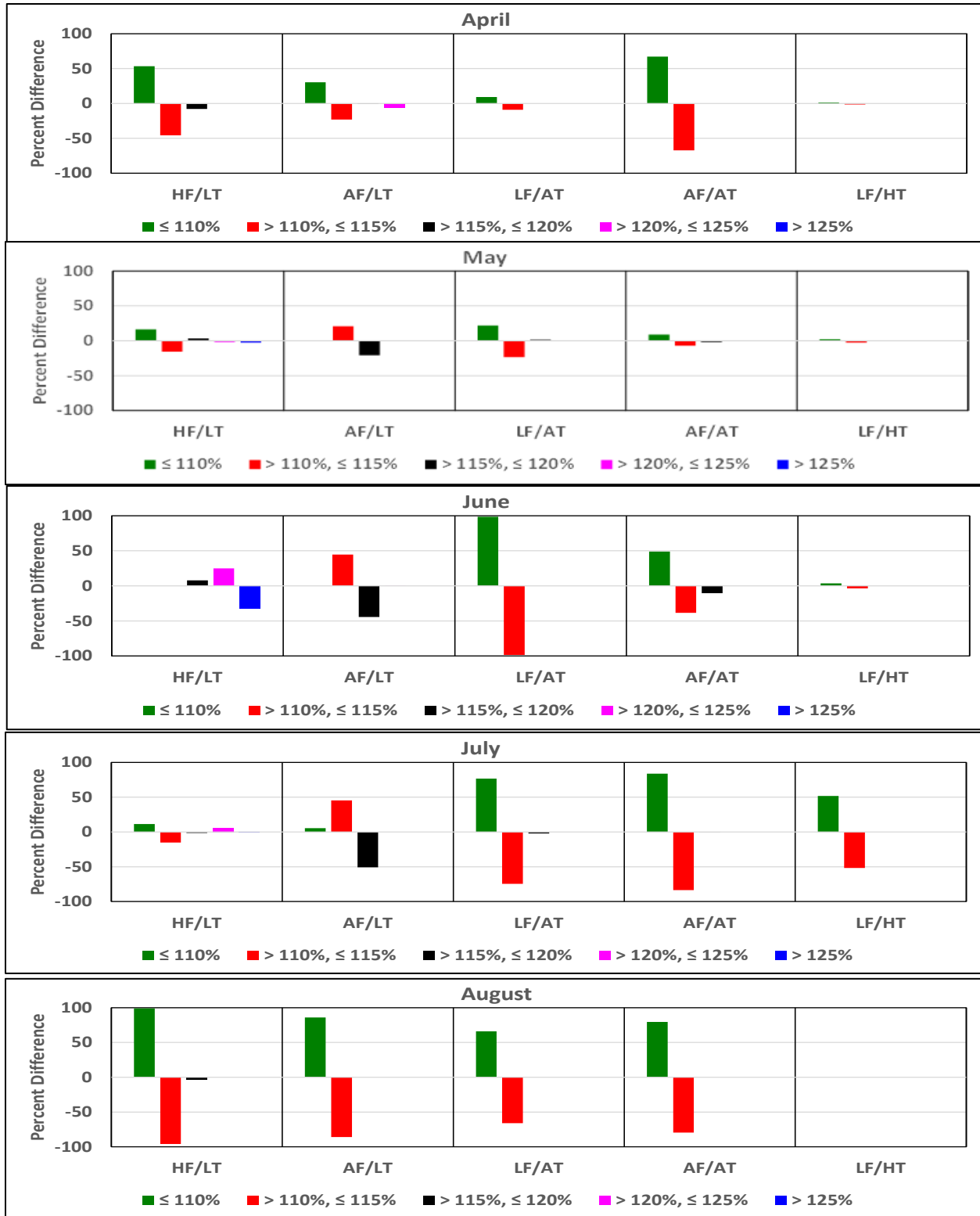
Figure 5-32. Differences to the Percent of Total Dissolved Gas that Would Occur Within Selected Ranges if Multiple Objective Alternative 2 is Implemented when Compared to the No Action Alternative at the Four Lower Snake River Dam Tailwater Locations Under a 5-Year Range of River and Meteorological Conditions

*Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix*



4022
4023
4024
4025
4026

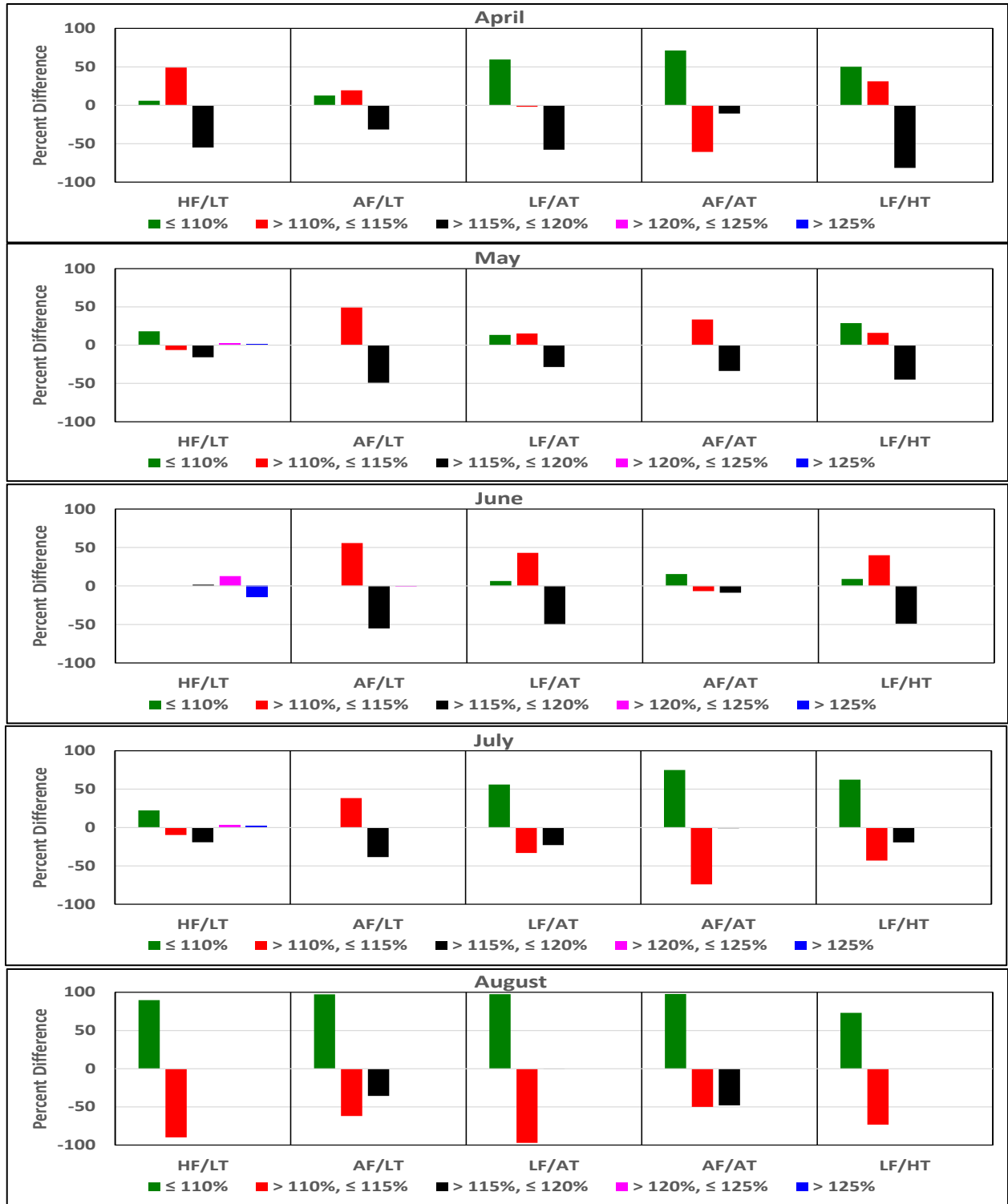
Figure 5-33. Differences in the Percent of Time that Total Dissolved Gas Would be Within Selected Ranges if Multiple Objective Alternative 2 is Implemented when Compared to the No Action Alternative at Lower Granite Dam Tailwater Under a 5-Year Range of River and Meteorological Conditions



4027
 4028
 4029
 4030
 4031

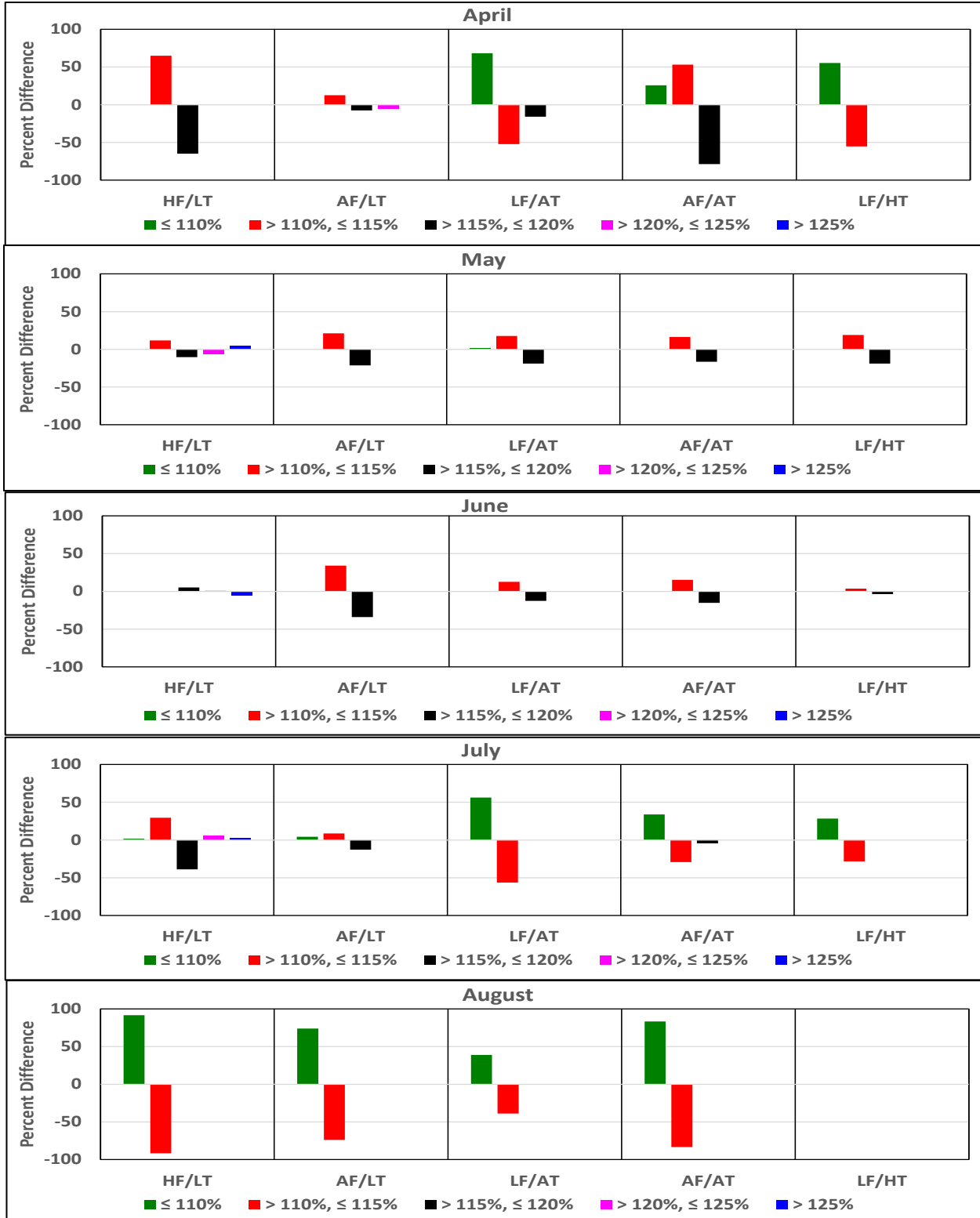
Figure 5-34. Differences in the Percent of Time that Total Dissolved Gas Would be Within Selected Ranges if Multiple Objective Alternative 2 is Implemented when Compared to the No Action Alternative at Little Goose Dam Tailwater Under a 5-Year Range of River and Meteorological Conditions

*Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix*



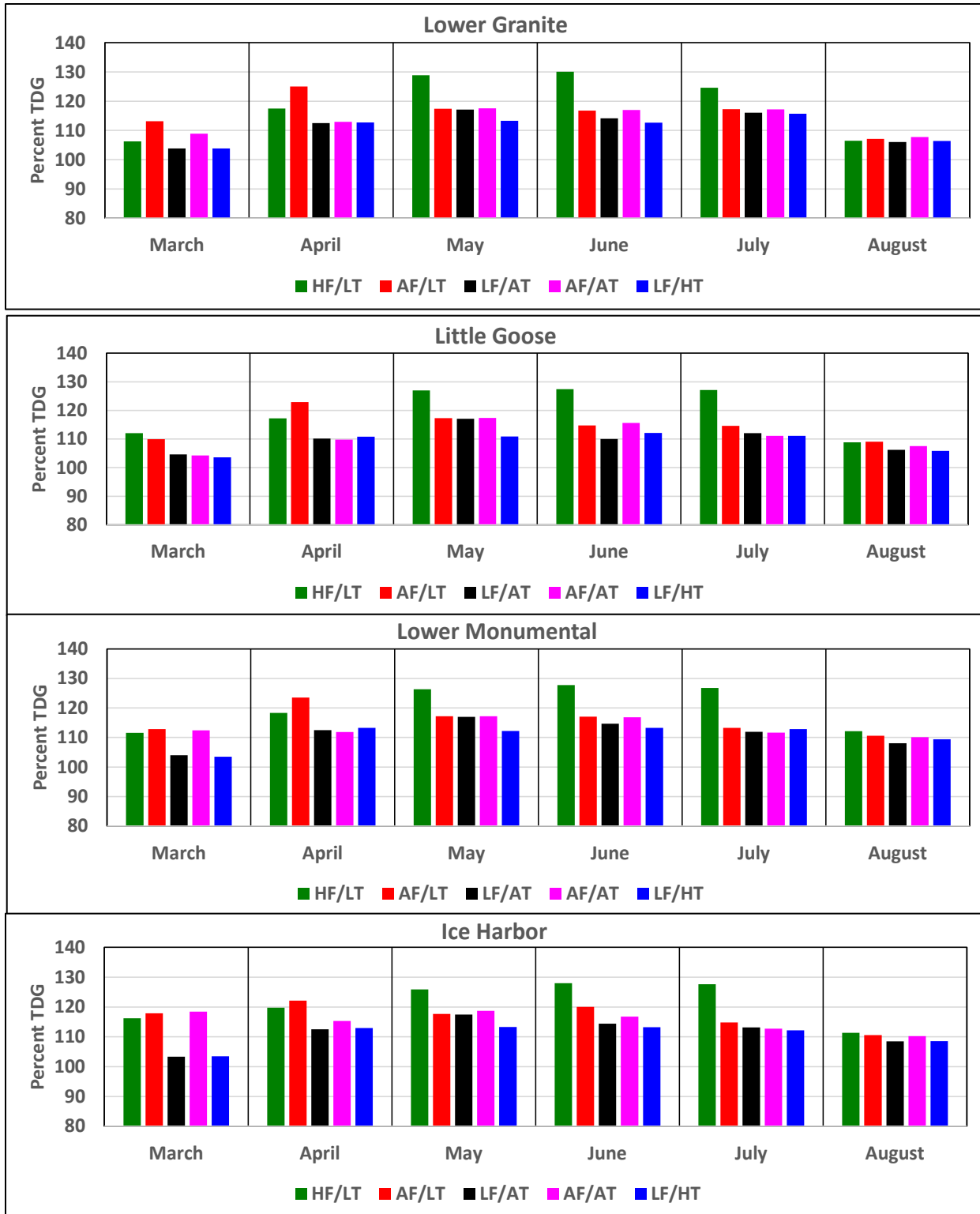
4032
4033
4034
4035
4036

Figure 5-35. Differences in the Percent of Time that Total Dissolved Gas Would be Within Selected Ranges if Multiple Objective Alternative 2 is Implemented when Compared to the No Action Alternative at Lower Monumental Dam Tailwater Under a 5-Year Range of River and Meteorological Conditions



4037
 4038
 4039
 4040
 4041

Figure 5-36. Differences in the Percent of Time that Total Dissolved Gas Would be Within Selected Ranges if Multiple Objective Alternative 2 is Implemented when Compared to the No Action Alternative at Ice Harbor Dam Tailwater Under a 5-year Range of River and Meteorological Conditions

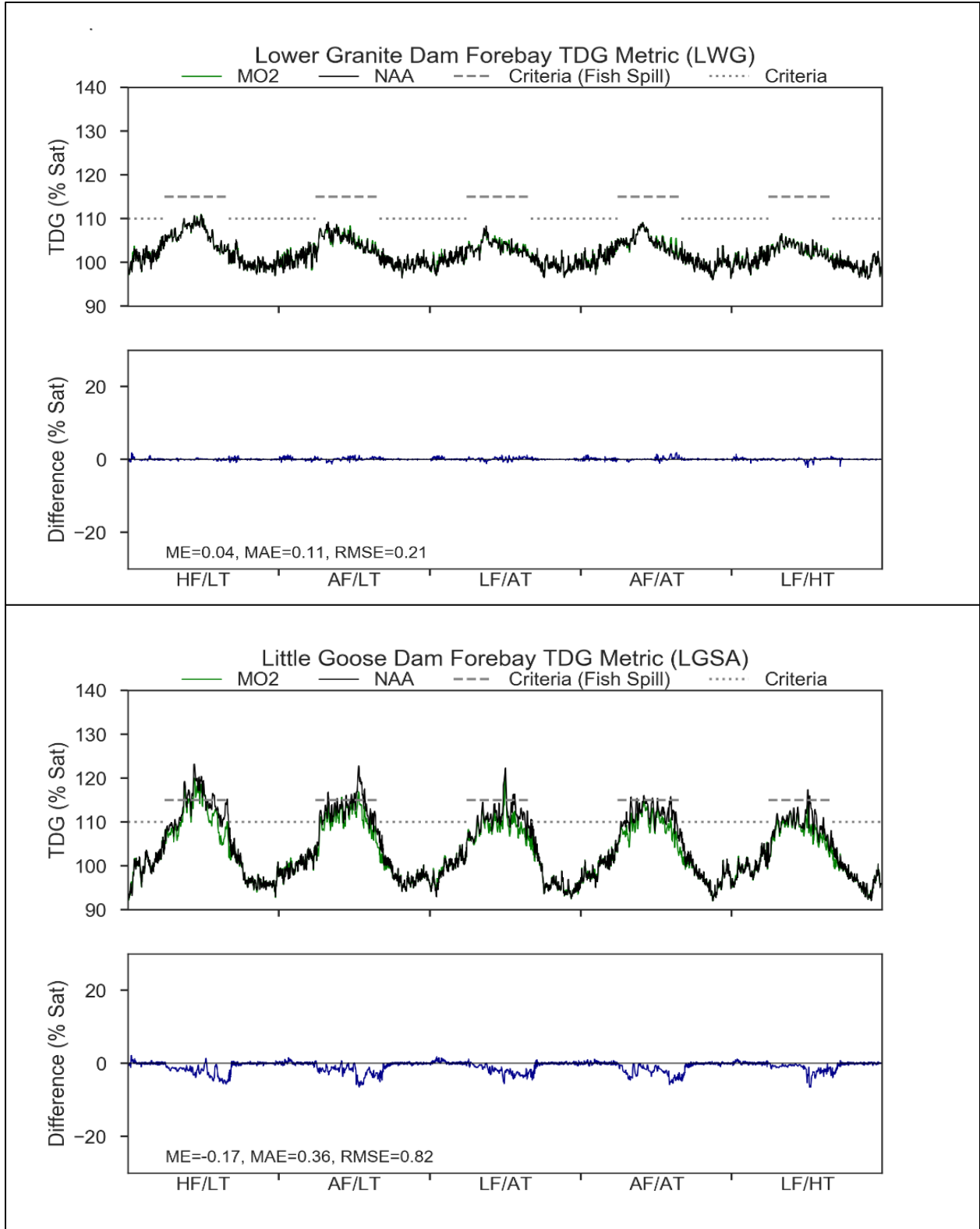


4042
 4043
 4044
 4045

Figure 5-37. Maximum Total Dissolved Gas that Would be Expected at the Four Lower Snake River Dam Tailwater Locations During the Fish Passage Season if Multiple Objective Alternative 2 is Implemented Under a 5-Year Range of River and Meteorological Conditions

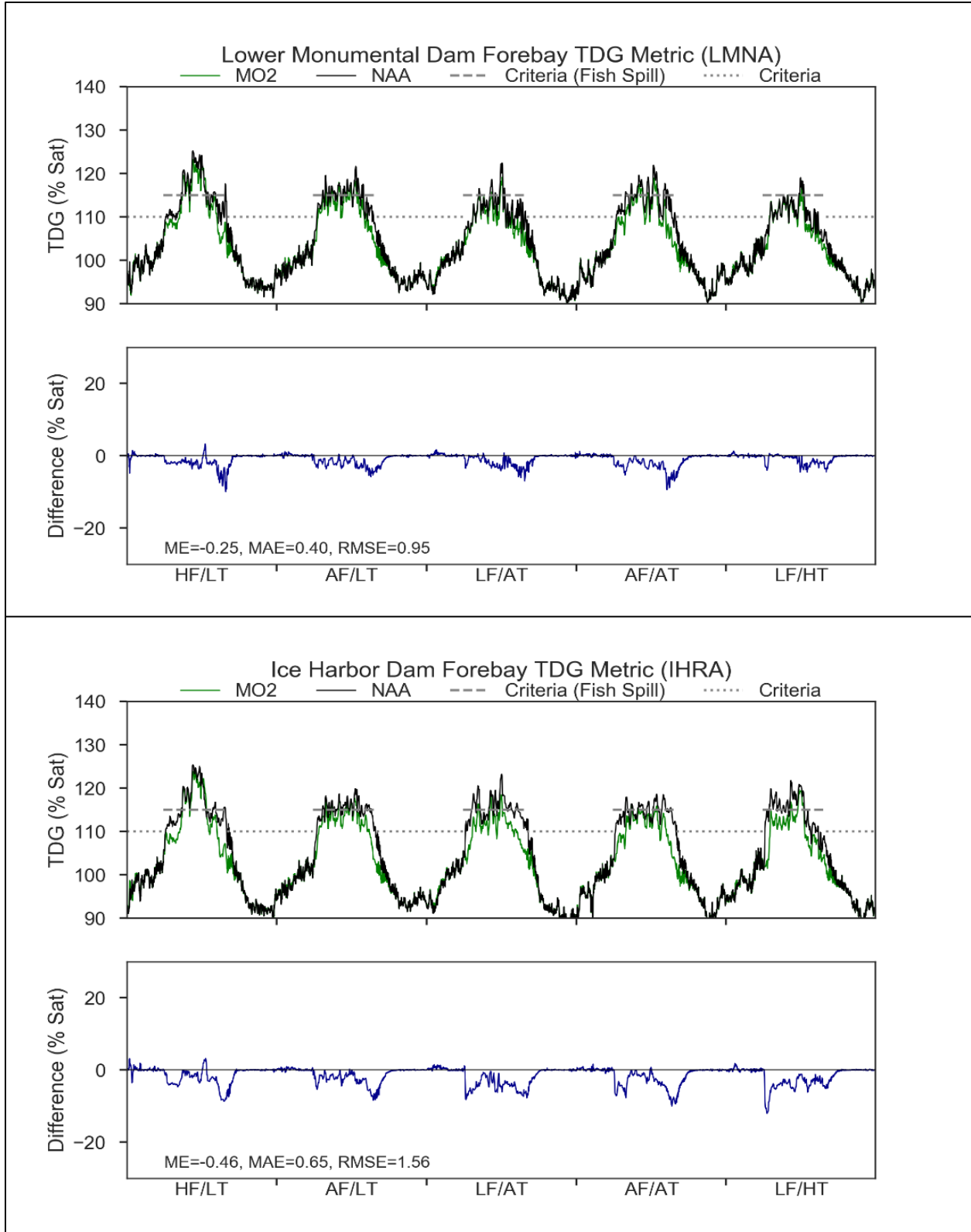
4046 The MO2 model results for the lower Snake River dam forebay locations show that TDG would
4047 often be greater than 110 percent (Figure 5-38. and Figure 5-39.). Maximum concentrations
4048 greater than 120 percent would occur during June and July during HF/LT conditions at the three
4049 lower projects. Gas saturation would range from 110 to 120 percent from April through August
4050 during AF/LT, LF/AT, and LF/HT conditions, as well as May through August of HF/LT and AF/AT
4051 conditions (Figure 5-40.). The exception to this pattern would be at Lower Granite forebay
4052 where the maximum gas saturation would only reach 112 percent during HF/LT June conditions
4053 and remain less than 110 percent the rest of the time.

4054 Comparisons of MO2 to No Action Alternative changes in the percent of time that forebay TDG
4055 saturation would occur within specific ranges for each month from April through August at each
4056 of the four lower Snake River projects are shown in Figure 5-41.. No differences were identified
4057 for Lower Granite Dam forebay. However, the trends at the three lower projects from April
4058 through August is for an increase in the proportion of values in the less than 110 percent
4059 category ranging from 7 to 41 percent, and corresponding decreases in the 110 to 115 percent
4060 and 115 to 120 percent categories (Figure 5-42. through Figure 5-44.). Individual monthly
4061 responses would occur at each project due to distances between the projects and degassing
4062 rates. There would be several instances, though not consistent across projects, when no
4063 change, or a very small change (less than 5 percent) would occur. Examples include the Little
4064 Goose forebay during April of HF/LT and LF/AT conditions, as well as August during LF/HT
4065 conditions. Minimal changes at Lower Monumental Dam would occur during LF/HT conditions
4066 in each month except July, as well as during April of LF/AT conditions. Maximum shifts toward
4067 values less than 110 percent at the three lower projects would occur during August when
4068 HF/LT, AF/LT, LF/AT, and AF/AT conditions prevail due to the lack of spill for fish. These
4069 downward shifts, 22 to 42 percent, would be least apparent at Lower Monumental forebay
4070 (Figure 5-45.) since TDG in that forebay is typically lower under the No Action Alternative than
4071 at Little Goose or Ice Harbor dams. The highest difference, 54 to 84 percent, between MO2 and
4072 the No Action Alternative would occur at Ice Harbor forebay (Figure 5-46.) because TDG at that
4073 location is typically higher under the No Action Alternative than at the upstream projects.

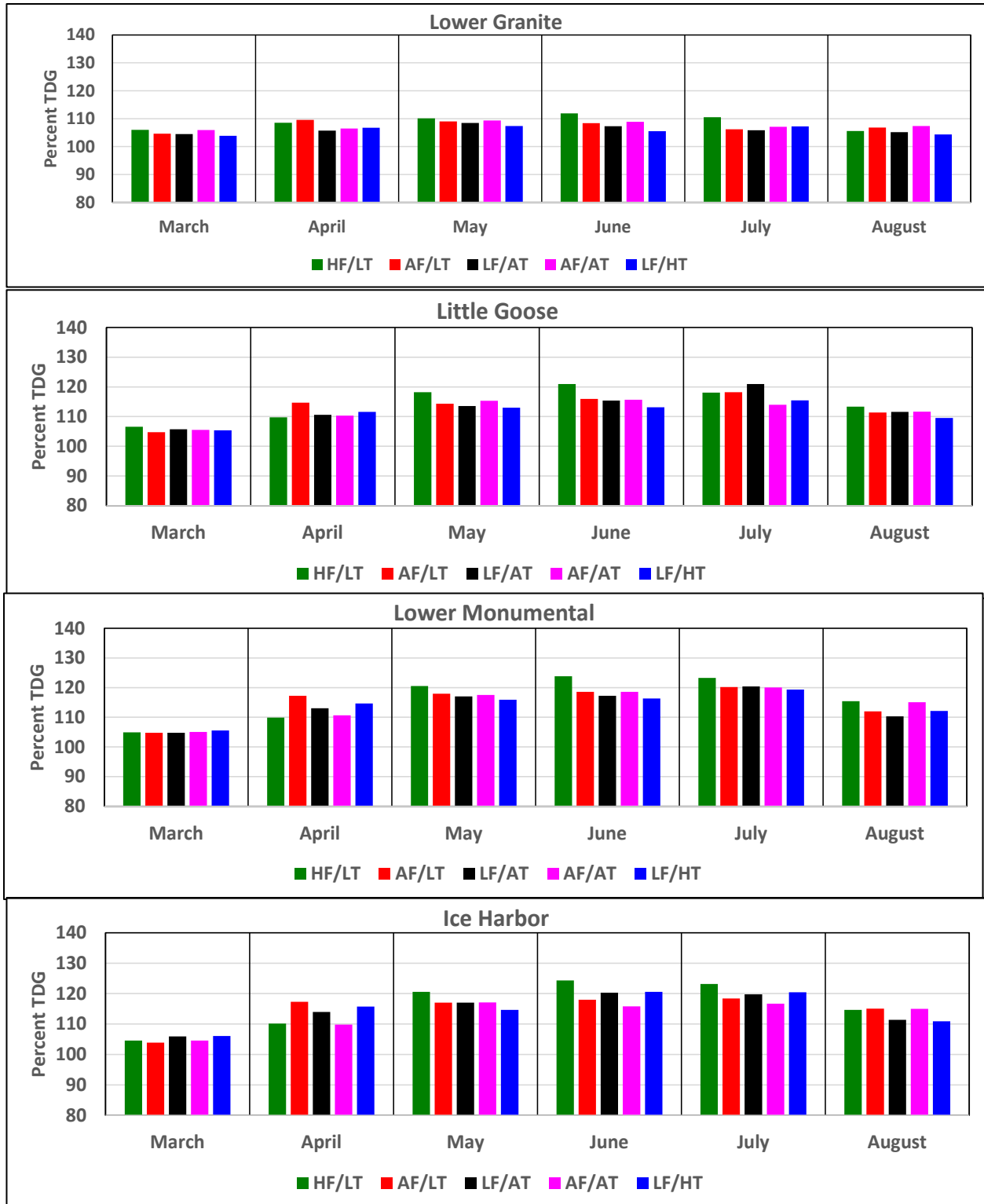


4074
 4075
 4076
 4077

Figure 5-38. Modeled Forebay Total Dissolved Gas for the No Action Alternative and Multiple Objective Alternative 2 at Lower Granite and Little Goose Dams Under a 5-Year Range of River and Meteorological Conditions

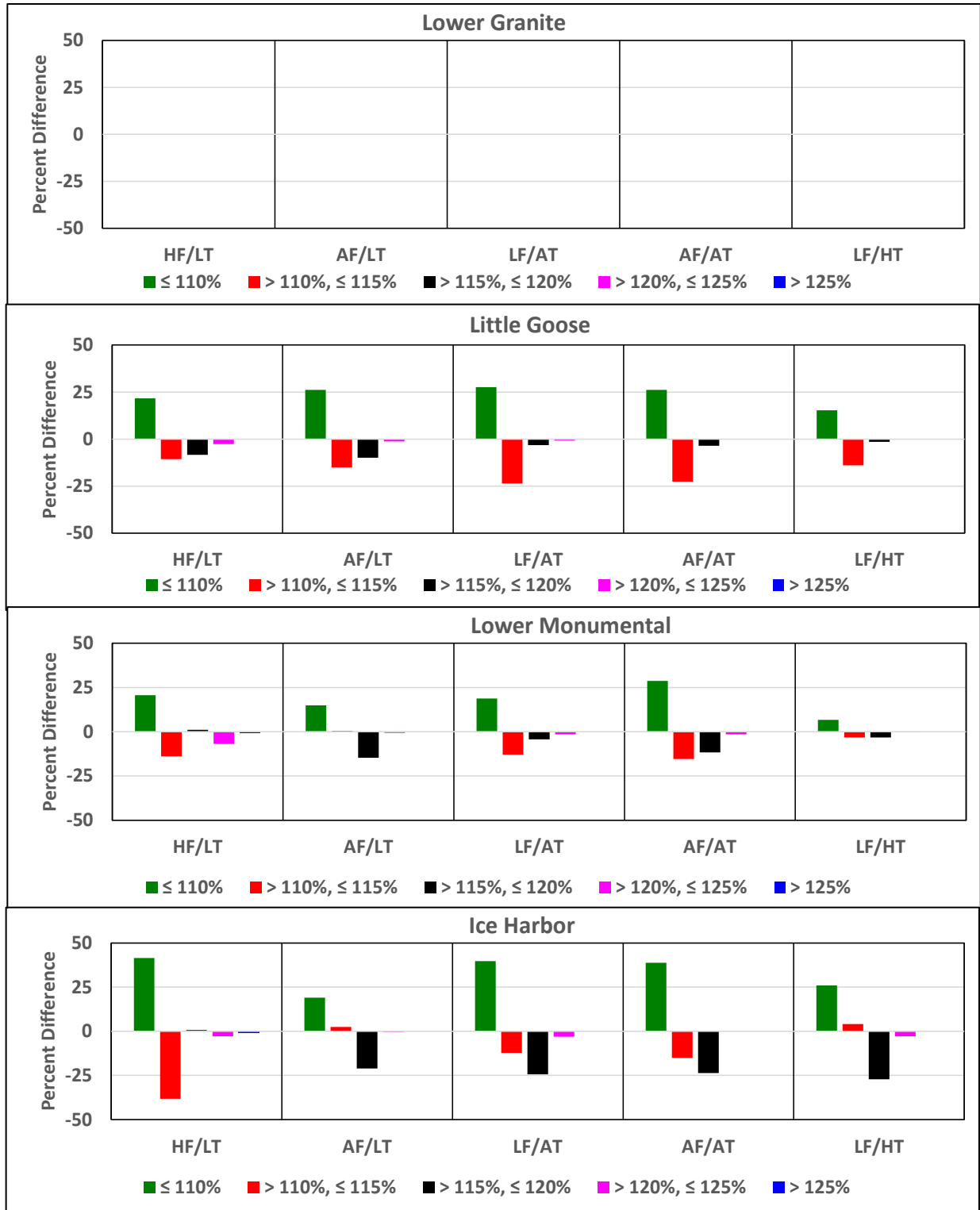


4078
 4079 **Figure 5-39. Modeled Forebay Total Dissolved Gas for the No Action Alternative and Multiple**
 4080 **Objective Alternative 2 at Lower Monumental and Ice Harbor Dams Under a 5-Year Range of**
 4081 **River and Meteorological Conditions**



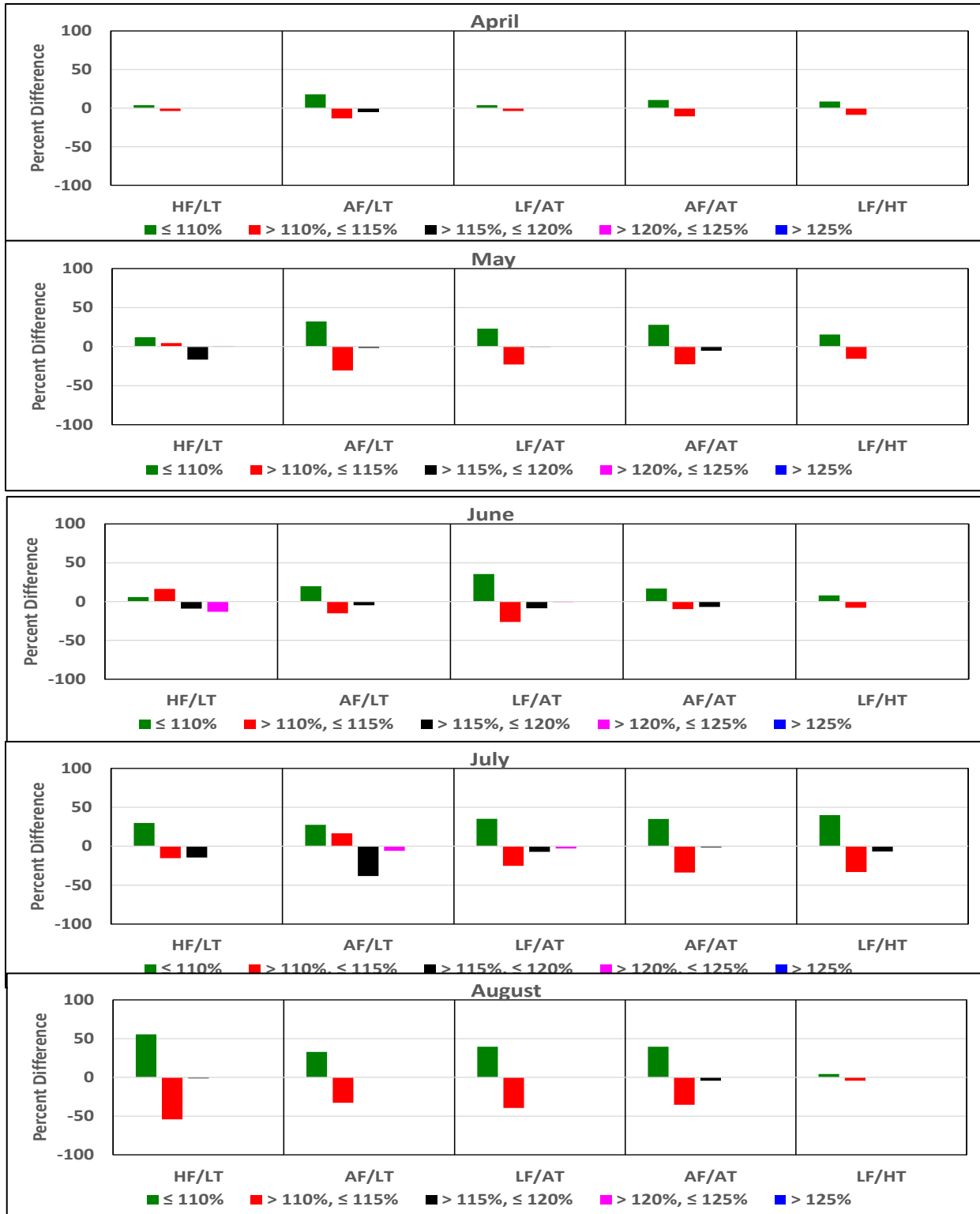
4082
 4083
 4084
 4085

Figure 5-40. Maximum Total Dissolved Gas that Would be Expected at the Four Lower Snake River Dam Forebay Locations During the Fish Passage Season if Multiple Objective Alternative 2 is Implemented Under a 5-Year Range of River and Meteorological Conditions



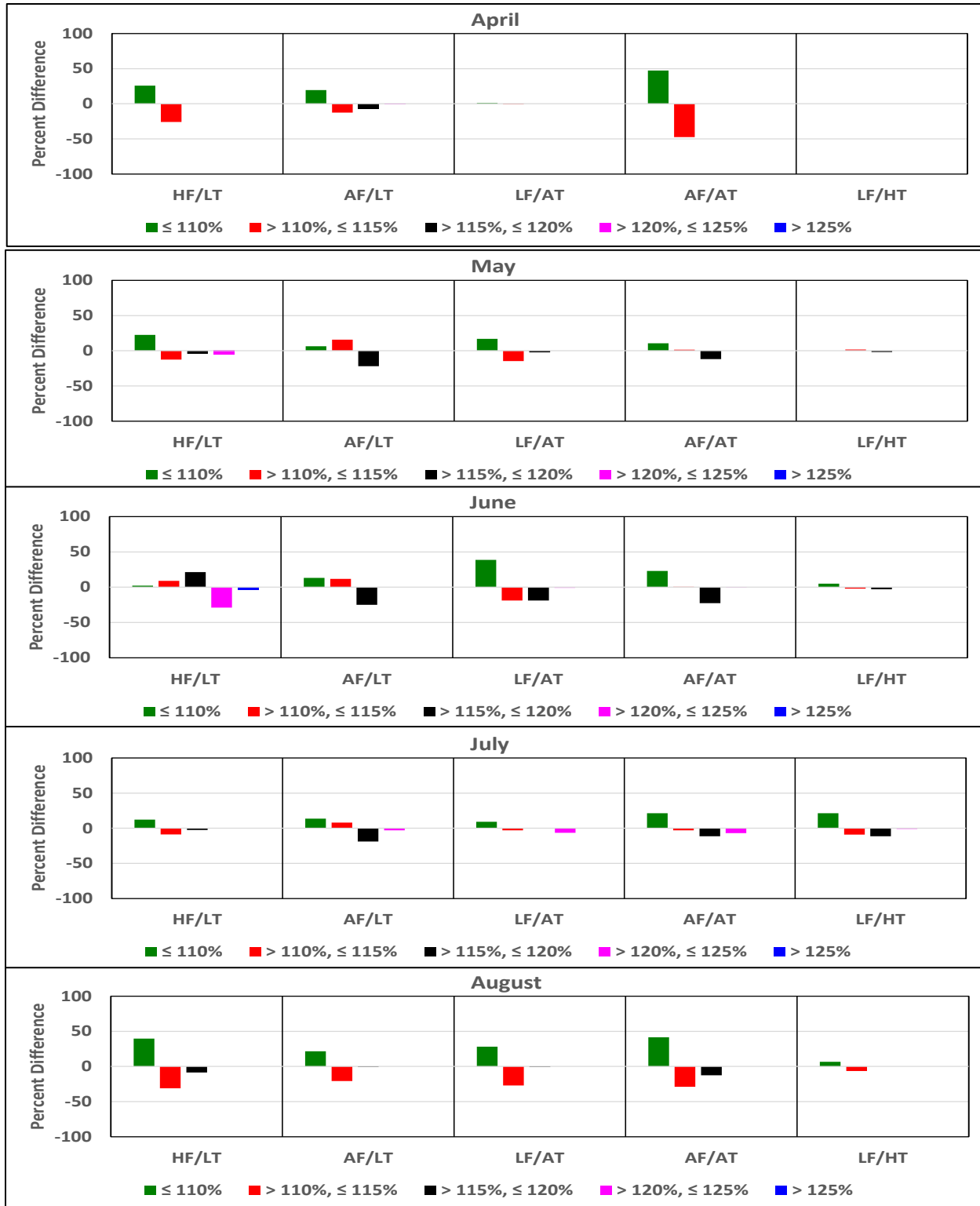
4086
 4087
 4088
 4089
 4090

Figure 5-41. Differences to the Percent of Total Dissolved Gas that Would Occur Within Selected Ranges from April Through August if Multiple Objective Alternative 2 is Implemented when Compared to No Action Alternative at the Four Lower Snake River Dam Forebay Locations Under a 5-Year Range of River and Meteorological Conditions



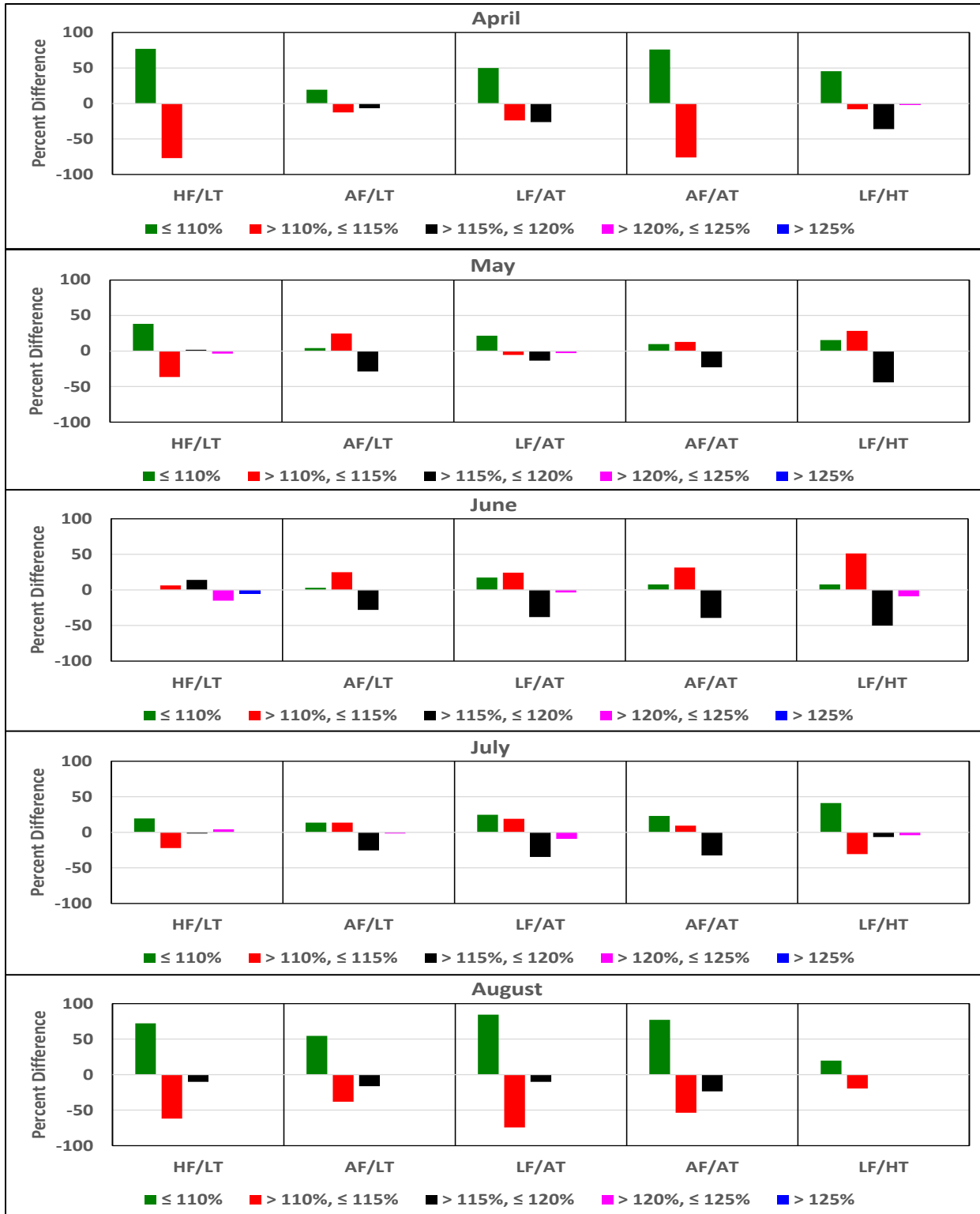
4091
 4092
 4093
 4094
 4095

Figure 5-42. Differences in the Percent of Time Total Dissolved Gas Would be Within Selected Ranges if Multiple Objective Alternative 2 is Implemented when Compared to the No Action Alternative at Little Goose Dam Forebay Under a 5-Year Range of River and Meteorological Conditions



4096
 4097
 4098
 4099
 4100

Figure 5-43. Differences in the Percent of Time Total Dissolved Gas Would be Within Selected Ranges if Multiple Objective Alternative 2 is Implemented when Compared to the No Action Alternative at Lower Monumental Dam Forebay Under a 5-Year Range of River and Meteorological Conditions



4101
 4102 **Figure 5-44. Differences in the Percent of Time Total Dissolved Gas Would be Within Selected**
 4103 **Ranges if Multiple Objective Alternative 2 is Implemented when Compared to the No Action**
 4104 **Alternative at Ice Harbor Dam Forebay Under a 5-Year Range of River and Meteorological**
 4105 **Conditions**

4106 **5.2.3 Other Physical, Chemical and Biological Processes**

4107 **5.2.3.1 Dworshak Dam and Reservoir**

4108 The lower water elevation of Dworshak Reservoir from April through June would result in a
4109 smaller surface area and consequently slower warming by solar radiation. Additionally,
4110 shallower water depths at the upper end of the reservoir where the North Fork Clearwater
4111 River, Little North Fork River, and Breakfast Creek enter would lead to higher flow velocities and
4112 delay in primary production.

4113 **5.2.3.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
4114 **Reservoirs**

4115 No changes are expected to occur with respect to the other physicochemical and biological
4116 parameters in the lower Snake River if MO2 is implemented.

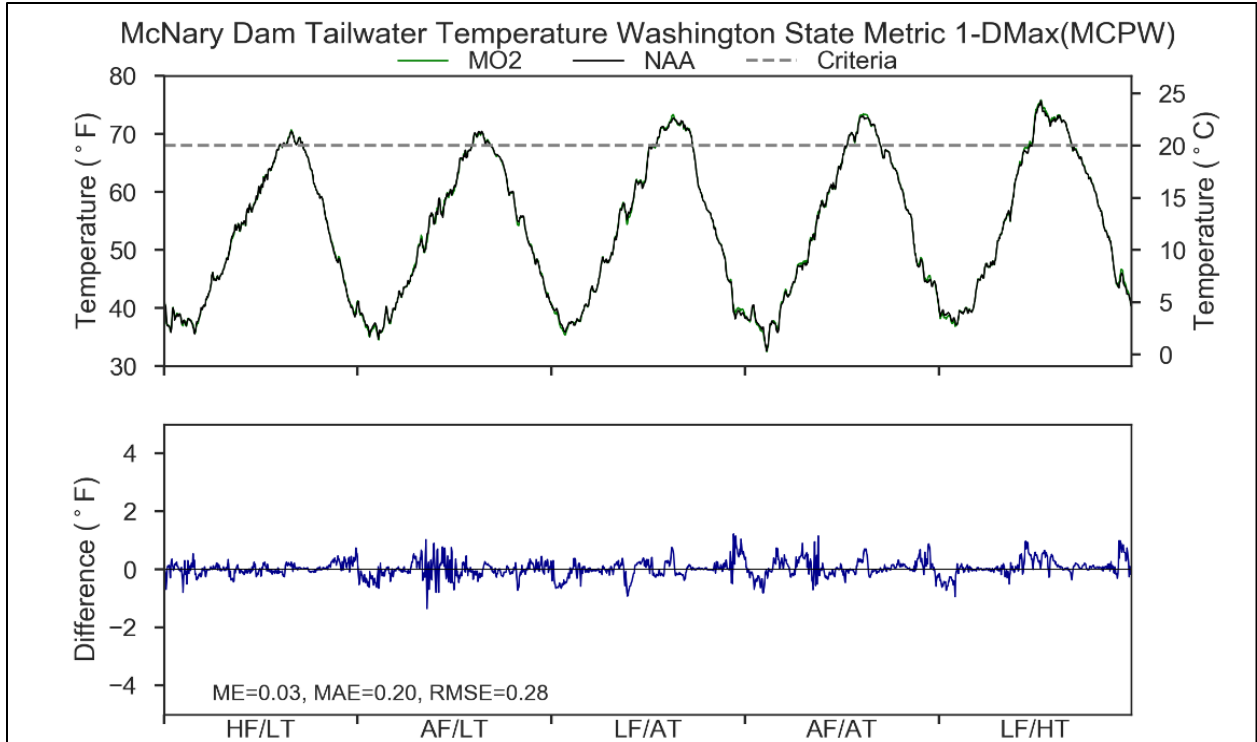
4117 **5.3 LOWER COLUMBIA RIVER**

4118 **5.3.1 Water Temperature**

4119 There are no specific structural or operational measures in MO2 that are expected to influence
4120 water temperatures in the lower Columbia River. Details are provided below.

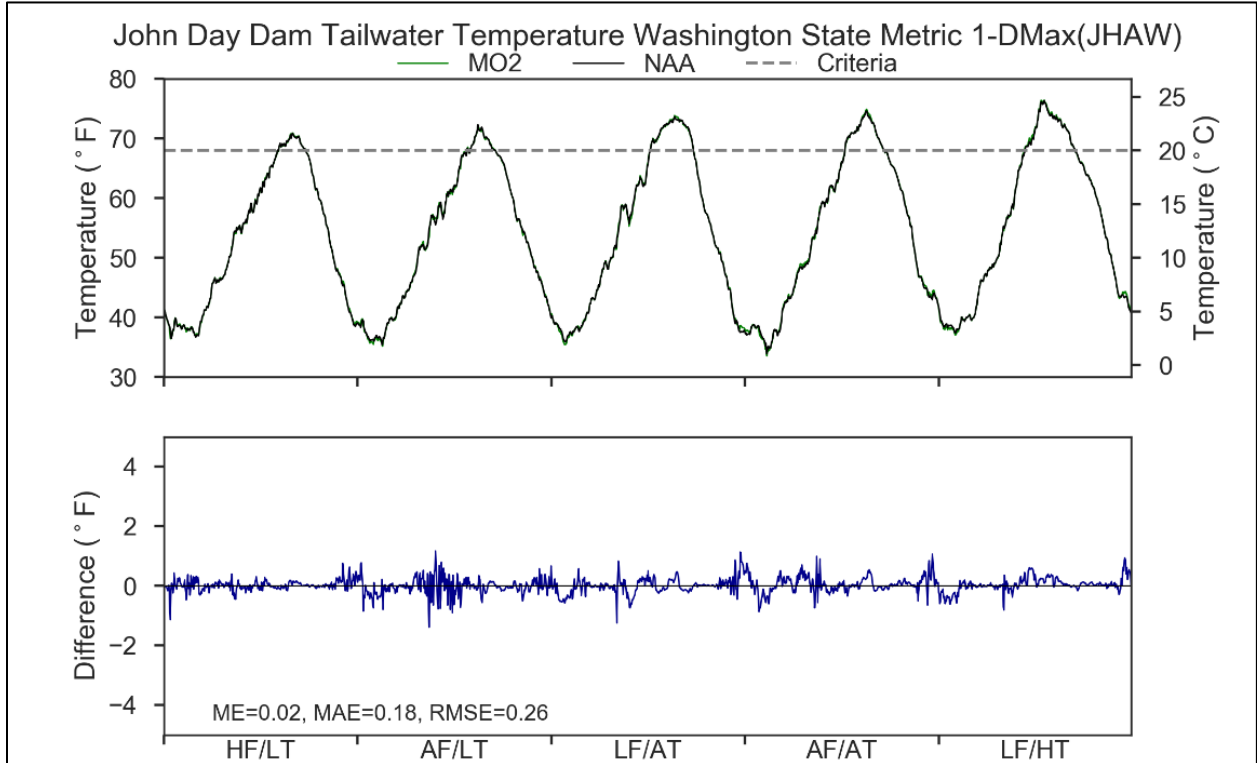
4121 **5.3.1.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

4122 The tailwater temperatures for MO2 at McNary, John Day, The Dalles, and Bonneville Dams
4123 were modeled under a 5-year range of river and meteorological conditions, and compared to
4124 the modeled results for the No Action Alternative (Figure 5-45. to Figure 5-48.). Just as with the
4125 No Action Alternative model results, the MO2 model results show that tailwater temperatures
4126 can exceed 68°F at all four dams during any of the years and conditions presented, and
4127 maximum water temperatures and the frequency of water temperature violations of state
4128 water quality standards would be higher during a year when river flows were lower than
4129 normal and summer ambient air temperatures were higher (as in LF/HT). The average
4130 frequency of water temperature violations of the State water quality standards would be nearly
4131 identical for the No Action Alternative and MO2 for all four lower Columbia River dams
4132 (Figure 5-49.). Generally, there would not be a significant difference in tailwater temperatures
4133 under the No Action Alternative and MO2.



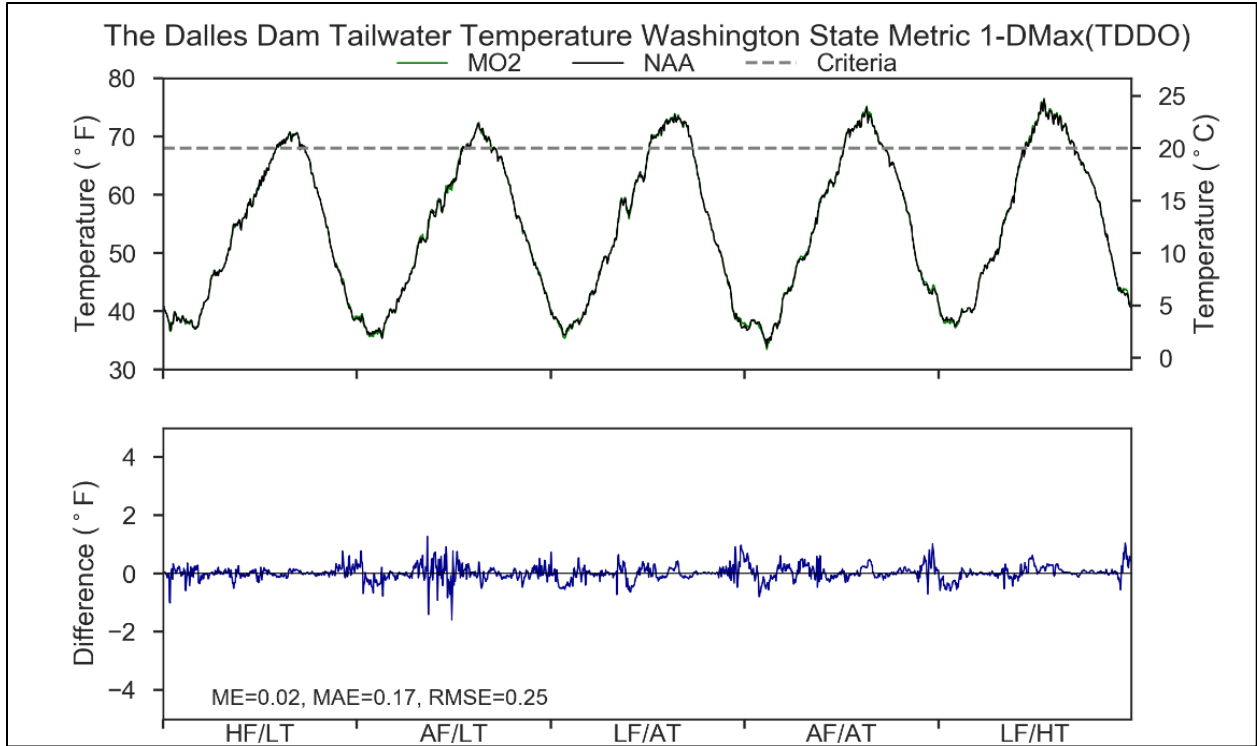
4134
 4135
 4136

Figure 5-45. Modeled Tailwater Temperature for Multiple Objective Alternative 2 at McNary Dam Under a 5-Year Range of River and Meteorological Conditions



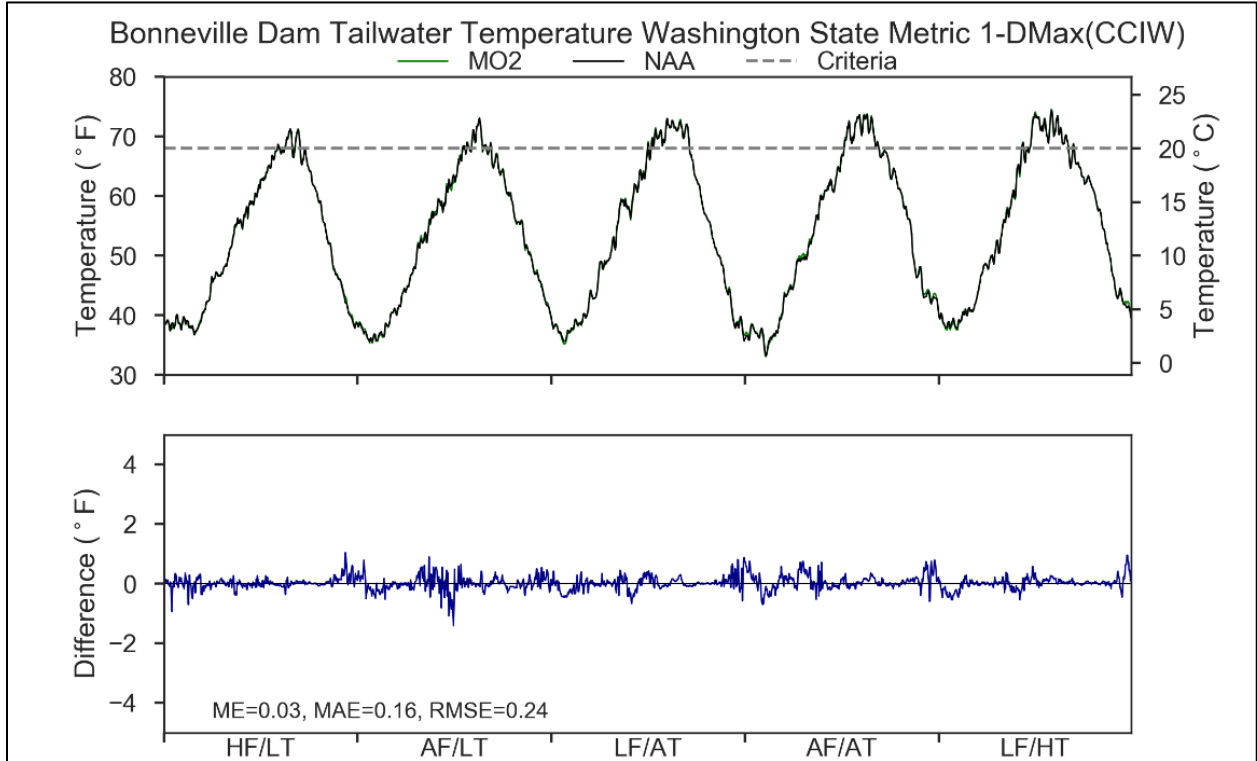
4137
 4138
 4139

Figure 5-46. Modeled Tailwater Temperature for Multiple Objective Alternative 2 at John Day Dam Under a 5-Year Range of River and Meteorological Conditions



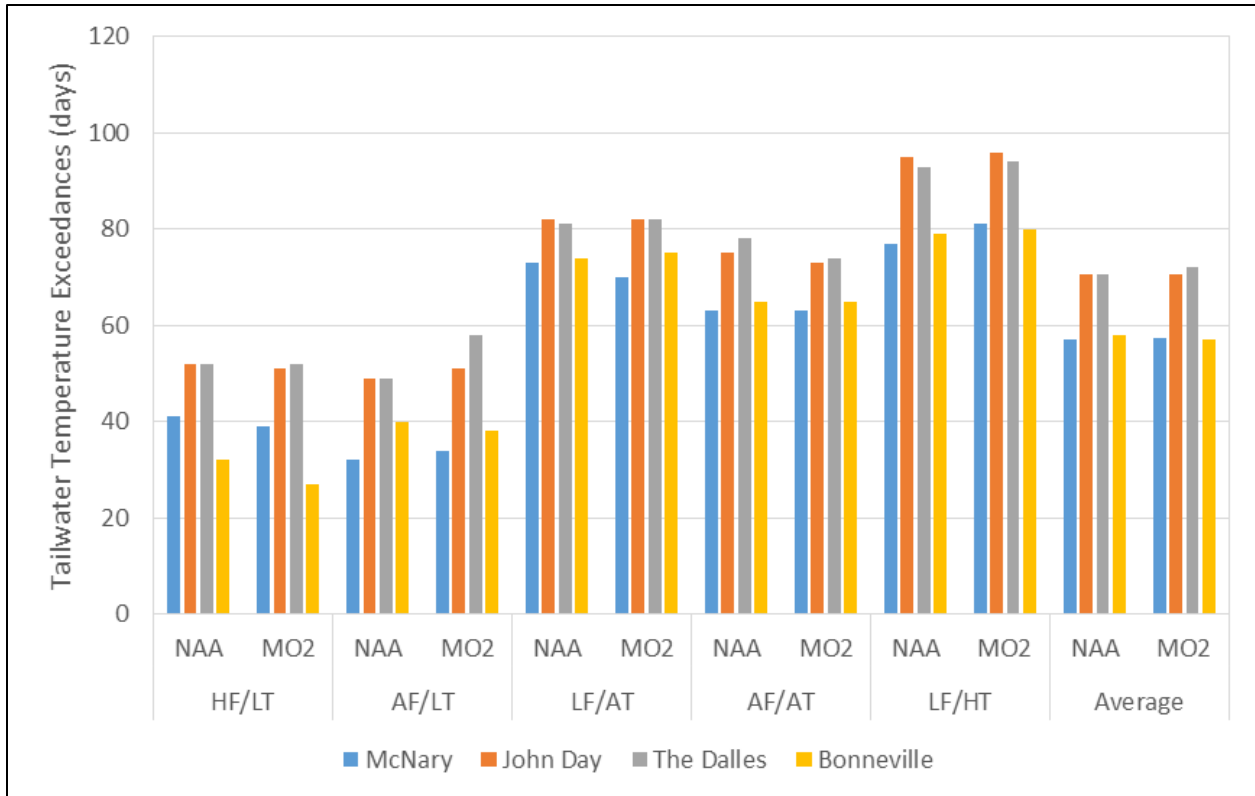
4140
 4141
 4142

Figure 5-47. Modeled Tailwater Temperature for Multiple Objective Alternative 2 at The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions



4143
 4144
 4145

Figure 5-48. Modeled Tailwater Temperature for Multiple Objective Alternative 2 at Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions



4146
 4147 **Figure 5-49. Frequency of Modeled Tailwater Temperature Violations to State Water Quality**
 4148 **Standards for the No Action Alternative and Multiple Objective Alternative 2 at McNary, John**
 4149 **Day, The Dalles, and Bonneville Dams Under a 5-Year Range of River and Meteorological**
 4150 **Conditions**

4151 **5.3.2 Total Dissolved Gas**

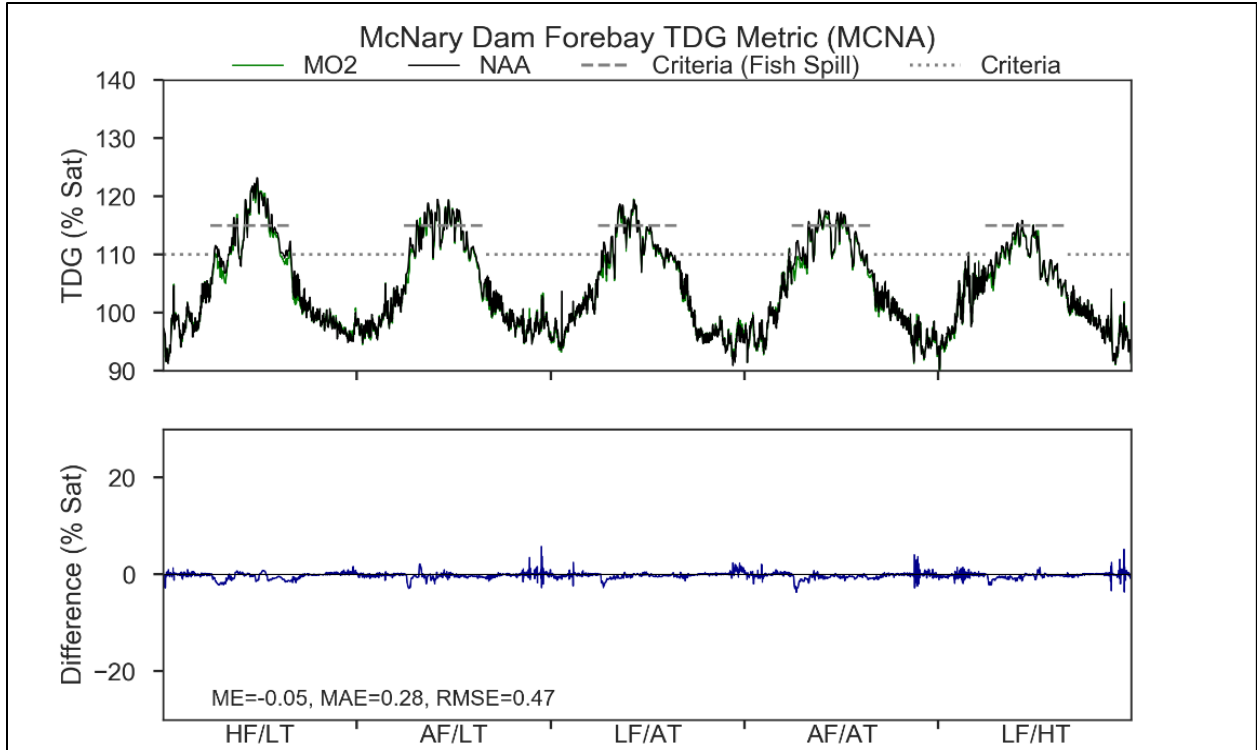
4152 Under MO2, the *Spill to 110% TDG*, which is the state TDG standard, limits juvenile fish passage
 4153 spill to 110 percent TDG as measured in-river, including tailraces and downstream forebays
 4154 except when minimum spill levels are higher including spill needed for powerhouse surface
 4155 passage routes, for spillway weirs, and/or for adult attraction. Additionally, spill during high-
 4156 flow and flood events would not be restricted to a cap of 110 percent TDG, but rather set to
 4157 levels necessary for safety. Lack-of-market spill would also continue and would follow on the
 4158 spill priority list. This limitation would begin April 10 and end at midnight July 31. Because of
 4159 the TDG limitation and the earlier end of fish passage spill, MO2 model results generally show
 4160 notable decreases in forebay and tailwater TDG saturations and in the frequency of violations
 4161 of current State TDG standards as compared to the No Action Alternative. Details are described
 4162 below.

4163 **5.3.2.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

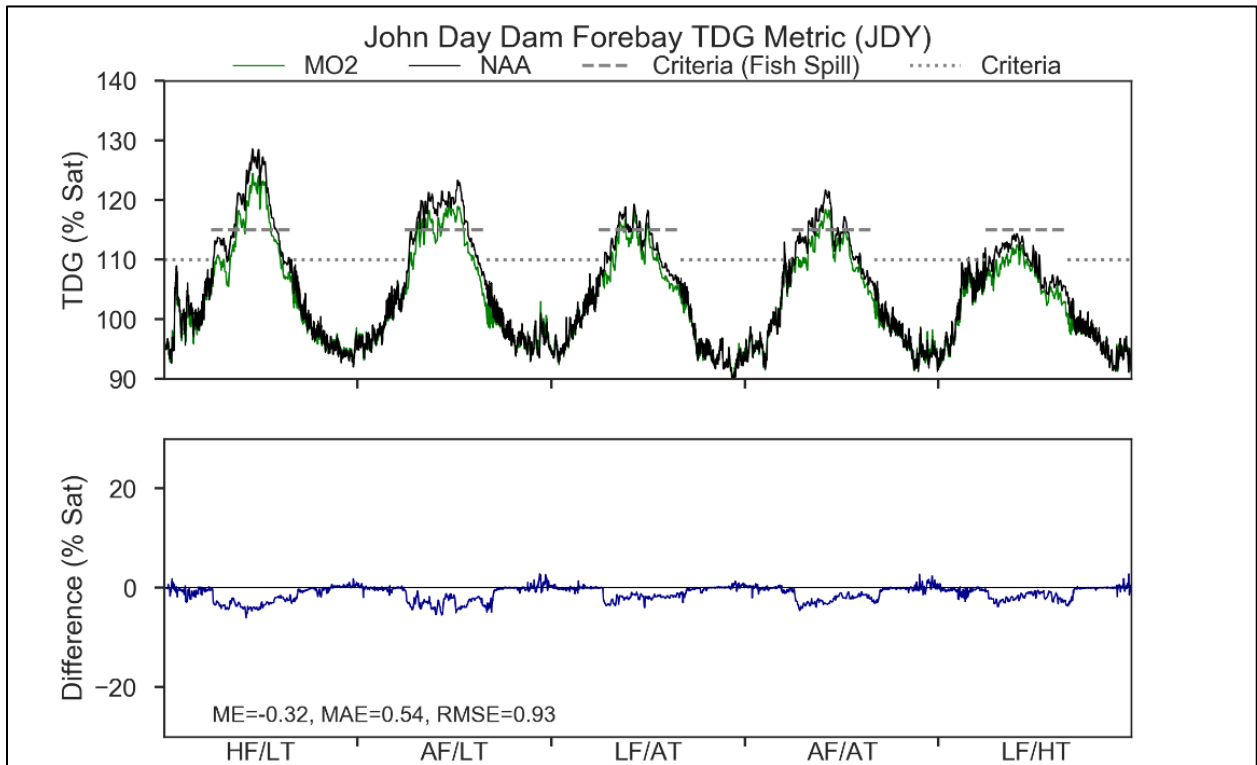
4164 Forebay TDG saturations for MO2 at McNary, John Day, The Dalles, and Bonneville Dams were
 4165 modeled under a 5-year range of river and meteorological conditions, and compared to the
 4166 modeled results for the No Action Alternative (Figure 5-50. - Figure 5-53.). The MO2 model

4167 results show that forebay TDG saturations can exceed the current 115 percent spill season TDG
4168 standard at all four dams during most of the years and conditions presented (the exceptions
4169 being John Day and The Dalles during low flow/high water temperature conditions). Maximum
4170 forebay TDG saturation would be higher during a year when river flows were higher than
4171 normal and summer ambient air temperatures were lower (as in 2011). Maximum forebay TDG
4172 saturations during spill season would be lower in MO2 as compared to the No Action
4173 Alternative for all four dams. In general, forebay TDG saturations would be lower during spill
4174 season at John Day, The Dalles, and Bonneville. Outside of the current juvenile fish spill season,
4175 the frequency of 110% TDG exceedances would be similar for MO2 and No Action at all four
4176 dams (Figure 5-54.). At McNary, the frequency of 110% TDG exceedances during the current
4177 juvenile fish spill season would be slightly less for MO2 than No Action, but the frequencies of
4178 115% TDG exceedances would be similar for the two alternatives (Figure 5-55.). At John Day,
4179 The Dalles, and Bonneville, the frequency of 110% and 115% TDG exceedances would be lower
4180 for MO2 than the No Action Alternative (Figure 5-55.).

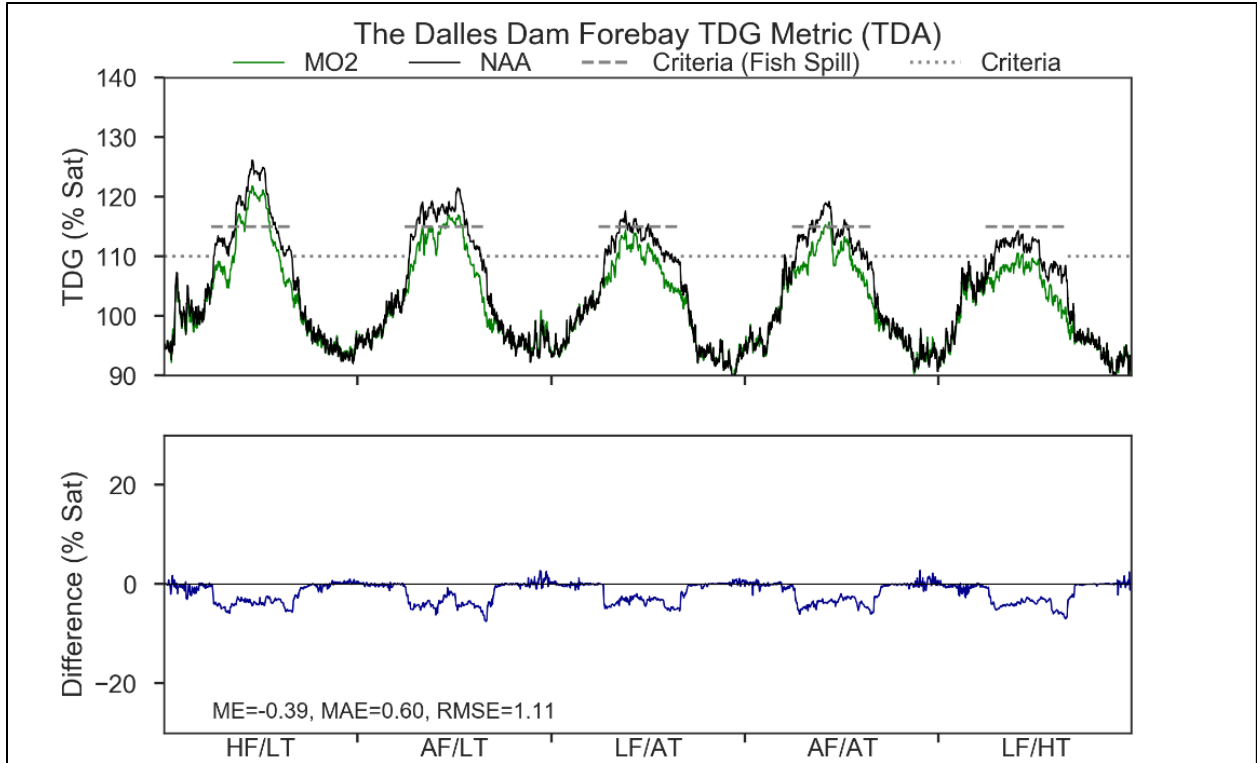
4181 Tailwater TDG saturations for MO2 at McNary, John Day, The Dalles, and Bonneville Dams were
4182 modeled under a 5-year range of river and meteorological conditions, and compared to the
4183 modeled results for the No Action Alternative (Figure 5-56. through Figure 5-59.). The MO2
4184 model results show that tailwater TDG saturations can exceed the current 120 percent spill
4185 season TDG standard at all four dams, but it depends on the river and meteorological
4186 conditions present. For example, tailwater TDG at Bonneville would be expected to exceed the
4187 120 percent spill season standard under all conditions, while the standard would be exceeded
4188 at John Day and The Dalles only under low air temperature conditions and at McNary only
4189 under average flow and low air temperature conditions. Maximum tailwater TDG saturation
4190 would be higher during a year when river flows were higher than normal and summer ambient
4191 air temperatures were lower (as in 2011). Tailwater TDG saturations would generally be lower
4192 in MO2 as compared to No Action Alternative for all four dams during spill season, and
4193 particularly in August because of the earlier end to juvenile fish spill. At all four dams, the
4194 frequency of 110% TDG exceedances outside of current juvenile fish spill would be lower than
4195 or remain about the same under MO2 as compared the No Action Alternative under all
4196 modeled river and meteorological conditions (Figure 5-60.). At McNary, The Dalles, and
4197 Bonneville, the frequency of 120% TDG exceedances during the current fish spill season would
4198 be lower (or otherwise remain at zero) under MO2 than the No Action Alternative under all
4199 modeled river and meteorological conditions (Figure 5-61.); at John Day, the frequency of 120%
4200 TDG exceedances would be similar for both MO2 and the No Action Alternative, though the
4201 frequency of 115% TDG exceedances would be significantly reduced.



4202
 4203 **Figure 5-50. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 2 at**
 4204 **McNary Dam Under a 5-Year Range of River and Meteorological Conditions**

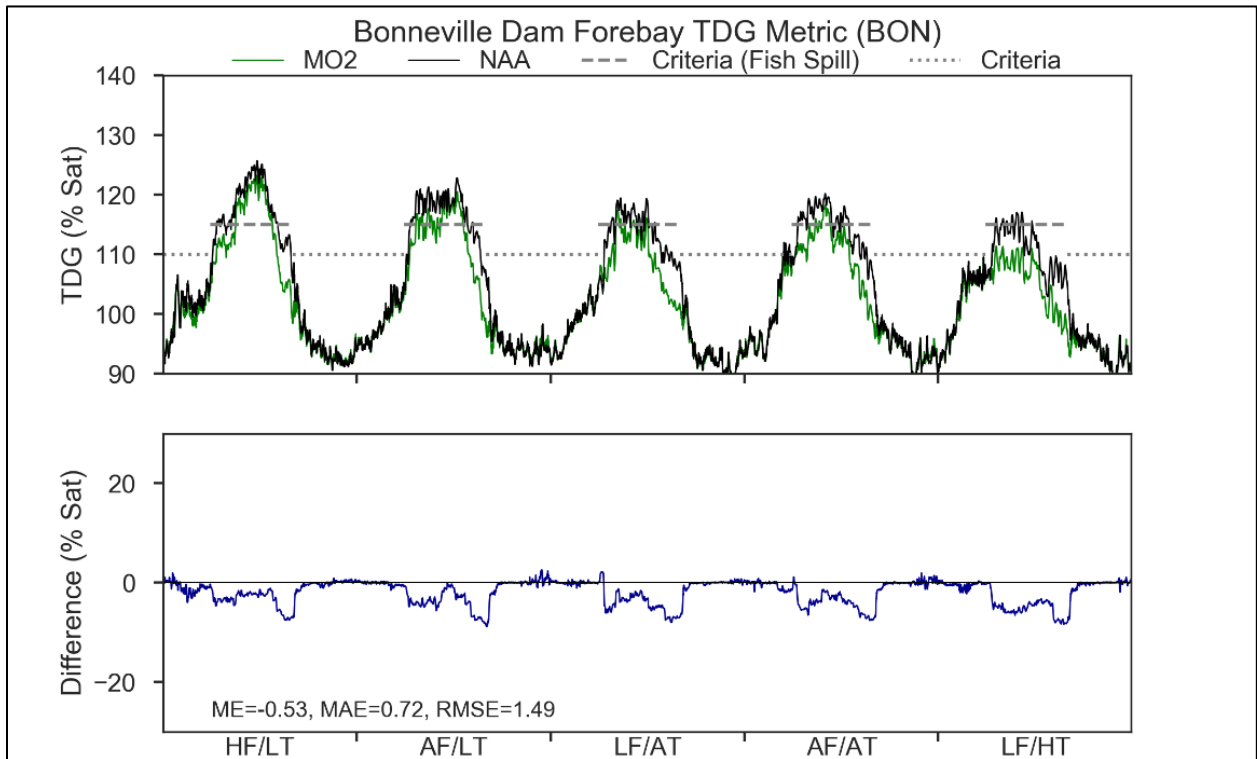


4205
 4206 **Figure 5-51. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 2 at John**
 4207 **Day Dam Under a 5-Year Range of River and Meteorological Conditions**



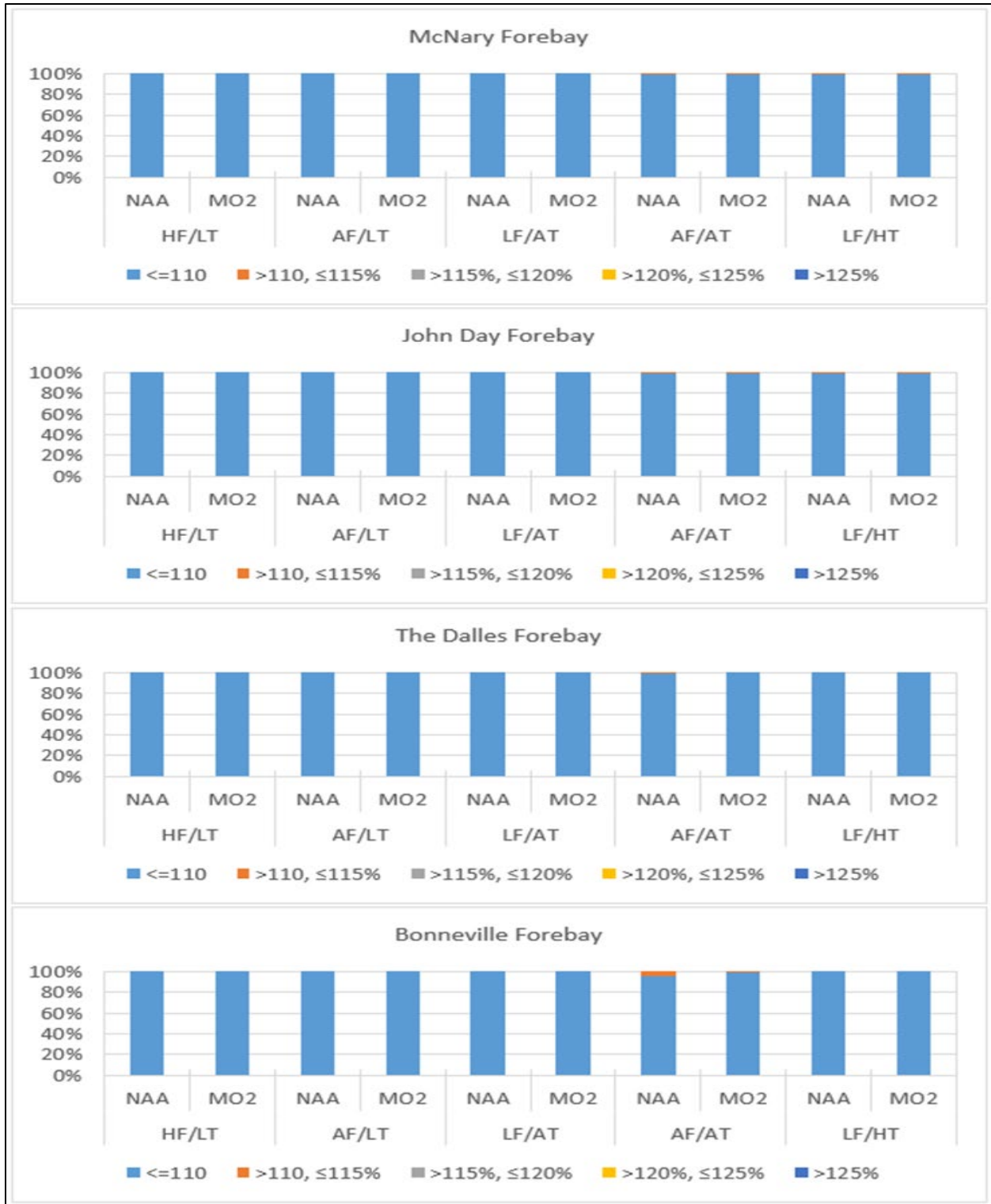
4208
 4209
 4210

Figure 5-52. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 2 at The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions



4211
 4212
 4213

Figure 5-53. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 2 at Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions

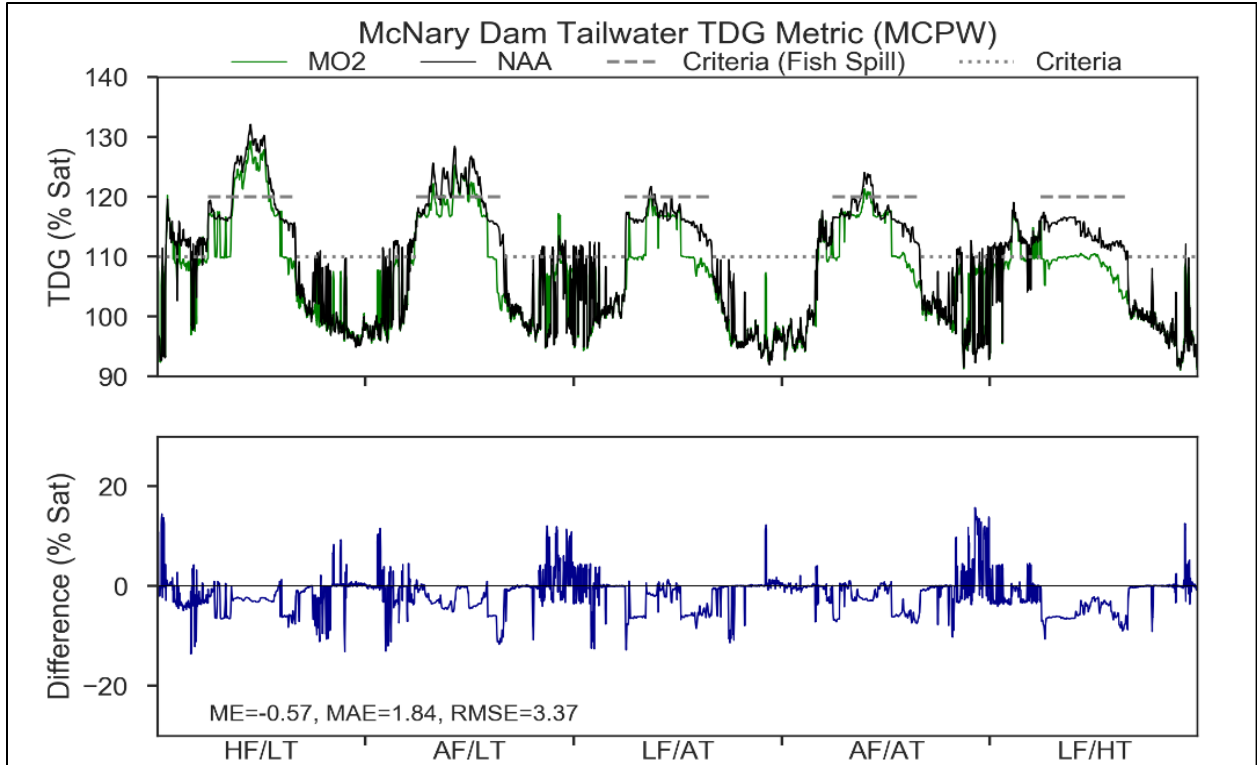


4214
 4215 **Figure 5-54. Frequency of Modeled Forebay Total Dissolved Gas Outside of Current Fish**
 4216 **Passage Spill Season for the No Action Alternative and Multiple Objective Alternative 2 at**
 4217 **McNary, John Day, The Dalles, and Bonneville Dams Under a 5-Year Range of River and**
 4218 **Meteorological Conditions**

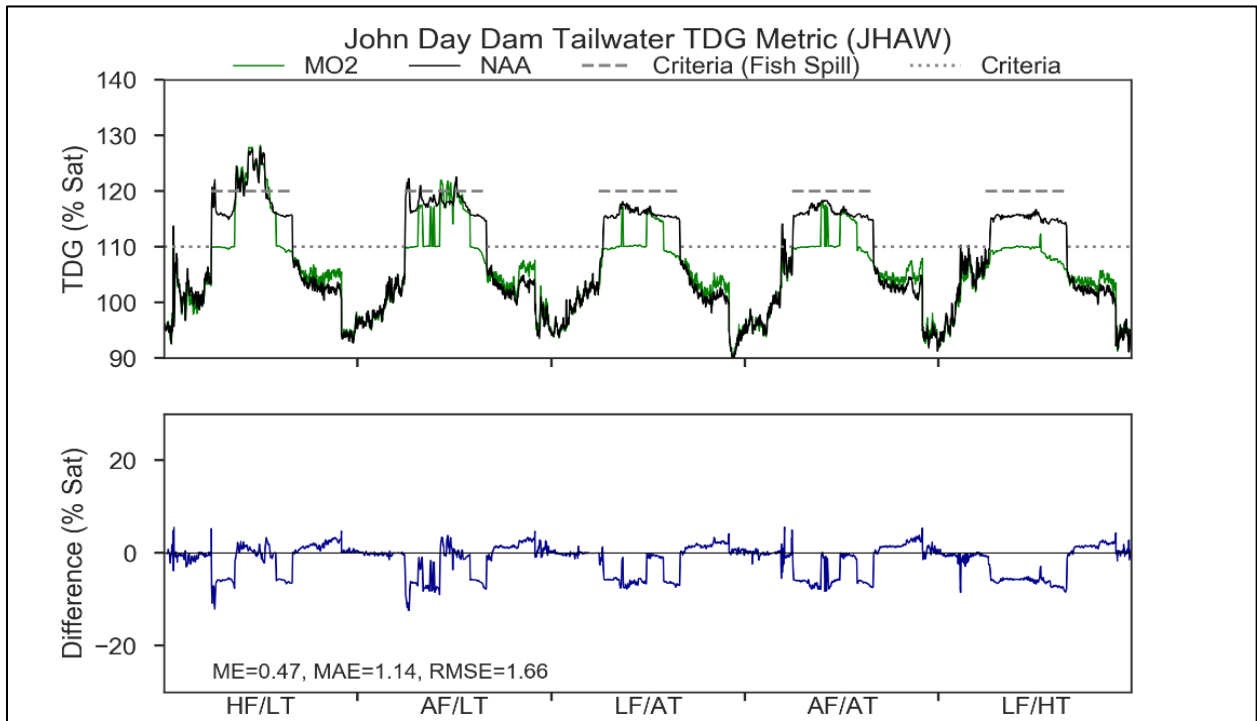
4219 Note: Current Fish passage spill season is from April 1 to August 31.



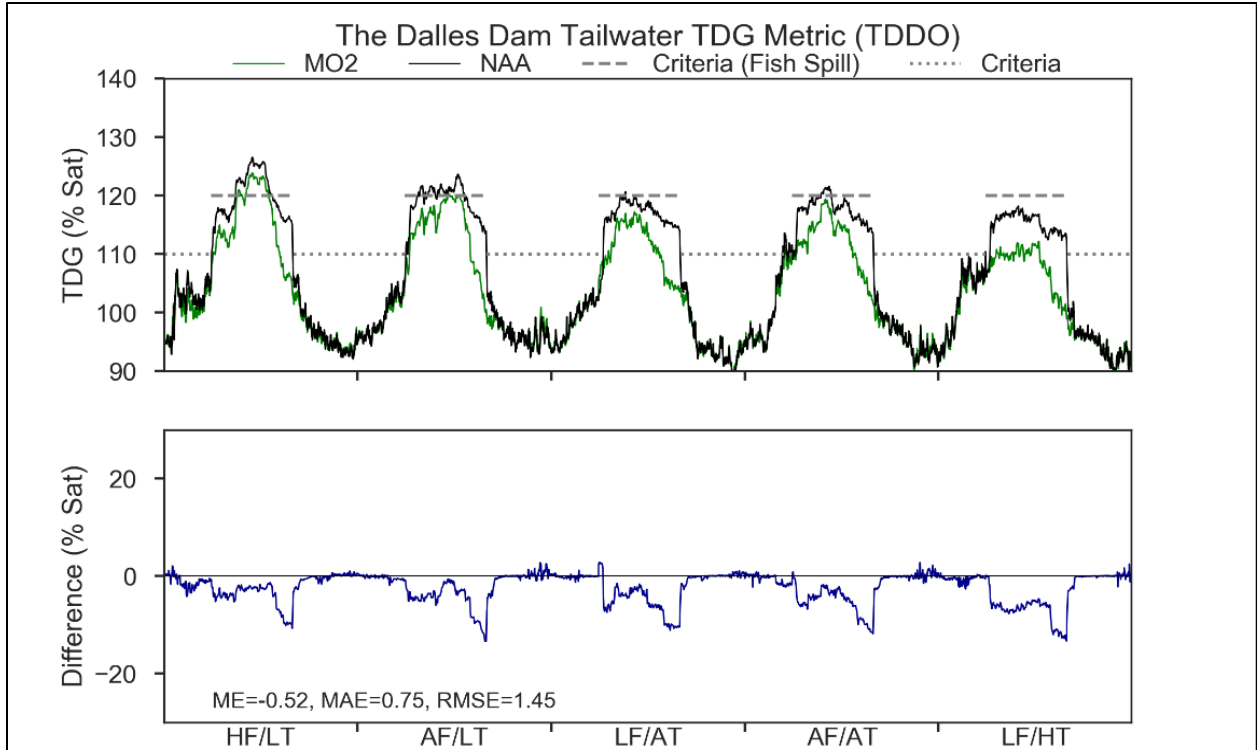
4220
 4221 **Figure 5-55. Frequency of modeled forebay Total Dissolved Gas violations of current 115**
 4222 **percent Total Dissolved Gas State water quality standards during current fish passage spill**
 4223 **season for the No Action Alternative and Multiple Objective Alternative 2 at McNary, John**
 4224 **Day, The Dalles, and Bonneville Dams under a 5-year range of river and meteorological**
 4225 **conditions**
 4226 Note: Current fish passage spill season is from April 1 to August 31.



4227
 4228 **Figure 5-56. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 2 at**
 4229 **McNary Dam Under a 5-Year Range of River and Meteorological Conditions**

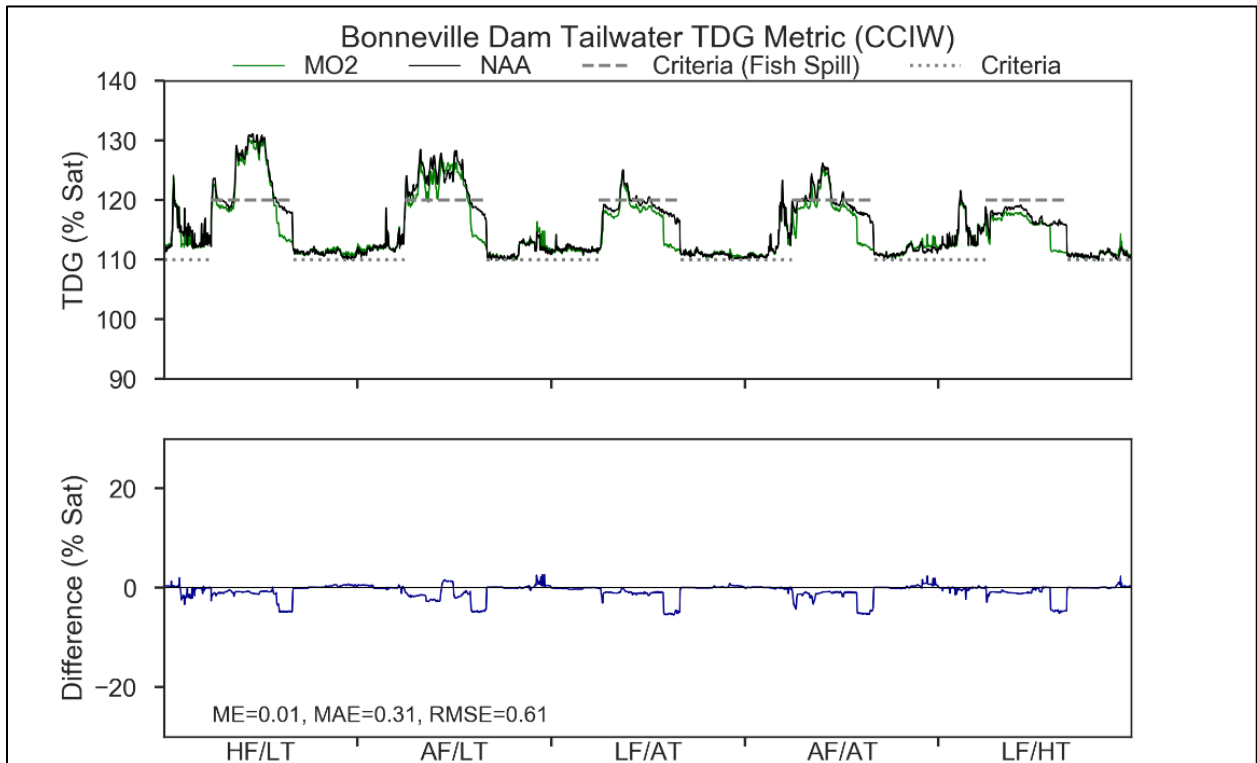


4230
 4231 **Figure 5-57. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 2 at**
 4232 **John Day Dam Under a 5-Year Range of River and Meteorological Conditions**



4233
 4234
 4235

Figure 5-58. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 2 at The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions



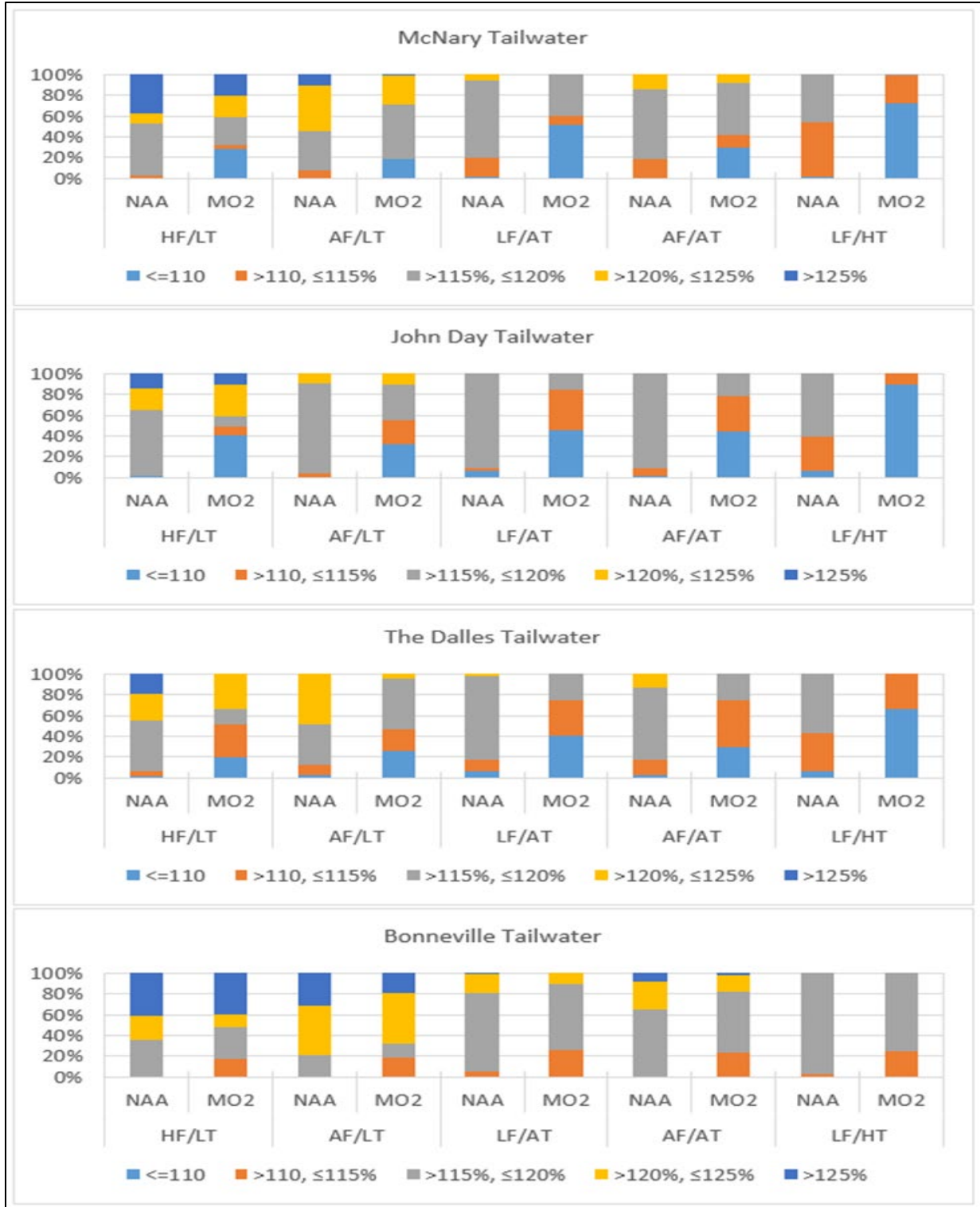
4236
 4237
 4238

Figure 5-59. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 2 at Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions



4239
 4240 **Figure 5-60. Frequency of Modeled Tailwater Total Dissolved Gas Outside of Current Fish**
 4241 **Passage Spill Season for the No Action Alternative and Multiple Objective Alternative 2 at**
 4242 **McNary, John Day, and The Dalles Dams Under a 5-Year Range of River and Meteorological**
 4243 **Conditions**

4244 Note: Current juvenile fish passage spill season is from April 1 – August 31.



4245
 4246
 4247
 4248
 4249
 4250

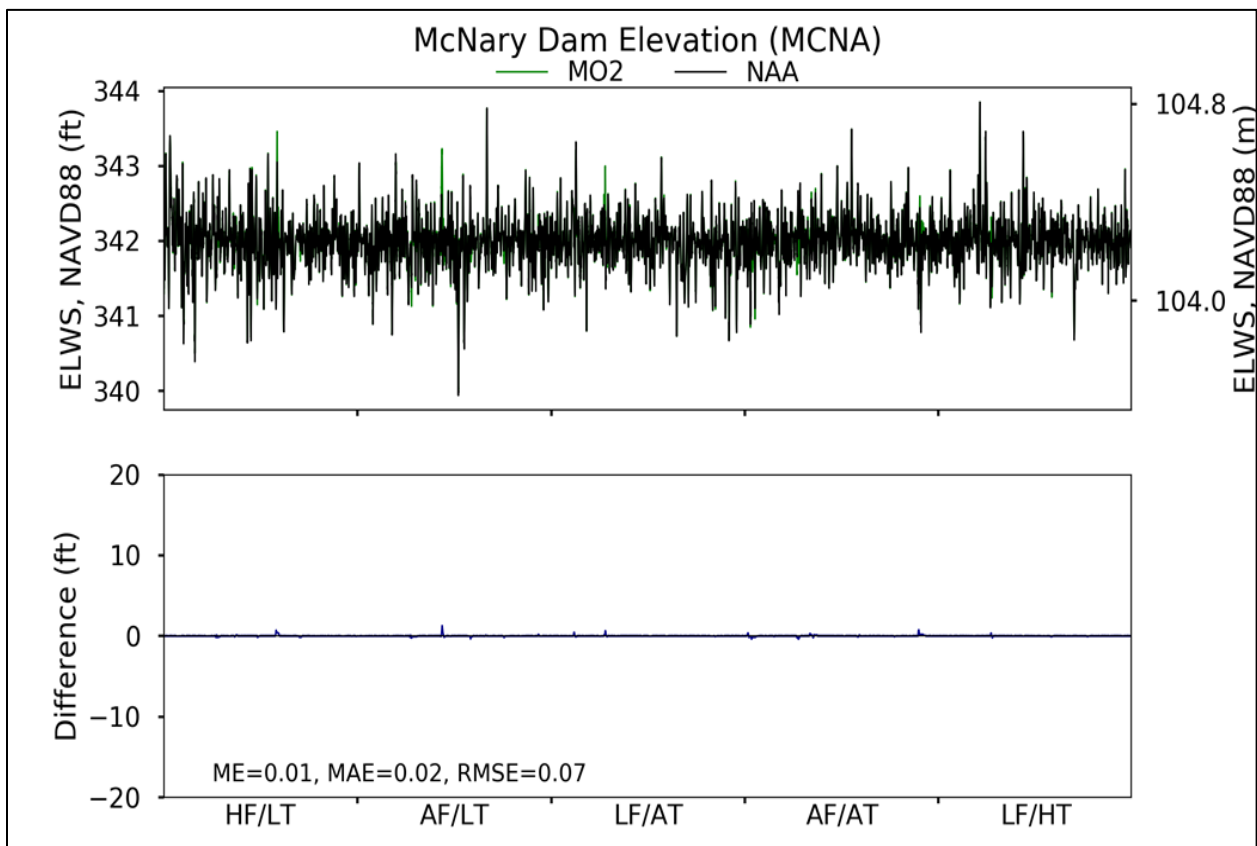
Figure 5-61. Frequency of Modeled Forebay Total Dissolved Gas Violations of Current 120 percent Total Dissolved Gas State Water Quality Standards During Fish Passage Spill Season for the No Action Alternative and Multiple Objective Alternative 2 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-Year Range of River and Meteorological Conditions
 Note: Current juvenile fish passage spill season is from April 1 to August 31.

4251 **5.3.3 Other Physical, Chemical, and Biological Processes**

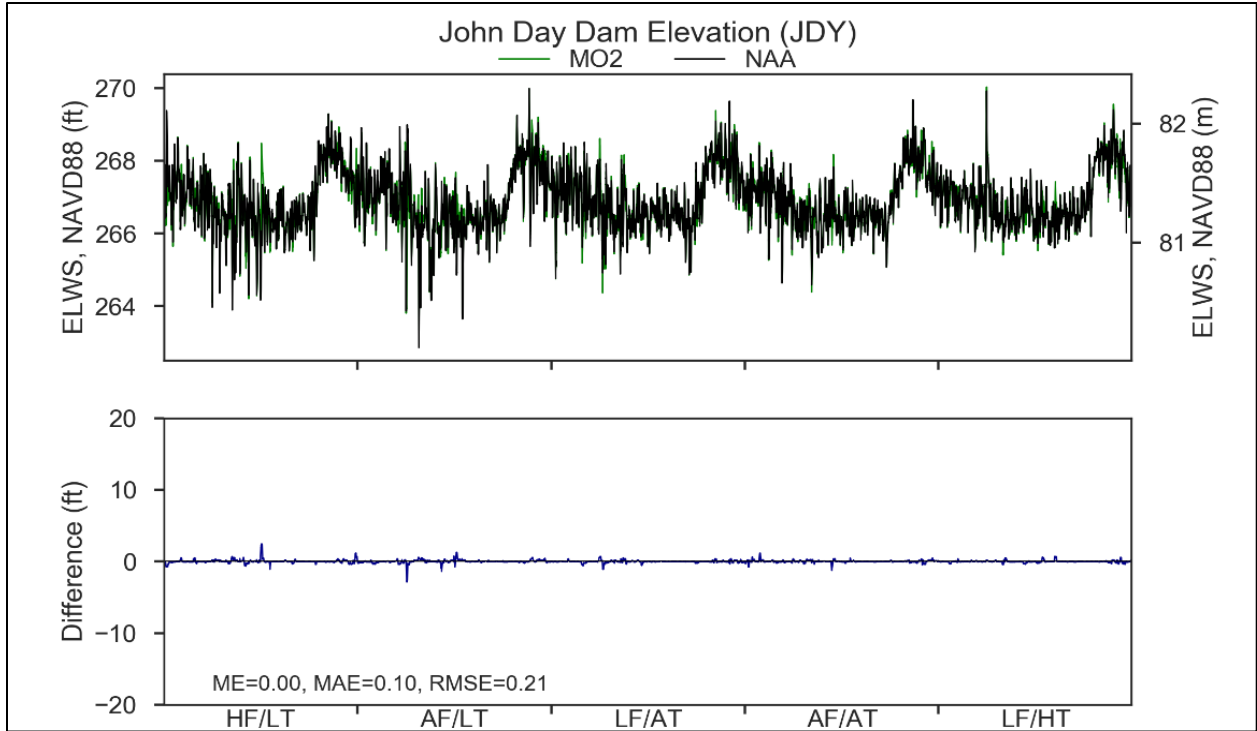
4252 **5.3.3.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

4253 Under the MO2 *John Day Full Pool* measure, the John Day pool would operate within the full
4254 reservoir operating range (262.5 to 266.5 feet, NGVD29) year-round except as needed for flood
4255 risk management. Currently, the John Day pool is restricted to operating within 1.5 feet above
4256 minimum irrigation pool during juvenile fish passage season (April through August). However,
4257 modeling suggests forebay elevations for MO2 will not be substantially different from forebay
4258 elevations for the No Action Alternative (Figure 5-62. through Figure 5-65.).

4259 The introduction of pollutants and excess nutrients from air deposition, farming and industrial
4260 activities, as well as urban runoff, is expected to continue under MO2. As with the No Action,
4261 emerging contaminants such as pharmaceuticals and new pesticides will also likely become
4262 more prevalent. The lower Columbia River contains a variety of human-sourced compounds,
4263 including metals and organic compounds. This condition is expected to remain generally
4264 unchanged, and it is expected that current water quality impairments would continue.

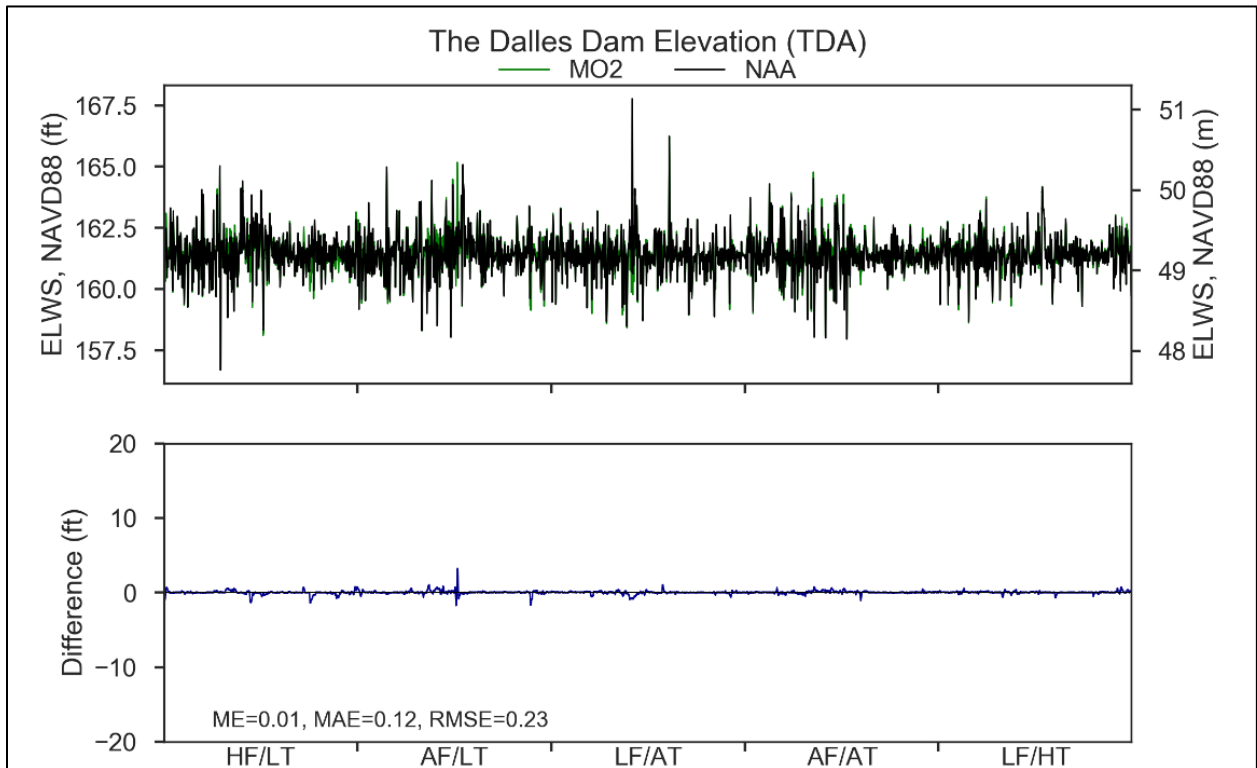


4265 **Figure 5-62. Modeled Forebay Elevation for Multiple Objective Alternative 2 at McNary Dam**
4266 **Under a 5-Year Range of River and Meteorological Conditions**
4267



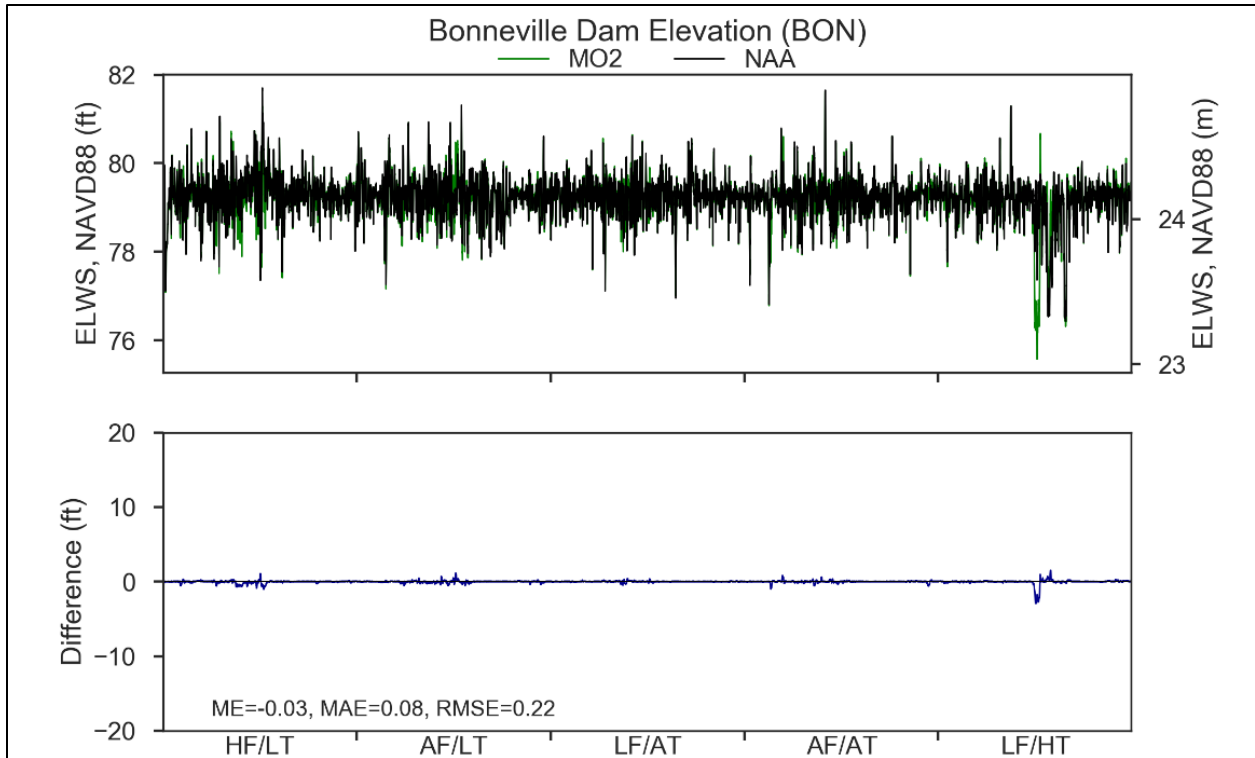
4268
4269
4270

Figure 5-63. Modeled Forebay Elevation for Multiple Objective Alternative 2 at John Day Dam Under a 5-Year Range of River and Meteorological Conditions



4271
4272
4273

Figure 5-64. Modeled Forebay Elevation for Multiple Objective Alternative 2 at The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions



4274
 4275 **Figure 5-65. Modeled Forebay Elevation for Multiple Objective Alternative 2 at Bonneville**
 4276 **Dam Under a 5-Year Range of River and Meteorological Conditions**

4277 **5.4 SEDIMENT PROCESSES**

4278 **5.4.1 Sediment Sources**

4279 MO2 includes structural changes aimed at improving juvenile fish passage; these proposed
 4280 measures would not affect sediment sources or movement. The proposed operational changes
 4281 generally have a goal of improving flexibility in operation and of improving in-stream (flow and
 4282 temperature) conditions for fish; changing the timing of flows or the temperature
 4283 characteristics does not affect sediment sources although changing reservoir water levels could
 4284 have an impact on the bioavailability of some sediment pollutants (Willacker et al. 2016). MO2
 4285 is not expected to affect land use throughout the basin, including upland recreation, flood
 4286 management, agricultural, timber, or mining activities, and is not expected to change
 4287 population growth patterns in the area of any of the affected reservoirs. Overall, MO2 is not
 4288 expected to affect sediment movement within the system.

4289 **5.4.2 Chemicals of Concern**

4290 No change is predicted to the list of sediment chemicals of concern throughout the basin,
 4291 compared to the existing conditions and No Action Alternative. The contaminants of concern
 4292 would remain metals, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds,
 4293 pesticides and pesticide degradation products, PCBs, dioxins, and nutrients (ammonia). Due to

4294 changes in reservoir operation, changes to water levels could affect the mobility and
4295 bioavailability of some pollutants such as mercury (Willacker et al. 2016).

4296 **5.5 CONCEPTUAL SITE MODEL**

4297 MO2 is not expected to affect sediment movement patterns, so the conceptual site model for
4298 sediment/dredging is the same as the conceptual site model(s) for the existing conditions and
4299 No Action Alternative. Portions of the Columbia Basin that are currently not dredged (Chief
4300 Joseph Reservoir) would not be dredged in the future. Areas of the basin that are currently
4301 maintained by dredging (such as at the confluence of the Snake River and Clearwater River)
4302 would continue to require periodic dredging. Sediment characterization following the Sediment
4303 Evaluation Framework (RSET 2018) or other applicable guidance would continue to be required
4304 for dredging or sediment-related projects.

4305 **5.6 WATER AND SEDIMENT QUALITY CONCLUSIONS**

4306 The most notable MO2 measures that affect water quality are as follows:

- 4307 • Spill to 110 *percent* TDG: Limit fish passage spill to 110 percent TDG at the lower Snake and
4308 Columbia projects.
- 4309 • Slightly Deeper Draft for Hydropower: Allow for a larger operating range at storage projects
4310 for hydropower flexibility.
- 4311 • Full Range Turbine Operations: Operate turbines across their full range of capacity.
- 4312 • Update System FRM Calculation, Winter System FRM Space, Planned Draft Rate at Grand
4313 Coulee, Sliding Scale at Libby and Hungry Horse, Modified Draft at Libby, December Libby
4314 Target Elevation: *Modify operations for FRM at Libby, Grand Coulee, and Hungry Horse*
4315 *Dams.*
- 4316 • Grand Coulee Maintenance Operations: Plan for major maintenance at Grand Coulee Dam.

4317 **5.6.1 Multiple Objective Alternative 2 Results – Water Temperature**

4318 In general, MO2 would result in negligible impacts to water temperature throughout the CRS.
4319 Deeper drawdowns of Dworshak Reservoir from the *Slightly Deeper Draft for Hydropower*
4320 measure could lead to slower warming of the surface waters because the smaller surface area
4321 would result in less warming by the sun in the early spring. Near-full pool would be reached by
4322 July, and thermal stratification for the remainder of the year would not change. Temperatures
4323 would remain less than 52 °F throughout the year, and overall water temperature effects
4324 downstream of Dworshak Dam under MO2 would be negligible using the logic presented in
4325 Section 3.4.3.2. Modeling assumptions may have resulted in misleading conclusions, in the
4326 lower Snake River. MO2 water temperatures in the lower Snake River would result in moderate
4327 to minor changes as modeled, compared to the No Action Alternative. However, ResSim
4328 modeling assumptions did not represent the intended operations and instead showed the
4329 reservoir would have a decreased refill probability, refilling to within 0.5 feet of the normal full

4330 reservoir elevation in about 48 percent of years. It is likely that in real-time operations, the
4331 refill probability for Dworshak Reservoir under MO2 would be higher than shown in modeled
4332 results, and more closely aligned to the No Action Alternative. Therefore, effects to water
4333 temperatures are considered negligible.

4334 **5.6.2 Multiple Objective Alternative 2 Results –Total Dissolved Gas**

4335 In general, the MO2 alternative would have little to no impact on TDG conditions below Libby,
4336 Albeni Falls and Chief Joseph dams as compared to No Action Alternative. TDG would likely be
4337 reduced downstream of Hungry Horse. Major reductions in TDG are expected downstream of
4338 Grand Coulee Dam due to the *Deeper Draft for Hydropower* measure, which is expected to
4339 reduce winter reservoir elevations and total project outflows at those projects. The *Grand*
4340 *Coulee Maintenance Operations* measure, in isolation, could result in significant increases in
4341 spill and TDG, in some cases producing TDG in excess of 130 percent for a limited time;
4342 however, this effect is largely offset in the spring and early summer by the other measures.

4343 Water quality model results indicate that some increases in TDG below Dworshak Dam would
4344 occur under MO2. However, during realtime implementation of this measure, this would be
4345 avoided so as not to violate water quality TDG standards. Minor reductions in TDG would be
4346 expected in the lower Snake and Columbia Rivers due to the *Spill to 110% TDG* measure, which
4347 calls for a reduction in downstream juvenile fish passage spill to not exceed a TDG limit of 110
4348 percent. Even though the 110 percent TDG limit would be hard to achieve due to minimum spill
4349 requirements, involuntary spill, and lack of market conditions, average TDG would still be lower
4350 as compared to the No Action Alternative.

4351 **5.6.3 Multiple Objective Alternative 2 Results –Other Water Quality Impacts**

4352 In general, MO2 would result in little to no change on other water quality parameters at Albeni
4353 Falls and Chief Joseph dams and reservoirs, as compared to the No Action Alternative. Due to
4354 lower winter reservoir elevations and increased outflows at Libby and Hungry Horse projects,
4355 resulting from the *Slightly Deeper Draft for Hydropower* measure, combined with the *Modified*
4356 *Draft at Libby* measure, a reduction in lake productivity may occur. This could result in lower
4357 growth rate in fish within and downstream of the reservoir. At Grand Coulee, the increased
4358 reservoir elevation fluctuations, associated with the *Slightly Deeper Draft for Hydropower* and
4359 FRM measures (*Winter System FRM Space*), could lead to increased mercury methylation, while
4360 the Planned Draft Rate at Grand Coulee measure, which decreases the planning draft rate of
4361 the reservoir to 0.8 feet per day could result in a decrease in bank erosion, sloughing, and
4362 overall turbidity in the reservoir.

4363 The *Deeper Draft for Hydropower* measure could result in shallower water depths at the upper
4364 end of Dworshak Reservoir where the North Fork Clearwater River, Little North Fork River, and
4365 Breakfast Creek enter, leading to higher flow velocities and a delay in primary production. In
4366 general, MO2 would have little to no impact on other water quality parameters at, the lower
4367 Snake River and the lower Columbia River projects as compared to the No Action Alternative.

4368 **5.6.4 Multiple Objective Alternative 2 Results –Sediment Quality**

4369 MO2 is not expected to affect land use throughout the basin, including upland recreation, flood
4370 management, agricultural, timber, or mining activities, and is not expected to change
4371 population growth patterns in the area of any of the affected reservoirs. No change is predicted
4372 to the list of sediment chemicals of concern throughout the basin, compared to the existing
4373 conditions and No Action Alternative.

4374

CHAPTER 6 - MULTIPLE OBJECTIVE ALTERNATIVE 3

4375 Multiple Objective Alternative 3 (MO3) was developed with the goal to meet objectives to
4376 benefit ESA-listed fish while integrating actions for water management flexibility for flood risk
4377 management. MO3 also sought to adapt to changing environmental conditions as described in
4378 Chapter 2, hydropower production at the remaining CRS projects, and water supply. This
4379 alternative includes many measures similar to previous alternatives, but it also includes
4380 breaching the lower Snake River dams. See Chapter 2 in the main EIS report for a complete
4381 description of the dam breach plus alternative. However, it should be noted that the sediment
4382 study for MO3 did not include existing bridges and therefore does not consider bridge-related
4383 scour and deposition potential. Structural measures for this alternative include:

- 4384 • Remove earthen embankments and adjacent structures, as required, at each dam to
4385 facilitate reservoir drawdown at the lower Snake River dams.
- 4386 • Modify existing equipment and dam infrastructure at the lower Snake River dams to adjust
4387 to drawdown conditions (Existing equipment would not be used for hydropower generation
4388 but would be used as low-level outlets for drawdown below spillway elevations).
- 4389 • Construction of additional powerhouse and/or spill surface passage routes at the McNary
4390 Project.

4391 **6.1 UPPER COLUMBIA RIVER BASIN**

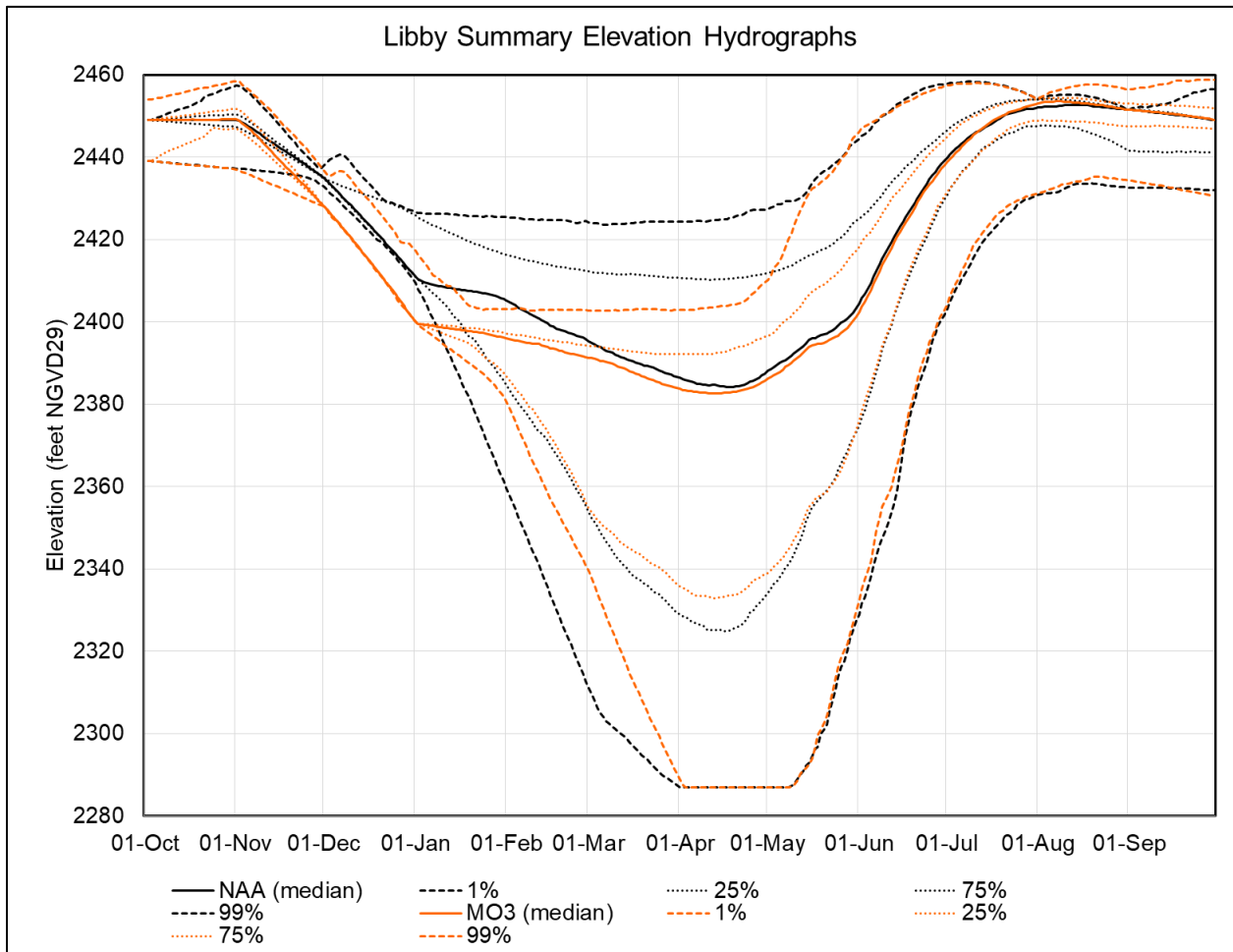
4392 **6.1.1 Water Temperature**

4393 **6.1.1.1 Libby and Hungry Horse Dams and Reservoirs**

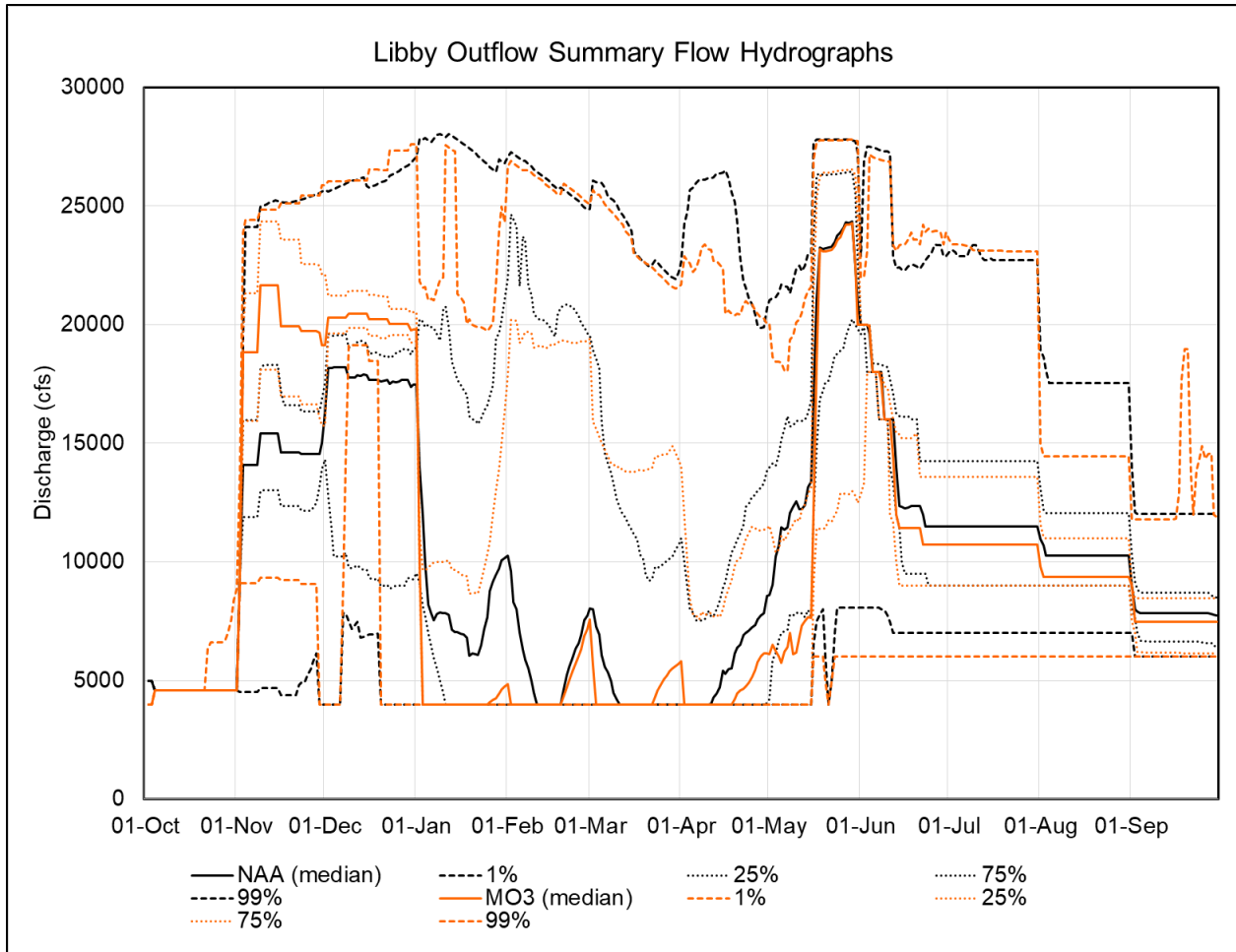
4394 For Libby Dam, MO3 is similar to Multiple Objective Alternative (MO2) and includes operational
4395 changes that could result in changes to draft and refill operations when compared to the No
4396 Action Alternative as shown in the summary hydrograph (Figure 6-1.). For the majority of years
4397 under MO3, the end-of-November draft elevation target is 8 feet lower than the No Action
4398 Alternative to facilitate a lower end-of-December target elevation of 2,400 feet NGVD29, which
4399 is about 11 feet lower than the majority of No Action Alternative years. January and February
4400 draft elevations are typically deeper under MO3 largely due to the prolonged impacts of the
4401 deeper November and December drafts. Final end-of-April draft elevation for the median and
4402 wettest quarter of years are similar to the No Action Alternative. However, for the driest 40
4403 percent of years, the end-of-April draft is about 11 to 19 feet deeper than the No Action
4404 Alternative. Reservoir refill and summer pool elevations are improved over the No Action
4405 Alternative with the reservoir reaching the end-of-July full pool about 6 percent more often
4406 than under the No Action Alternative. August and September reservoir elevations under MO3
4407 are about 1 to 4 feet greater than under the No Action Alternative. In general, the MO3 drafting
4408 changes would result in lower water elevations in Lake Koocanusa from November through
4409 April, with substantially lower end-of-April water elevations (11 to 19 feet) in the driest 40
4410 percent of years. It should be noted that these changes do vary by water year, water forecast,
4411 and time of year. A summary hydrograph for Lake Koocanusa, representing the probability of

4412 the reservoir elevation on any given day under MO3 and the No Action Alternative is shown in
 4413 Figure 6-1..

4414 MO3 largely impacts Libby Dam outflows and Kootenai River flows from about November
 4415 through April (Figure 6-2.). When compared to the No Action Alternative, median average MO3
 4416 outflows are about 14 to 34 percent greater in November and December, 11 to 42 percent less
 4417 from January through April, and about 5 to 9 percent less from May through September.
 4418 Outflows are decreased in late April and May due to increased refill. For the median condition,
 4419 sturgeon pulses remain the same. The pattern and magnitude of flow changes from Libby Dam
 4420 are clearly seen downstream in the Kootenai River at Bonners Ferry, Idaho, and in a much
 4421 diluted condition as far downstream as the Columbia River and Lake Roosevelt. The increased
 4422 outflow from Libby Dam in November and December results in an increase in median monthly
 4423 river water elevations of 1.4 to 1.8 feet in the free-flowing reach below Libby Dam and about
 4424 1.6 feet at Bonners Ferry. Decreased January through April flows result in a decrease in median
 4425 monthly Kootenai River water elevations by as much as 2 feet.



4426 **Figure 6-1. Libby Dam-Lake Kocanusa Summary Forebay Elevations for Multiple Objective**
 4427 **Alternative 3 Versus the No Action Alternative**
 4428



4429
 4430 **Figure 6-2. Libby Dam-Lake Koocanusa Summary Outflows for Multiple Objective Alternative**
 4431 **3 Versus No Action Alternative**

4432 Similar to the No Action Alternative, Libby Dam’s SWS provides some ability to adjust where in
 4433 the water column water is drawn from. The range of the SWS bulkheads is from elevation 2,409
 4434 feet to 2,200 feet NGVD29. Because SWS protocol maintains at least 30 feet of submergence
 4435 over the top row of the bulkheads for hydraulic stability, the SWS has the ability to perform
 4436 under the full range of possible MO3 drawdown operations with a similar efficiency as under
 4437 the No Action Alternative. Modeled forebay elevations under MO3 are predicted to be well
 4438 within the operating range of the SWS and similar to the ranges observed in historical years
 4439 described in Section 3.1.1.1.

4440 The ability of the SWS to manage discharge temperatures under a variety of drawdown and
 4441 inflow conditions will continue under MO3. However, for the SWS to achieve the best possible
 4442 downstream temperatures, thermal stratification must be present in the forebay. The onset of
 4443 thermal stratification is difficult to predict and can vary from year to year due to reasons such
 4444 as inflow volumes, inflow temperatures, reservoir drawdown elevation, discharge volumes, and
 4445 weather conditions. Historical temperature data suggests that holding the pool higher results in
 4446 colder reservoir temperatures and difficulty for the SWS to achieve the best possible

4447 downstream temperatures. When the pool is drafted deeper, the pool volume is less thereby
4448 allowing for greater warming in the spring and summer from warmer inflows and warming air
4449 temperatures.

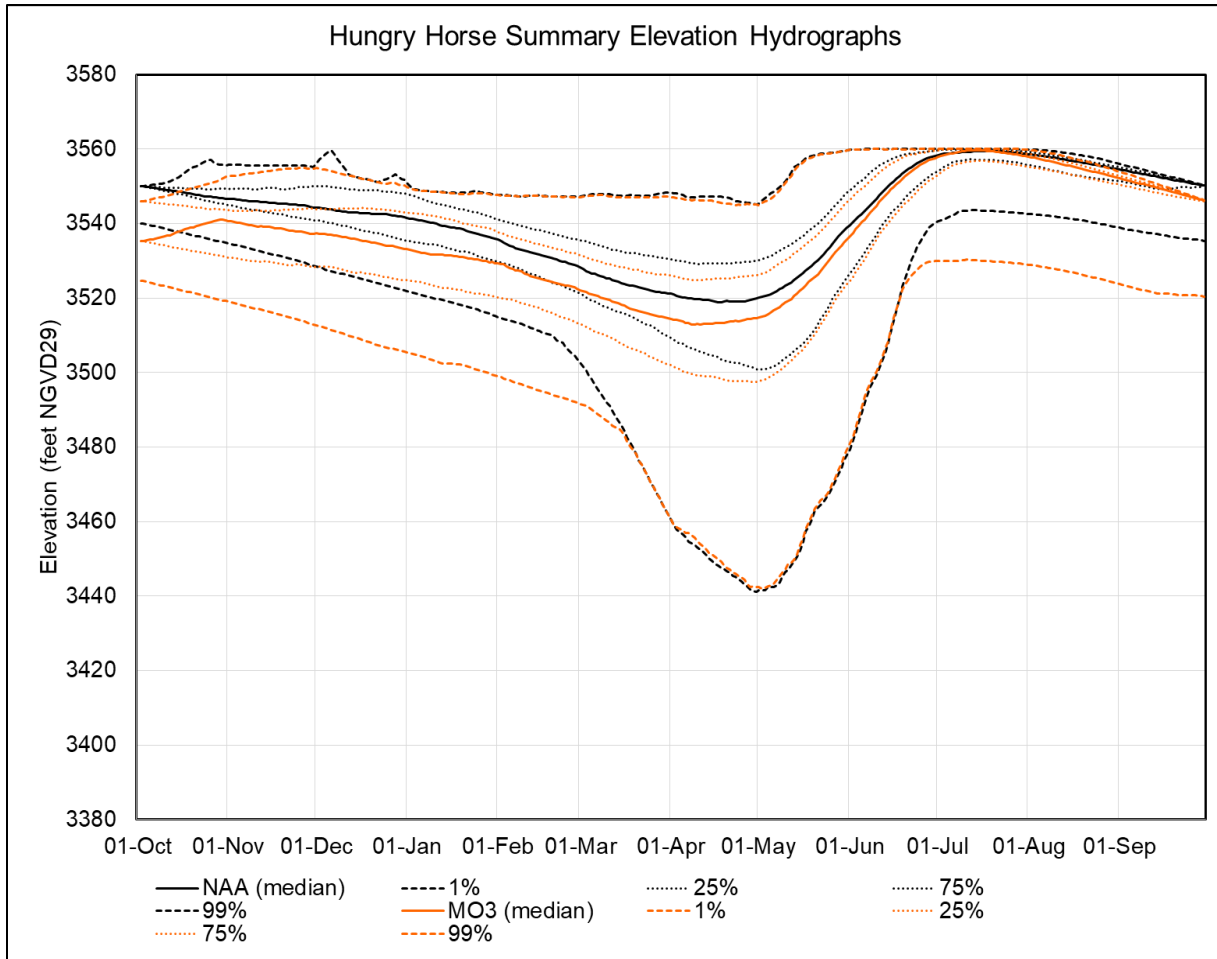
4450 The lower reservoir elevations under MO3 for the driest 40 percent of years are likely
4451 substantial enough to result in a change in forebay temperatures and thermal stratification
4452 compared to the No Action Alternative. These lower reservoir elevations should result in
4453 slightly warmer reservoir temperatures and earlier thermal stratification during the spring,
4454 resulting in a greater ability for the SWS to achieve downstream water temperature objectives
4455 when compared to the No Action Alternative. Under the No Action Alternative, downstream
4456 river temperatures during the fall and winter are generally several degrees warmer than pre-
4457 dam Kootenai River conditions, while water released from the dam during the spring and
4458 summer is generally several degrees cooler than natural river conditions. Overall, the
4459 limitations of the SWS that exist for the No Action Alternative are expected to continue for
4460 MO3.

4461 Changes in downstream temperatures from Libby Dam to Bonners Ferry may result from MO3
4462 increasing the median average monthly flows in November and December and decreasing the
4463 median monthly flows in January through April. During the cold winter months, Kootenai River
4464 water can cool by several degrees between Libby Dam and Bonners Ferry if flows are held low.
4465 Therefore, by increasing November and December flows, MO3 may increase downstream
4466 temperatures. However, by decreasing the flows from January through April, MO3 may
4467 decrease temperatures by allowing the natural cooling of the river as it moves downstream.
4468 These lower winter temperatures in the Kootenai River would benefit winter spawning fish
4469 species, such as burbot, which require near-freezing river temperatures (<35.6°F or <2°C) to
4470 spawn.

4471 Under MO3, three operational measures apply to Hungry Horse Dam:

- 4472 • Sliding Scale at Libby And Hungry Horse
- 4473 • Hungry Horse Additional Water Supply
- 4474 • Ramping Rates for Safety

4475 The operational measure Hungry Horse Additional Water Supply would allow for the additional
4476 release of 90 kaf of stored water during the summer after the typical refill period for water
4477 supply; operational measure Sliding Scale at Libby And Hungry Horse would implement a sliding
4478 scale draft based on a local forecast (rather than The Dalles forecast); and operational measure
4479 Ramping Rates for Safety would lift all ramping rate limitations when restrictions are not for
4480 safety. None of these operational measures would likely have an impact on the ability to
4481 operate the SWS based on reservoir elevations expected under MO3 (Figure 6-3.). The deeper
4482 draft associated with carryover impacts from *Hungry Horse Additional Water Supply* results in
4483 lower reservoir elevations in winter. Although selective withdrawal would continue to be
4484 operational, drawing the reservoirs down lower in the winter may allow for greater warming in
4485 the reservoir and downstream in the early spring.

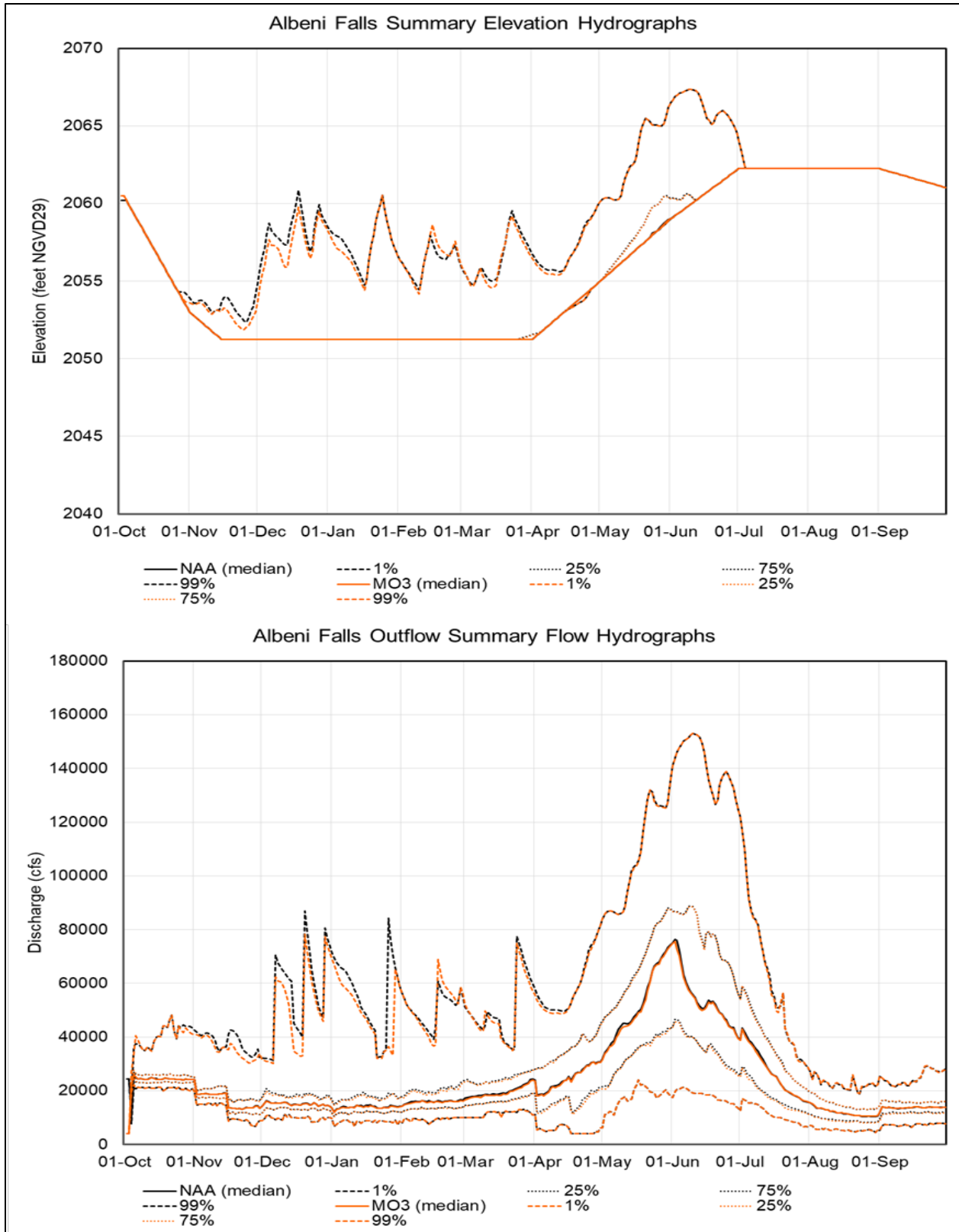


4486
 4487 **Figure 6-3. Hungry Horse Reservoir Summary Elevation Hydrograph for Multiple Objective**
 4488 **Alternative 3 Versus No Action Alternative**

4489 **6.1.1.2 Albeni Falls Dam and Reservoir**

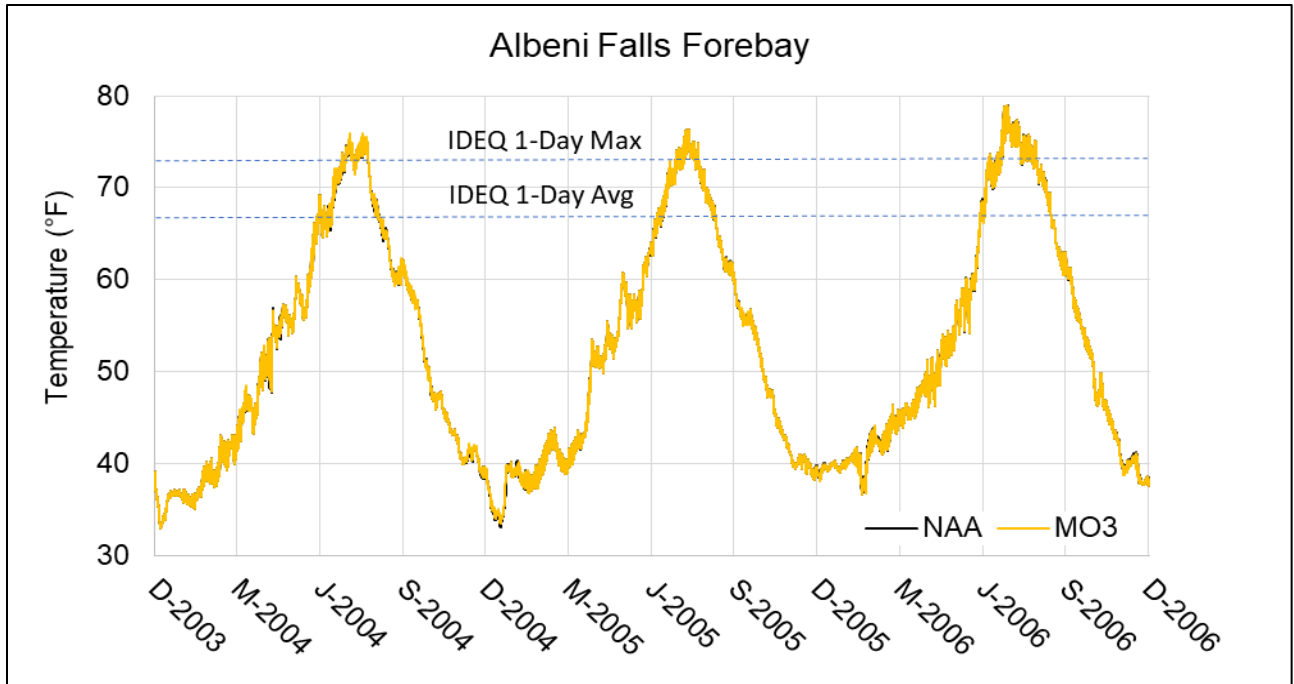
4490 Under the MO3 Alternative, Lake Pend Oreille and the Pend Oreille River will experience little
 4491 change in elevation and flow compared to the No Action Alternative. Although flow reductions
 4492 for Hungry Horse under MO3 can be seen through the Pend Oreille River Basin, flow reductions
 4493 are increasingly diluted moving downstream. As such, under MO3, Lake Pend Oreille and the
 4494 Pend Oreille River will see very little hydrological change compared to the No Action Alternative
 4495 (Figure 6-4.).

4496 Water temperatures in the Pend Oreille River upstream and downstream of Albeni Falls Dam
 4497 were modeled using W2 for the period 2004 through 2006. The reason for using this time
 4498 period is described in Section 2.2.3. W2 model results indicate little change in water
 4499 temperatures upstream and downstream of Albeni Falls Dam. In general, temperature changes
 4500 between MO3 and the No Action Alternative is about ± 0.2 to -1.4 degrees Fahrenheit (± 0.1 to
 4501 0.8 degree Celsius) with increases and decreases evenly distributed (Figure 6-5. and
 4502 Figure 6-6.).



4503
 4504
 4505

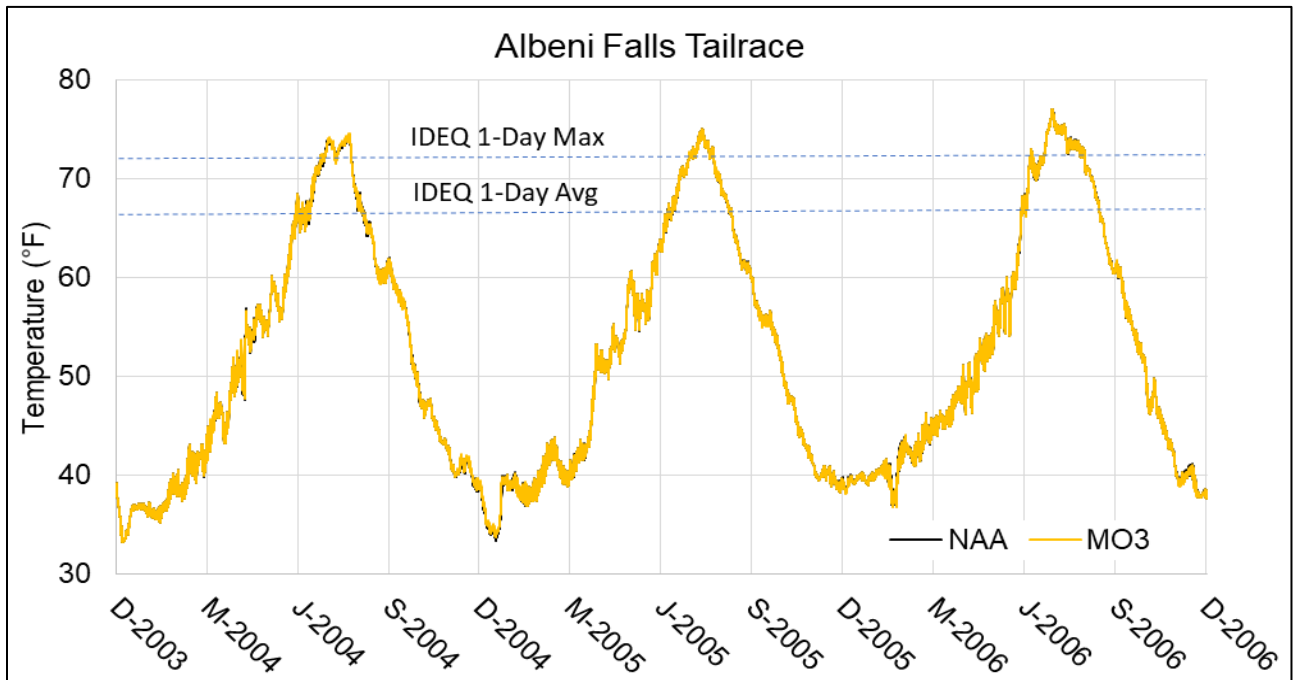
Figure 6-4. Albeni Falls Reservoir Summary Elevation Hydrographs and Outflows for Multiple Objective Alternative 3 Versus No Action Alternative



4506
4507
4508
4509
4510

Figure 6-5. Modeled Forebay Temperatures for No Action Alternative and Multiple Objective Alternative 3 at Albeni Falls for 2004 to 2006

Note: IDEQ 1-Day Maximum temperature standard of 22°C and 1-Day Average standard of 19°C shown for comparison.



4511
4512
4513
4514
4515

Figure 6-6. Modeled Tailwater Temperatures for No Action Alternative and Multiple Objective Alternative 3 at Albeni Falls for 2004 to 2006

Note: IDEQ 1-Day Maximum temperature standard of 22°C and 1-Day Average standard of 19°C shown for comparison.

4516 **6.1.1.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

4517 Under MO3, the operations of Grand Coulee Dam and Lake Roosevelt above the dam are
4518 altered by four operational measures:

- 4519 • *Update System FRM Calculation*
- 4520 • *Grand Coulee Maintenance Operations*
- 4521 • *Planned Draft Rate at Grand Coulee*
- 4522 • *Lake Roosevelt Additional Water Supply*

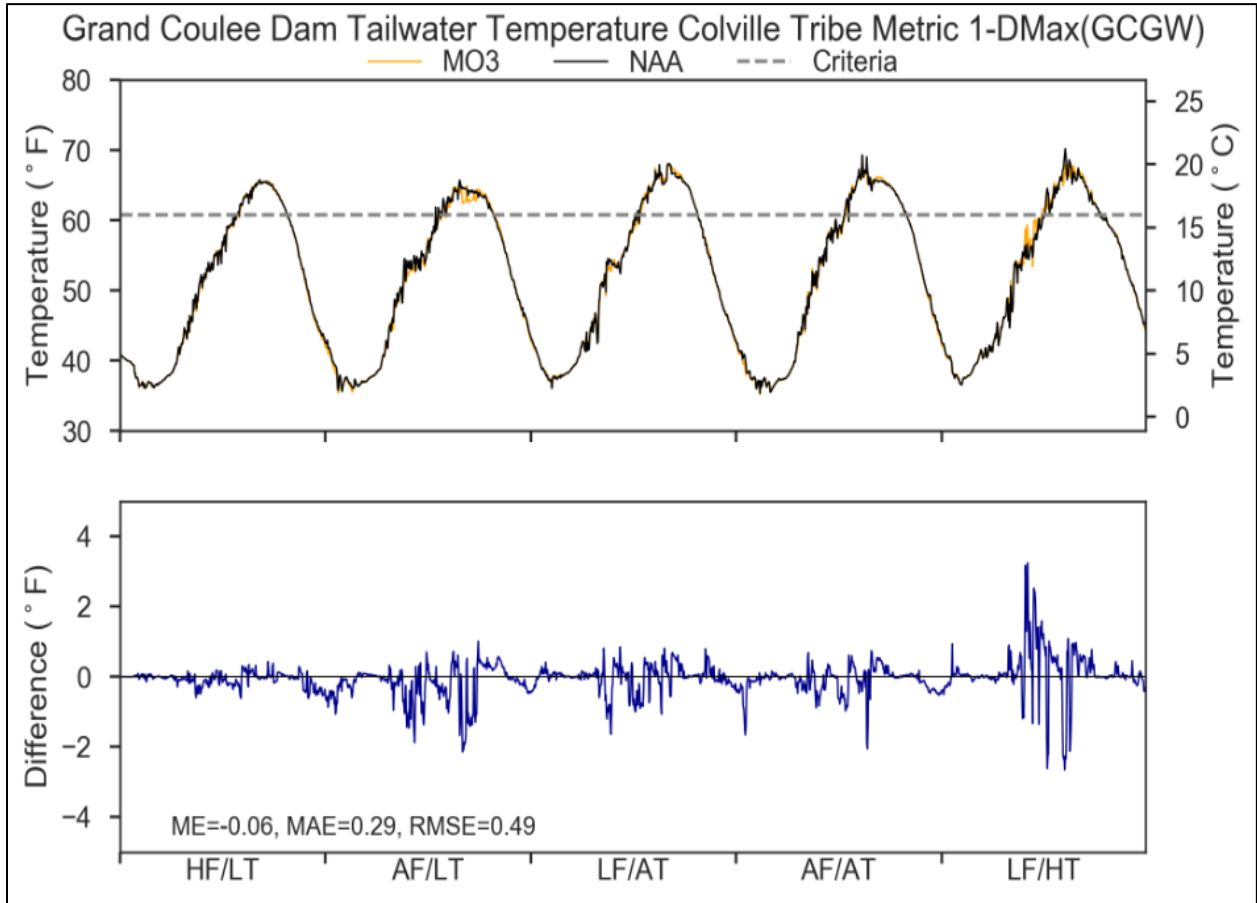
4523 *Grand Coulee Maintenance Operations* would address operational constraints for ongoing
4524 Grand Coulee maintenance of power plants and reduce the hydraulic capacity through the
4525 power plants, increasing the likelihood of spill, but this is largely offset by the impacts of other
4526 measures on spring flows. Operational measure *Lake Roosevelt Additional Water Supply*
4527 increases pumping for irrigation and municipal and industrial (M&I) purposes, directly reducing
4528 outflows. Increased withdrawal under this operational measure would begin in March (0.6 kcfs
4529 increase in pumping) and increase through the summer to a maximum additional withdrawal of
4530 4.1 kcfs in July. A more in-depth discussion of these operational measures and their effects can
4531 be found in [Section H&H-MO3].

4532 Many of the MO3 measures impact winter and spring storage and outflows; however, they are
4533 not expected to impact temperatures significantly. MO3 water temperatures are nearly
4534 identical to conditions under the No Action Alternative in Lake Roosevelt and the Columbia
4535 River downstream. In the reservoir, the impacts are greatest near Grand Coulee Dam and are
4536 reduced toward the U.S.-Canada border wherein the impacts from MO3 are almost
4537 unnoticeable at Hall Creek. These differences, on average, are very small in the reservoir for
4538 MO3.

4539 For the LF/HT-type years, the modeled water temperature downstream of Grand Coulee during
4540 the spring and early summer months are approximately 0.3 degree Fahrenheit warmer, which is
4541 within the margin of error for the model, (for the period May through July) than the No Action
4542 Alternative. These differences are likely due to a combination of the water year type (extreme
4543 low flow year with high temperatures susceptible to changes in operations), operational
4544 changes resulting in reduced outflows (FRM and Water Supply measures), and potentially
4545 simplifying assumptions in the modeling. An additional factor influencing spring and summer
4546 temperatures in some years may be winter and spring operations that decrease storage during
4547 that period, which would potentially reduce the cold water mass that would influence the
4548 inflowing temperature signal from upstream.

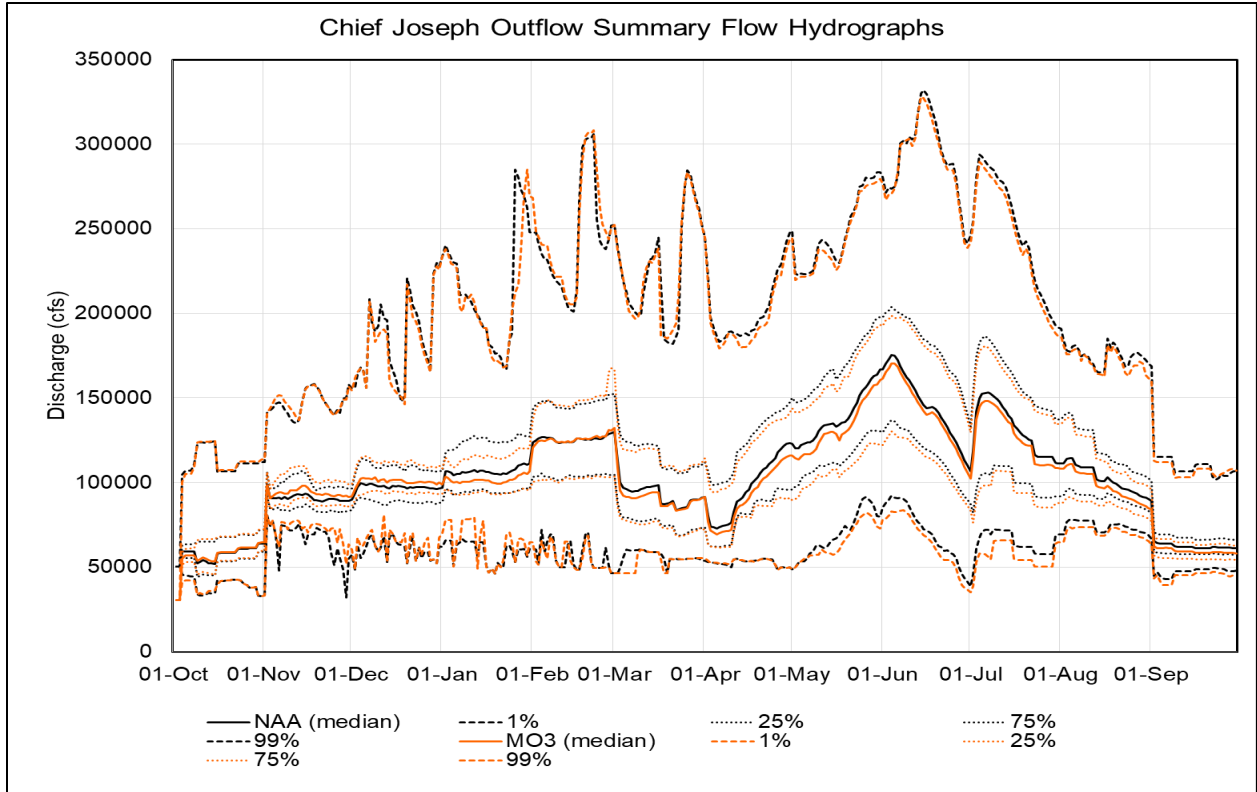
4549 Additionally, based on the 5-year period presented in Figure 6-7., the Washington State water
4550 quality criteria of 61°F would be exceeded, on average, by an additional two days per year
4551 compared to the No Action Alternative. The small flow pattern change in Grand Coulee Dam

4552 outflows would be seen through Rufus Woods Lake and downstream in the tailwater of Chief
 4553 Joseph Dam.

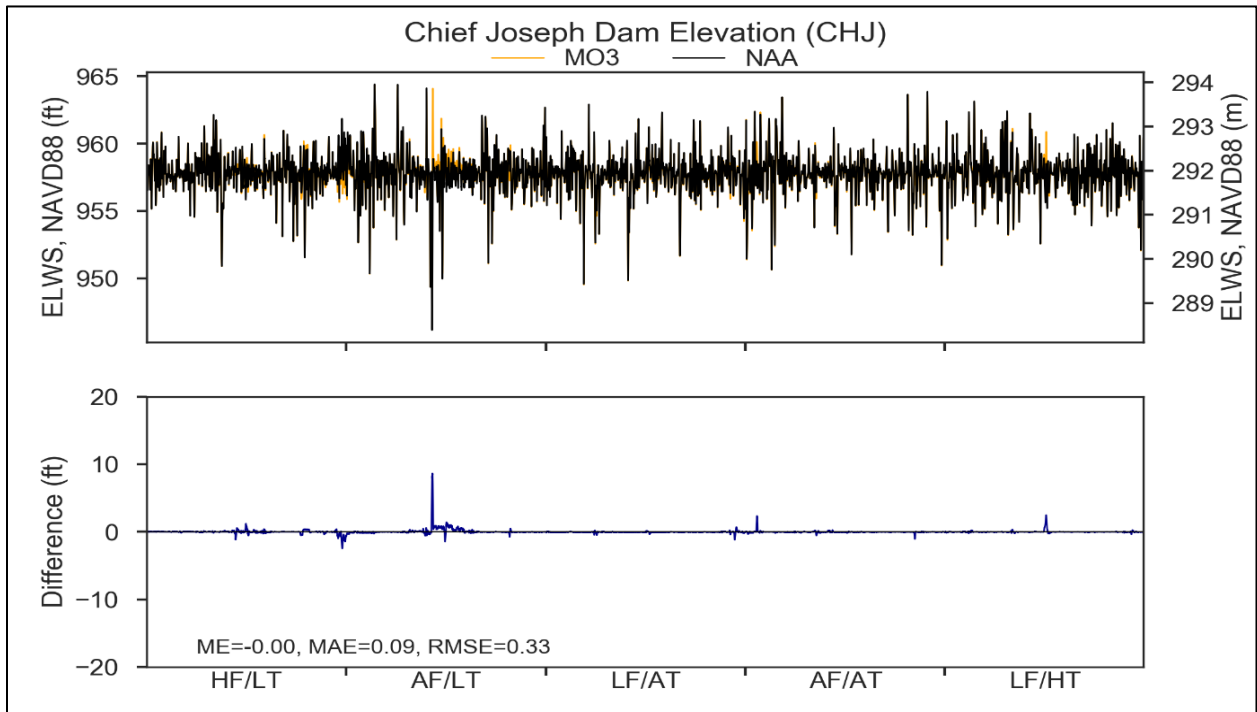


4554 **Figure 6-7. Modeled Tailwater Temperature for the No Action Alternative and Multiple**
 4555 **Objective Alternative 3 at Grand Coulee Dam Under a 5-Year Range of River and**
 4556 **Meteorological Conditions Compared to the Confederated Colville Tribe 1-D Maximum Water**
 4557 **Quality Standard**
 4558

4559 Under MO3, reservoir elevation changes and corresponding project outflow changes predicted
 4560 at Grand Coulee Dam would carry downstream through Rufus Woods Lake to Chief Joseph
 4561 Dam. In general, monthly average outflows out of Chief Joseph Dam would be similar to the No
 4562 Action Alternative. Average monthly outflows would slightly increase in November and
 4563 December by 2 to 4 percent, reflecting the increased outflow from Libby Dam during this time
 4564 period. Average monthly outflows would slightly decrease by 1 to 5 percent from January
 4565 through September, largely related to changes in Libby Dam operations, Grand Coulee
 4566 operations and the *Lake Roosevelt Additional Water Supply* measure (Figure 6-8.). Since Chief
 4567 Joseph Dam is a run-of-river project, little change to forebay elevations would occur for MO3
 4568 when compared to the No Action Alternative (Figure 6-9.).

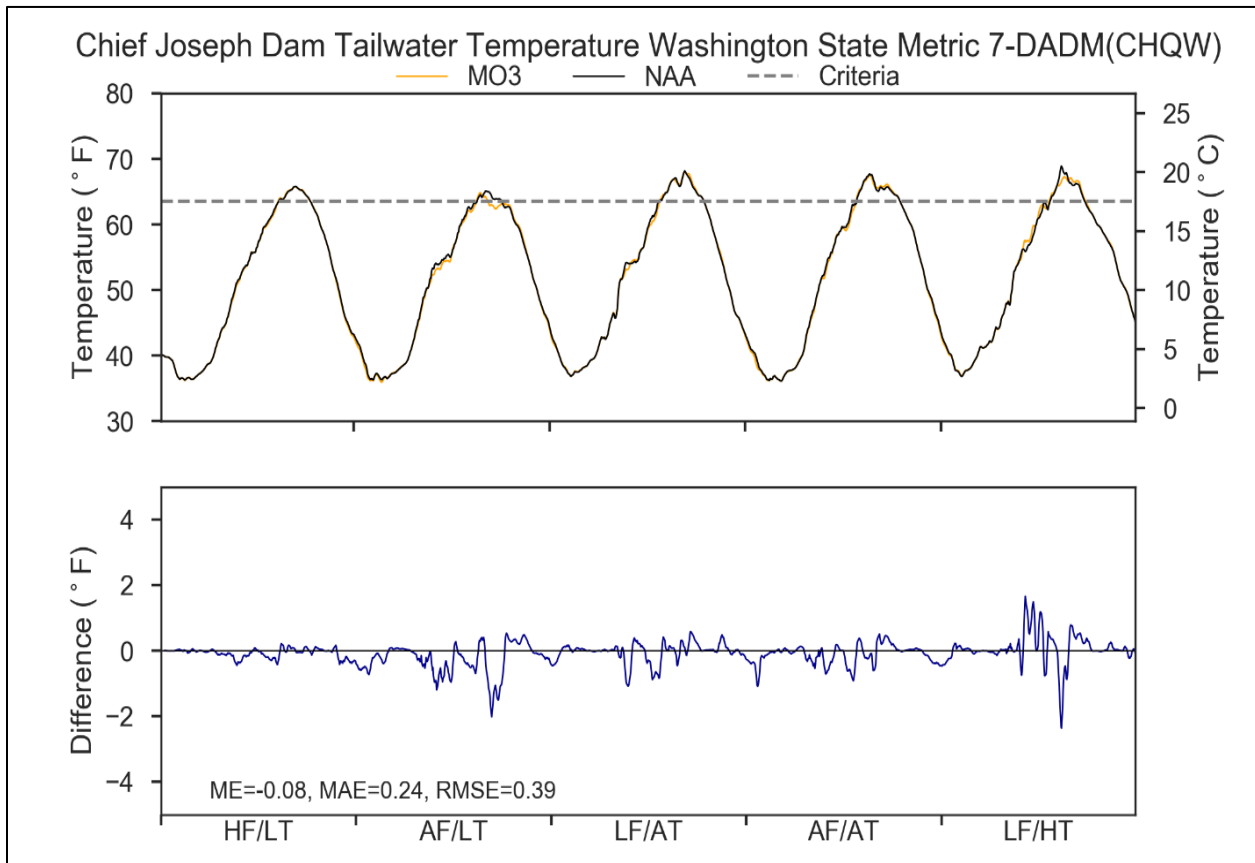


4569
 4570 **Figure 6-8. Chief Joseph Dam-Rufus Woods Lake Outflows for Multiple Objective Alternative 3**
 4571 **Versus No Action Alternative**



4572
 4573 **Figure 6-9. Chief Joseph Dam-Rufus Woods Lake Forebay Elevations Multiple Objective**
 4574 **Alternative 3 Versus No Action Alternative**

4575 Water temperatures under MO3 at Chief Joseph Dam tailwater are similar to or slightly cooler
 4576 than the No Action Alternative with the majority of temperature differences in the ± 1 to 2
 4577 degrees Fahrenheit range (Figure 6-10.). In general, temperatures modeled for MO3 are similar
 4578 to or slightly cooler than the No Action Alternative for most river and meteorological
 4579 conditions. In particular, maximum summer temperatures are typically 0.5 to 2 degrees
 4580 Fahrenheit cooler for MO3 under the 5-year range of river flow and meteorological conditions.
 4581 An exception is for the LF/HT scenario where river temperatures in the spring are expected to
 4582 be up to 2 degrees Fahrenheit warmer under MO3. Tailwater temperatures under both MO3
 4583 and the No Action Alternative are predicted to exceed the tribal water temperatures standard
 4584 (1-day maximum of 18°F) as well as the Washington State standard of 63.5°F (17.5°C) as
 4585 measured by the 7-day average of the daily maximum temperature in August and September.
 4586 Similar to the No Action Alternative, there is little difference in temperature between Grand
 4587 Coulee Dam tailwater (Figure 6-7.) and Chief Joseph Dam tailwater conditions (Figure 6-10.)
 4588 under MO3, showing that water temperatures released from Lake Roosevelt are passed
 4589 through Rufus Woods Lake mainly unchanged.

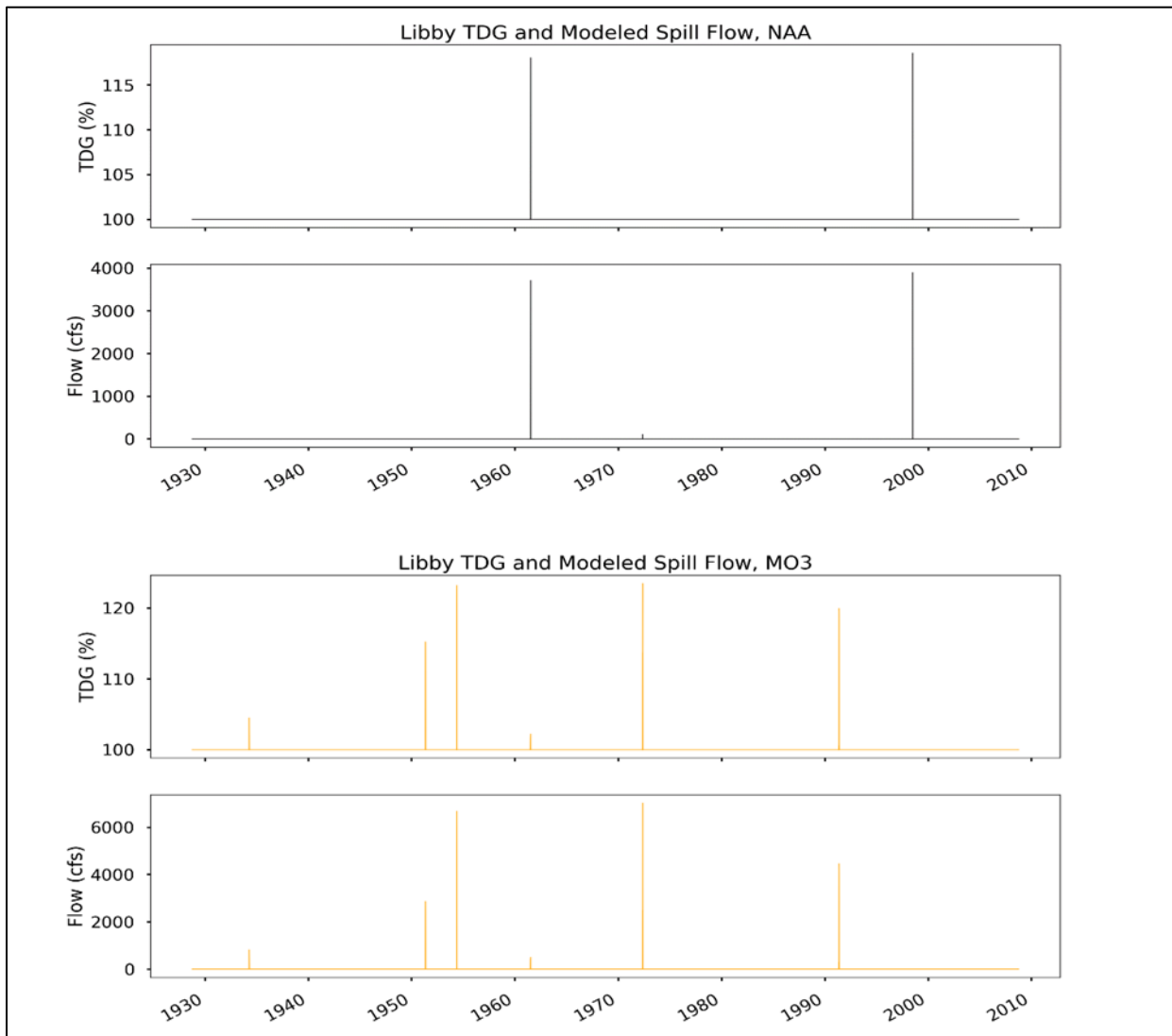


4590
 4591 **Figure 6-10. Modeled Tailwater Temperature for the No Action Alternative and Multiple**
 4592 **Objective Alternative 3 at Chief Joseph Dam Under a 5-Year Range of River and**
 4593 **Meteorological Conditions**

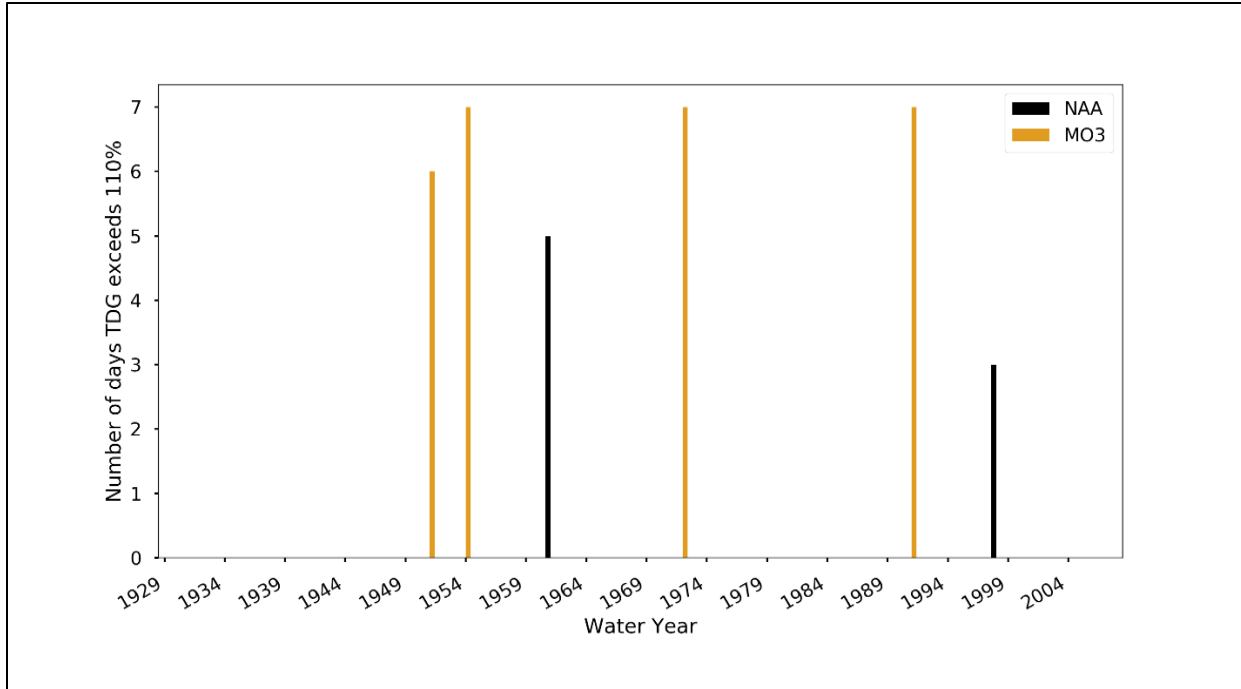
4594 **6.1.2 Total Dissolved Gas**

4595 **6.1.2.1 Libby and Hungry Horse Dams and Reservoirs**

4596 Libby Dam is typically operated to minimize spill due to associated water quality concerns such
4597 as elevated TDG. Under MO3, Libby Dam’s draft and refill operations will be modified resulting
4598 in an increase in the highest releases from the dam. This operational change is predicted to
4599 increase the chance of spill at Libby Dam. The 80-year period of record flows (1928 to 2008)
4600 were used to predict TDG, as presented in Figure 6-11.. This shows that the number of years
4601 where spill could occur increases from 3 years under the No Action Alternative to 5 years under
4602 MO3. The number of days exceeding 110 percent would increase as well, from 8 days for the
4603 No Action Alternative to 27 days for MO3 (Figure 6-12.). Although spill from Libby Dam for the
4604 80-year model period are predicted to increase under MO3, the frequency of spill is still small.



4605 **Figure 6-11. Modeled Tailwater Total Dissolved Gas and Spillway Flows for the No Action**
4606 **Alternative and Multiple Objective Alternative 3 at Libby Dam over an 80-Year Period**
4607



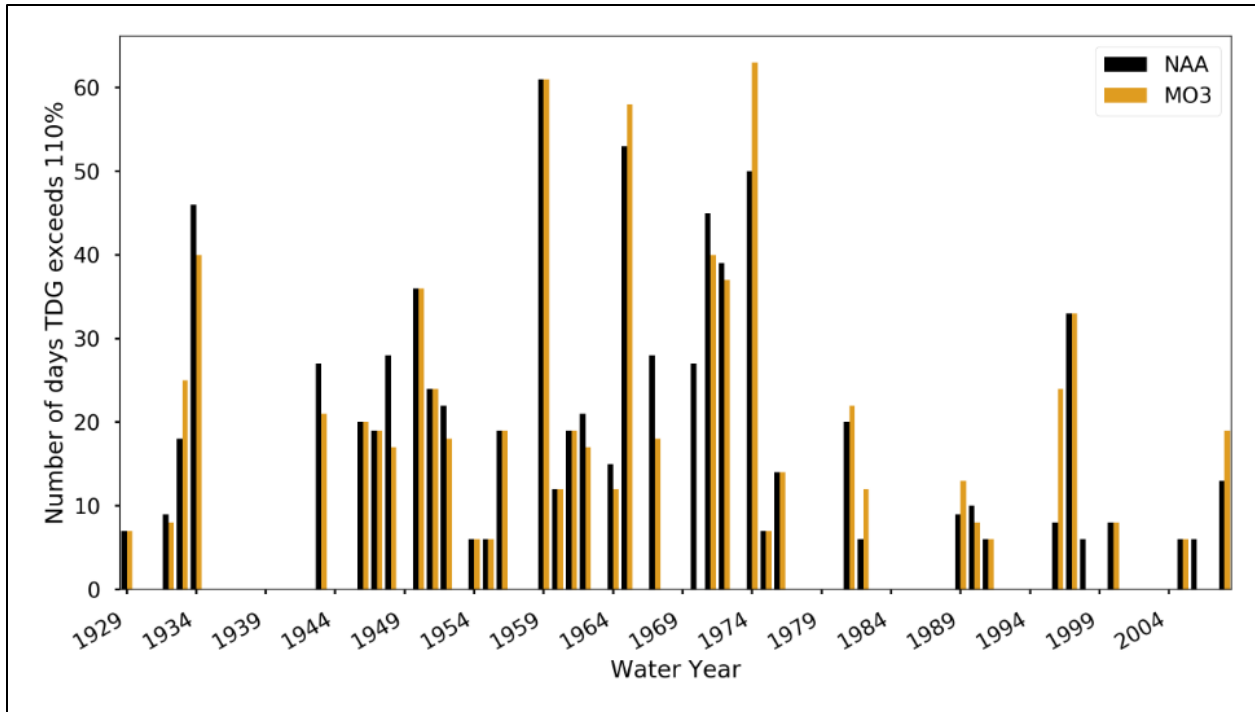
4608
4609 **Figure 6-12. Number of Days Modeled Tailwater Total Dissolved Gas Exceeds the 110 percent**
4610 **State of Montana Water Quality Standards for the No Action Alternative and Multiple**
4611 **Objective Alternative 3 at Libby Dam over an 80-Year Period**

4612 Under MO3, the operations of Hungry Horse Dam are altered by three operational measures:

- 4613 • *Hungry Horse Additional Water Supply*
- 4614 • *Sliding Scale at Libby And Hungry Horse*
- 4615 • *Ramping Rates for Safety*

4616 The additional draft provided in these measures, particularly the additional 90 kaf of draft in dry
4617 years under *Hungry Horse Additional Water Supply*, could reduce the likelihood of spill and
4618 associated elevated TDG concentrations in the following spring. These flow and spill impacts are
4619 small, therefore, TDG below the dam under MO3 is expected to be relatively similar to the No
4620 Action Alternative in most years.

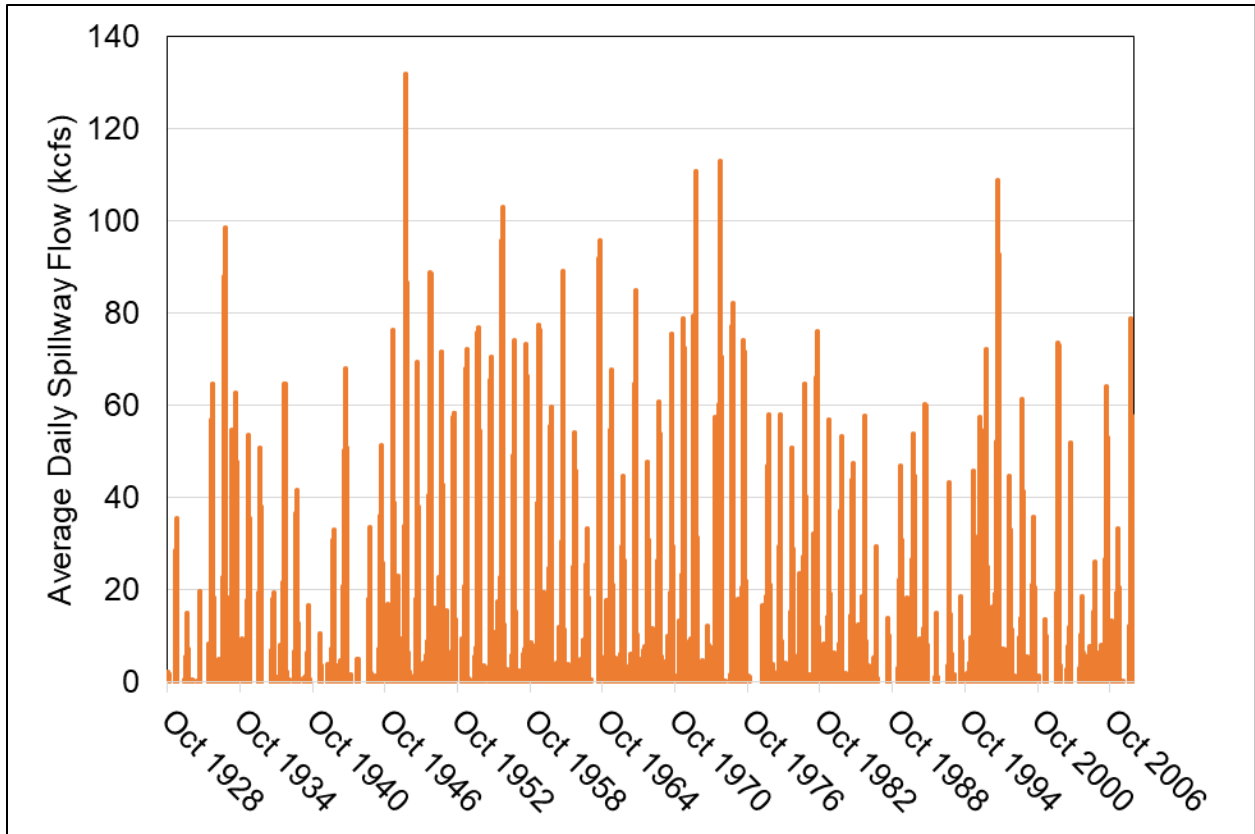
4621 Figure 6-13. shows the number of days that TDG is anticipated to exceed 110 percent below
4622 Hungry Horse Dam under MO3, for the period of record flows (1929 through 2008). The
4623 number of days that TDG goes above the State of Montana water quality standard of 110
4624 percent in MO3 is similar to the No Action Alternative. Some years would see more violations
4625 while others would see fewer. On average, TDG would exceed 110 percent in the river below
4626 the dam approximately 0.5 days more per year compared to the No Action Alternative. These
4627 are results of ResSim modeled operations, which do not consider spill when making releases for
4628 water supply (*Hungry Horse Additional Water Supply*), as would be done in real time. In
4629 application, it would be unlikely that spill would be required to meet water supply needs.



4630
 4631 **Figure 6-13. Number of Days that Total Dissolved Gas is Above the 110 percent State Water**
 4632 **Quality Standard Under the No Action Alternative and Multiple Objective Alternative 3 at**
 4633 **Hungry Horse Dam**

4634 **6.1.2.2 Albeni Falls Dam and Reservoir**

4635 TDG in the Pend Oreille River upstream of Albeni Falls Dam can be greater than 110 percent
 4636 largely because of spillway releases from Cabinet Gorge Dam located on the Clark Fork River
 4637 about 55 miles upstream of Albeni Falls Dam. During most years, Albeni Falls Dam spills during
 4638 high flow spring runoff. In general, spillway discharges up to about 10 kcfs can increase TDG
 4639 saturations over forebay levels by about 1 to 2 percent, while spill between 10 to 50 kcfs can
 4640 increase TDG saturations downstream of Albeni Falls by about 5 to 9 percent. When Pend
 4641 Oreille River flows exceed about 50 to 60 kcfs, Albeni Falls Dam powerhouse operations are
 4642 suspended and the spillway gates are raised, allowing the river to flow relatively un-impounded
 4643 across the dam. Under these high flow conditions, Albeni Falls Dam produces no TDG as the
 4644 river is essentially free flowing. Spillway flows at Albeni Falls Dam were modeled under MO3
 4645 and the No Action Alternative for the 80-year period from 1928 to 2008 using the ResSim model
 4646 (Figure 6-14.). There would be little difference in spillway flows between MO3 and the No
 4647 Action Alternative. For both alternatives, spillway flows are predicted to range between 1 and
 4648 50 kcfs in nearly every year at Albeni Falls Dam, with many years having spill exceed about 60
 4649 kcfs resulting in free-flowing conditions. These similar spillway flows under MO3 and the No
 4650 Action Alternative are expected to result in no change in TDG saturations downstream of Albeni
 4651 Falls Dam.



4652

4653

4654

Figure 6-14. Modeled Tailwater Spillway Flows for the No Action Alternative and Multiple Objective Alternative 3 at Albeni Falls Dam over an 80-Year Period

4655

6.1.2.3 Grand Coulee and Chief Joseph Dams and Reservoirs

4656

None of the operational measures in MO3 would notably affect TDG levels within Lake Roosevelt, which are largely influenced by upstream dams that are outside the scope of this analysis. Changes in operations of upstream dams result in an increase in inflows in November and December at Grand Coulee, which may have minor impacts on inflowing TDG but are not captured by the system modeling.

4661

The operational measure *Planned Draft Rate at Grand Coulee* would result in a slightly earlier draft in Lake Roosevelt in wetter years as early as January; Update System FRM Calculation determines the deepest draft point in the spring, and in some years is slightly deeper. These changes result in increased flows in the winter and decreased flows in April through July, which reduce spill in some situations (Figure 6-16).

4666

Starting in March, the increase in water withdrawal (0.6 kcfs) from Lake Roosevelt under operational measure *Lake Roosevelt Additional Water Supply* also decreases outflows and spill from Grand Coulee; however, this influence is not significant until April (3.2 kcfs increase in pumping and decrease in outflows) and continues through the summer period. A more in-depth discussion of these operational measures and their effects can be found in [Section H&H-MO3].

4667

4668

4669

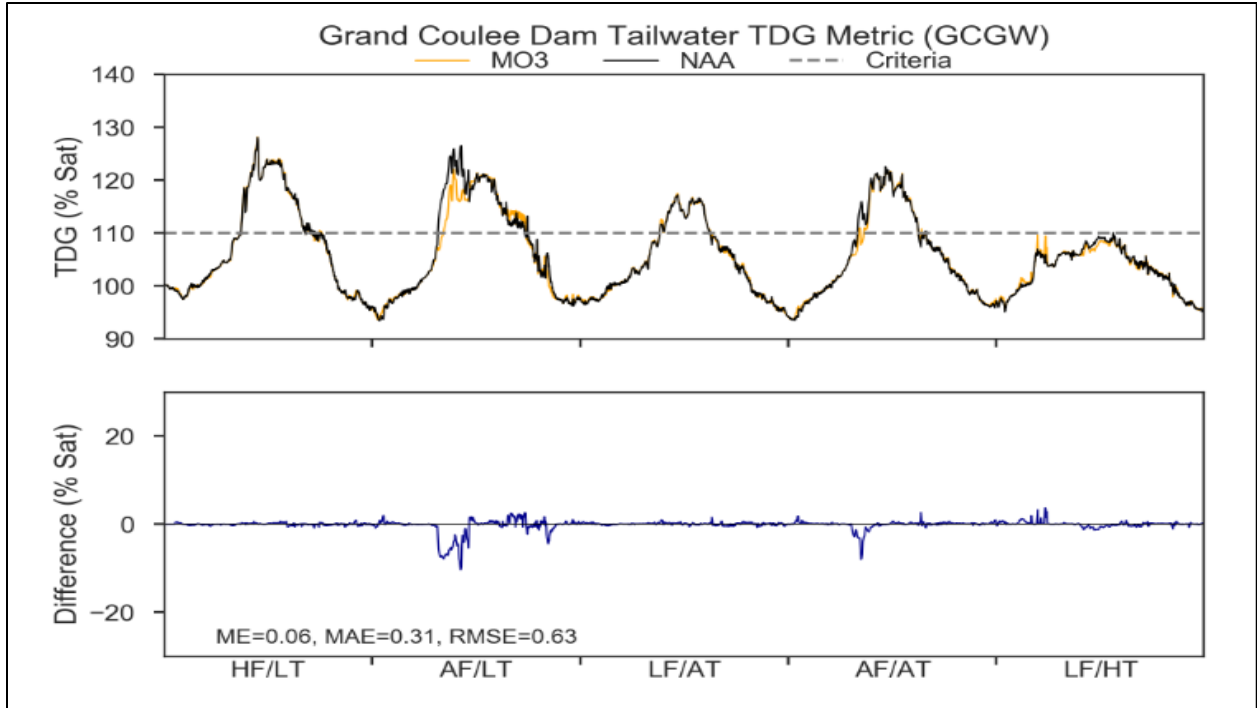
4670

4671 Overall, MO3 operational measures would result in higher Columbia River flows below the dam
4672 from December to February, when TDG is generally below the 110 percent Washington State
4673 and Colville Tribes water quality standards. On average, the decrease in outflow and spill
4674 associated with the operational measure Lake Roosevelt Additional Water Supply results in a
4675 decrease in the modeled TDG for May and June by about 5 percent, typically when the highest
4676 seasonal TDG concentrations are observed below the dam.

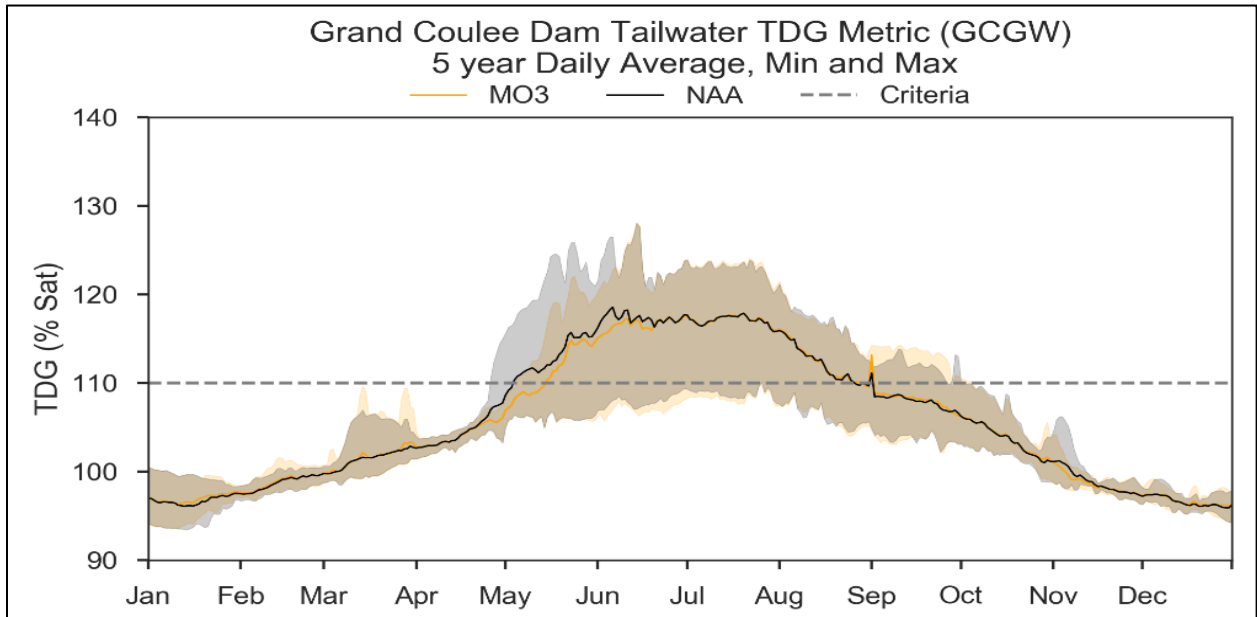
4677 The *Grand Coulee Maintenance Operations* measure has the potential to increase spill through
4678 the reduction in the hydraulic capacity of the powerhouse at Grand Coulee; however, the other
4679 actions have a larger impact on outflows and associated spill. The *Grand Coulee Maintenance*
4680 *Operations* measure in isolation could result in significant increases in spill and TDG, in some
4681 cases producing TDG in excess of 130 percent for a limited duration. An additional impact that
4682 is expected from Grand Coulee Maintenance Operations is the potential for slightly deeper spill
4683 over the drum gates (when the forebay elevation is greater than 1,267 feet, NGVD29).
4684 Information to assess the magnitude of water quality impacts is unavailable but would likely
4685 result in small increases in TDG. In wet conditions, it is anticipated that potential maintenance
4686 activities could be delayed in advance of spill to allow spill over more gates. Another factor not
4687 considered in the analysis is that as maintenance occurs, there would be an increase to
4688 hydraulic capacity as more units become available. This would result in reduced spill and TDG in
4689 some cases; however, the other actions have a larger impact on outflows and associated spill.

4690 As shown in Figure 6-15., the combination of the MO3 operational measures tend to offset
4691 each other in the analysis of the alternative, and in some cases, result in a reduction in TDG.
4692 Average TDG is slightly lower (0.2 percent) but results in about 0.5 days of more Washington
4693 State water quality violations per year. Additionally, in the highest flow years, TDG
4694 concentration may be reduced in May and June under MO3 due to the water supply measure
4695 (*Lake Roosevelt Additional Water Supply*) (Figure 6-16.). The shaded area in the figure shows
4696 the entire range of TDG predicted by the MO3 and No Action Alternative simulations. The
4697 model indicates reductions in TDG in the early months compared to the No Action Alternative
4698 in high water years. Therefore, compared to the No Action Alternative, MO3 could reduce TDG,
4699 but the number of daily Washington State water quality violations in the Columbia River below
4700 the dam would mostly remain the same.

4701 TDG at the forebay of Chief Joseph Dam is largely a function of the TDG released upstream from
4702 Lake Roosevelt and Grand Coulee Dam because little degassing occurs in Rufus Woods Lake.
4703 High inflow TDG saturations to Lake Roosevelt from Canada, as well as spill from Grand Coulee
4704 Dam via the outlet tubes, can increase TDG saturations in Rufus Woods Lake at the Chief Joseph
4705 Dam forebay to over 130 percent for a limited time. During periods when incoming TDG levels
4706 are above approximately 120 percent, spilling at Chief Joseph Dam over the spillway deflectors
4707 can degas the water and reduce downstream system TDG loading. Therefore, Chief Joseph Dam
4708 is often used to help manage overall system TDG production in the mainstem Columbia River.
4709 In addition, to avoid spilling through the outlet tubes at Grand Coulee Dam, spill is often shifted
4710 from Grand Coulee to Chief Joseph Dam to take advantage of the lower TDG produced by
4711 spilling over the deflectors. These operational strategies are expected to continue under MO3.



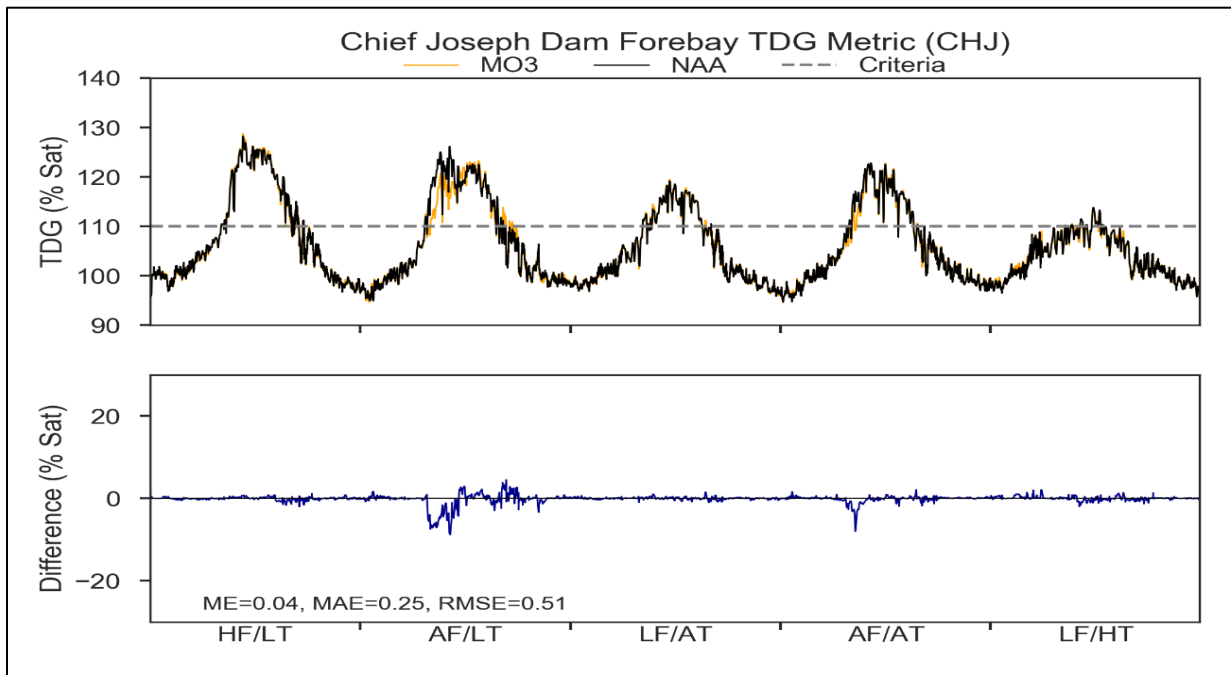
4712
 4713 **Figure 6-15. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and**
 4714 **Multiple Objective Alternative 3 at Grand Coulee Dam Under a 5-Year Range of River and**
 4715 **Meteorological Conditions**



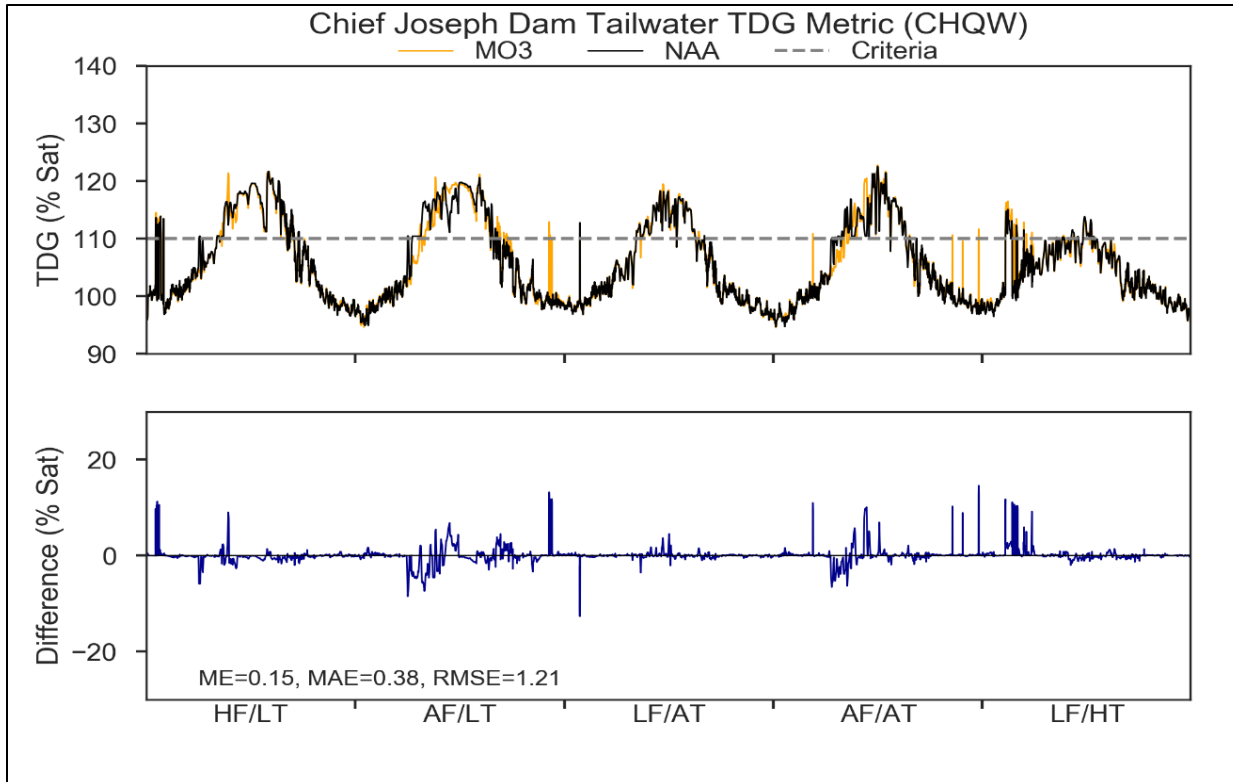
4716
 4717 **Figure 6-16. Modeled Range of Tailwater Total Dissolved Gas for the No Action Alternative**
 4718 **and Multiple Objective Alternative 3 at Grand Coulee Dam Under a 5-Year Range of River and**
 4719 **Meteorological Conditions**

4720 Chief Joseph Dam TDG saturations at the forebay and tailwater modeled under MO3 were
 4721 compared to the No Action Alternative (Figure 6-17.). In general, MO3 forebay TDG saturations

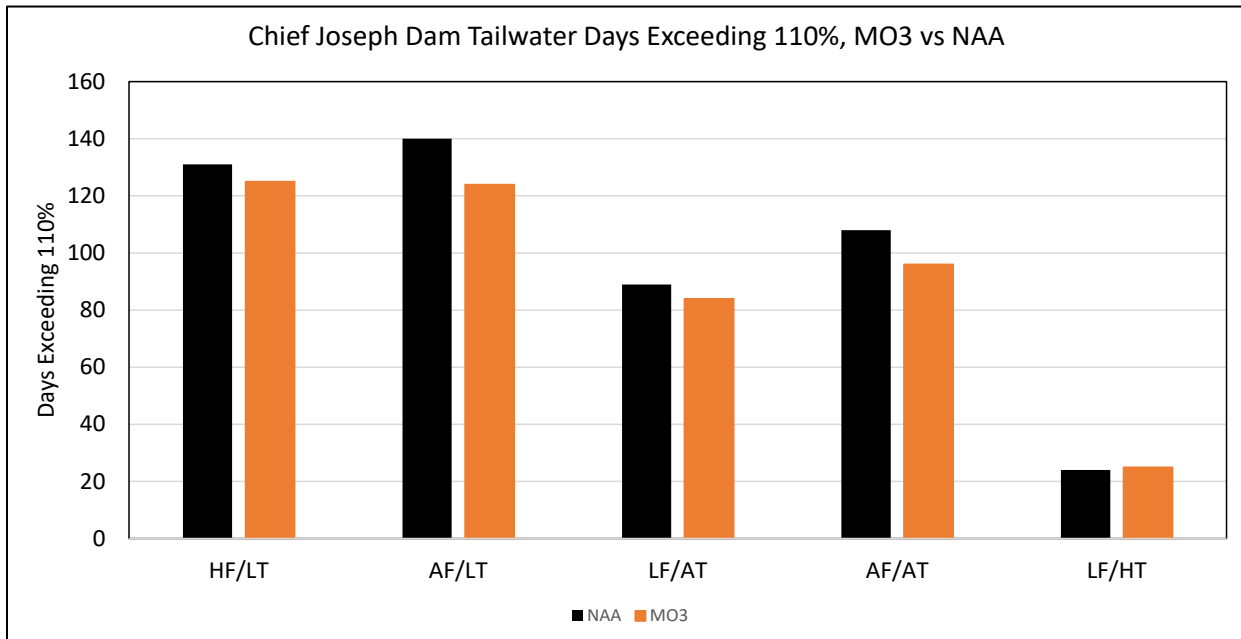
4722 are predicted to be similar to, or slightly lower than, the No Action Alternative under a wide
4723 range of flow and air temperature conditions. Tailwater TDG saturations under MO3 are
4724 predicted to be both lower and higher than the No Action Alternative depending on flow and
4725 meteorological conditions. The number of days the tailwater exceeds the 110 percent TDG
4726 criteria is predicted to be slightly lower under MO3 for all flow and meteorological conditions
4727 (Figure 6-19.), likely due to the FRM and water supply measures implemented at Grand Coulee
4728 Dam. Decreased TDG saturations between the forebay and tailwater during higher spill years
4729 such as 2011 (HF/LT) and 2012 (AF/LT) modeled under the No Action Alternative would
4730 continue under the MO3 Alternative. It is expected that under MO3, Chief Joseph Dam would
4731 continue to decrease TDG during high spill years when TDG saturations greater than about 120
4732 percent occur in the forebay.



4733
4734 **Figure 6-17. Modeled Forebay Total Dissolved Gas Saturations for the No Action Alternative**
4735 **and Multiple Objective Alternative 3 at Chief Joseph Dam Under a 5-Year Range of River and**
4736 **Meteorological Conditions**



4737
 4738 **Figure 6-18. Modeled Tailwater Total Dissolved Gas Saturations for the No Action Alternative**
 4739 **and Multiple Objective Alternative 3 at Chief Joseph Dam Under a 5-Year Range of River and**
 4740 **Meteorological Conditions**



4741
 4742 **Figure 6-19. Days Exceeding the 110 percent TDG criteria for the No Action Alternative and**
 4743 **Multiple Objective Alternative 3 at Chief Joseph Dam Tailwater Under a 5-Year Range of River and**
 4744 **Meteorological Conditions**

4745 **6.1.3 Other Physical, Chemical, and Biological Processes**

4746 **6.1.3.1 Libby and Hungry Horse Dams and Reservoirs**

4747 MO3 modifies operations at Libby Dam resulting in changes in reservoir drawdown rates and
4748 water elevations of Lake Koochanusa that may impact physical, chemical, and biological water
4749 quality parameters when compared to existing conditions and the No Action Alternative. In
4750 general, the MO3 reservoir drawdowns would result in lower water elevations in Lake
4751 Koochanusa from November through April, with substantially lower end-of-April water
4752 elevations (11 to 19 feet) in the driest 40 percent of years. Reservoir refill and summer pool
4753 elevations are improved over the No Action Alternative with the reservoir reaching full pool by
4754 the end of July, and maintaining August and September reservoir elevations at about 1 to 4 feet
4755 greater than under the No Action Alternative. For water quality concerns, of particular interest
4756 are the 11- to 19-foot lower end-of-April water elevations because they equate to less volume
4757 of water in Lake Koochanusa during the spring runoff and a shorter water retention time.

4758 Retention time, which is the inverse of the flushing rate, refers to the length of time water
4759 remains in a waterbody. Water quality chemical and biological parameters of concern in Lake
4760 Koochanusa that may be impacted by changes in the reservoir elevation and retention times,
4761 under MO3, include suspended sediments, nutrients such as phosphorus and nitrogen, trace
4762 metals such as selenium, and phytoplankton such as cyanobacteria and diatoms. For a long,
4763 narrow, deep waterbody like Lake Koochanusa, shorter retention times may allow certain
4764 chemical constituents in inflowing waters to move farther down-reservoir toward the forebay
4765 and outflow before settling out or transforming.

4766 It is likely that the end-of-April drawdown elevation and the corresponding reservoir volume, as
4767 well as spring runoff volume and the corresponding phosphorus and sediment concentrations,
4768 are all factors in determining how far down-reservoir total phosphorus and suspended
4769 sediments reach. Historical data show that Lake Koochanusa is a sink for phosphorus and
4770 sediments, with little inflow concentrations moving down-reservoir past Libby Dam. A recent
4771 study by Yassien and Ward (2018) concluded that from 2014 through 2017, the total
4772 phosphorus retention in the reservoir ranged from 80 to 93 percent. Under MO3, the lower
4773 reservoir elevations for the driest 40 percent of years would likely allow sediments and total
4774 phosphorus from the inflow to move farther down-reservoir before settling out.

4775 Lake Koochanusa does not appear to be a sink for nitrogen, and most of the inflowing nitrate
4776 passes down-reservoir to the forebay and Kootenai River regardless of reservoir elevations and
4777 retention times. Increased nitrate loadings to Lake Koochanusa, largely due to coal mining
4778 operations in British Columbia and low phosphorus concentrations, have created a large
4779 imbalance in the nitrogen-to-phosphorus ratio, with the ratio often exceeding 100:1 at the
4780 forebay, resulting in strong phosphorus limitation. Despite rising nitrate concentrations in Lake
4781 Koochanusa, algal blooms appear to have been kept in check by the strong phosphorus limitation
4782 under existing conditions and the No Action Alternative. However, it is possible that the
4783 operational changes proposed for MO3 may increase total phosphorus concentrations in Lake
4784 Koochanusa, which could result in changes in phytoplankton densities and functional types.

4785 Increasing selenium concentrations in Lake Kooconusa from coal mining operations in British
4786 Columbia are a concern, and have been thoroughly discussed for the No Action Alternative and
4787 MO1. Over the next 25 years, it is expected that coal production in the Kootenai River
4788 watershed may continue to increase. Although there does not yet appear to be an increasing
4789 trend in water column selenium concentrations in the reservoir, there is concern that without
4790 water quality treatment, the continued selenium loadings to Lake Kooconusa may lead to
4791 additional selenium contamination. It is possible that the lower end-of-April reservoir
4792 elevations for the driest 40 percent of years under MO3 may alter the movement, cycling and
4793 transformation of selenium in the reservoir and downstream in the Kootenai River, possibly
4794 resulting in water and sediment quality impacts.

4795 Median reservoir elevations under MO3 would be lower during the spring, potentially flushing
4796 some early food sources from Libby Reservoir; however, during the growing season, mid-June
4797 through September, reservoir elevations would be 1 to 4 feet higher as compared to the No
4798 Action Alternative. As such, Lake Kooconusa should not experience major changes to the
4799 physical, chemical, or biological processes compared to the No Action Alternative. Additionally,
4800 changes in the median average monthly outflows from Libby Dam during the mid-June through
4801 September time frame are relatively minor (reduction of 5 to 9 percent when compared to the
4802 No Action Alternative), which result in only a 0.3-foot decrease in median monthly elevation in
4803 the Kootenai River downstream of Libby Dam, and should not greatly impact the variability of
4804 (periodically wetted) zone productivity.

4805 Hungry Horse median reservoir elevations are expected to be lower under MO3 as compared to
4806 the No Action Alternative, particularly in early spring and summer (Figure 6-3.). These
4807 elevations combined with higher outflows in late spring/early summer could reduce in-lake
4808 productivity and food availability for resident fish species (ISAB 1997, Fraley et. al 1989).

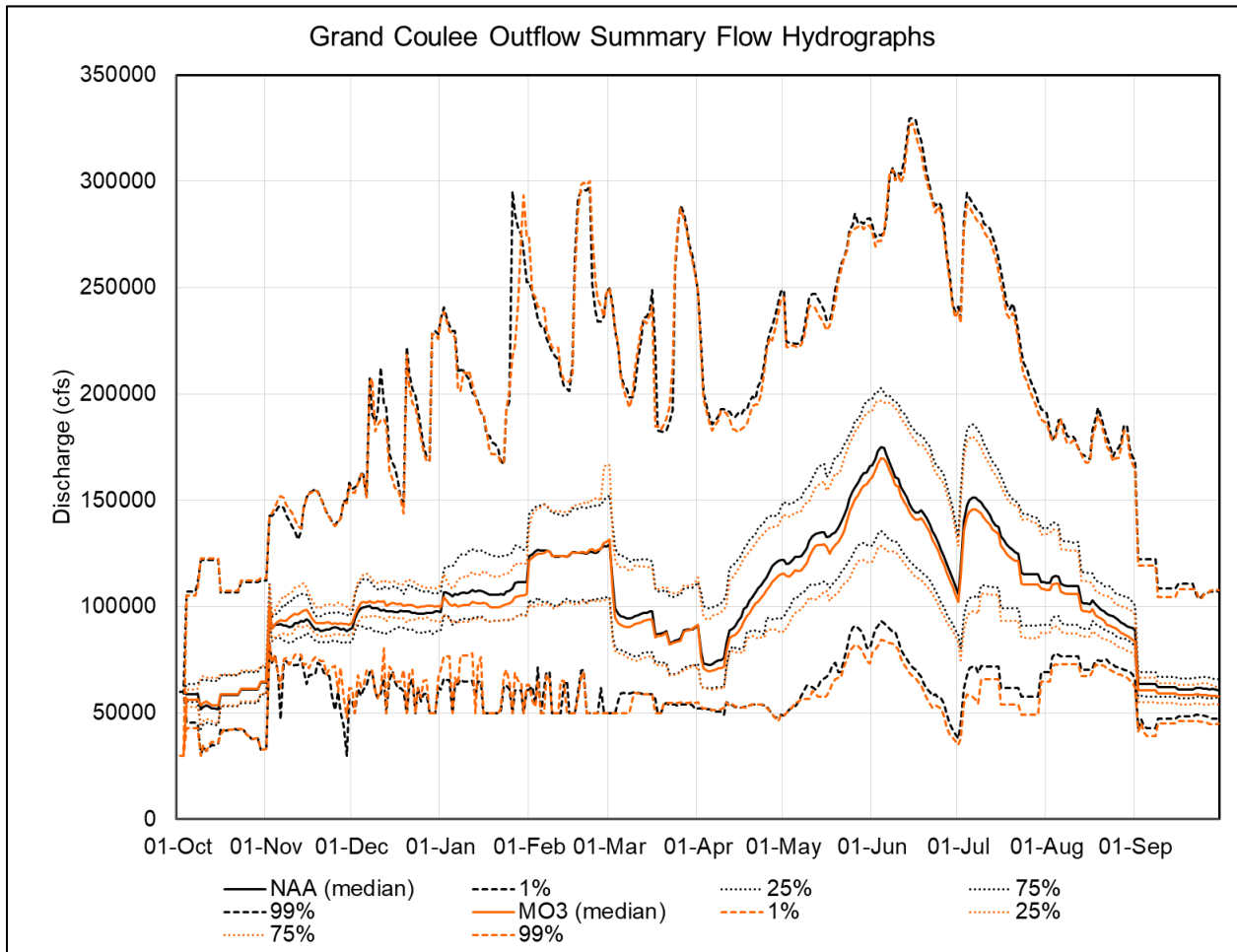
4809 Water level fluctuations in reservoirs may increase methyl-mercury concentrations in the
4810 waterbody as seasonally inundated areas of a reservoir have higher rates of methylation
4811 activity when compared to permanently inundated areas of a reservoir (Willacker et al. 2016).
4812 Studies suggest that methyl-mercury has a greater probability of entering the food web during
4813 the spring and summer growing seasons (January to July) (Willacker et al. 2016). Under MO3,
4814 the measures don't change the cyclic occurrence of inundation and exposure but do result in
4815 earlier and longer exposure of sediments that may have some impact on mercury methylation
4816 in Hungry Horse Reservoir. However, unlike other downstream locations such as Lake
4817 Roosevelt, mercury has not been recorded as a concern at Hungry Horse Reservoir as the only
4818 likely mercury input at this location is through airborne pollution deposition.

4819 **6.1.3.2 Albeni Falls Dam and Reservoir**

4820 Under MO3, there are little to no changes to operations at Albeni Falls Dam. The physical,
4821 chemical, and biological water quality of Lake Pend Oreille and the Pend Oreille River described
4822 under the No Action Alternative are expected to remain unchanged.

4823 **6.1.3.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

4824 Under MO3, retention time of water through the reservoir could increase during the growing
4825 season as compared to the No Action Alternative (Figure 6-20.). Lake Roosevelt tends to display
4826 relatively low primary productivity throughout the year. However, with slightly longer water
4827 retention times, some locations of the reservoir may experience phytoplankton blooms. These
4828 blooms have the potential to increase pH and decrease dissolved oxygen during die-off

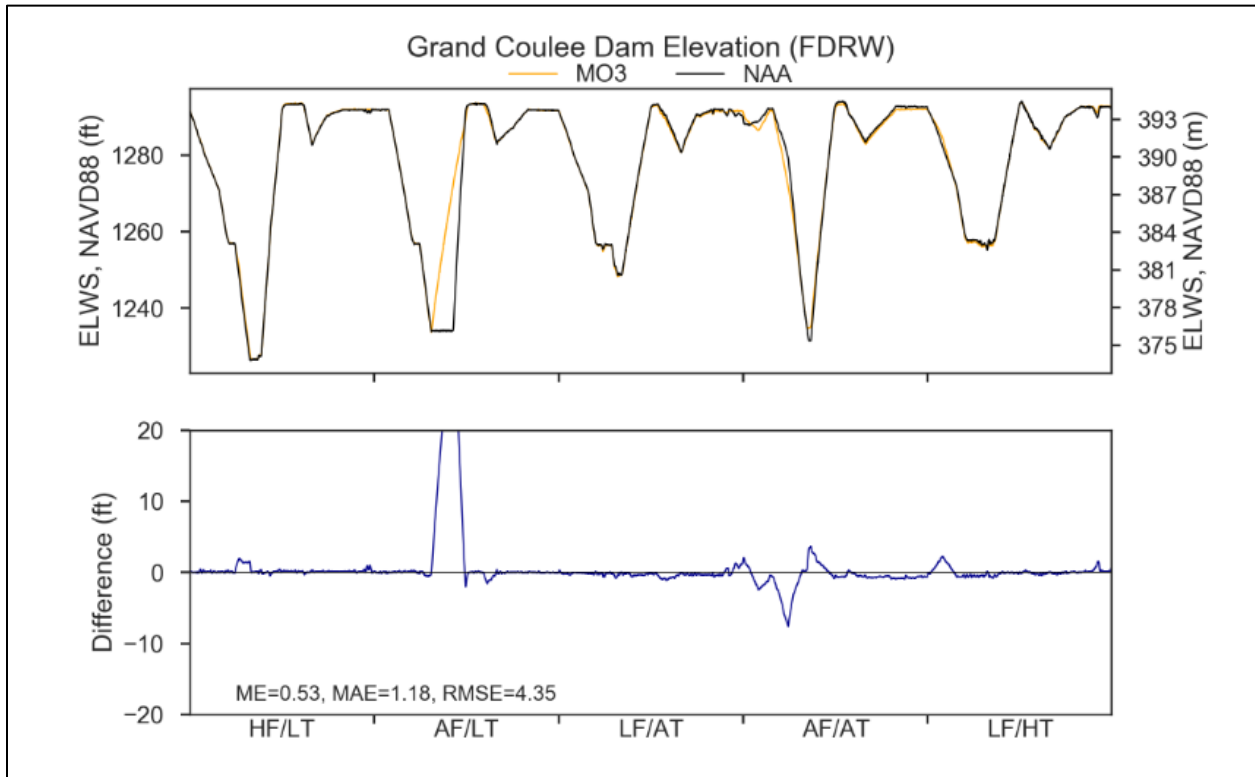


4829
4830 **Figure 6-20. Summary Discharge Hydrograph, Grand Coulee Dam, for Multiple Objective**
4831 **Alternative 3 Versus No Action Alternative**

4832 The operational measure, *Decrease to Grand Coulee Draft Rate*, changes the target maximum
4833 drawdown from 1.0 foot per day to a target of 0.8 foot per day. Mass wasting, such as small
4834 local landslides and bank erosion within Lake Roosevelt, has been related to the rate of
4835 drawdown and refill at Grand Coulee Dam. Decreases in these mass wasting events should
4836 result in decreases in turbidity.

4837 Water level fluctuations in reservoirs have been attributed to increased methyl-mercury in the
4838 waterbody because seasonally inundated areas of a reservoir can have higher rates of

4839 methylation activity when compared to permanently inundated areas of a reservoir (Willacker
4840 et al. 2016). Studies suggest that methyl-mercury has a greater probability of entering the food
4841 web during the spring and summer growing seasons (January to July) (Willacker et al. 2016).
4842 Under MO3, the measures would not change the cyclic occurrence of inundation and exposure,
4843 but may result in earlier and longer exposure of sediments that may have some impact on
4844 mercury methylation in Lake Roosevelt. The lower panel of Figure 6-21. shows the difference in
4845 Lake Roosevelt water elevation throughout the year between MO3 and the No Action
4846 Alternative. Modeling indicates that the average reservoir elevation is expected to remain
4847 about 7 feet lower under this alternative as compared to No Action Alternative. Overall, MO3
4848 may slightly increase the rate of mercury cycling within Lake Roosevelt.



4849 **Figure 6-21. Modeled Forebay Elevations for the No Action Alternative and Multiple Objective**
4850 **Alternative 3 at Grand Coulee Dam Under a 5-Year Range of River and Meteorological**
4851 **Conditions**
4852

4853 MO3 includes modified operations at Grand Coulee Dam that would result in some changes in
4854 monthly outflows to Rufus Woods Lake and Chief Joseph Dam. However, only minor changes to
4855 operational conditions at Chief Joseph Dam are expected. As such, the physical, chemical, and
4856 biological water quality of Rufus Woods Lake and the Columbia River downstream of Chief
4857 Joseph Dam under MO3 are expected to remain relatively unchanged from the No Action
4858 Alternative.

4859 **6.2 LOWER SNAKE RIVER BASIN**

4860 There would not be any operational or structural changes at Dworshak Dam that would directly
4861 impact reservoir elevations or outflow.

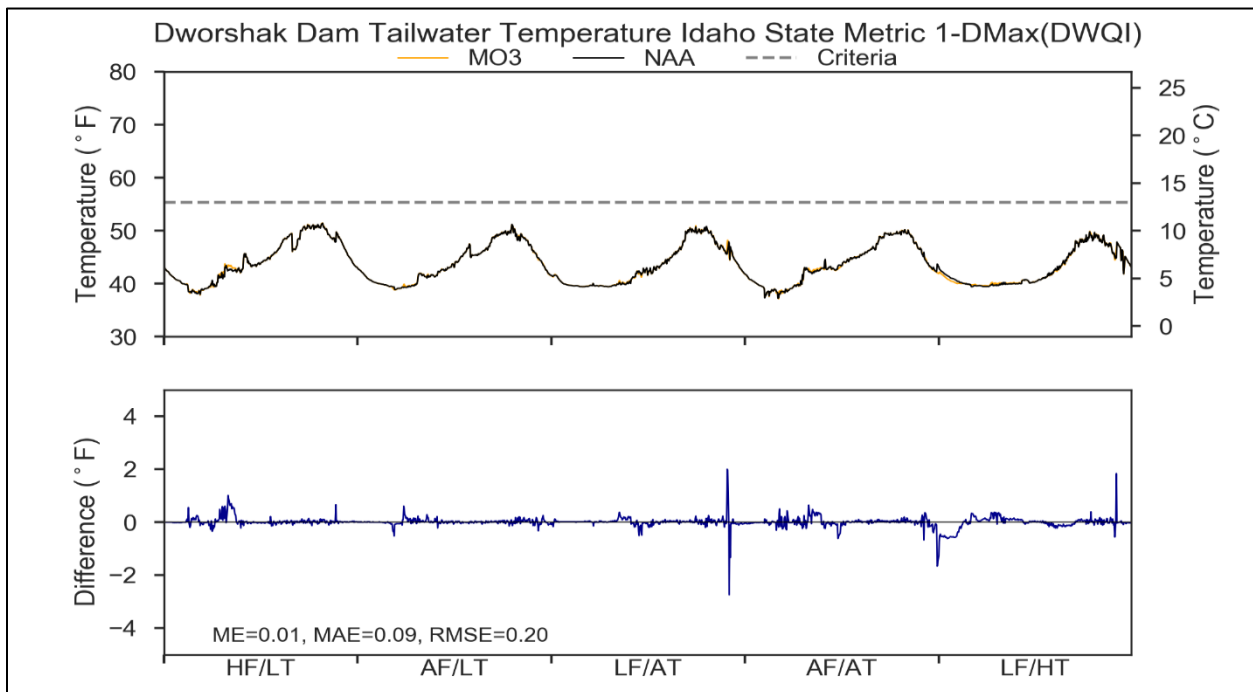
4862 The primary structural change associated with MO3 that would affect water quality in the lower
4863 Snake River is breaching the earthen embankments and adjacent structures, as required, at
4864 each of the four dams to facilitate reservoir drawdown and dam breaching. Breaching the dams
4865 would result in dramatic changes in water levels throughout the reach. The four current
4866 impoundments would be replaced with a free-flowing river, forming a relatively consistent
4867 hydraulic gradient paralleling the grade of the canyon itself.

4868 **6.2.1 Water Temperature**

4869 Two models were used to predict MO3 water temperatures. The 2D W2 model was applied to
4870 Dworshak Dam releases as it has been for the other alternatives. The one-dimensional HEC-RAS
4871 model was used for the lower Snake River MO3 evaluation because that model is better suited
4872 for mixed river conditions that would occur if the dams were breached (Section 2.2.2).

4873 **6.2.1.1 Dworshak Dam and Reservoir**

4874 Since project operations at Dworshak Dam would not change in MO3, the outflow
4875 temperatures modeled for MO3 would be very similar to the modeled results for the No Action
4876 Alternative, with temperatures remaining less than 52°F throughout the year (Figure 6-22.).
4877 Thermal stratification in the reservoir would also not change.



4878 **Figure 6-22. Modeled Tailwater Temperature for the No Action Alternative and Multiple**
4879 **Objective Alternative 3 at Dworshak Dam Under a 5-Year Range of River and Meteorological**
4880 **Conditions**
4881

4882 **6.2.1.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
4883 **Reservoirs**

4884 Water temperatures in the lower Snake River would change from the No Action Alternative if
4885 MO3 was implemented (Figure 6-23. through Figure 6-26.). One difference would be the rate of
4886 warming and cooling that would occur in the Snake River. Water temperatures would warm
4887 sooner in the spring and cool more quickly in the fall under MO3 due to the elimination of the
4888 reservoirs, which are known to cause water temperature lags in the Snake River under No
4889 Action conditions. Figure 6-27. also shows that the differences between MO3 and the No
4890 Action Alternative increase as the water flows toward the Columbia River. What this suggests is
4891 that water temperature conditions at Lower Granite will continue to be dominated by
4892 Dworshak operations. The effect of the Dworshak operations, however, will diminish as water
4893 travels the ~140 river miles down to the Ice Harbor Dam location.

4894 In general, Snake River water temperatures would be warmer in the spring under MO3, with
4895 the exception of May. During this month, total river flows are highest due to snowmelt (i.e.
4896 spring freshet), resulting in overall cooler water temperatures throughout the lower Snake
4897 River as compared to the No Action Alternative. Summer water temperatures would be both
4898 warmer and cooler than the No Action Alternative, depending on meteorological conditions.
4899 During summer heat waves, water temperatures would warmer than the No Action Alternative,
4900 but would respond much more quickly to cooling events that follow. The lower Snake River
4901 would begin to cool August and throughout the remainder of the year, with larger differences
4902 between MO3 and No Action Alternative occurring as the water progresses from upstream to
4903 downstream. August temperatures at Lower Granite Dam would only be expected to cool 0.2
4904 degree Fahrenheit on average under MO3, as compared to No Action, while water
4905 temperatures at Ice Harbor would cool by upwards of 1.8 degrees Fahrenheit. Temperature
4906 differences between MO3 and No Action Alternative would be largest during November,
4907 ranging from an average of 3.6 degrees Fahrenheit at Lower Granite to 8.4 degrees Fahrenheit
4908 at Ice Harbor Dam.

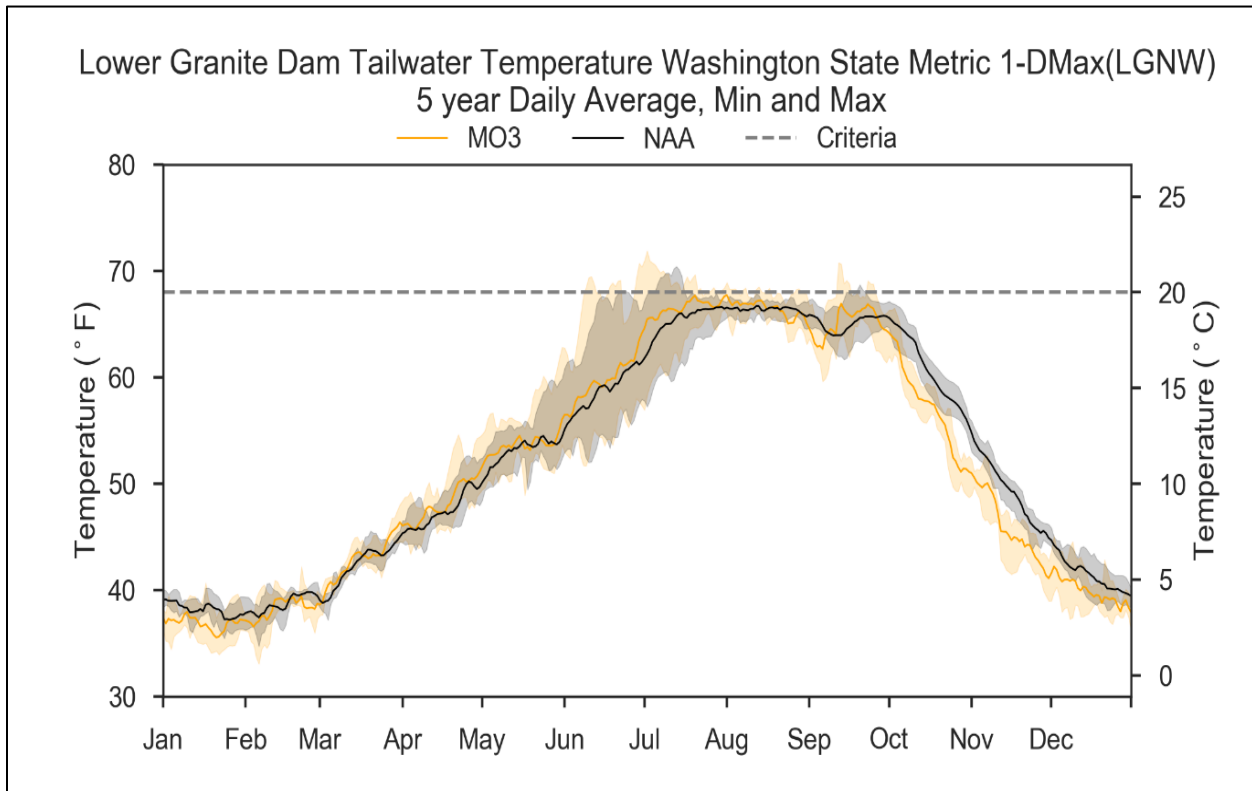
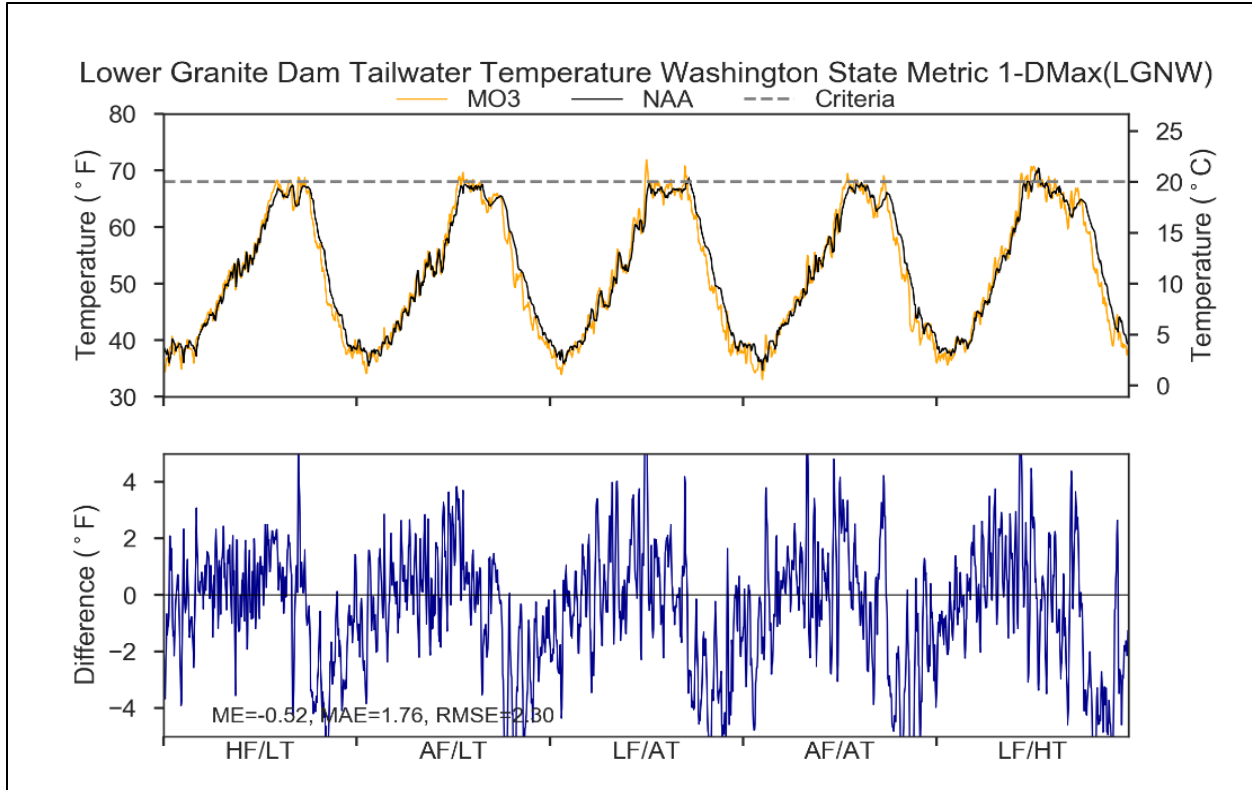
4909 Maximum daily temperatures that would be expected under MO3 are shown in Figure 6-28..
4910 Maximum temperatures generally increase downstream and the warmest daily temperatures
4911 would occur during June or July when LF/HT and LF/AT conditions were present. Maximum
4912 temperatures at that time would range from approximately 72°F at Lower Granite Dam to 76°F
4913 at Ice Harbor Dam. Maximum temperatures would also be greater than 68°F during August at
4914 all locations under all flow/air temperatures, as well as during September when HF/LT, LF/AT,
4915 and AF/AT conditions occur.

4916 The changes in the percent of time that water temperatures would be greater than 68°F if MO3
4917 was implemented at the four lower Snake River projects are shown in Table 6-1.. At Lower
4918 Granite Dam, the amount of time that the water temperatures would be greater than this
4919 threshold from June through September would either not change or increase. Increases could
4920 occur during any flow/meteorological condition, ranging from less than 2 percent during LF/AT
4921 conditions to over 23 percent during LF/HT conditions. At the remaining three locations, there

4922 would be a general trend toward a reduction in the amount of time temperatures would be
4923 greater than 68°F, especially during August and September with AF/LT, LF/AT, AF/AT, and LF/HT
4924 conditions. The largest August decreases would occur at Lower Monumental Dam where the
4925 changes during these four flow/meteorological conditions would range from 45 to 53 percent.
4926 The August changes for the same flow/meteorological conditions would be less at Ice Harbor
4927 Dam, ranging from 20 to 46 percent. The September decreases at Ice Harbor Dam would be
4928 greater than at any of the other three projects. Additionally, this project is the only one where
4929 there would be decreases in the amount of time when temperatures are greater than 68°F
4930 during HF/LT conditions, compared to increases at the other three projects.

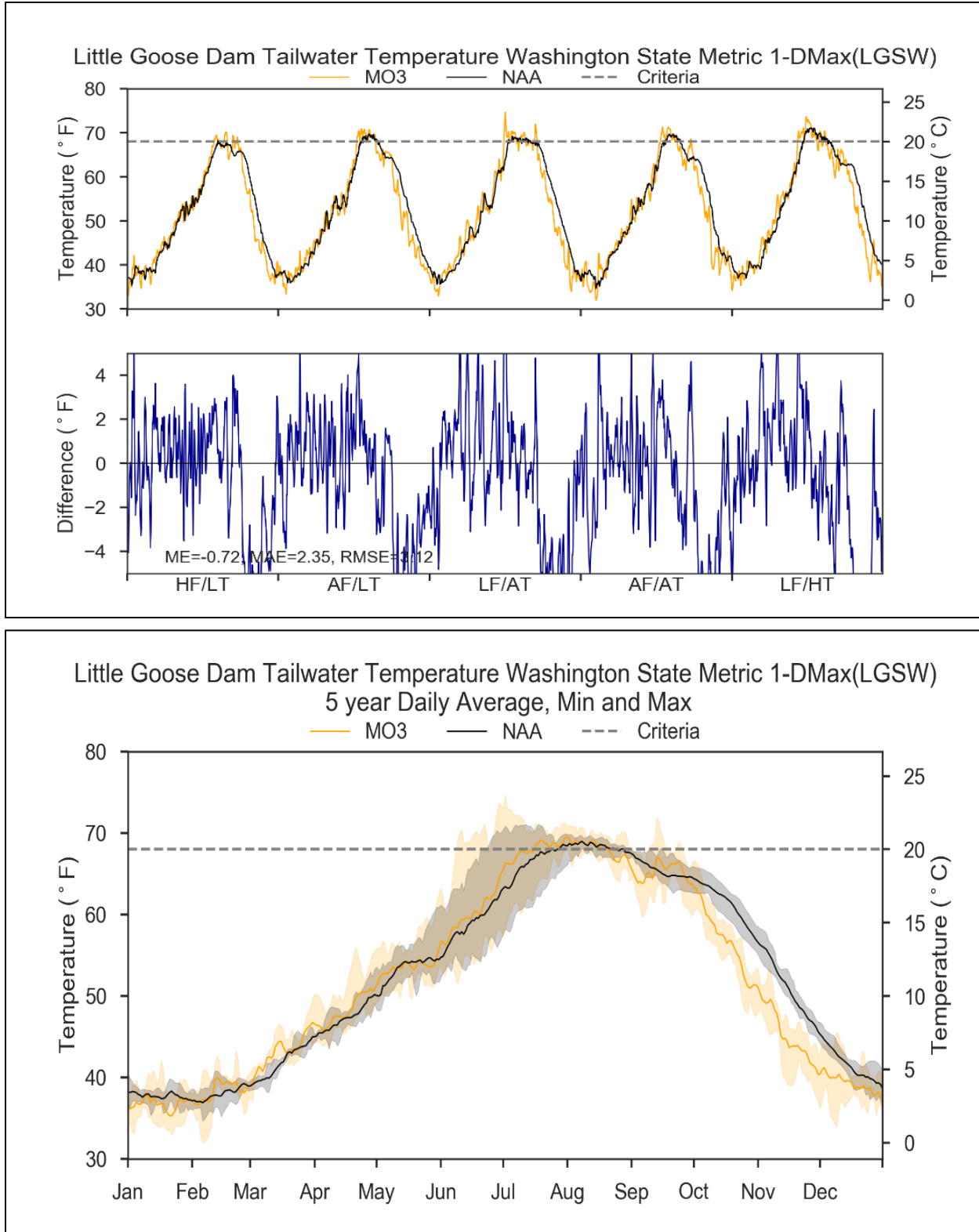
4931 Further details regarding the number of days per month when maximum water temperatures
4932 would be greater than 56°F, 64°F, and 68°F under MO3 at each modeling point and flow/air
4933 temperature condition are presented in Table 6-2. through Table 6-5.. The overall trend
4934 indicates that the number of days exceeding a given temperature increases as the water flows
4935 toward the Columbia River. During April, most of the daily maximum temperatures would be
4936 less than 56°F, the only exceptions occurring at the Little Goose and Ice Harbor locations during
4937 LF/HT conditions. By July, every day of the month would have temperatures exceeding 56°F at
4938 every location modeled and for all flow/air temperature conditions. Temperatures would also
4939 exceed 64°F, and in many cases 68°F, during AF/LT, AF/AT, LF/AT, and LF/HT conditions. Lower
4940 temperatures would be expected during HF/LT conditions at all locations, as well as the Lower
4941 Granite site where there would be fewer days with temperatures greater than 68°F than at the
4942 downstream sites. August would be expected to have the warmest water temperatures. Most
4943 or all of the days would experience temperatures greater than 64°F at each location, but the
4944 number of days that temperatures would be greater than 68°F would be least at Lower Granite
4945 (ranging from 2 to 7 days) and greatest at Ice Harbor Dam (21 to 31 days) due to the larger
4946 influence that Dworshak Dam releases has on Lower Granite Dam as compared to Ice Harbor
4947 Dam. Beginning in September, temperatures would still exceed 56°F at every site, but the
4948 number of days when temperatures exceed 64°F and 68°F would start to diminish. By
4949 November, water temperatures would be less than 56°F in the entire river.

4950 Diel temperature fluctuations would also increase if MO3 was implemented. Average diel
4951 temperature differences seldom exceed 1 degree Fahrenheit under the No Action Alternative,
4952 and are typically between 0.5 and 1.0 degrees Fahrenheit from April through August. Average
4953 differences would range from 2.5 to 3.5 degrees Fahrenheit for the same time period if MO3
4954 was implemented (Figure 6-29.). Daily temperature differences during the winter would
4955 typically be less than 1 degree Fahrenheit near Lower Granite Dam and range from 1 to 1.5
4956 degrees Fahrenheit at the three remaining river locations that were modeled.



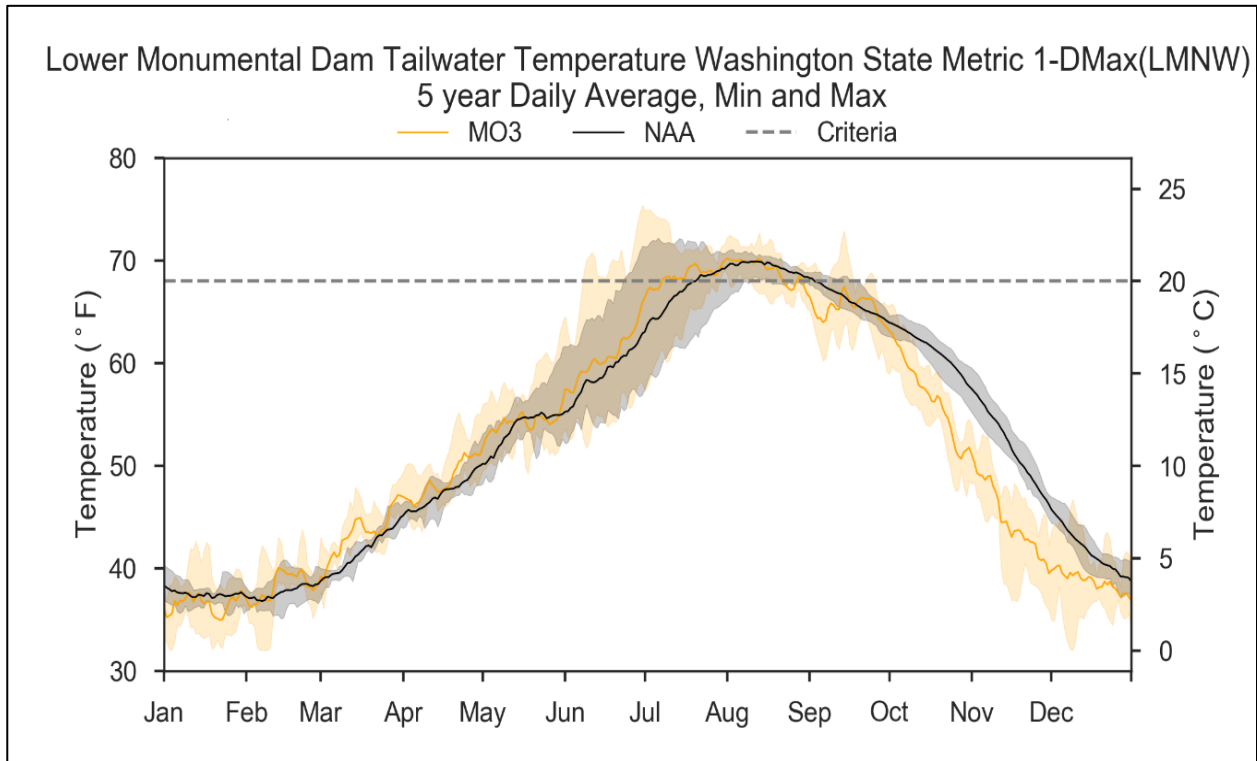
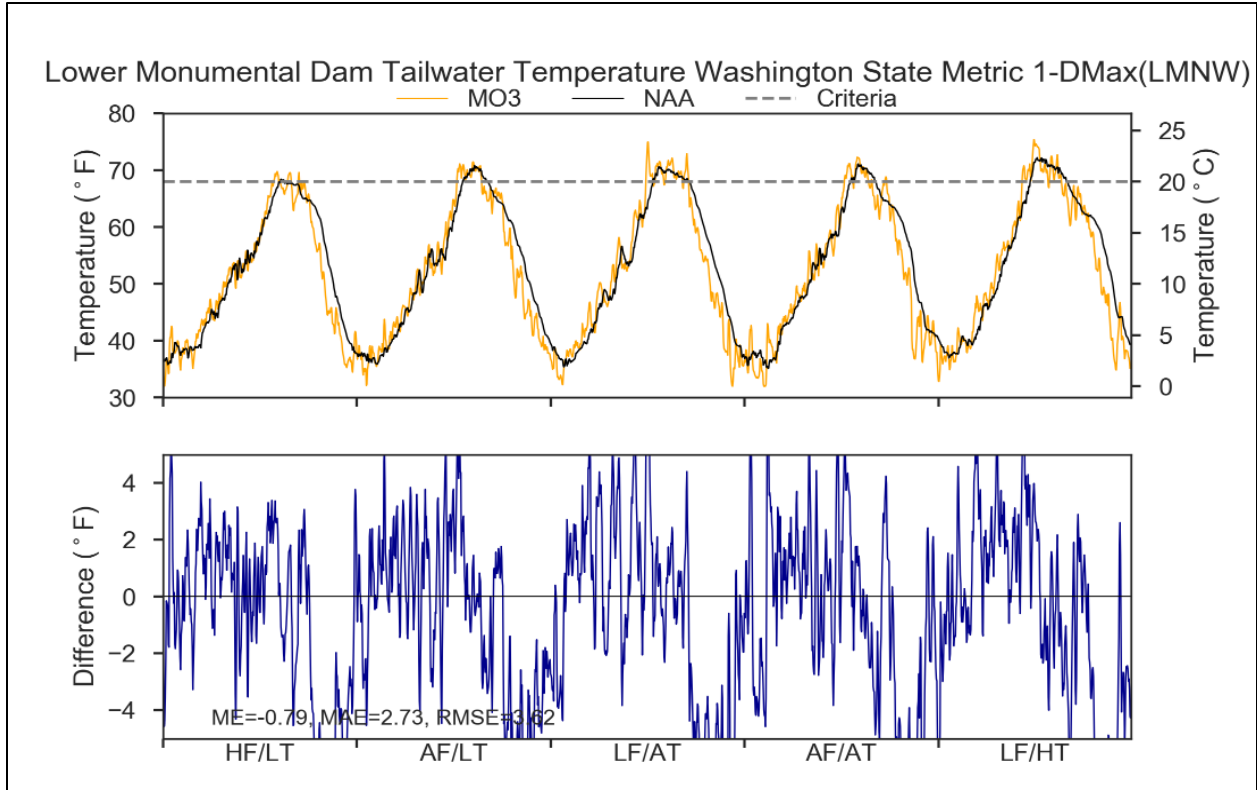
4957
 4958
 4959
 4960

Figure 6-23. Modeled Tailwater Temperatures for the No Action Alternative and Multiple Objective Alternative 3 at Lower Granite Dam for Individual Flow and Meteorological Conditions and Averaged 5-Year Conditions



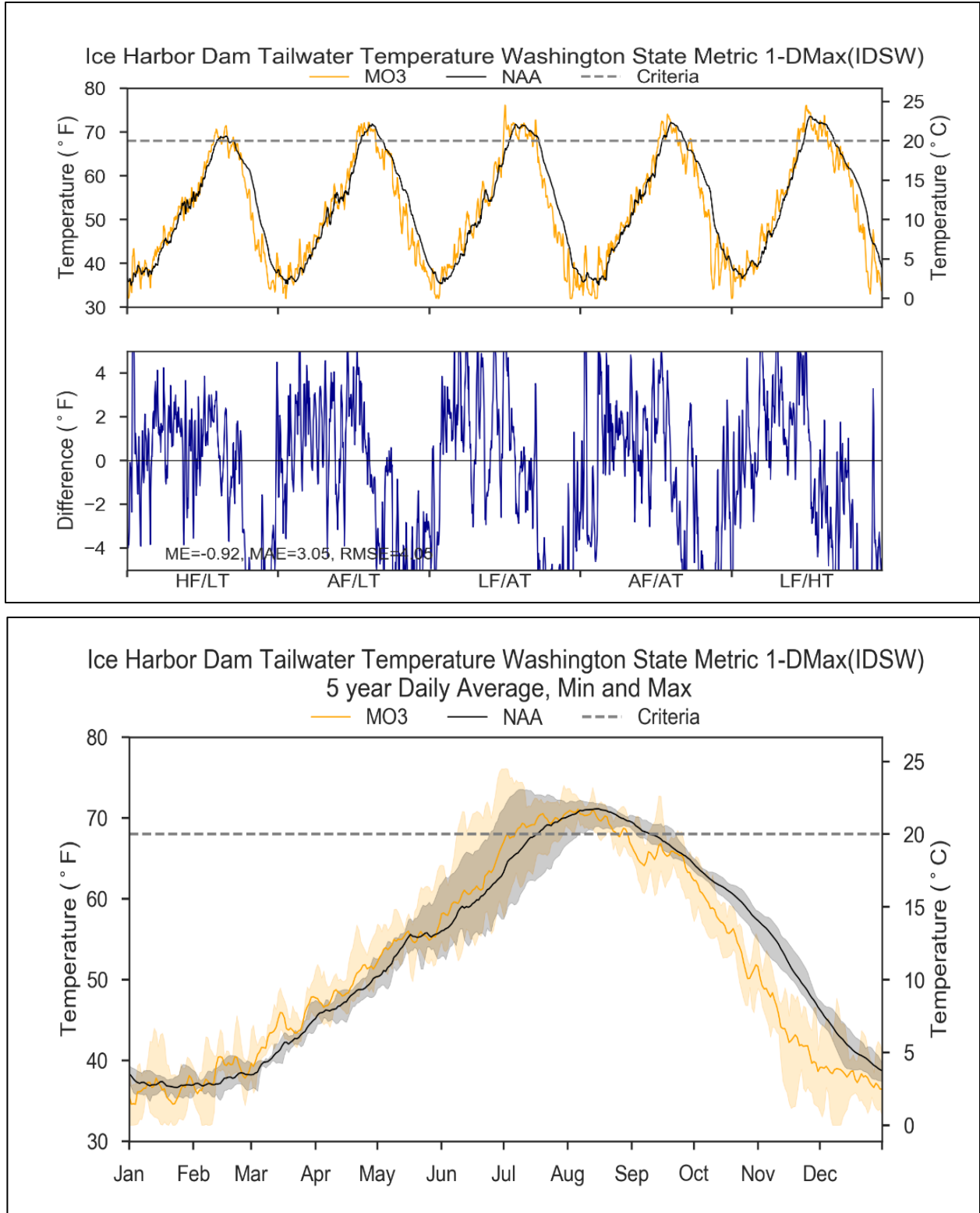
4961
 4962
 4963
 4964

Figure 6-24. Modeled Tailwater Temperatures for the No Action Alternative and Multiple Objective Alternative 3 at Little Goose Dam for Individual Flow and Meteorological Conditions and Averaged 5-Year Conditions



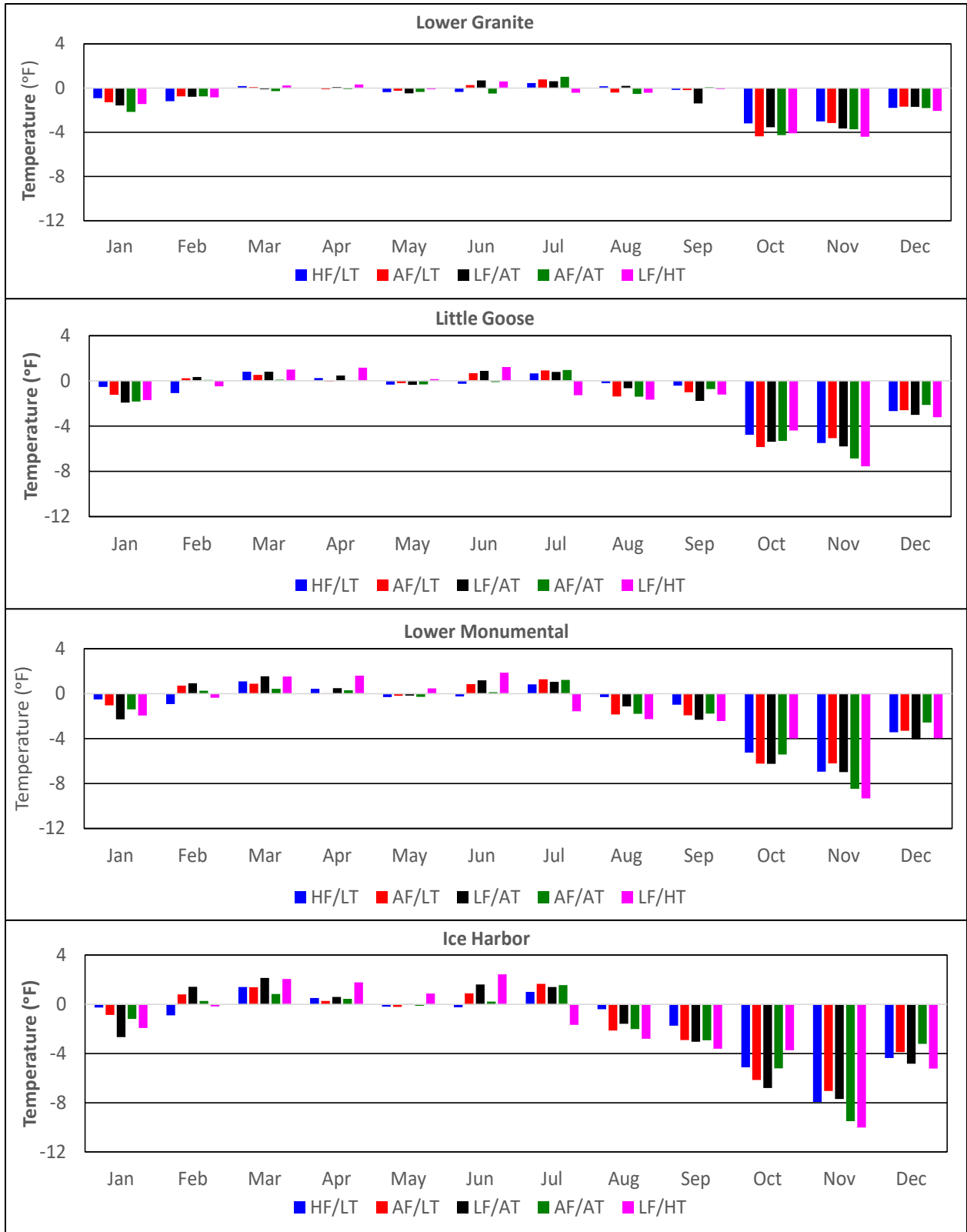
4965
 4966
 4967
 4968

Figure 6-25. Modeled Tailwater Temperatures for the No Action Alternative and Multiple Objective Alternative 3 at Lower Monumental Dam for Individual Flow and Meteorological Conditions and Averaged 5-Year Conditions



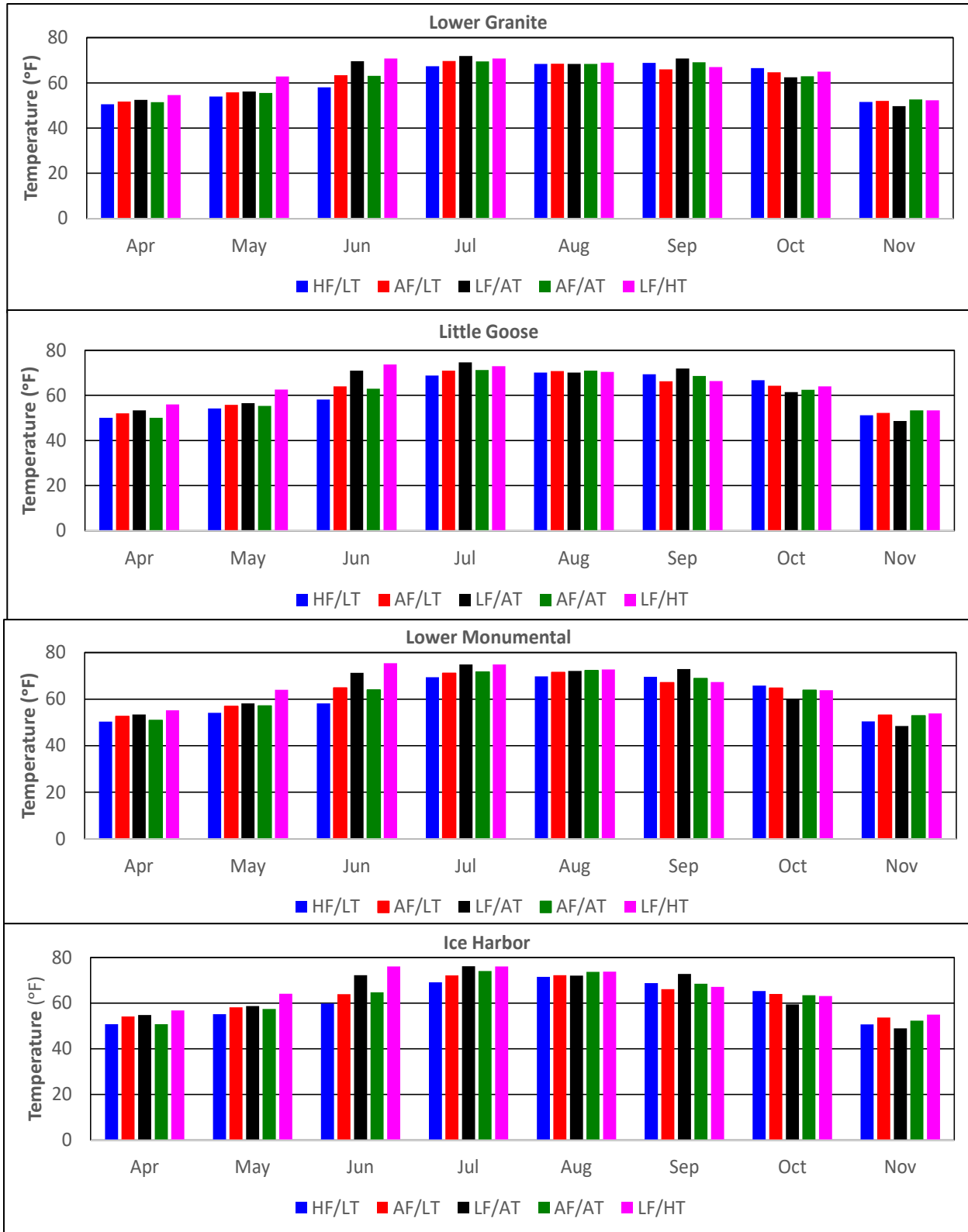
4969
 4970
 4971
 4972

Figure 6-26. Modeled Tailwater Temperatures for the No Action Alternative and Multiple Objective Alternative 3 at Ice Harbor Dam for Individual Flow and Meteorological Conditions and Averaged 5-Year Conditions



4973
 4974
 4975

Figure 6-27. Average Temperature Differences Between Multiple Objective Alternative 3 and No Action Alternative for each Month at the Four Lower Snake River Dam Locations



4976
 4977
 4978
 4979

Figure 6-28. Model Results for the Maximum Daily Temperatures that Would be Anticipated at the Four Lower Snake River Dam Locations if Multiple Objective Alternative 3 is Implemented

4980 **Table 6-1. Changes in the Percent of Time Water Temperatures Would be Greater than 68°F if**
4981 **Multiple Objective Alternative 3 is Implemented at the Four Lower Snake River Projects**

Project	Month	Flow and Air Temperature Conditions				
		HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
Lower Granite	June	0.0	0.0	1.4	0.0	23.5
	July	0.0	8.9	12.5	8.6	5.0
	August	3.6	3.2	1.7	4.7	4.8
	September	11.1	0.0	6.0	3.2	0.0
Little Goose	June	0.0	0.0	2.8	0.0	15.1
	July	1.5	9.9	8.1	12.3	-40.2
	August	22.4	-36.9	-17.5	-52.8	-30.9
	September	7.9	0.0	17.3	2.4	0.0
Lower Monumental	June	0.0	0.0	3.2	0.0	25.2
	July	2.7	17.0	7.4	18.9	-24.6
	August	14.4	-47.7	-45.3	-46.9	-53.2
	September	2.9	-2.5	-26.1	-3.9	-3.1
Ice Harbor	June	0.0	0.0	3.9	0.0	42.5
	July	2.3	23.8	25.5	16.5	-10.9
	August	-23.5	-30.9	-20.2	-30.0	-45.7
	September	-5.2	-25.4	-32.1	-25.2	-16.1

4982 **Table 6-2. Number of Days per Month when Daily Maximum Water Temperatures at the**
4983 **Current Lower Granite Tailwater Station Location Would be Within Selected Temperature**
4984 **Ranges Under Multiple Objective Alternative 3**

Month	Temperature	Flow and Air Temperature Conditions				
		HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
April	≤56°F	30	30	30	30	30
	>56°F, ≤64°F	0	0	0	0	0
	>64°F, ≤68°F	0	0	0	0	0
	>68°F	0	0	0	0	0
May	≤56°F	31	31	29	31	12
	>56°F, ≤64°F	0	0	2	0	19
	>64°F, ≤68°F	0	0	0	0	0
	>68°F	0	0	0	0	0
June	≤56°F	22	10	0	7	0
	>56°F, ≤64°F	8	20	30	23	30
	>64°F, ≤68°F	0	0	3	0	24
	>68°F	0	0	1	0	13
July	≤56°F	0	0	0	0	0
	>56°F, ≤64°F	31	31	31	31	31
	>64°F, ≤68°F	14	26	31	28	31
	>68°F	0	11	6	7	14

*Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix*

Month	Temperature	Flow and Air Temperature Conditions				
		HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
August	≤56°F	0	0	0	0	0
	>56°F, ≤64°F	31	31	31	31	31
	>64°F, ≤68°F	31	31	30	31	27
	>68°F	7	2	2	4	5
September	≤56°F	0	0	0	0	0
	>56°F, ≤64°F	30	30	30	30	30
	>64°F, ≤68°F	24	24	24	16	15
	>68°F	5	0	5	2	0
October	≤56°F	7	12	16	9	10
	>56°F, ≤64°F	24	19	15	22	21
	>64°F, ≤68°F	5	2	0	0	3
	>68°F	0	0	0	0	0
November	≤56°F	30	30	30	30	30
	>56°F, ≤64°F	0	0	0	0	0
	>64°F, ≤68°F	0	0	0	0	0
	>68°F	0	0	0	0	0

4985 **Table 6-3. Number of Days Per Month when Daily Maximum Water Temperatures at the**
 4986 **Current Little Goose Tailwater Station Location Would be Within Selected Temperature**
 4987 **Ranges Under Multiple Objective Alternative 3**

Month	Temperature	Flow and Air Temperature Conditions				
		HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
April	≤56°F	30	30	30	30	29
	>56°F, ≤64°F	0	0	0	0	1
	>64°F, ≤68°F	0	0	0	0	0
	>68°F	0	0	0	0	0
May	≤56°F	31	31	29	31	13
	>56°F, ≤64°F	0	0	2	0	18
	>64°F, ≤68°F	0	0	0	0	0
	>68°F	0	0	0	0	0
June	≤56°F	22	10	1	7	0
	>56°F, ≤64°F	8	20	29	23	30
	>64°F, ≤68°F	0	0	4	0	24
	>68°F	0	0	2	0	21
July	≤56°F	0	0	0	0	0
	>56°F, ≤64°F	31	31	31	31	31
	>64°F, ≤68°F	13	26	31	27	31
	>68°F	2	22	26	20	26
August	≤56°F	0	0	0	0	0
	>56°F, ≤64°F	31	31	31	31	31
	>64°F, ≤68°F	31	31	31	31	30
	>68°F	18	22	16	20	11

*Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix*

Month	Temperature	Flow and Air Temperature Conditions				
		HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
September	≤56°F	0	0	0	0	0
	>56°F, ≤64°F	30	30	30	30	30
	>64°F, ≤68°F	29	24	22	20	16
	>68°F	7	0	8	2	0
October	≤56°F	7	14	19	10	10
	>56°F, ≤64°F	24	17	12	21	21
	>64°F, ≤68°F	5	1	0	0	0
	>68°F	0	0	0	0	0
November	≤56°F	30	30	30	30	30
	>56°F, ≤64°F	0	0	0	0	0
	>64°F, ≤68°F	0	0	0	0	0
	>68°F	0	0	0	0	0

4988 **Table 6-4. Number of Days per Month when Daily Maximum Water Temperatures at the**
 4989 **Current Lower Monumental Tailwater Station Location Would be Within Selected**
 4990 **Temperature Ranges Under Multiple Objective Alternative 3**

Month	Temperature	Flow and Air Temperature Conditions				
		HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
April	≤56°F	30	30	30	30	30
	>56°F, ≤64°F	0	0	0	0	0
	>64°F, ≤68°F	0	0	0	0	0
	>68°F	0	0	0	0	0
May	≤56°F	31	29	25	29	2
	>56°F, ≤64°F	0	2	6	2	29
	>64°F, ≤68°F	0	0	0	0	1
	>68°F	0	0	0	0	0
June	≤56°F	23	8	0	4	0
	>56°F, ≤64°F	7	22	30	26	30
	>64°F, ≤68°F	0	1	5	0	26
	>68°F	0	0	2	0	23
July	≤56°F	0	0	0	0	0
	>56°F, ≤64°F	31	31	31	31	31
	>64°F, ≤68°F	15	29	31	29	31
	>68°F	3	24	28	21	29
August	≤56°F	0	0	0	0	0
	>56°F, ≤64°F	31	31	31	31	31
	>64°F, ≤68°F	31	31	31	31	31
	>68°F	15	23	28	23	20
September	≤56°F	0	0	0	0	0
	>56°F, ≤64°F	30	30	30	30	30
	>64°F, ≤68°F	28	27	21	20	17
	>68°F	3	0	14	3	0

*Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix*

Month	Temperature	Flow and Air Temperature Conditions				
		HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
October	≤56°F	9	12	23	10	10
	>56°F, ≤64°F	22	19	8	21	21
	>64°F, ≤68°F	4	2	0	0	0
	>68°F	0	0	0	0	0
November	≤56°F	30	30	30	30	30
	>56°F, ≤64°F	0	0	0	0	0
	>64°F, ≤68°F	0	0	0	0	0
	>68°F	0	0	0	0	0

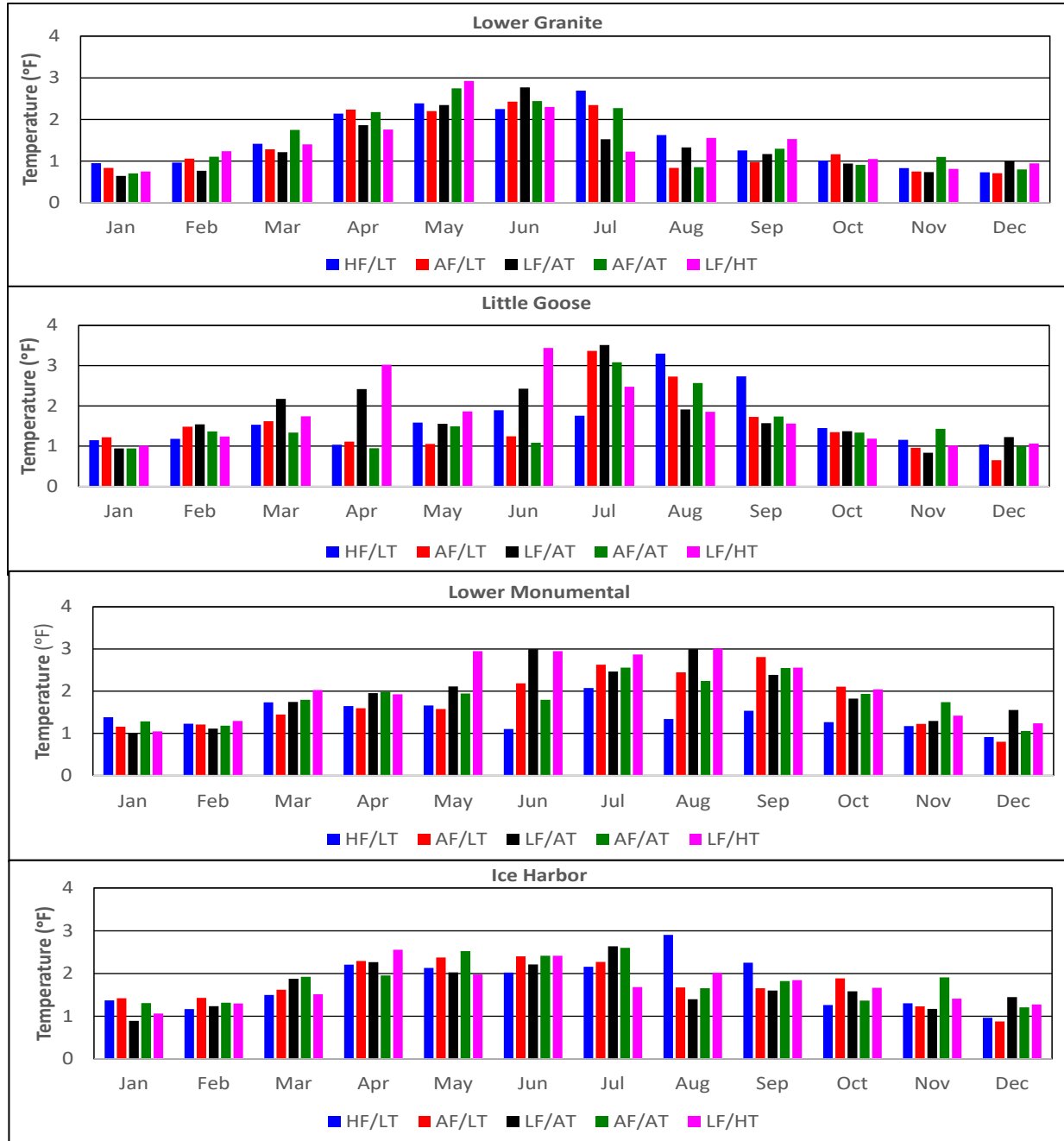
4991 **Table 6-5. Number of Days per Month when Daily Maximum Water Temperatures at the**
 4992 **Current Ice Harbor Tailwater Station Location Would be Within Selected Temperature Ranges**
 4993 **Under Multiple Objective Alternative 3**

Month	Temperature	Flow and Air Temperature Conditions				
		HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
April	≤56°F	30	30	30	30	28
	>56°F, ≤64°F	0	0	0	0	2
	>64°F, ≤68°F	0	0	0	0	0
	>68°F	0	0	0	0	0
May	≤56°F	31	27	23	25	6
	>56°F, ≤64°F	0	4	8	6	25
	>64°F, ≤68°F	0	0	0	0	1
	>68°F	0	0	0	0	0
June	≤56°F	17	7	0	1	0
	>56°F, ≤64°F	13	23	30	29	30
	>64°F, ≤68°F	0	0	5	4	26
	>68°F	0	0	2	0	22
July	≤56°F	0	0	0	0	0
	>56°F, ≤64°F	31	31	31	31	31
	>64°F, ≤68°F	16	30	31	30	31
	>68°F	2	24	31	24	30
August	≤56°F	0	0	0	0	0
	>56°F, ≤64°F	31	31	31	31	31
	>64°F, ≤68°F	31	31	31	31	31
	>68°F	27	23	31	25	21
September	≤56°F	0	0	0	0	0
	>56°F, ≤64°F	30	30	30	30	30
	>64°F, ≤68°F	28	23	20	21	12
	>68°F	2	0	14	3	0
October	≤56°F	11	17	23	10	10
	>56°F, ≤64°F	20	14	8	21	21
	>64°F, ≤68°F	4	0	0	0	0
	>68°F	0	0	0	0	0

*Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix*

Month	Temperature	Flow and Air Temperature Conditions				
		HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
November	≤56°F	30	30	30	30	30
	>56°F, ≤64°F	0	0	0	0	0
	>64°F, ≤68°F	0	0	0	0	0
	>68°F	0	0	0	0	0

4994



4995

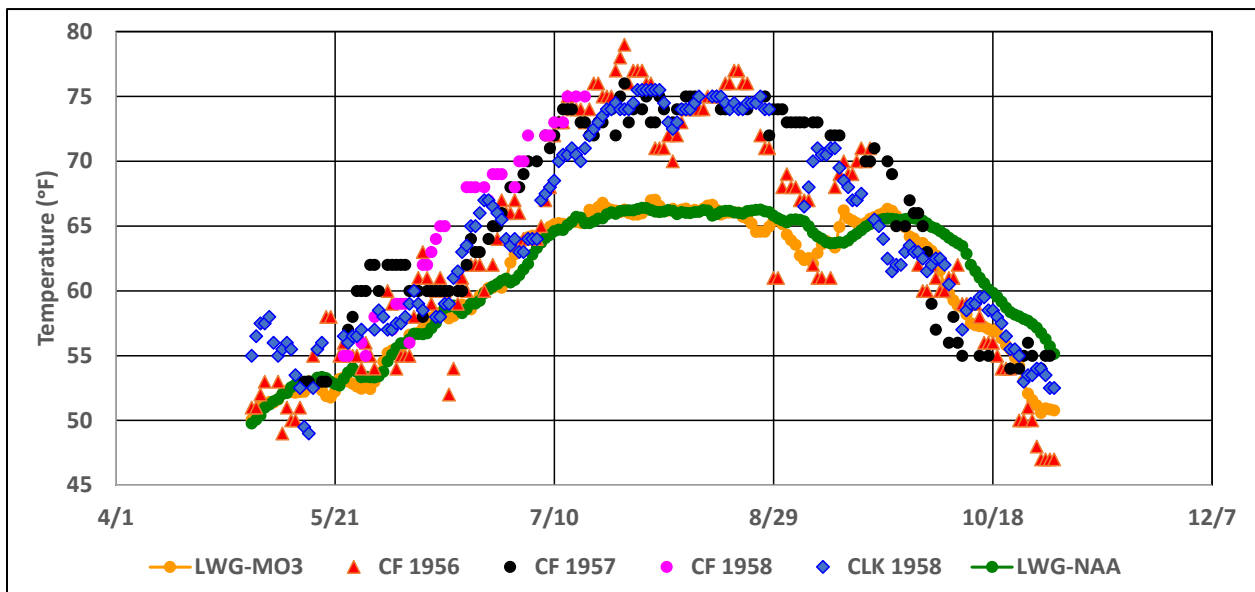
4996

4997

4998

Figure 6-29. Average Diel Temperature Differences by Month that Would Occur at the Four Current Lower Snake River Station Locations if Multiple Objective Alternative 3 is Implemented

4999 The water temperatures modeled for MO3 are also compared to available lower Snake River
5000 pre-dam field measurements. During 1956, 1957, and 1958, the USGS measured river
5001 temperatures near Central Ferry, Washington, at the bridge on U.S. Highway 295, or
5002 approximately 24 miles downstream from the current location of Lower Granite Dam (USGS
5003 1960, 1961, 1964). The measurements were recorded once per day at 4 p.m. Water
5004 temperatures were also recorded in 1958 approximately 0.25 mile upstream from Clarkston,
5005 Washington, at the Yacht Club by an operator identified as BCF (Corps 2002a). The historical
5006 May through October data, along with daily average water temperatures for MO3 and the No
5007 Action Alternative at the Lower Granite tailwater location are shown in Figure 6-30.. During July
5008 and August, the 1950s water temperatures averaged 7 to 8 degrees Fahrenheit higher than the
5009 average MO3 model results. Maximum daily differences were 10 to 12 degrees Fahrenheit
5010 higher in the 1950s. The data also shows that the river warmed-up sooner during June prior to
5011 construction of the four lower Snake River projects. Average June temperatures ranged from
5012 1.6 degrees Fahrenheit higher in 1956 to 5.4 degrees Fahrenheit higher in 1958. The delayed
5013 heating predicted for MO3 may be a consequence of slower heating due to the middle and
5014 upper Snake River reservoirs combined with the influence that Dworshak Dam operations have
5015 on the lower Snake River.



5016
5017 **Figure 6-30. Comparison of Average Multiple Objective Alternative 3 and No Action**
5018 **Alternative Model Results for the Current Lower Granite Tailwater Location to Historical**
5019 **Slope River Water Temperatures Recorded near Central Ferry and Clarkston, Washington**
5020 Note: CF = Central Ferry; CLK = Clarkston.

5021 Air temperature comparisons between the late 1950s and more recent intervals were also
5022 made using data from the National Weather Service station at the Nez Perce County Airport in
5023 Lewiston, Idaho. The average May through October air temperatures from that location all
5024 show an increasing trend from 1948 when the period of record starts through 2018. The
5025 monthly averages for 1956, 1957, 1958, and 2011 to 2015 mean are shown in Table 6-6.. The
5026 comparison shows that the mean 2011 to 2015 air temperatures were slightly cooler during

5027 May than they were from 1956 through 1958, the same in June, and warmer during July
5028 through October.

5029 A comparison of Snake River flows in the late 1950s and the 2011 to 2015 interval were also
5030 made. The 1956 to 1958 flow data was obtained from the discontinued USGS gaging station
5031 (number 13343500) that was located downstream from Clarkston, Washington, where it
5032 operated between 1915 and 1972. The 2011 to 2015 flow data was obtained from the Lower
5033 Granite Dam project. The May and June 1956 to 1958 river flows were higher than the 1916 to
5034 1972 average, and 1.4 to 1.8 times greater than the 2011 to 2015 mean (Table 6-6.). In contrast,
5035 average 2011 to 2015 July through September flows were 1.1 to 1.4 times greater than the
5036 mean for the 1956 to 1958 flows, likely due in part to the summer Dworshak Dam releases.
5037 Average October flows were approximately 1.2 times higher in the late 1950s. The upstream
5038 Brownlee Dam was completed in 1958, but any effect of this project on the flows for this time
5039 period could not be separated from inter-annual variability.

5040 **Table 6-6. Average Monthly Lewiston, Idaho, Air Temperatures and Snake River Flows for**
5041 **1956, 1957, 1958, and 2011 to 2015**

Year	May	June	July	August	September	October
Average Monthly Air Temperatures (°F) at the Lewiston Nez Perce County Airport Weather Station in Lewiston, Idaho						
1956	60.1	62.7	74.0	69.9	62.8	49.6
1957	60.7	65.7	71.5	69.6	65.9	50.5
1958	64.6	68.6	75.5	76.3	62.4	53.1
2011–2015	59.8	67.5	77.2	76.6	67.5	54.5
Average Monthly Snake River Flows (kcfs) at the Discontinued USGS Gaging Station (13343500) Downstream from Clarkston, Washington						
1956	186.5	149.3	42.3	25.0	23.3	27.4
1957	199.4	127.5	35.9	21.9	22.1	25.6
1958	161.4	104.0	30.2	19.2	22.6	23.5
Average Monthly Snake River Discharge (kcfs) at Lower Granite Dam						
2011–2015	98.7	90.6	50.7	27.5	24.1	21.2

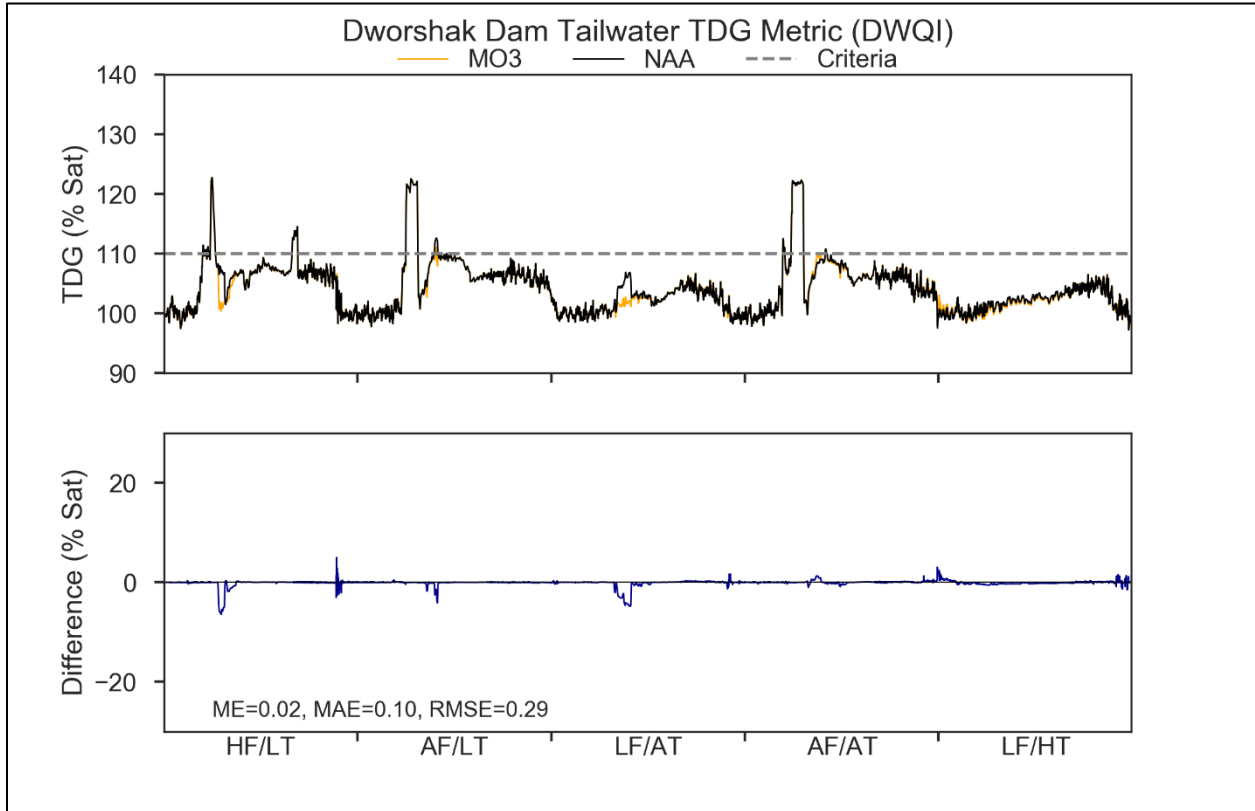
5042 **6.2.2 Total Dissolved Gas**

5043 TDG saturation related to MO3 was modeled for Dworshak Dam tailwater but not for the lower
5044 Snake River dam forebay or tailwater locations. Predicting TDG in a free-flowing river would
5045 have been outside the model’s calibration range, and the results would not be reliable. TDG
5046 during the breaching phase was estimated from data collected during the 1992 drawdown.

5047 **6.2.2.1 Dworshak Dam and Reservoir**

5048 Dworshak Dam tailwater TDG under MO3 would be very similar to the No Action Alternative
5049 (Figure 6-31.), with a few exceptions. First, there would be 89 fewer hours during late May of an
5050 AF/LT year and 17 fewer hours during June of an AF/AT year when the TDG would exceed 110
5051 percent (Figure 6-31.). Second, there are two additional periods when the TDG is already less

5052 than 110 percent under No Action Alternative, but would be even lower under MO3 for an
 5053 extended period of time. The one instance would occur during April of a HF/LT year when the
 5054 TDG would be 4 to 6 percent less or approximately 300 hours. The second instance would occur
 5055 during May and June of a LF/AT year when there would be approximately 600 hours when the
 5056 average TDG would be 3.7 percent less during MO3, but the difference could be as high as 5
 5057 percent for several days. These differences are due to changes in total outflow and spill that
 5058 would occur as a result of shifts in flow at the other Columbia River Basin projects and regional
 5059 power demands.



5060
 5061 **Figure 6-31. Modeled Tailwater Total Dissolved Gas for the No Action Alternative and**
 5062 **Multiple Objective Alternative 3 at Dworshak Dam Under a 5-Year Range of River and**
 5063 **Meteorological Conditions**

5064 **6.2.2.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
 5065 **Reservoirs**

5066 TDG would increase during part of the year prior to breaching. This would occur because only
 5067 three powerhouse units, which can pass a total of approximately 60 kcfs, would be available.
 5068 Since average spring runoff flows can average 140 to 150 kcfs, and daily flows can exceed 200
 5069 kcfs, during a high-flow year additional water would have to be discharged over the spillways.
 5070 The 1992 drawdown study at Lower Granite Dam identified the following spill/TDG
 5071 relationships for 2- to 3-hour spill durations: approximately 30 kcfs resulted in TDG ranging
 5072 from 113 to 119 percent; approximately 65 kcfs resulted in TDG ranging from 119 to 123

5073 percent; and a spill of approximately 100 kcfs resulted in TDG ranging from 126 to 135 percent
5074 (Corps 1993). These relationships are very similar to the ones currently observed at the project.
5075 During implementation of the 1992 drawdown, the TDG saturation also exceeded the current 1-
5076 hour, 125 percent limit (applicable during the fish spill season) at Lower Granite Dam and
5077 reached 134.7 percent on one occasion (Corps 1993).

5078 A few additional results from the 1992 drawdown study that are relevant to MO3 include:

- 5079 • Lowering the forebay elevation did not reduce TDG.
- 5080 • Lowering the tailwater elevation caused an increase in TDG at higher flow rates compared
5081 to what would occur at normal tailwater elevations under equal flow amounts.
- 5082 • Discharges from a combination of powerhouse and spillway operations did not significantly
5083 mix within the first few miles of the dam.
- 5084 • The TDG data obtained during the 1992 drawdown test did not reflect the cumulative
5085 increase in TDG that would occur if consecutive dams were spilling water. For a given spill
5086 quantity, an increase of an additional 80 percent of the increase observed at the previous
5087 dam would occur (Corps 1993). For example, if an increase in saturation of 20 percent was
5088 measured from the forebay to tailwater at Lower Granite Dam (100 percent in the forebay
5089 and 120 percent in the tailwater) for a given spill quantity, then the expected tailwater
5090 saturation levels below Little Goose Dam would be approximately 136 percent. This
5091 estimate would depend on factors such as powerhouse discharge, tailwater depth,
5092 dissipation rates, etc.

5093 Lower Snake River TDG was not modeled for MO3. As described above, elevated TDG would
5094 occur during the breaching process. However, once the dams were breached, the hydraulic
5095 head currently present as a result of each dam would no longer occur and spill that entrains air
5096 would no longer occur. Under new river conditions, geographically localized TDG above 110
5097 percent may periodically occur for short durations due to formation of plunge pools and
5098 turbulence during high-flow conditions.

5099 **6.2.3 Other Physical, Chemical, and Biological Processes**

5100 **6.2.3.1 Dworshak Dam and Reservoir**

5101 The physicochemical and biological process in Dworshak Reservoir and downstream of the
5102 project would not differ from the No Action Alternative if MO3 is implemented.

5103 **6.2.3.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and** 5104 **Reservoirs**

5105 Elevated suspended solids concentrations that would occur during and for some time after
5106 breaching would affect water quality. Suspended solids concentration is expected to peak at
5107 more than 24,000 mg/L during the first breach and 16,000 mg/L during the second event

5108 (Appendix C, *River Mechanics*). Concentrations greater than 5,000 mg/L would last for 26 and
5109 18 days during the first and second dam removal events, respectively.

5110 Since the concentrations of nitrogen and phosphorus associated with the sediments and
5111 interstitial water are higher than in the overlying water, a net transfer of these nutrients to the
5112 river would occur. Ammonia concentrations are of particular interest since they can be toxic to
5113 aquatic life, and are dependent on seasonal pH and temperature conditions. The pH of the river
5114 during late summer and fall when breaching would occur, as well as during May and June when
5115 peak runoff occurs, typically ranges from 7.5 to 8.0 units, but can reach 8.5 units. Mid-October
5116 through December water temperatures range from 35.6°F (2°C) to 62.6°F (17°C), with an
5117 average of 46.4°F (8°C). May through June temperatures are warmer, ranging from 48.2°F (9°C)
5118 to 73.4°F (23°C), with an average of 57.2°F (14°C). The EPA (2013) provides a detailed discussion
5119 and tables regarding the dependence of acute and chronic ammonia toxicity on temperature
5120 and pH. At an average temperature of 57.2°F (14°C) the chronic criterion ranges from 1.1 mg/L
5121 to 2.1 mg/L of total ammonia between a pH range of 7.5 to 8.0 units. The chronic concentration
5122 ranges are higher at lower water temperatures and pH values. For example, at the same
5123 temperature but with a pH range of 6.5 to 7.0 units, the criteria ranges from 2.8 to 3.1 mg/L,
5124 and at a temperature of 46.4°F (8°C) and pH values again ranging from 7.5 to 8.0 units, the
5125 criteria ranges from 1.7 mg/L to 3.0 mg/L. Average ammonia elutriate concentrations that were
5126 determined for the four lower Snake River reservoirs in 1997 (USACE, 2002) range from 2.5
5127 mg/L to 3.6 mg/L, with some individual values exceeding 12 mg/L. Actual water column
5128 concentrations would differ from elutriate concentrations, but these comparisons indicate that
5129 there is a potential for ammonia toxicity under MO3. A more concise estimate of the
5130 magnitude, duration, and frequency of possible in-water ammonia concentrations and resulting
5131 toxicity to fish would require additional sediment characterization coupled with fate/transport
5132 modeling.

5133 The current concentrations of nitrogen and phosphorus in the lower Snake River are a blend of
5134 the higher concentrations originating from the middle Snake River and the very low
5135 concentrations in the Clearwater River. These inflow concentrations vary seasonally, and the
5136 resulting downstream concentrations are influenced by the percentage of flow originating from
5137 each source. Nutrient concentrations currently do not display statistically significant changes
5138 from RM 129 down to RM 2. With anticipated mean travel time reduced from 25 to 2 days
5139 under MO3, it is not expected that lower Snake River concentrations would differ from inflows
5140 as a result of free-flowing river conditions.

5141 Dissolved oxygen concentrations in the river would be affected if MO3 is implemented. Very
5142 low, and even anoxic, conditions would occur during breaching and periodically afterward as
5143 sediments become re-suspended and create an oxygen demand. This would especially be
5144 anticipated under the first year of breaching when Lower Granite and Little Goose are
5145 deconstructed, sending high amounts of suspended sediments into Lower Monumental
5146 Reservoir where few tributaries exist to counteract the oxygen demand that would be created.
5147 To estimate the short-term effects of reservoir drawdown and breaching on dissolved oxygen
5148 concentrations, a simplistic modeling approach that focused on Lower Monumental Reservoir

5149 was pursued using two methods (Annex C). The first method was developed using correlations
5150 of measured data from Fall Creek Lake, Oregon (USGS Gage 14151000, Fall Creek Blw Winberry
5151 Creek, Near Fall Creek, OR). The second method was based on the mobilization of anoxic pore
5152 water and the biochemical oxidation of organic matter associated with deposited and re-
5153 mobilized/re-suspended sediments during reservoir drawdown and dam breach. This method
5154 assumed sediment oxygen demand (SOD) rates of 0.1, 0.5, 1.0, and 2.0 grams per square meter
5155 per day ($\text{g}/\text{m}^2/\text{day}$). The two highest rates are based on measurements obtained from several
5156 Snake River sediment cores that were collected in 1997 (Normandeau 1999) and ranged from
5157 0.8 to 2.2 $\text{g}/\text{m}^2/\text{day}$. The grain size and organic matter content of these samples correspond
5158 reasonably well with the sediment composition assumptions made by the H&H River Mechanics
5159 team—83 percent silt/clay and 5 percent organic matter (Appendix C, *River Mechanics*).

5160 A comparison of volume-weighted dissolved oxygen concentration results from both methods
5161 are summarized for two model segments/locations (at the head of Lower Monumental
5162 Reservoir and in the forebay) for each pulse of high total suspended solids following drawdown
5163 and breach (Table 6-7.). The estimated number of days when the oxygen concentrations would
5164 be less than 5 mg/L, 2.5 mg/L, and 0.5 mg/L (anoxia) under Method 1 (data correlation) and
5165 Method 2 (with an SOD of 0.5 $\text{g}/\text{m}^2/\text{d}$) in the headwater are similar and range from 21-23 days,
5166 15-19 days, and 11-17 days, respectively. The estimated number of days when the oxygen
5167 concentrations would be less than 5 mg/L, 2.5 mg/L, and 0.5 mg/L (anoxia) under Method 1
5168 (data correlation) and Method 2 (with an SOD of 0.5 $\text{g}/\text{m}^2/\text{d}$) in the forebay range from 17-20
5169 days, 4-7 days, and 0 days, respectively. Method 2 with a SOD of 0.1 $\text{g}/\text{m}^2/\text{d}$ results in nominal
5170 dissolved oxygen concentration effects with respect to the three dissolved oxygen criteria and
5171 locations selected, while estimated dissolved oxygen concentration effects with SOD rates of
5172 1.0 and 2.0 $\text{g}/\text{m}^2/\text{d}$ suggest the longest periods of low dissolved oxygen within the Lower
5173 Monumental pool.

5174 Extended periods of anoxia would be greater in the headwater segment of the Lower
5175 Monumental pool as compared to the forebay, or area of reservoir just upstream of Lower
5176 Monumental Reservoir. In addition, the first peak of sediment (during reservoir drawdown)
5177 would likely create worse dissolved oxygen conditions as compared to the second peak (dam
5178 breach) based on estimated total suspended sediment concentrations predicted by the
5179 sediment transport model, HEC-RAS 5.0.7 (Appendix C, *River Mechanics*).

5180 **Table 6-7. Number of Days when the Volume-Weighted Average Dissolved Oxygen**
 5181 **Concentration in Lower Monumental Reservoir is Estimated to be Below Selected Criteria**
 5182 **During the Two Peaks in Suspended Sediment Derived from a Hypothetical Dam Breach**

TSS Pulses	DO Criteria (mg/L)	Headwater (Segment 2)					Forebay (Segment 28)				
		Method 1	Method 2				Method 1	Method 2			
		Data Correlation	SOD 0.1	SOD 0.5	SOD 1.0	SOD 2.0	Data Correlation	SOD 0.1	SOD 0.5	SOD 1.0	SOD 2.0
First Peak August–September)	< 5	21	5	23	32	37	17	1	20	27	29
	< 2.5	15	1	19	27	33	4	0	7	14	22
	< 0.5	11	0	17	23	32	0	0	0	0	0
Second Peak October–December)	< 5	10	2	14	19	22	14	1	18	26	28
	< 2.5	7	0	10	18	20	8	0	9	19	23
	< 0.5	6	0	7	15	19	0	0	0	0	0

5183 Notes: DO = dissolved oxygen.

5184 Dissolved oxygen concentrations that would occur during subsequent spring freshet events
 5185 were not modeled. However, concentrations are anticipated to be greater than the 8 mg/L
 5186 Washington State standard after the free-flowing river state becomes established.

5187 Primary production in the lower Snake River reservoirs is currently based mainly on pelagic
 5188 (open water) phytoplankton and would undergo changes during and after the 2-year dam
 5189 breaching period. The overall contribution of phytoplankton to system productivity would be
 5190 reduced due to the increased suspended solids concentrations, surface scums that can occur as
 5191 a result of the nutrients in the suspended solids, turbidity that would limit light transmission,
 5192 and the reduction in river volume per unit length. Most of the attached benthic algae, as well as
 5193 benthic macroinvertebrates that currently inhabit shoreline areas, would die from desiccation
 5194 after the water level is reduced (Corps 1993). The accumulated fine material would be moved
 5195 downstream over time. The Corps (2002b) estimated that it would take 5 to 10 years to erode
 5196 embedded sediments and return the substrate to a combination of sand, cobble, and bedrock,
 5197 depending on river location, annual runoff, and precipitation. The recent river mechanics study
 5198 prepared for this EIS estimated that it would take from 2 to 7 years following removal for the
 5199 coarser sands and gravels stored in the reservoirs to scour down to pre-dam bed elevation
 5200 throughout the reach and establish a new quasi-equilibrium condition.

5201 A return to riverine conditions would allow the development of attached benthic algae that
 5202 would replace pelagic phytoplankton as the dominant primary producers (Corps 2002a).
 5203 Benthic colonization (details provided in the Fish and Wildlife Section) of new substrate could
 5204 take several seasons to reach full productivity. Therefore, there may be a period of reduced
 5205 overall primary production as the contribution from phytoplankton diminishes but the attached
 5206 benthic algae have not fully colonized new substrate. When the river reaches equilibrium,
 5207 primary production would be expected to be higher per length of river than when it was
 5208 impounded (Corps 2002a). The anticipated elevated benthic algal production is a function of
 5209 more available substrate and shallower water depths that allow more sunlight to reach the
 5210 river bottom.

5211 Nuisance algal growth would also shift from pelagic, or open water, to epiphytic (growing on
5212 rocks) types. Blue-green algae blooms consisting of *Anabaena* sp., *Microcystis* sp, and
5213 *Aphanizomenon* sp. would not occur in the main river but could still appear in backwater areas.
5214 Attached filamentous algae such as *Didymosphenia* sp. (currently identified in the Clearwater
5215 River) along with *Cladophora* sp., *Melosira* sp., *Cymbella* sp., *Oscillatoria* sp., *Gomphomena* sp.,
5216 and *Fragillaria* sp. that were identified during the 1997 attached benthic algae survey
5217 (Normandeau 1999) would drift downstream.

5218 Secondary production would also change if MO3 is implemented (Corps 2002). Zooplankton
5219 would become minor components of the food web and aquatic insect larvae would become the
5220 main secondary producers (details regarding the expected changes to the benthic
5221 macroinvertebrate community are provided in the fish and wildlife section).

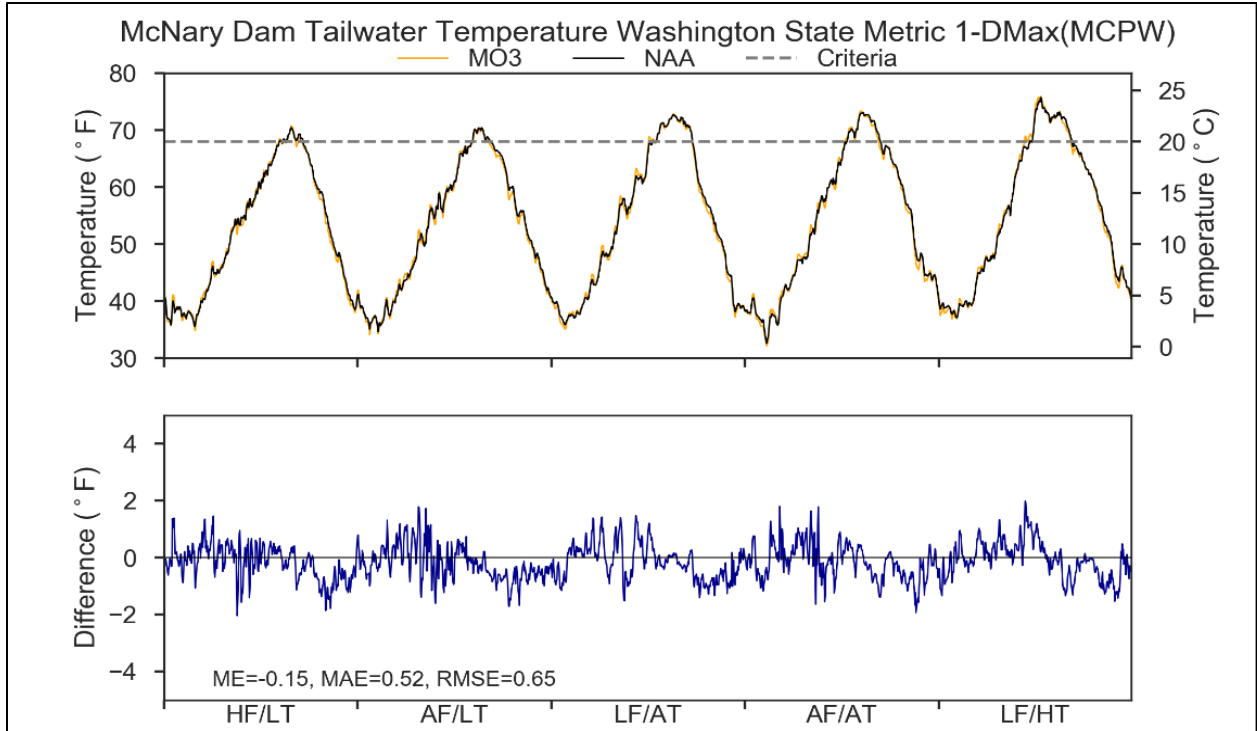
5222 **6.3 LOWER COLUMBIA RIVER**

5223 **6.3.1 Water Temperature**

5224 The *Breach Snake Embankments* measure calls for the breaching of the lower four Snake River
5225 dams (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) and a return to a more
5226 river-like system for ESA-listed species. Due to the less surface area and shorter travel times
5227 resulting from removal of the lower Snake River dams, MO3 model results for the lower Snake
5228 River show, as compared to the No Action Alternative, faster heating and cooling in the spring
5229 and fall, respectively, and more diel and day-to-day variability. These impacts to water
5230 temperature are substantially diminished downstream of McNary Dam. Details are described
5231 below.

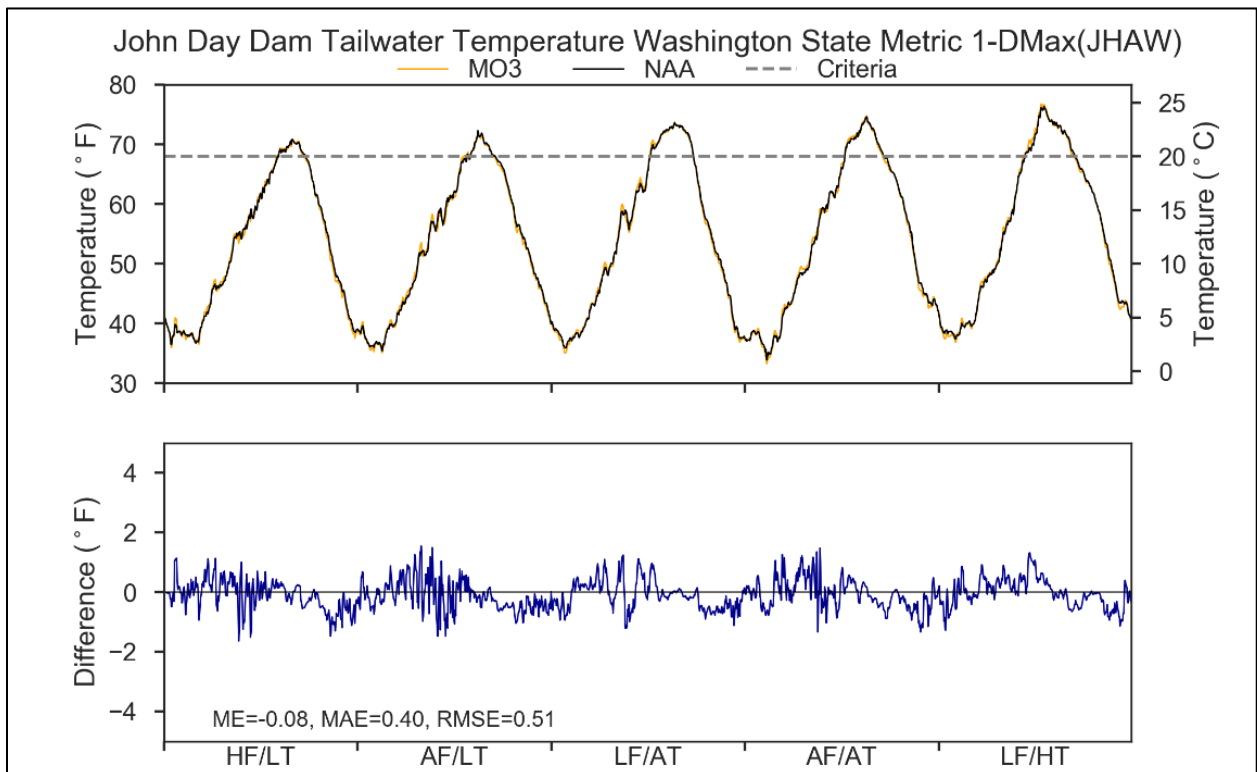
5232 **6.3.1.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

5233 The tailwater temperatures for MO3 at McNary, John Day, The Dalles, and Bonneville Dams
5234 were modeled under a 5-year range of river and meteorological conditions, and compared to
5235 the modeled results for the No Action Alternative (Figure 6-32. through Figure 6-35.). Just as
5236 with the No Action Alternative model results, MO3 model results show that tailwater
5237 temperatures can exceed 68°F at all four dams during any of the years and conditions
5238 presented. Maximum water temperatures and the frequency of water temperature violations
5239 of state water quality standards would be higher during a year when river flows were lower
5240 than normal and summer ambient air temperatures were higher (as in LF/HT). Under MO3,
5241 greater diel and day-to-day variability would be apparent in the lower Columbia River, but it
5242 would be far less pronounced than the lower Snake River, and the magnitude of variability
5243 would diminish from McNary to Bonneville. The average frequency of water temperature
5244 violations of the State water quality standards would be nearly identical for the No Action
5245 Alternative and MO3 for all four Lower Columbia River dams, though there are some minor
5246 differences depending on the dam and the river and meteorological conditions (Figure 6-36.).
5247 Generally, the difference in tailwater temperatures under the No Action Alternative and MO3
5248 would be minor, with differences up to 2 degrees Fahrenheit occurring occasionally.



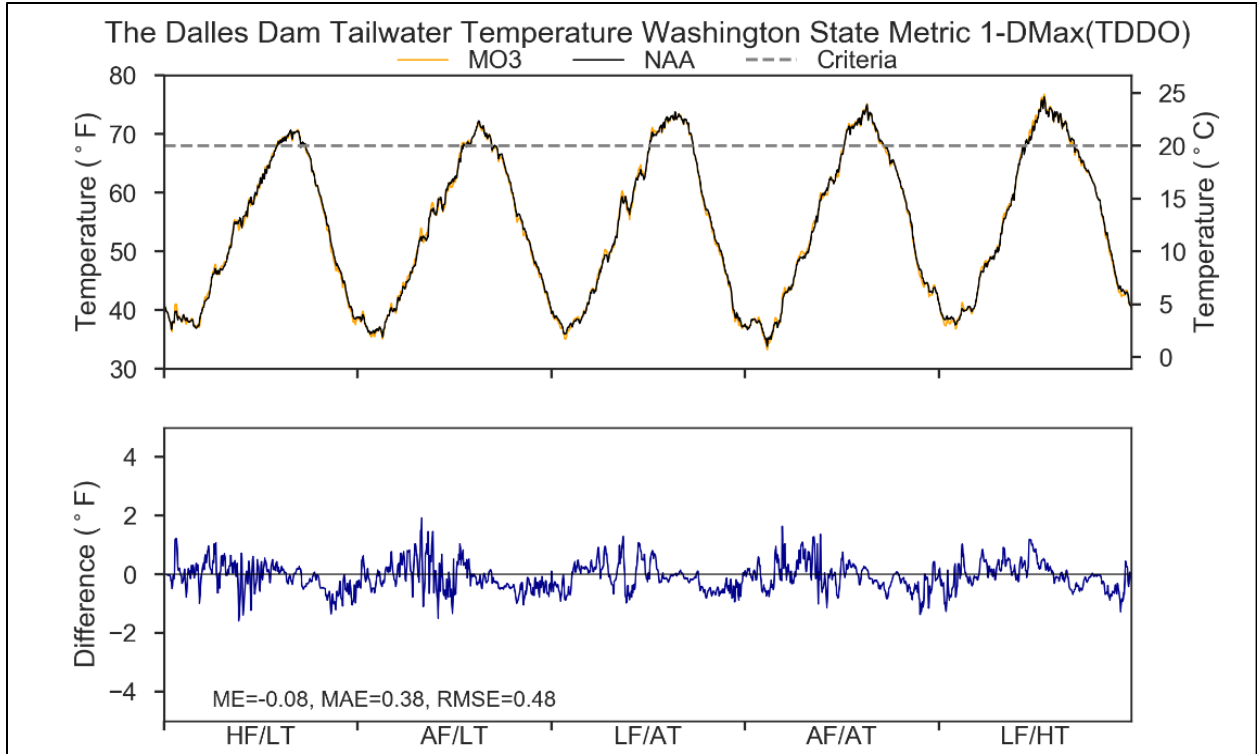
5249
 5250
 5251

Figure 6-32. Modeled Tailwater Temperature for Multiple Objective Alternative 3 at McNary Dam Under a 5-Year Range of River and Meteorological Conditions



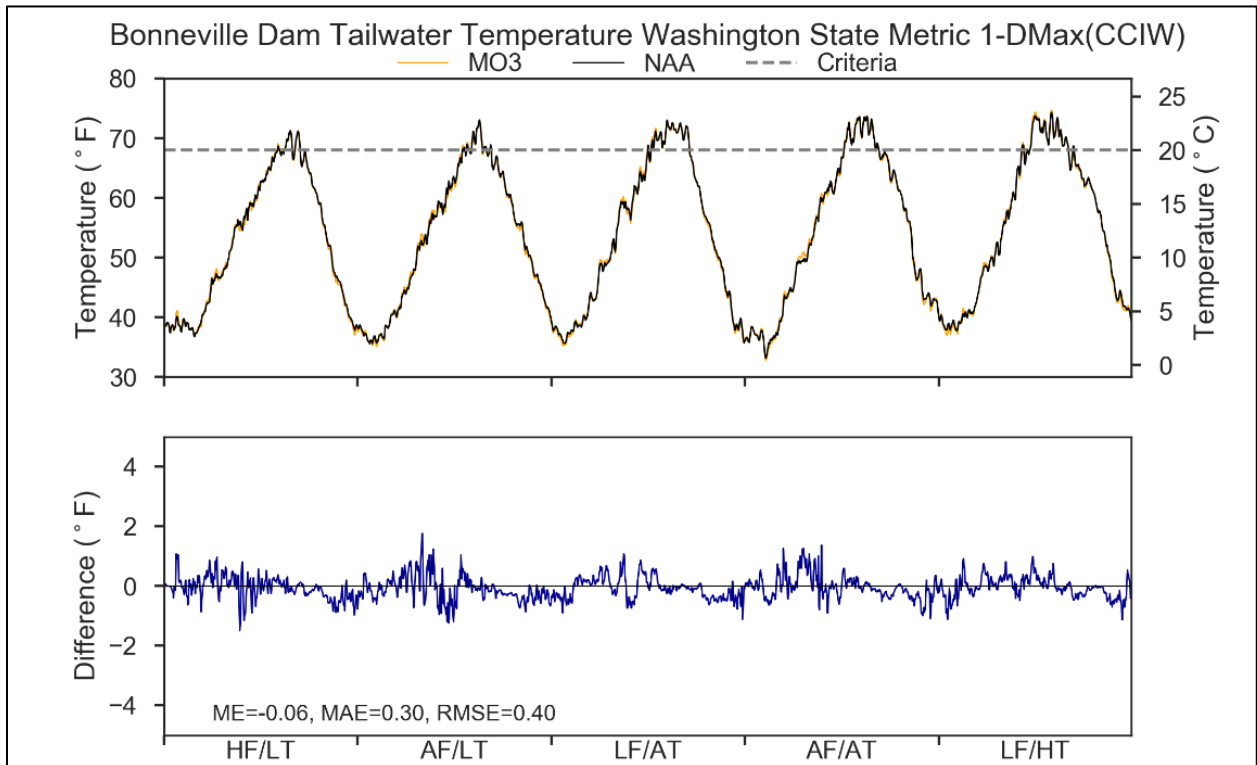
5252
 5253
 5254

Figure 6-33. Modeled Tailwater Temperature for Multiple Objective Alternative 3 at John Day Dam Under a 5-Year Range of River and Meteorological Conditions



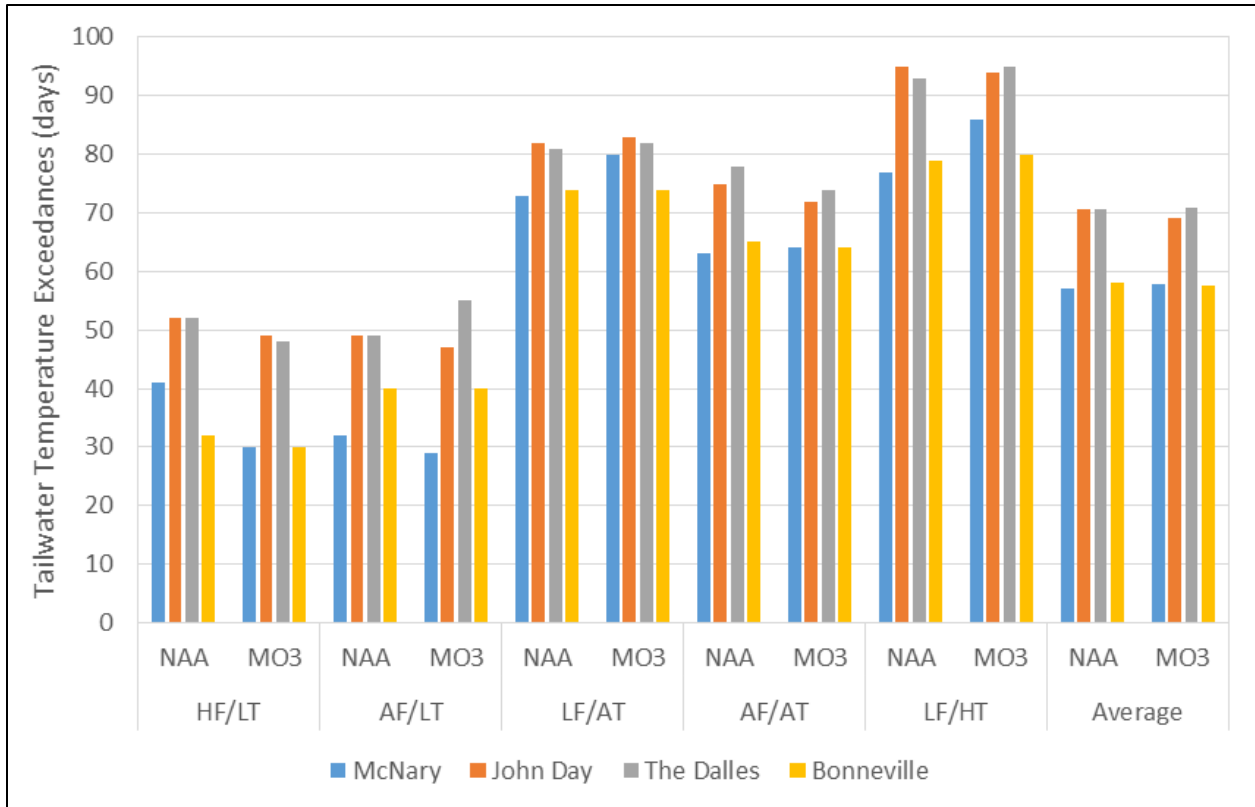
5255
5256
5257

Figure 6-34. Modeled Tailwater Temperature for Multiple Objective Alternative 3 at The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions



5258
5259
5260

Figure 6-35. Modeled Tailwater Temperature for Multiple Objective Alternative 3 at Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions



5261
5262 **Figure 6-36. Frequency of Modeled Tailwater Temperature Violations to State Water Quality**
5263 **Standards for the No Action Alternative and Multiple Objective Alternative 3 at McNary, John**
5264 **Day, The Dalles, and Bonneville Dams Under a 5-Year Range of River and Meteorological**
5265 **Conditions**

5266 **6.3.2 Total Dissolved Gas**

5267 The *Breach Snake Embankments* measure calls for the breaching of the lower Snake River
5268 Dams. Without these dams in place, it is expected that forebay TDG, upstream of McNary Dam
5269 in particular, would be less than the No Action Alternative because sustained, elevated TDG is
5270 not expected to be produced in the lower Snake River without the dams.

5271 The Spring Spill to 120% TDG limits juvenile fish passage spill to not exceed a 120 percent TDG
5272 in the tailrace of all four lower Columbia River dams from April 10 to June 15; there is no
5273 forebay TDG limit under MO3. Additionally, the *Reduced Summer Spill* measure aims to reduce
5274 the duration of summer juvenile fish passage spill at the lower Columbia River dams, ending
5275 summer spill on July 31. MO3 model results show, as compared to the No Action Alternative,
5276 similar or higher tailwater TDG saturations in April through June and lower tailwater TDG
5277 saturations in August. Details are described below.

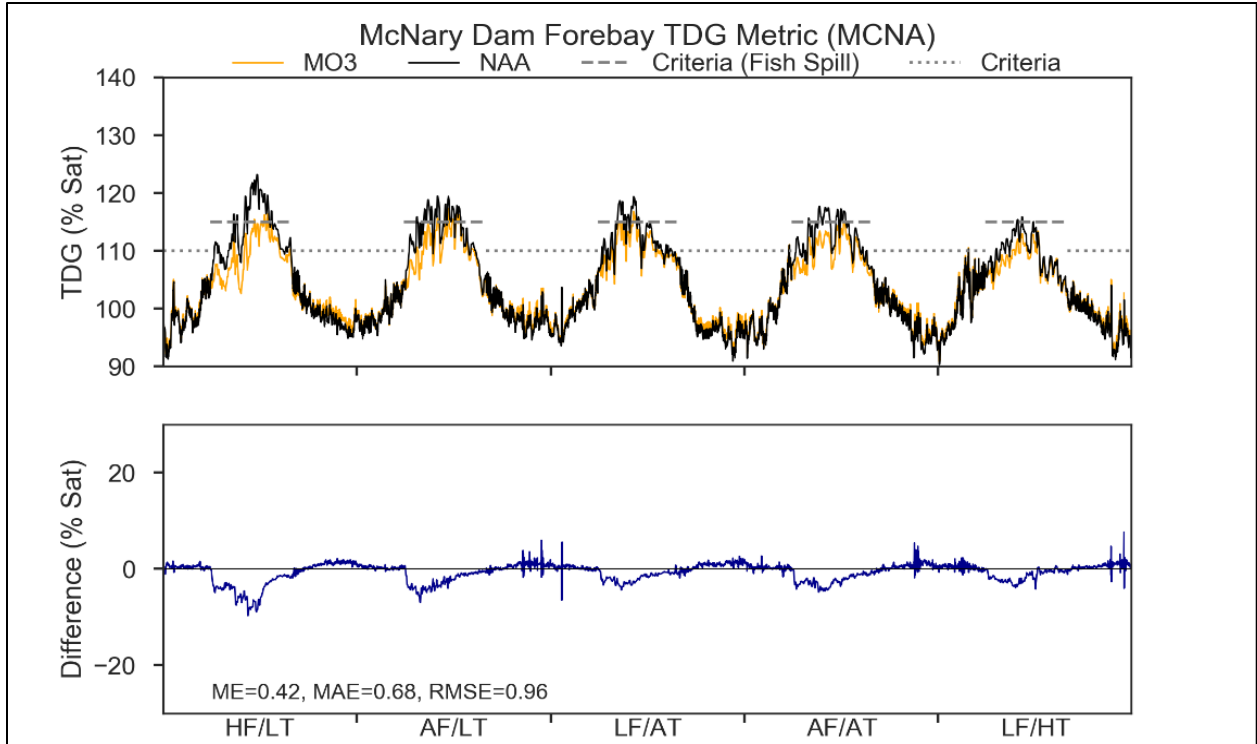
5278 **6.3.2.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

5279 Forebay TDG saturations for MO3 at McNary, John Day, The Dalles, and Bonneville Dams were
5280 modeled under a 5-year range of river and meteorological conditions and compared to the

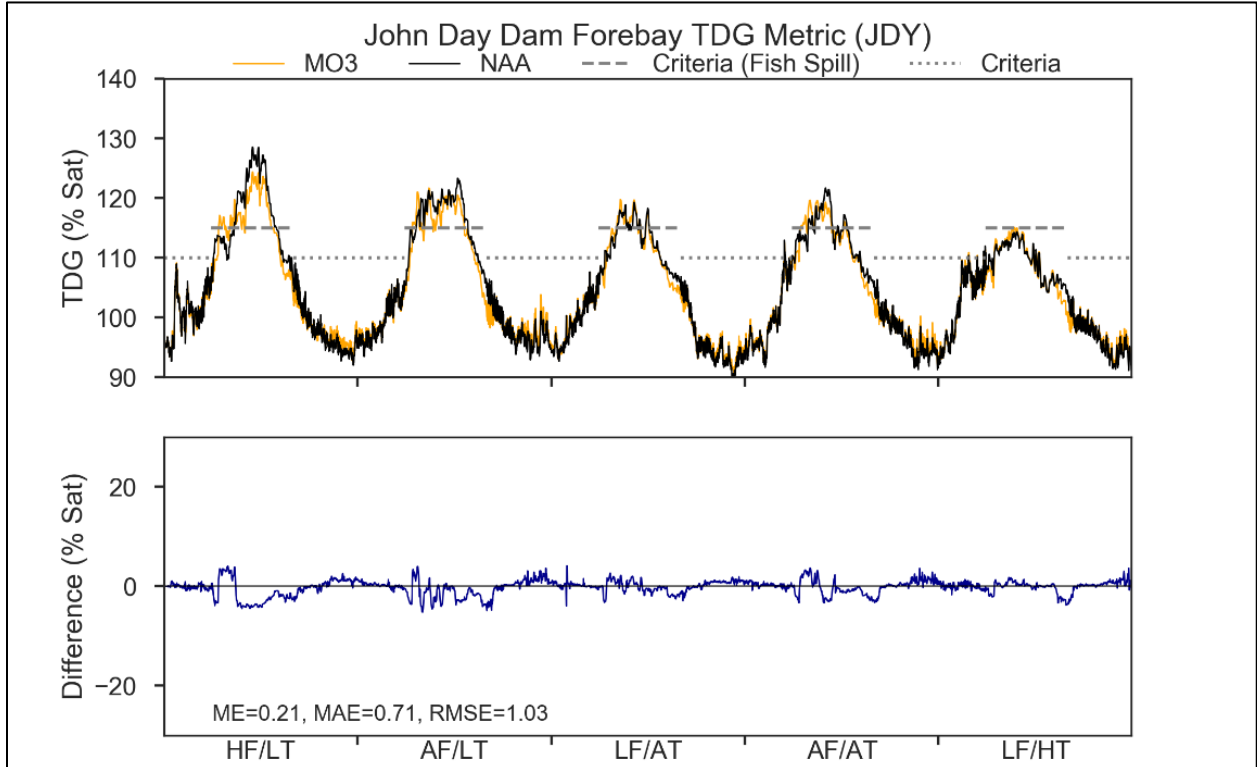
5281 modeled results for the No Action Alternative (Figure 6-37. to Figure 6-40.). Although MO3 does
5282 not include a measure limiting forebay TDG, model results are compared to the current 115
5283 percent TDG standard for direct comparison to the No Action Alternative. Results show that
5284 forebay TDG saturations can exceed the current 115 percent forebay TDG standard during the
5285 spill season at all four dams during most years and conditions presented; however, TDG levels
5286 are lower in McNary forebay under MO3 versus the No Action Alternative due to the
5287 elimination of TDG generation in the lower Snake River reach. Maximum forebay TDG
5288 saturation would be higher during a year when river flows were higher than normal (HF/LT).
5289 Maximum forebay TDG saturations in MO3, as compared to the No Action Alternative, would
5290 be higher at The Dalles and Bonneville Dams under low-flow and high air temperature
5291 conditions (LF/HT); under all other conditions, maximum forebay TDG saturations would be
5292 similar or lower under MO3 as compared to the No Action Alternative. This is due to the *Spring*
5293 *Spill to 120% TDG* measure, which calls for higher tailwater TDG, which would increase forebay
5294 TDG (as compared to the No Action Alternative), as well.

5295 Under MO3, the average frequency of 110% TDG outside of the juvenile fish spill season would
5296 be similar to or slightly less under MO3 as compared to the No Action Alternative for all
5297 modeled river and meteorological conditions (Figure 6-41.). This is partially due to a reduction
5298 in the lack of market spill estimated for the No Action Alternative as compared to MO3. At John
5299 Day, The Dalles, and Bonneville, the frequency of 115% TDG exceedances during the juvenile
5300 fish spill season would be greater under MO3 than the No Action Alternative under all modeled
5301 river and meteorological conditions except average flow/low temperature (AF/LT), during
5302 which the frequency of 115% TDG exceedances would be about the same (Figure 6-42.). At
5303 McNary, the frequency of 115% TDG exceedances during the juvenile fish spill season would be
5304 lower under MO3 than the No Action Alternative (Figure 6-42.).

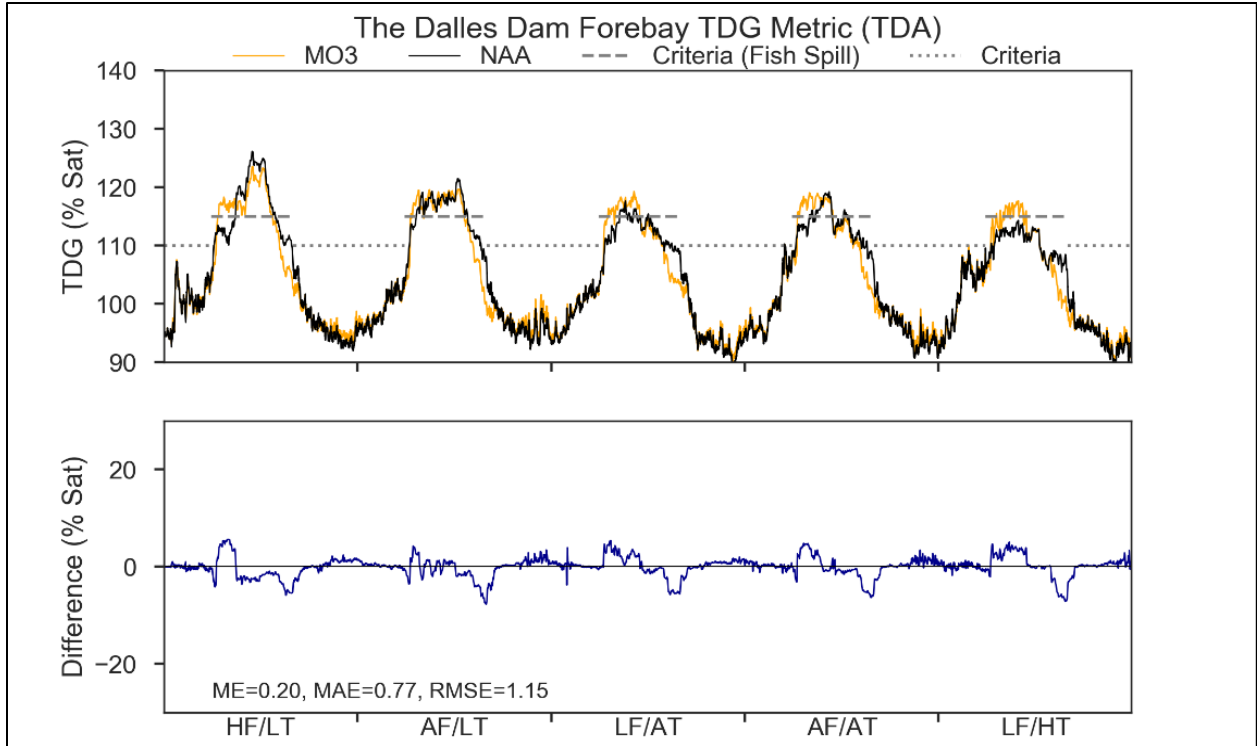
5305 The MO3 model results show that tailwater TDG saturations can exceed the current 120
5306 percent spill season TDG standard at all four dams during most of the years and conditions
5307 presented (the only exceptions being at McNary and John Day under LF/HT conditions) (Figure
5308 6-43). Maximum tailwater TDG saturation would be higher during a year when river flows were
5309 higher than normal and summer ambient air temperatures were lower (as in the HF/LT year).
5310 Tailwater TDG saturations would be similar or higher in MO3 as compared to the No Action
5311 Alternative for all four dams from April 10 to June 15, but lower at all four dams in August.
5312 Under MO3, the frequency of of 110% TDG exceedances outside the spill season would be
5313 similar to or slightly less than under the No Action Alternative for all modeled river and
5314 meteorological conditions (Figure 6-47.). This is partially due to a reduction in the lack of
5315 market spill estimated for the No Action Alternative as compared to MO3. Generally, the
5316 frequency of 120% TDG exceedances during the juvenile fish spill season would be greater
5317 under MO3 than the No Action Alternative under all modeled river and meteorological
5318 conditions, though there is some variation depending on the particular dam and condition (e.g.,
5319 McNary and John Day under the LF/HT condition when no 120% exceedances are expected;
5320 Figure 6-48.).



5321
 5322 **Figure 6-37. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 3 at**
 5323 **McNary Dam Under a 5-Year Range of River and Meteorological Conditions**

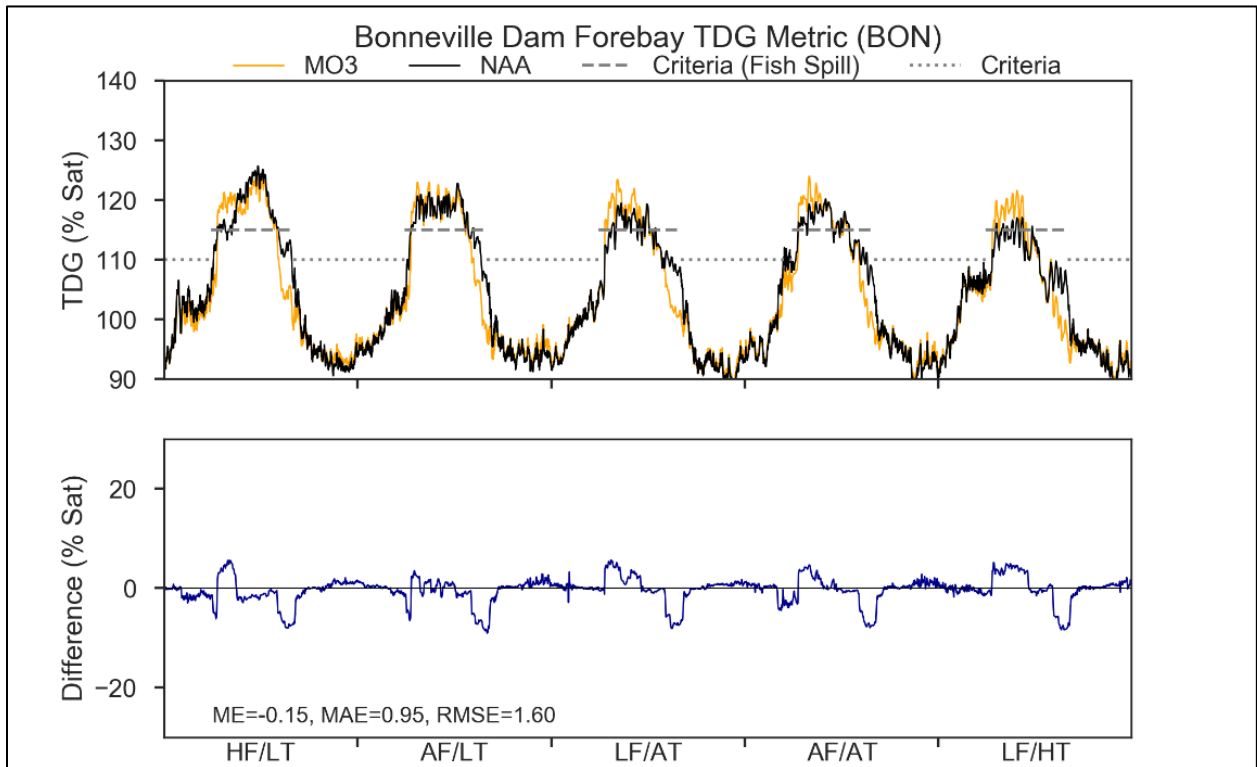


5324
 5325 **Figure 6-38. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 3 at John**
 5326 **Day Dam Under a 5-Year Range of River and Meteorological Conditions**



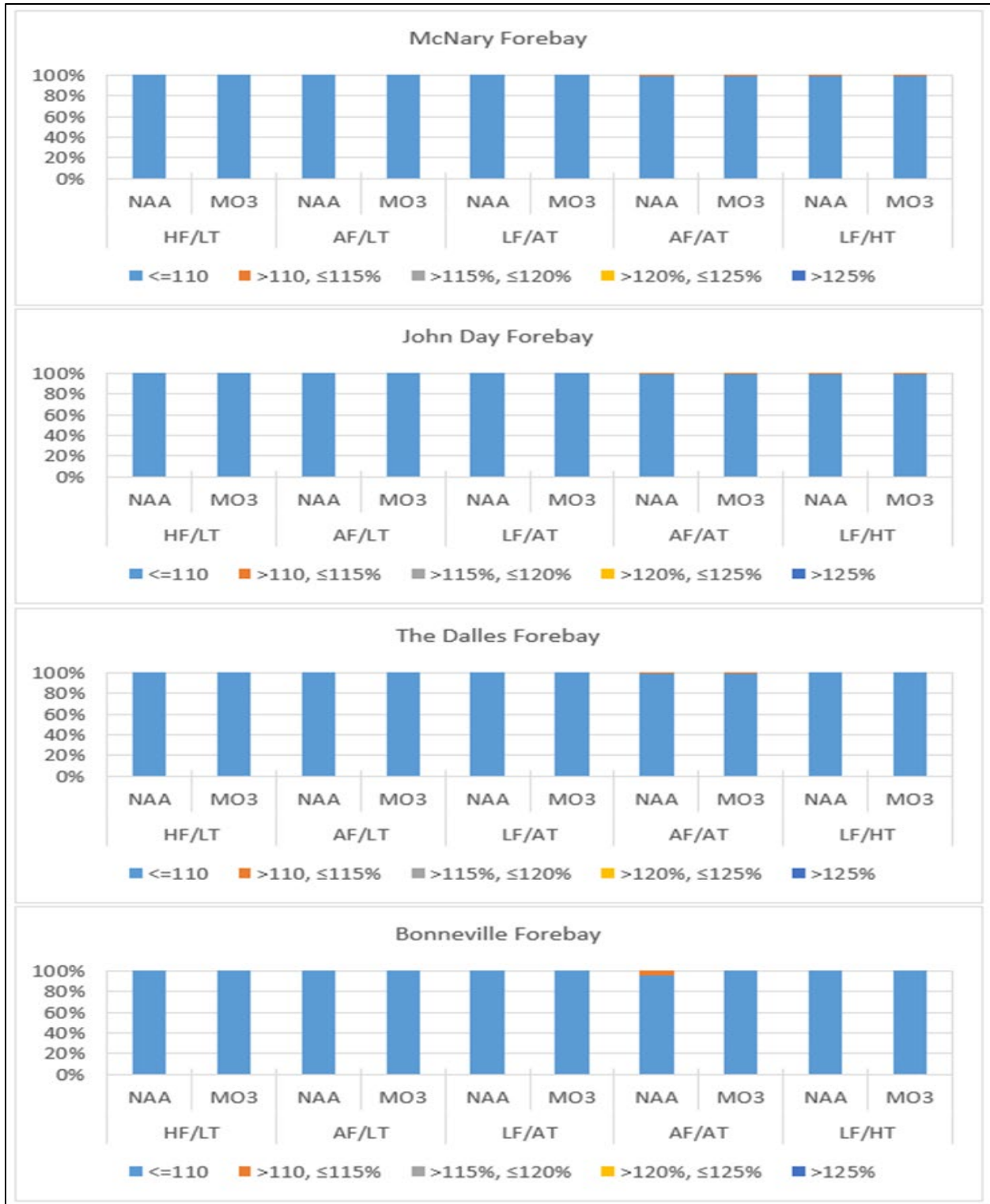
5327
 5328
 5329

Figure 6-39. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 3 at The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions



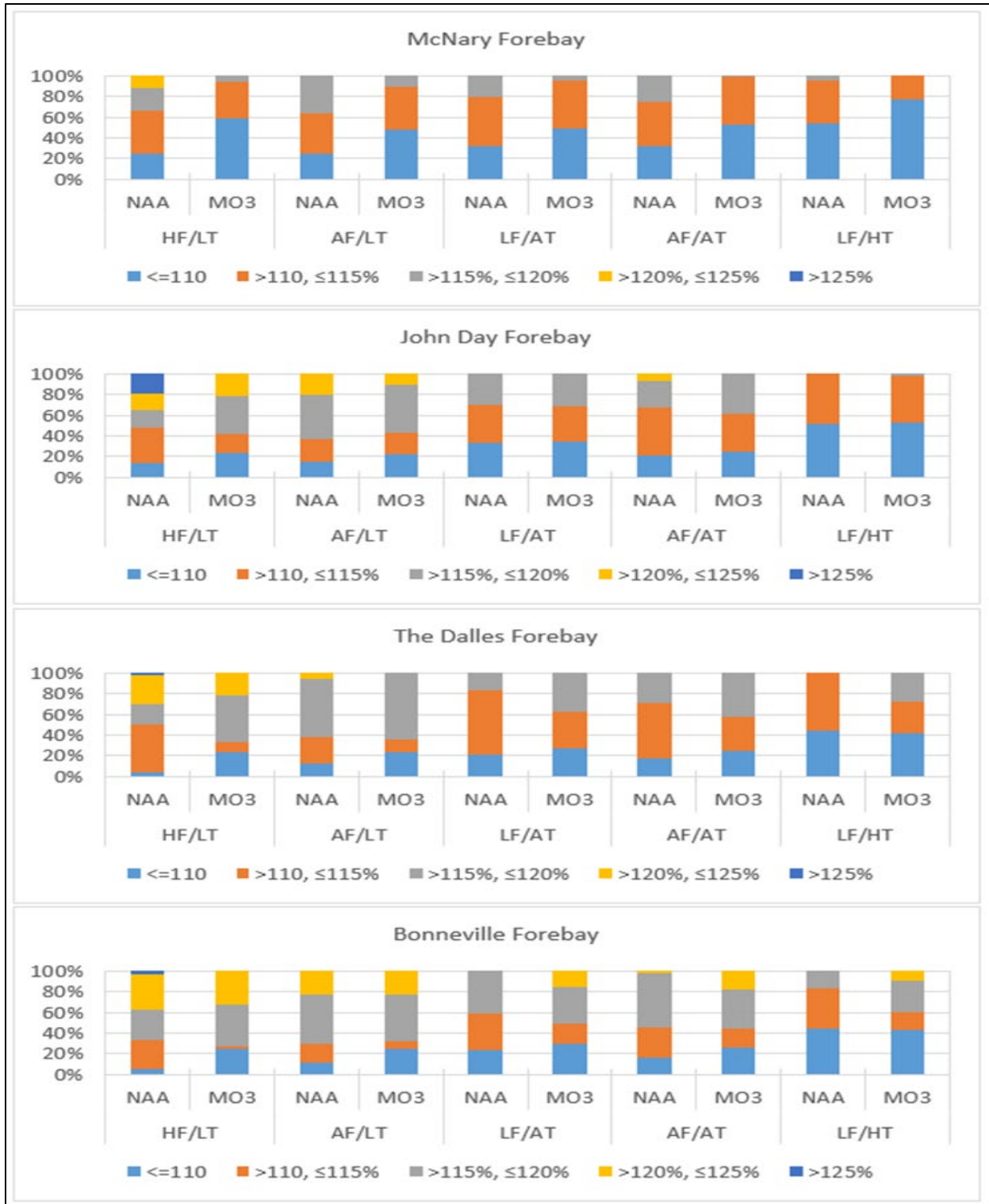
5330
 5331
 5332

Figure 6-40. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 3 at Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions



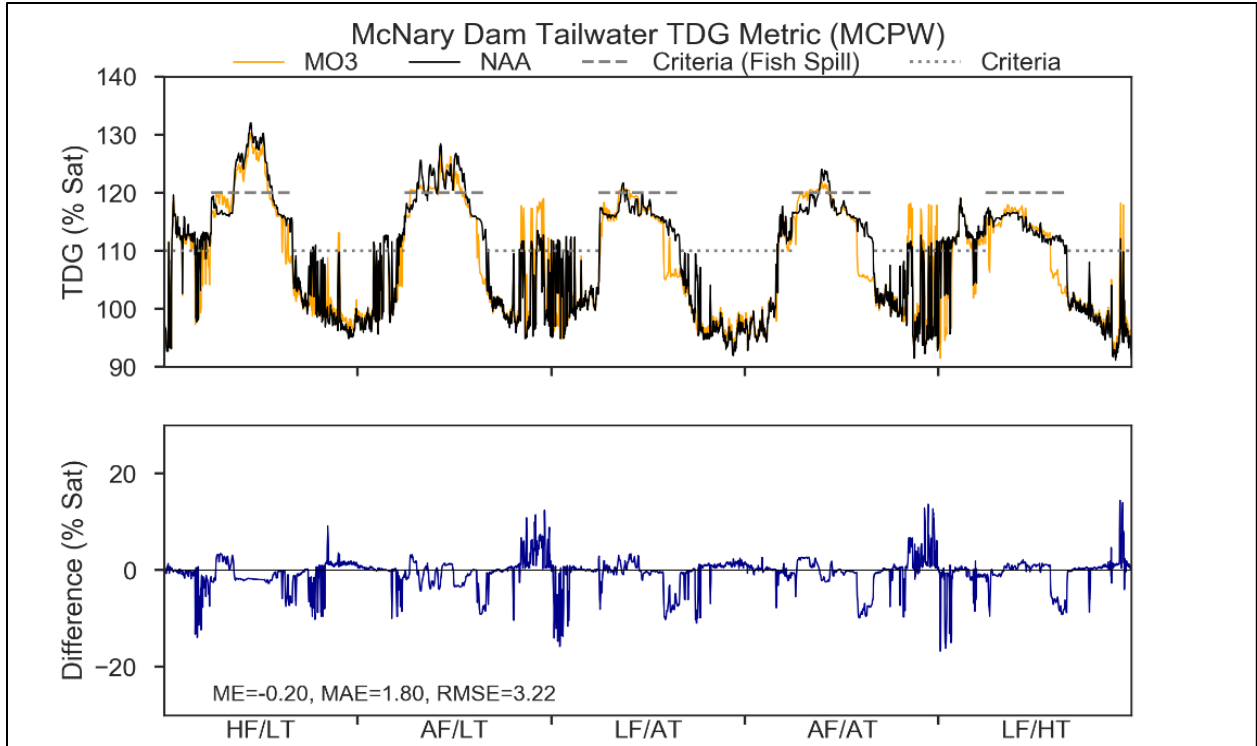
5333
 5334 **Figure 6-41. Frequency of Modeled Forebay Total Dissolved Gas Outside of Current Fish**
 5335 **Passage Spill Season for the No Action Alternative and Multiple Objective Alternative 3 at**
 5336 **McNary, John Day, The Dalles, and Bonneville Dams Under a 5-Year Range of River and**
 5337 **Meteorological Conditions**

5338 Note: Current fish passage spill season is from September 1 to March 31.

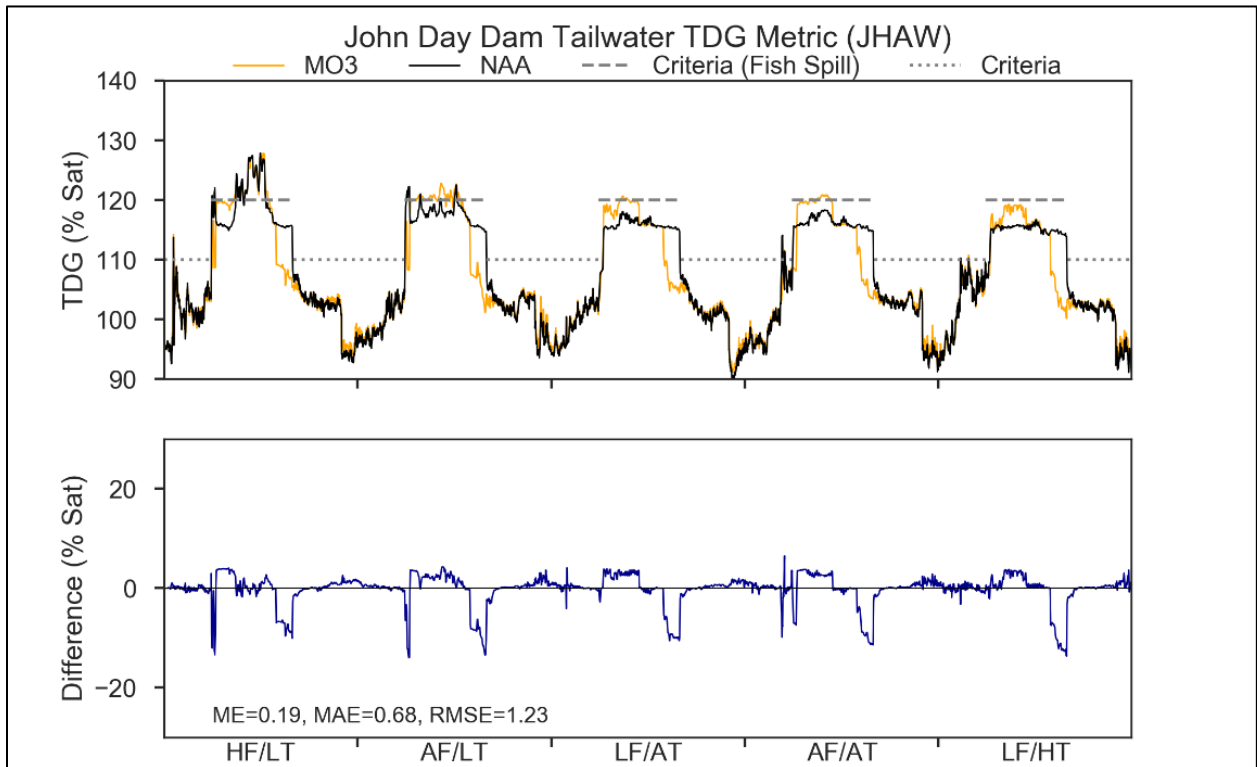


5339
 5340
 5341
 5342
 5343
 5344

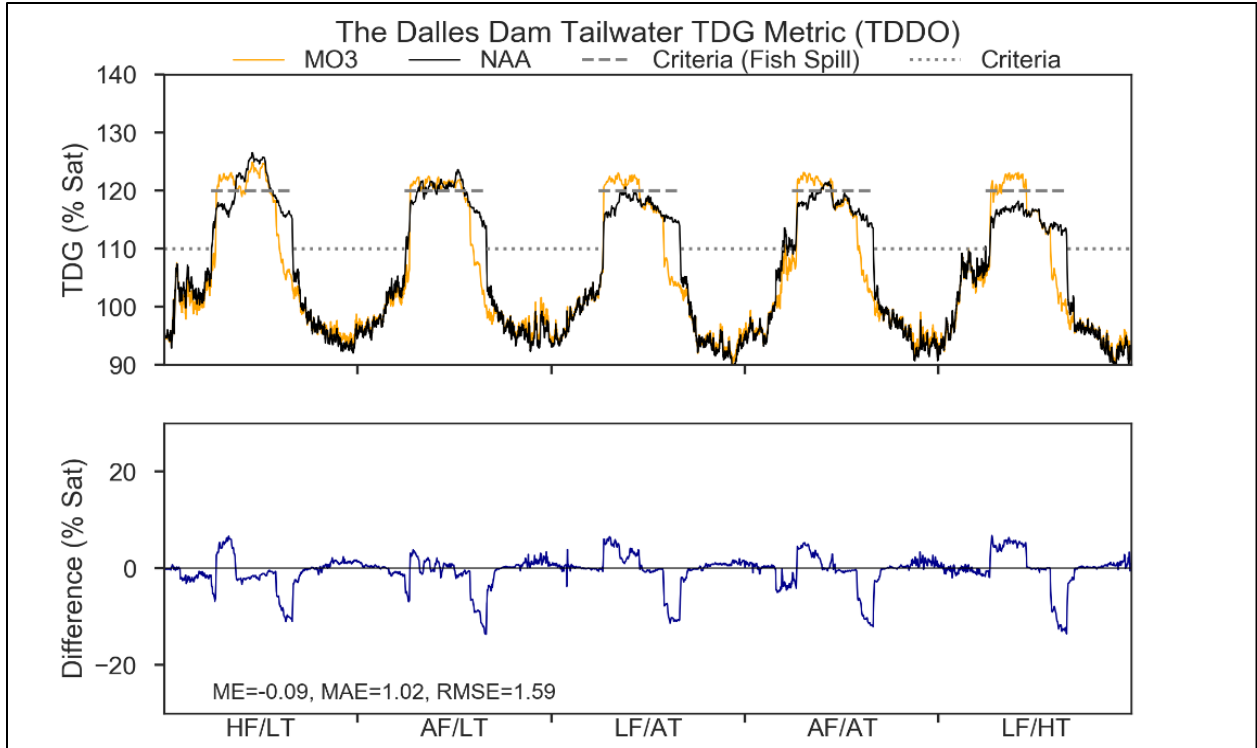
Figure 6-42. Frequency of Modeled Forebay Total Dissolved Gas Violations of Current 115 Percent Total Dissolved Gas State Water Quality Standards During Current Fish Passage Spill for the No Action Alternative and Multiple Objective Alternative 3 at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-Year Range of River And Meteorological Conditions
 Note: Current fish passage spill season is from April 1 to August 31.



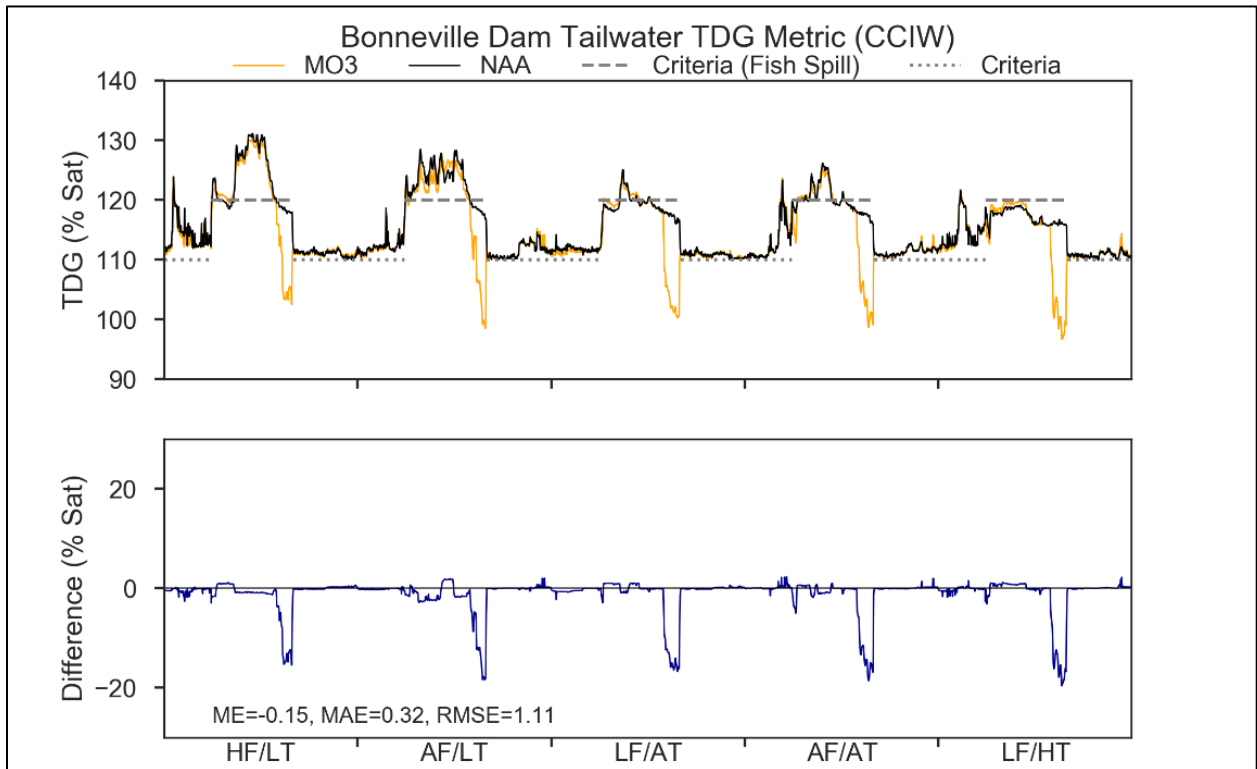
5345
 5346 **Figure 6-43. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 3 at**
 5347 **McNary Dam Under a 5-Year Range of River and Meteorological Conditions**



5348
 5349 **Figure 6-44. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 3 at**
 5350 **John Day Dam Under a 5-Year Range of river and meteorological Conditions**



5351
 5352 **Figure 6-45. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 3 at**
 5353 **The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions**

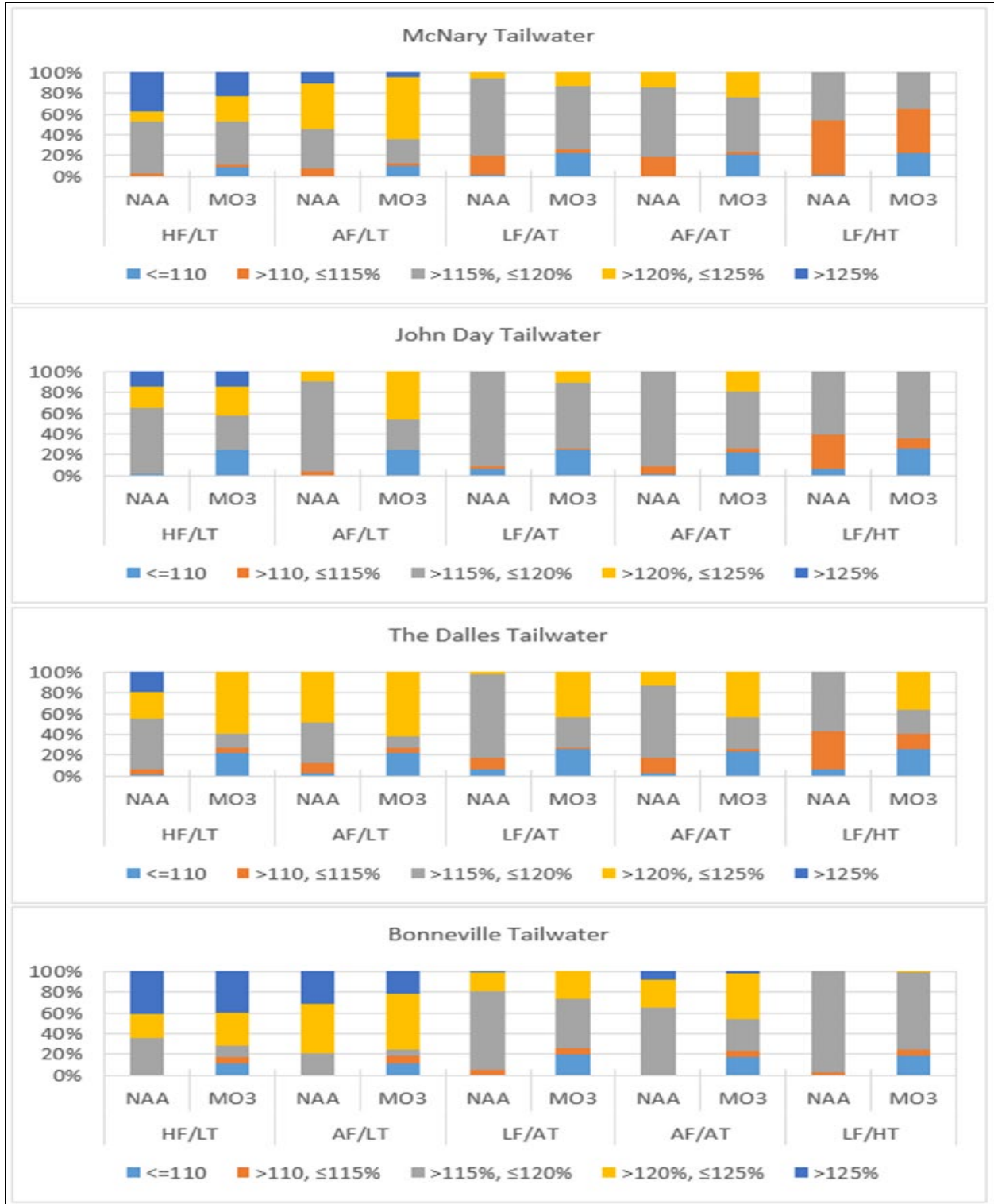


5354
 5355 **Figure 6-46. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 3 at**
 5356 **Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions**



5357
 5358
 5359
 5360
 5361

Figure 6-47. Frequency of Modeled Tailwater Total Dissolved Gas Outside of Current Fish Passage Spill Season for the No Action Alternative and Multiple Objective Alternative 3 at McNary, John Day, and The Dalles Dams Under a 5-Year Range of Meteorological Conditions
 Note: Current Fish Passage Spill Season is from April 1 to August 31.



5362
 5363 **Figure 6-48. Frequency of Modeled Forebay Total Dissolved Gas During Current Fish Passage**
 5364 **Spill Season for the No Action Alternative and Multiple Objective Alternative 3 at McNary,**
 5365 **John Day, The Dalles, and Bonneville Dams Under a 5-Year Range of River and Meteorological**
 5366 **Conditions**

5367 Note: Current Fish passage spill season is April 1 to August 31.

5368 **6.3.3 Other Physical, Chemical, and Biological Processes**

5369 **6.3.3.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

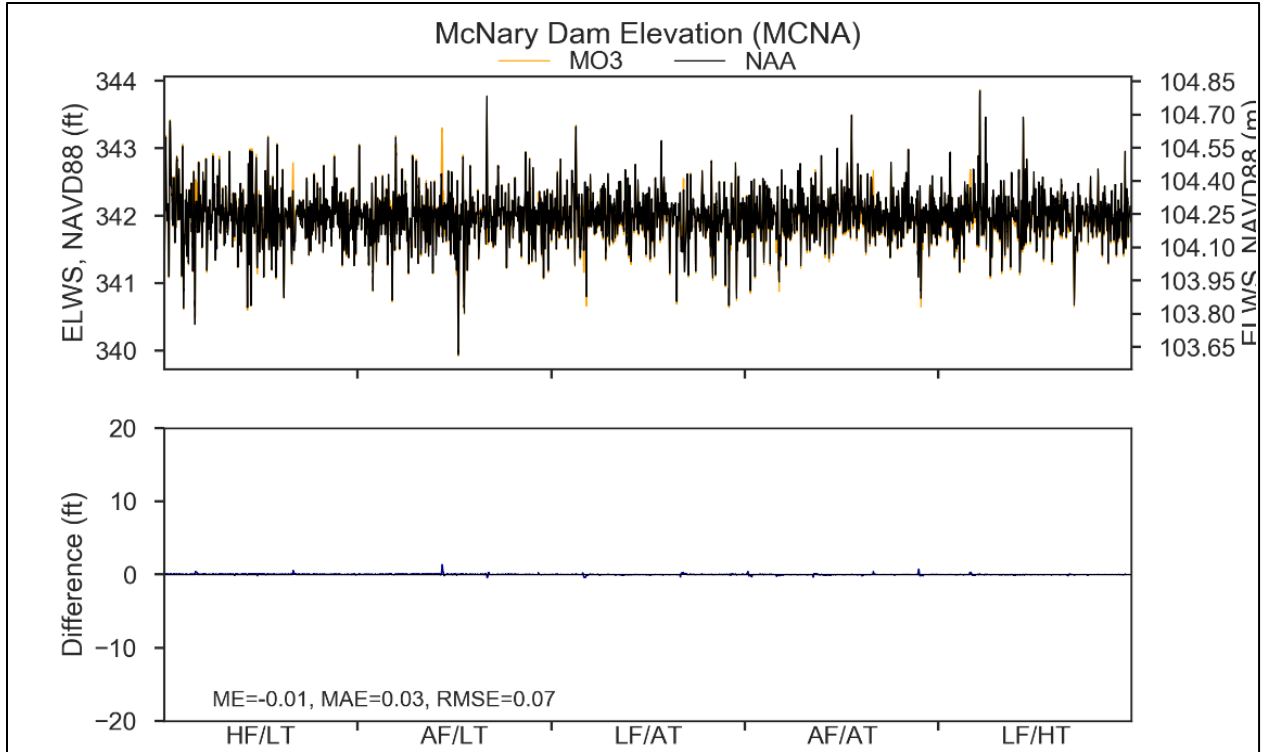
5370 The lower Columbia River contains a variety of human-sourced compounds, including metals
5371 and organic compounds. The introduction of pollutants and excess nutrients from farming and
5372 industrial activities, as well as urban runoff, is expected to continue under MO3. As with the No
5373 Action Alternative, emerging contaminants such as pharmaceuticals and new pesticides will
5374 also likely become more prevalent. This condition is expected to remain.

5375 Breaching of the dams under MO3 would result in an estimated average annual sediment
5376 volume of 12.6 million cubic yards (Mcy) being transported downstream to the McNary forebay
5377 in the years immediately following breaching (near-term). As comparison, an annual average of
5378 0.8 Mcy would be expected under the No Action Alternative (Appendix C, *River Mechanics*).
5379 Eventually, the Snake River will reach a new quasi-equilibrium condition and largely pass
5380 incoming sediment load; an annual average of 3.6 Mcy would be expected to enter the McNary
5381 Reservoir in the long term.

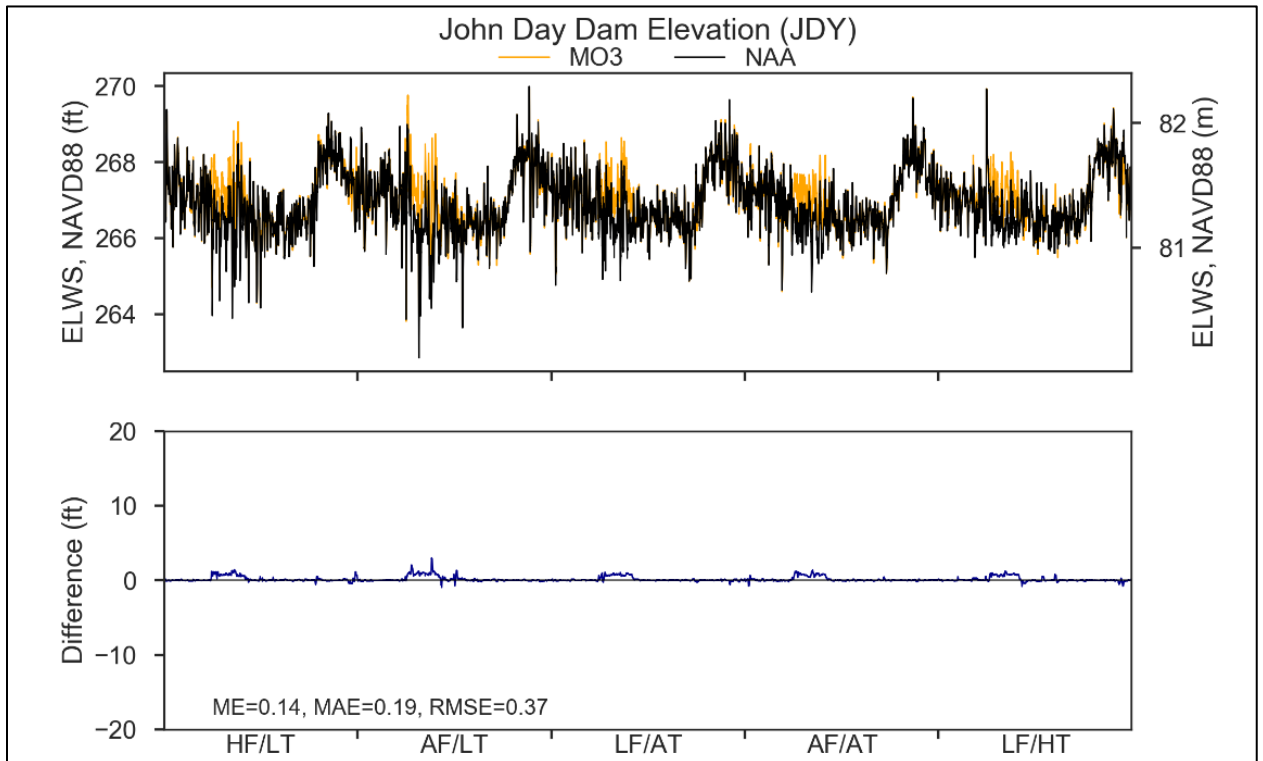
5382 Approximately 30 to 35 percent of the total sediment entering the McNary Reservoir would be
5383 expected to pass McNary Dam under MO3, both in the near and long term. The sediment not
5384 trapped by McNary would be composed almost entirely of clay and silt and are expected to
5385 remain in suspension and travel to the estuary. Little material is expected to settle in the
5386 reservoirs downstream of McNary Reservoir.

5387 Some negative impacts associated with the sediment transport would be expected in the
5388 McNary Reservoir. Dissolved oxygen, light attenuation, phytoplankton, zooplankton, and
5389 productivity would likely be depressed, while TSS, turbidity, nutrients, organics, and metals
5390 would likely increase. Near-term transport of silt- and clay-sized particles downstream of
5391 McNary Dam would not likely cause significant impacts to the downstream reservoirs, since the
5392 majority of sediment would be trapped by McNary Dam. The near-term increases in suspended
5393 sediment and turbidity (and associated impacts) would eventually level off, and more typical
5394 seasonal fluctuations would occur in the long term in the McNary forebay and downstream.

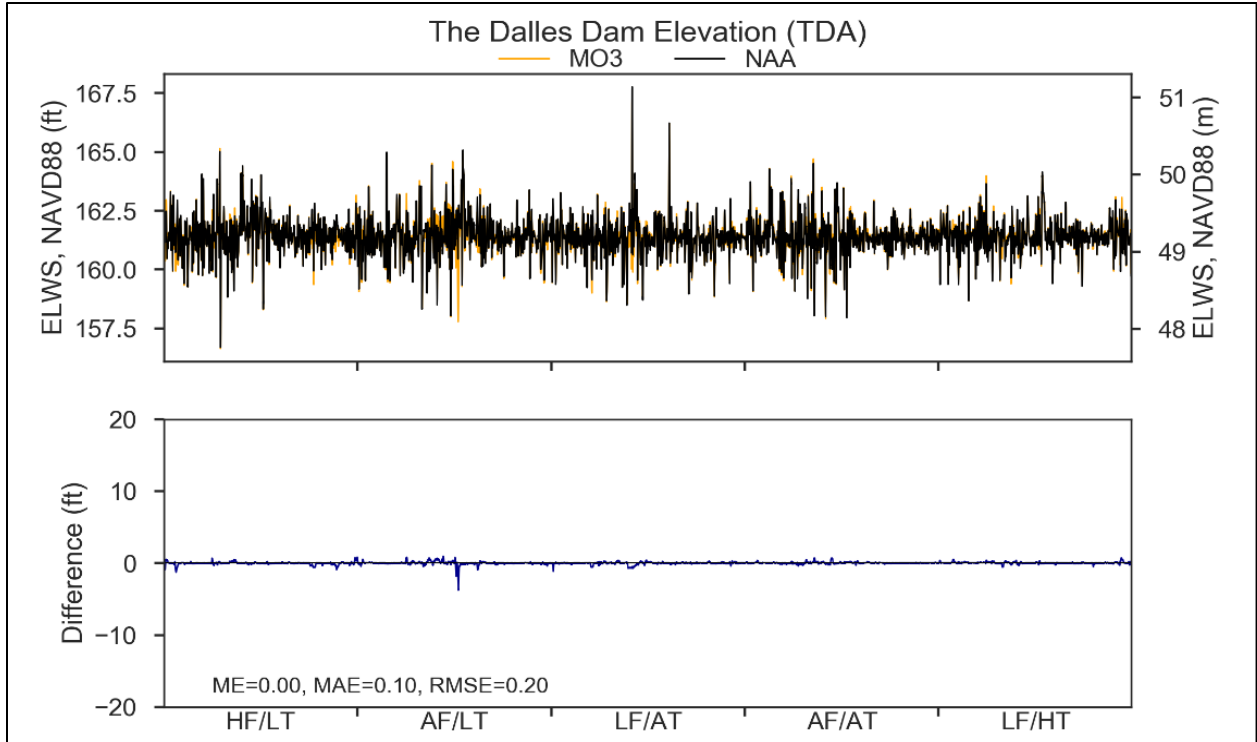
5395 Additionally, under the *John Day Full Pool* measure, flow and pool elevation restrictions are
5396 partially lifted to increase hydropower generation and hydropower flexibility to integrate
5397 renewable resources. Safety-related restrictions would continue, including meeting FRM
5398 elevations and flows, maintaining ramp rates for minimizing dam erosion, and maintaining grid
5399 reliability. Specifically, the *Ramping Rates for Safety* measure calls for ramping rate limitations
5400 at all dams to be defined only for the purposes of safety and engineering; the *John Day Full Pool*
5401 measure reduces the restrictions on seasonal pool elevations at John Day, except as needed for
5402 FRM. Modeling results suggest there would be minor pool elevation differences between MO3
5403 and the No Action Alternative (Figure 6-49. through Figure 6-52.). Manipulating the water level
5404 could have minor, short-term TSS and associated impacts (turbidity, light attenuation, and/or
5405 chemicals that may be associated with TSS, such as nutrients, metals, and organics). However,
5406 the impact is expected to be negligible in the lower Columbia River reservoirs.



5407
 5408 **Figure 6-49. Modeled Forebay Elevation for Multiple Objective Alternative 3 at McNary Dam**
 5409 **Under a 5-Year Range of River and Meteorological Conditions**

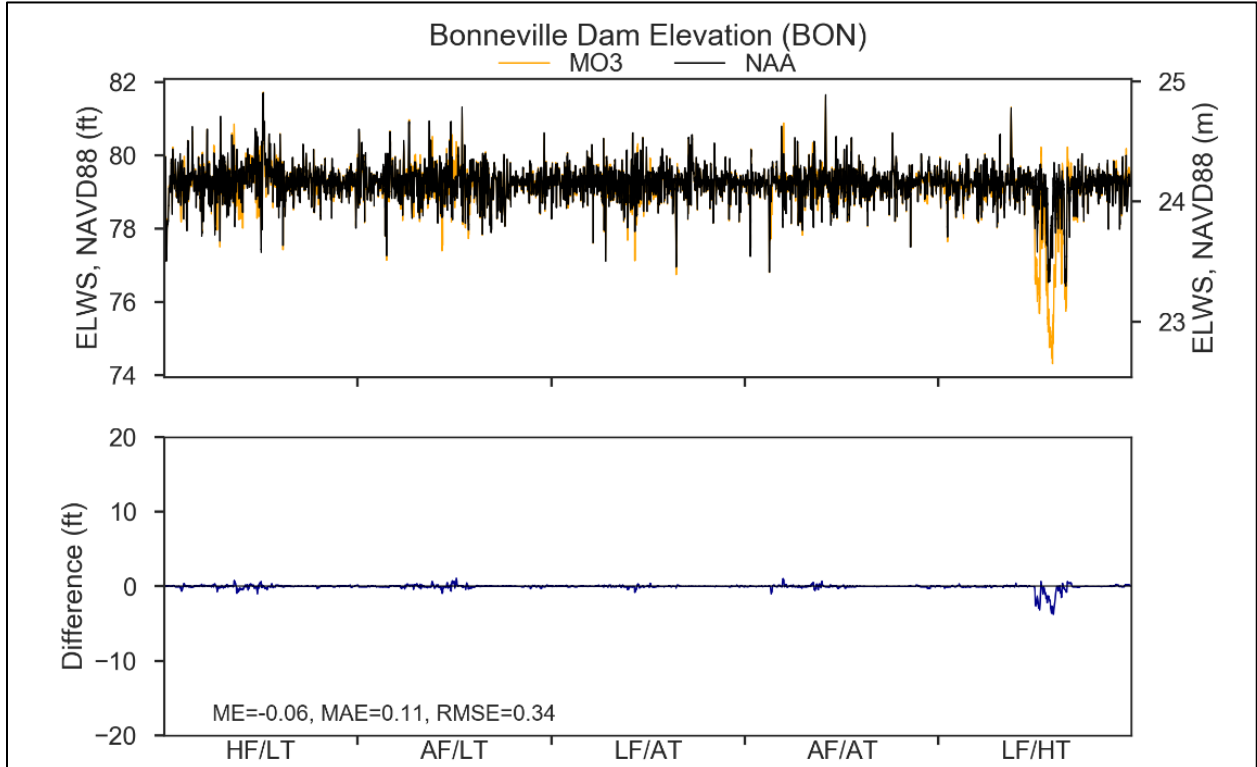


5410
 5411 **Figure 6-50. Modeled Forebay Elevation for Multiple Objective Alternative 3 at John Day Dam**
 5412 **Under a 5-Year Range of River and Meteorological Conditions**



5413
5414
5415

Figure 6-51. Modeled Forebay Elevation for Multiple Objective Alternative 3 at The Dalles Dam Under a 5-Year Range of River and Meteorological Conditions



5416
5417
5418

Figure 6-52. Modeled Forebay Elevation for Multiple Objective Alternative 3 at Bonneville Dam Under a 5-Year Range of River and Meteorological Conditions

5419 **6.4 SEDIMENT PROCESSES**

5420 **6.4.1 Columbia River Sediment**

5421 MO3 includes various operational changes for the Columbia River dams. These changes would
5422 have little impact on sediment sources, movement, or contamination within the Columbia River
5423 sediment. Sediment shoaled behind the dams would remain at depth, undisturbed by water
5424 level fluctuations, the timing of water releases, hydropower generation or lack thereof, and fish
5425 passage activities. Historically sourced pollutants would remain in the shoaled sediment, with
5426 organic compounds slowly degrading over time and metals remaining in the sediment matrix. It
5427 is anticipated that sediment conditions within the Columbia River System, with the exception of
5428 McNary Reservoir, would remain similar to the No Action Alternative. Changes to McNary
5429 Reservoir sediment are discussed below, in conjunction with the lower Snake River sediment.

5430 **6.4.2 Lower Snake River Sediment**

5431 MO3 includes breaching the four lower Snake River dams, which would have a great impact on
5432 sediment shoaling, movement, and the distribution of pollutants associated with the sediment.
5433 The following discussion is based on the movement of sediment modeled by the River
5434 Mechanics group (Appendix C, *River Mechanics*). The reader is referred to that information on
5435 the details of sediment migration associated with the dam breach. The discussion in this section
5436 focuses on the pollutants associated with the sediment, the water quality impacts associated
5437 with the sediment movement, and changes to shoaling patterns.

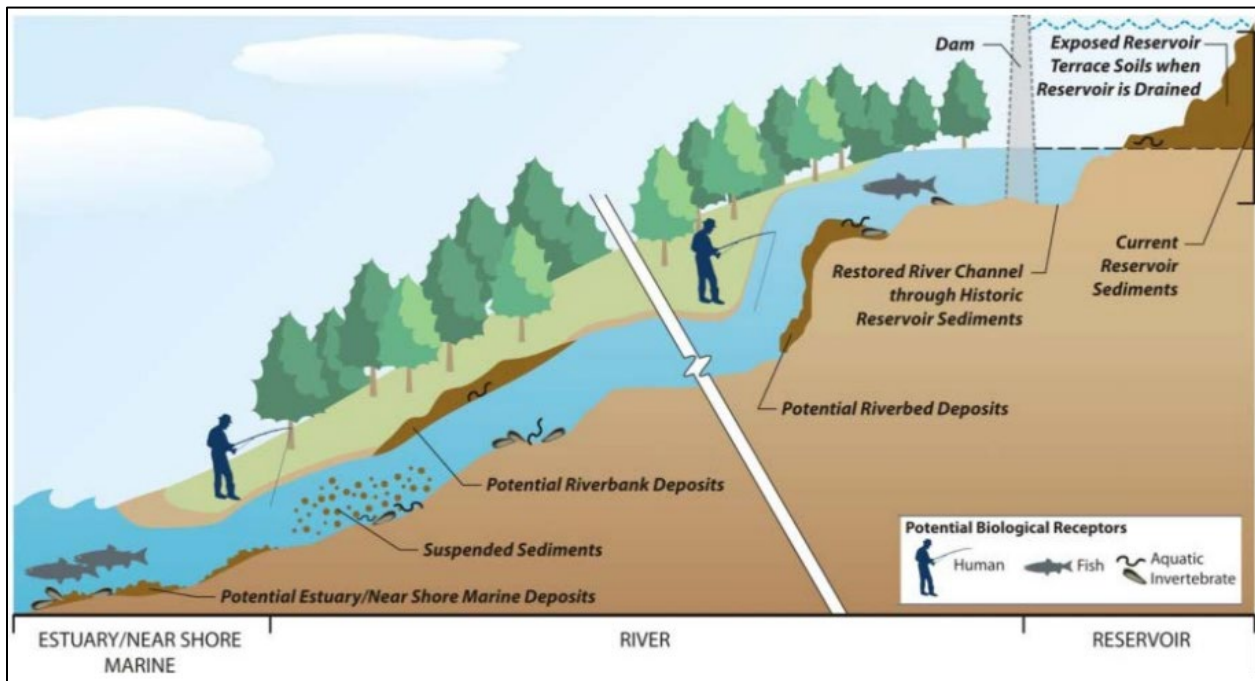
5438 Sediment began shoaling behind the lower Snake River dams as they were constructed. Since
5439 the dams were constructed in order from Ice Harbor to Lower Monumental, Little Goose, and
5440 then Lower Granite, sediment moving down the Snake River shoaled mainly behind the dam
5441 furthest upriver. Each of the dams has at least some amount of shoaled sediment. The quality
5442 of this material is not well documented for some areas within the lower Snake River; however,
5443 the sediment quality is assumed to be impacted by human-sourced chemicals. This is based on
5444 the age of the shoaled sediment; the prevalence of fish tissue impairments, which indicate that
5445 the sediment could be a reservoir for bio-accumulative compounds; and the sediment data
5446 available for some areas. Measurable concentrations of dioxins, glyphosate and its degradation
5447 byproduct aminomethylphosphonic acid, DDT and the degradation byproducts DDE and DDD,
5448 aldrin, PCBs, dibenzofuran, and hexachlorobenzene have been found in various sediment
5449 samples (<https://www.nwd.usace.army.mil/CRSO/Documents/>). In general, sandy sediment has
5450 accumulated above Silcott Island (in Lower Granite Reservoir), and material downstream from
5451 this, including below Lower Granite Dam and behind the other lower Snake River dams, is
5452 mostly silt and clay. The sediment shoaled behind the lower Snake River and McNary dams has
5453 not been sampled in over 20 years and there is uncertainty in the chemical characteristics of
5454 the sediment.

5455 Sediment behind the dams is shoaled throughout the reservoirs, in the channel, and on what
5456 was originally the banks of the Snake River. The depth and distribution is variable, but the total
5457 volume estimated to be shoaled within the lower Snake River is approximately 178 Mcy

5458 (Appendix C, *River Mechanics*). Based on the modeling conducted by the River Mechanics
5459 group, it is anticipated that most of this sediment would be released after the lower Snake
5460 River dams are breached. A conceptual model is used as the basis to discuss the conditions that
5461 would be experienced at different times during the dam breach process and afterward.

5462 6.4.2.1 *Conceptual Site Model*

5463 Based on the River Mechanics Team's work, it is possible to summarize the sediment release
5464 scenario by time period and to identify the sediment related water quality and other impacts
5465 for those times (Table 6-8.). Figure 6-53. shows an example of the conceptual model for the
5466 system post-breach.



5467
5468 **Figure 6-53. Conceptual Model of Sediment Within River System After Dam Breach**

5469 Source: Randle & Bountry 2017)

5470

5471 **Table 6-8. Summary of Conceptual Model for Dam Breach-Related Sediment Releases Over Time**

Year/Time Frame	Sediment Behavior	Sediment-Related Impacts
Year 1 (August–October)	Sediment within the channel behind Lower Granite and Little Goose Dams would be released during the dam breach process. Very high concentrations of suspended sediment would be liberated for several months. A large quantity of sediment would move. A majority of the sediment would temporarily accumulate above Lower Monumental Dam.	<ul style="list-style-type: none"> • Very high suspended solids result in loss of clarity in water, loss of sunlight penetration. • Very high suspended solids result in near zero dissolved oxygen because anaerobic sediments and associated organic material deplete oxygen in water. • Disturbance of sediment releases potentially high concentrations of nutrients, some metals, and other soluble pollutants into the water moving downstream. • Suspended solids move downstream and deposit in new locations, smothering benthic and aquatic biota (plants and animals). • Very high suspended solids interferes with water intakes/potable water uses. • Movement of bio-accumulative compounds with fine-grained sediment movement; pollutants deposit into new areas where aquatic organisms can be exposed.
Spring of Year 1 (spring immediately following the first two dam reaches)	Precipitation would wash shoaled bank material to the channel. Additional sediment within the channel, plus the bank material that erodes into the channel, would move downstream. The amount of sediment that moves would depend on spring high water conditions; higher flows would result in more sediment movement.	<ul style="list-style-type: none"> • Seasonally high suspended solids, but not as high as during dam breach. • Erosion of banks where sediment had previously shoaled. • Higher suspended sediment is associated with lower dissolved oxygen; however, the seasonally high flows and comparatively lower suspended solids concentrations would cause fewer oxygen impairment issues. Similarly, other water quality issues (high nutrient concentrations, for example) would be experienced but not as severely as during the dam breach process.
Year 2 (August – October)	Sediment within the channel behind Lower Monumental and Ice Harbor Dams would be released during the dam breach process, including material that had previously moved downstream from Little Goose and Lower Granite Dams. Very high concentrations of suspended sediment would be liberated during the breach. Again, a large quantity of sediment would move (12.6 Mcy). This sediment would deposit near the confluence of the Snake and Columbia Rivers and within McNary Reservoir.	<ul style="list-style-type: none"> • Very high suspended solids result in loss of clarity in water, loss of sunlight penetration. • Very high suspended solids result in near zero dissolved oxygen because anaerobic sediments and associated organic material deplete oxygen in water. • Disturbance of sediment releases potentially high concentrations of nutrients, some metals, and other soluble pollutants into the water moving downstream. • Suspended solids move downstream and deposit in new locations, smothering benthic and aquatic biota (plants and animals). • Very high suspended solids interferes with water intakes/potable water uses. • Movement of bio-accumulative compounds with fine-grained sediment movement; pollutants deposit into new areas where aquatic organisms can be exposed.

*Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix*

Year/Time Frame	Sediment Behavior	Sediment-Related Impacts
Spring of Year 2	Additional sediment within the channel plus some shoaled bank material would move. The amount would depend on spring high water conditions; higher flows would result in more sediment movement.	<ul style="list-style-type: none"> • Seasonally high suspended solids, but not as high as during dam breach. • Erosion of banks where sediment had previously shoaled. • Higher suspended sediment is associated with lower dissolved oxygen; however the seasonally high flows and comparatively lower suspended solids concentrations would cause fewer oxygen impairment issues. Similarly, other water quality issues (high nutrient concentrations, for example) would be experienced but not as severely as during the dam breach process.
Years 2–7 (depending on weather and river flow conditions)	Coarser-grained materials and bank materials would continue to erode during high flow conditions such as during spring run-off or large storm events. These materials would move downstream toward McNary Reservoir; the transport would continue until the sediment reaches a stable shoaled configuration.	<ul style="list-style-type: none"> • Newly shoaled material would be a potential source of pollution exposure for both aquatic and terrestrial species for several years until the system reaches a new normal. Fish tissue concentrations of pollutants are likely to be higher than pre-breach. (National Research Council, 2007, 2001) • Groundwater discharges and bank seepage along the new banks of the lower Snake River would continue to cause erosion as the system adjusts to the new river level. Contaminated groundwater at some locations may add pollution to the river. • Point dischargers may need to adjust their treatment and discharges in response to changes to the receiving waters, which will be a river and not a large lake. Some discharge points may need relocation. Some discharges could require changes to the treatment processes. • Continued erosion of banks where sediment had previously shoaled with dams. • Seasonally high suspended solids, but not as high as during dam breach process and with correspondingly fewer water quality impacts. • Sediment reaches more stable shoal configurations and released sediment becomes buried by new material (reducing pollutant exposure).

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

Year/Time Frame	Sediment Behavior	Sediment-Related Impacts
Longer Term (more than 5–10 years)	Sediment entering the lower Snake River would move downstream over time. Over the long term, very little material would shoal in the lower Snake River, with the exception of new backwater areas created by the dams after breach, and along historical backwater areas such as near islands within the channel. The bulk of the sediment entering the lower Snake River (estimated to total 3.6 Mcy per year) would move into McNary Reservoir, with approximately 2.4 Mcy shoaling in the reservoir, and the rest of the fine-grained materials passing downstream and ultimately to the estuary (Appendix C, <i>River Mechanics</i>).	<ul style="list-style-type: none"> • Lower Snake River experiences much less shoaling, with shoaling limited to backwater areas as seen historically. • Suspended solids are higher than pre-breach, but not “high” compared to other rivers. Suspended solids concentrations are anticipated to be in the range of 30 mg/L (Appendix C, <i>River Mechanics</i>). • River water quality experiences much more natural riverine conditions, including seasonal and daily fluctuations in temperature, dissolved oxygen, suspended solids, and other water quality parameters. • Fish tissue concentrations adjust to new conditions in the river (anticipated lower than pre-breach in Snake River, but possibly still elevated in McNary Reservoir due to existing pollution load in the sediment). • Some former shoaled material would be left on the banks of the river and would remain as “land” instead of eroding. Banks reach a more stable condition. Upland areas are vegetated or have erosion control installed as needed for localized conditions.

5472 Note: By the end of the first 2 years of dam breach, a very large fraction of the fine-grained sediment would have moved into the end of the Snake River (near
5473 the confluence with the Columbia River) and into the McNary Reservoir within the Columbia River. This material would likely continue to redistribute within
5474 the river system and McNary Reservoir for several years until it eventually reaches a stable shoal configuration. However, it should be noted that the sediment
5475 study for MO3 did not include existing bridges and therefore does not consider bridge-related scour and deposition potential.

5476

5477 **6.4.3 McNary Reservoir**

5478 Sediment released from the lower Snake River dams will move downstream and is anticipated
 5479 to be mostly trapped within McNary Reservoir. Initially, released sediment will move
 5480 downstream but may form temporary shoals along the end of the Snake River and into the
 5481 Columbia River, including near the confluence. The sediment will continue to move for a
 5482 number of years in response to seasonal high flows until the sediment reaches a more stable
 5483 configuration.

5484 The sediment released to McNary Reservoir will carry any sorbed pollutants along with it. This
 5485 material will at least temporarily cover downstream areas, including habitat areas, with the
 5486 result that initially McNary Reservoir will likely experience higher surficial pollutant
 5487 concentrations. Over time, the released sediment will be covered with newer material that
 5488 enters the system and covers the older material.

5489 In the longer term, sediment from the Clearwater and Snake Rivers will no longer be detained
 5490 behind dams on the lower Snake River, so that sediment will travel into McNary Reservoir.
 5491 Estimates are that approximately two-thirds of the sediment entering the McNary Reservoir will
 5492 settle within the reservoir. The remaining sediment will consist of fine-grained clays and silts
 5493 that are suspended in the water and are expected to travel to the estuary. Little material is
 5494 expected to settle past McNary Reservoir (Appendix C, *River Mechanics*).

5495 **6.4.4 Water Quality Issues**

5496 The release of a large volume of sediment in a short time would cause extreme short-term
 5497 water quality changes in the lower Snake River (Table 6-9.). Some of these changes may have
 5498 large impacts on aquatic organisms. A main issue is that the suspended solids (fine sediment
 5499 that mixes into the water column and is carried along with the water) would be extremely high
 5500 during the breaching process and immediately afterward. Elevated concentrations of
 5501 suspended solids would also be experienced during high flow (storm flow, spring freshet,
 5502 snowmelts) conditions for the first few years after breaching, as material in the channel
 5503 redistributes and material left on bank areas erodes into a more stable configuration. The
 5504 elevated suspended solids concentrations could block light and could physically smother
 5505 aquatic organisms, especially plants and benthic organisms.

5506 **Table 6-9. Estimated Suspended Solids Concentrations During Dam Breaching Process**

	First Dam Removal	Second Dam Removal
Peak concentration	24,300 mg/L	16,100 mg/L
Location of peak concentration	RM 69.6	RM 7.59
Duration > 5,000 mg/L	26 days	17.75 days
Duration > 10,000 mg/L	76 days	48.75 days
Average concentration before dam removal	1.9 mg/L	2.3 mg/L
Average concentration after dam removal	30.4 mg/L	32.3 mg/L

5507 1/ Average concentrations for years October 2024 to October 2041.

5508 The fine-grained sediment released into the water column would also cause chemical changes
 5509 to the water. The buried sediment is anoxic and contains organic compounds that exert
 5510 biochemical oxygen demand (organic compounds react with oxygen or are consumed by
 5511 microorganisms that use oxygen). When very large amounts of anoxic sediment are mixed with
 5512 the water column, the dissolved oxygen would be used up. Oxygen would re-enter the water,
 5513 but through the surface of the water column; the surface area would limit the reaeration of the
 5514 river. The condition during breaching is expected to be a large plume of muddy water that
 5515 contains little to no dissolved oxygen.

5516 The impact of the suspended sediment on dissolved oxygen was estimated two different ways
 5517 based on available information. First, suspended sediment data from the River Mechanics Team
 5518 modeling was correlated to turbidity and dissolved oxygen concentrations following the
 5519 relationships published by Schenk and Bragg (2014). These relationships were developed for
 5520 Falls Creek Lake, Oregon; it is expected that the sediment in the lower Snake River is similar in
 5521 grain size but perhaps different in chemical composition than the Falls Creek Lake material.
 5522 Second, calculations were made based on assumed average characteristics of the lower Snake
 5523 River sediment. Values chosen for calculations include an assumed sediment oxygen demand of
 5524 0.5 g/m²/day based on literature values, an assumed wet bulk density for the sediment of 1.5
 5525 g/cm³ to represent average conditions, and an assumption that 83 percent of the suspended
 5526 solids were silt/clay and 5 percent of that material is volatile solids based on the information
 5527 provided by River Mechanics. Both approaches yielded similar dissolved oxygen estimated
 5528 conditions (Table 6-10.).

5529 **Table 6-10. Number of Days Below Dissolved Oxygen Thresholds in Lower Monumental**
 5530 **Reservoir**

Peak	DO Threshold	Forebay (Lower Monumental Reservoir)	Head of Lower Monumental Reservoir
First Peak	5 mg/L	18–21 days	24–28 days
	2.5 mg/L	9–11 days	16–20 days
Second Peak	5 mg/L	14–17 days	7–11 days
	2.5 mg/L	5–7 days	6–8 days

5531 It is noted that Lower Monumental Reservoir should experience more dissolved oxygen impacts
 5532 than Ice Harbor or McNary Reservoirs. The Ice Harbor reservoir is expected to receive less
 5533 sediment during the breach of Lower Granite and Little Goose dams than Lower Monumental,
 5534 since a larger fraction of sediment will settle temporarily in Lower Monumental reservoir. After
 5535 the second set of dam breaches, sediment will move into McNary Reservoir; however, that
 5536 reservoir also receives high flows from the Columbia River, which are expected to provide an
 5537 input of high dissolved oxygen content water that will help lessen the impacts of the sediment
 5538 oxygen demand.

5539 The fine-grained sediment also holds nutrients such as nitrogen (ammonia) and phosphorus
 5540 compounds; these compounds tend to be very soluble and would be expected to be released
 5541 when the shoaled sediment is disturbed as part of the dam breaching process. Nutrients can

5542 interfere with the ecological system balance and cause unbalanced growth of algae.
5543 Uncontrolled growth of algae in turn causes large dissolved oxygen swings (diurnal pattern with
5544 very high concentrations during the day and very low concentrations at night), pH changes, and
5545 loss of clarity. The release of nutrients from the sediment during dam breach would be a
5546 transient issue, however, because the large initial load of dissolved nutrients released during
5547 the breach would wash downstream with the water flow. It should be noted that the resulting
5548 river conditions would be quite different than the current reservoir conditions, with respect to
5549 algae and algal blooms. It is likely that cyanobacteria blooms would be eliminated from the
5550 lower Snake River. However, as long as nutrients are introduced to the river, either as point or
5551 non-point sources, the river conditions would show some water quality impacts related to the
5552 ensuing biological activity. Those long-term impacts are unrelated to the sediment condition.

5553 Metals entrained in the sediment matrix may be released, depending on the chemical state and
5554 whether they are bound in undissolved minerals. Metals are naturally occurring; however,
5555 metals can also be human-sourced pollutants. Sediment data available for the Lower Granite
5556 Reservoir indicate that metals concentrations are generally low
5557 (<https://www.nwd.usace.army.mil/CRSO/Documents/>). Changes to dissolved oxygen
5558 concentration (redox state of the water) could affect metal solubility, although this would be
5559 expected to be a short-term issue for most metals. Mercury could be an exception to this
5560 conclusion, however, because the redox state could cause mercury cycling.

5561 Independent of the water quality, the riverine physical conditions would be very different than
5562 the current reservoir configurations, which could impact point (National Pollutant Discharge
5563 Elimination System) dischargers to the river. There are at least 15 point dischargers along the
5564 lower Snake River, mostly located near the Lewiston and Clarkston areas. These include
5565 industrial and public treatment facilities. Point dischargers may need to adjust their treatment
5566 and discharges in response to changes to the receiving waters, which will be a river and not a
5567 large lake. Some discharge points may need relocation. Some discharges could require changes
5568 to the treatment processes.

5569 The persistent, bio-accumulative compounds such as pesticides and other large organic
5570 compounds are not likely to be a short-term issue for water quality, since these compounds
5571 have very low solubility. These compounds would tend to stay with the sediment particles and
5572 would be redeposited in new shoals that form after the breach. These newly shoaled areas
5573 would represent fresh exposure opportunities for aquatic organisms, particularly benthic
5574 organisms that colonize the new shoals. Fish that consume the benthic organisms exposed to
5575 the pollutants would themselves potentially be exposed, leading to bioaccumulation
5576 throughout the food web (National Research Council 2007, 2001; Meier et al. 2015). This
5577 condition would likely persist for a number of years, until the sediment released during the dam
5578 breach process reaches a stable configuration and subsequent sediment deposits (presumably
5579 with lower pollution levels) cover the material. See the Future Research discussion below for
5580 additional thoughts on this topic.

5581 Groundwater is naturally connected to rivers and lakes. Breaching the lower Snake River dams
5582 would lower the water level in the river. This would in turn impact the groundwater table of the
5583 land adjacent to the river. Some areas may discharge to the river at high rates as bank seeps,
5584 especially in the short term as the conditions around the river adjust to the new water level and
5585 flow patterns. There are a number of identified sites along the river where groundwater
5586 contamination exists (<https://www.nwd.usace.army.mil/CRSO/Documents/>). Some of these
5587 areas have the potential to discharge pollutants to the river. Soluble pollutants would move
5588 downstream with the water and would be very dilute. Less soluble compounds, including those
5589 that tend to bioaccumulate, would likely become sorbed to sediment particles and would
5590 remain in suspension or be deposited depending on shoaling conditions. Since very little
5591 sediment would be expected to shoal in the lower Snake River after dam breach (Appendix C,
5592 *River Mechanics*), much of this pollution would likely accumulate in McNary Reservoir.

5593 **6.4.5 Future Research**

5594 Additional sediment characterization is needed prior to the breach of dams along the lower
5595 Snake River. Specifically, the concentrations of bio-accumulative compounds and other
5596 pollutants needs to be better defined to determine whether mitigation is needed or is possible
5597 for sediment related impacts to water quality. Key goals of this investigation would include:

- 5598 • The sediment shoaled behind the dams has not been sampled in over 20 years and there is
5599 considerable uncertainty in the chemical characteristics of the sediment. A general goal is to
5600 comprehensively characterizing the sediment following the SEF (RSET 2018). This includes
5601 the material shoaled in all four lower Snake River reservoirs.
- 5602 • More specifically, it should be determined whether there are pockets of sediment that have
5603 high concentrations of pollutants such that the sediment does not meet in water placement
5604 criteria such as those laid out in the SEF (RSET 2018). The goal would be to determine if
5605 there are pockets of sediment that should be removed and disposed of in a confined
5606 location prior to dam breach activities. Contaminants of concern for this include
5607 bioaccumulative compounds and mercury.
- 5608 • The potential for bio-accumulation of persistent compounds in fish during and immediately
5609 after the dam breach needs to be determined. Specific features of this investigation should
5610 include:
 - 5611 ○ After additional sediment quality data are collected, a contaminant transport model
5612 (such as the Long-Term Fate model, LTFATE) should be used to investigate the fate of
5613 the contaminants associated with the sediment. Particular aspects of concern include
5614 the impact of sediment contaminant impacts on downstream drinking and irrigation
5615 water intakes.
 - 5616 ○ Modeling the food web (bioaccumulation/biomagnification) using a model such as
5617 AQUATOX to help inform fish monitoring activities and predict impacts on subsistence
5618 fishing communities. Modeling metals using a biotic ligand model could help define
5619 transient or longer term impacts of the chemical changes to the water column that
5620 could be triggered by the dam breach. There are multiple models that could be used to

5621 study various aspects of the potential water quality changes that accompany the release
5622 of the sediment.

5623 ○ Fish tissue sampling and monitoring, commencing before the dam breach process and
5624 continuing for a number of years afterwards would confirm the modeling efforts. Fish
5625 monitoring would need additional coordination with State and Tribal officials, to ensure
5626 that efforts are coordinated and subsistence fisher populations are included in the
5627 analysis.

5628 ● Sediment oxygen demand and elutriate nutrient concentrations should be measured, and
5629 modeling and laboratory scale testing should be conducted to better estimate the impact of
5630 the dam breach on water quality during the high solids release events. Specific issues to
5631 investigate include the degree and extent of oxygen depletion, the concentration of
5632 nutrients released, the potential for ammonia toxicity, and the fate and transport of the
5633 soluble nutrients downstream including the impacts to downstream reservoirs.

5634 These lines of investigation would help define the sediment-related impacts to the environment
5635 from the dam breach. Other water quality related impacts from the sediment release, such as
5636 the low dissolved oxygen concentrations during the high suspended solids events and the
5637 release of nutrients to the water column, are not easily controlled. Low dissolved oxygen
5638 concentrations could theoretically be off-set by adding temporary aeration systems, however
5639 given the magnitude of the flows in the lower Snake River, it is not known if this is possible in
5640 any meaningful sense. Additional investigation during design phase could be done to determine
5641 if aeration would be possible and beneficial. The timing and stages of the drawdown process
5642 could be further modeled and coupled with water quality modeling to determine whether it is
5643 possible to decrease the potential water quality impacts.

5644 **6.5 WATER AND SEDIMENT QUALITY CONCLUSIONS**

5645 The most notable MO3 measures that affect water quality include:

- 5646 ● *Breach Snake Embankments*: Remove earthen embankments as required at each lower
5647 Snake River dam.
- 5648 ● *Spring Spill to 120% TDG*: Modify spring juvenile fish passage spill to 120 percent tailwater
5649 TDG plus no forebay TDG spill cap in the lower Columbia River.
- 5650 ● *Reduce Summer Spill*: End summer juvenile fish passage spill in the lower Columbia River by
5651 July 31.
- 5652 ● *Above 1% Turbine Operations*: Operate turbines within and above 1 percent peak efficiency
5653 only at lower Columbia River dams.
- 5654 ● *Sliding Scale at Libby and Hungry Horse, Modified Draft at Libby, December Libby Target*
5655 *Elevation, Update System FRM Calculation, and Planned Draft Rate at Grand Coulee*: These
5656 measures maximize operating flexibility and improve overall systems operations, including
5657 winter FRM at Libby and Grand Coulee.

- 5658 • *Grand Coulee Major Maintenance Operations*: Planned major maintenance at Grand Coulee.
- 5659 • *Lake Roosevelt Additional Water Supply, Hungry Horse Additional Water Supply, and Chief*
- 5660 *Joseph Dam Project Additional Water Supply*: These measures modify operations to meet
- 5661 existing contractual water supply obligations at Grand Coulee, Hungry Horse, and Libby
- 5662 Dams.

5663 **6.5.1 Multiple Objective Alternative 3 Results – Water Temperature**

5664 In general, MO3 would result in little to no change in water temperature conditions at Libby,
5665 Hungry Horse, Albeni Falls, Dworshak, Grand Coulee, Chief Joseph and the lower Columbia
5666 River dams and reservoirs, as compared to the No Action Alternative. Downstream of Libby
5667 Dam, higher November and December outflows, to meet the end-of-December draft, may delay
5668 the natural cooling of the Kootenai River downstream of the dam. The additional draft of 20
5669 feet in Lake Koocanusa, however, may allow the reservoir to warm earlier in the spring and
5670 summer, providing earlier warming to water temperatures downstream of the dam. This could
5671 benefit downstream resident fish species. In general, water temperature effects downstream of
5672 Libby are negligible.

5673 Considerable changes to water temperatures in the lower Snake River would be anticipated
5674 under MO3 due to the dam breach measures. Water temperatures would respond accordingly
5675 and shift from a lentic to lotic system, with more rapid warming in the spring and cooling in the
5676 fall as compared to the No Action Alternative condition. Water temperatures would respond to
5677 diel fluctuations in air temperatures and passing storm events. Warmer summer water
5678 temperatures could be expected at times, as compared to the No Action Alternative, with
5679 exceedances to the 68°F target in the Lower Granite tailrace during hot weather events. Little
5680 to no change in water temperatures would be expected in the lower Columbia River.

5681 **6.5.2 Multiple Objective Alternative 3 Results – Total Dissolved Gas**

5682 In general, MO3 would have little to no impact on TDG conditions below Libby, Hungry Horse,
5683 Albeni Falls, and Dworshak as compared to the No Action Alternative. Downstream of Grand
5684 Coulee Dam, major reductions in overall TDG may occur in the spring and early summer due to
5685 the *Lake Roosevelt Additional Water Supply* and various FRM measures. TDG effects anticipated
5686 at Grand Coulee are expected to be carried downstream into Rufus Woods Lake. During high-
5687 flow years, the spillway deflectors at Chief Joseph Dam would provide some degassing of
5688 elevated TDG generated from upstream Canadian dam and Grand Coulee Dam operations. TDG
5689 effects downstream of Chief Joseph Dam are negligible.

5690 TDG would be greatly reduced in the lower Snake River without the four lower Snake River
5691 dams in place. The hydraulic head currently present (under the No Action Alternative) would no
5692 longer exist and spill that entrains air would no longer occur. Under new river conditions,
5693 geographically localized TDG above 110 percent may periodically occur for short durations due
5694 to formation of plunge pools and turbulence during high-flow conditions; however, this is not
5695 expected to create persistent TDG like that observed under the No Action Alternative.

5696 Minor reductions in TDG in the forebay and tailwater of McNary Dam would be expected under
5697 MO3. This is due to the lack of TDG received from upstream sources (dams in the lower Snake
5698 River) as is the case in the No Action Alternative. Under MO3, the *Spring Spill to 120 percent*
5699 *TDG*, measure calls for tailwater TDG limits to be set to 120 percent without a forebay TDG
5700 limit. As comparison, current TDG limits under the No Action Alternative are set to 120 percent
5701 in the tailwater and 115 percent in the forebay. In August, downstream juvenile fish passage
5702 spill would be curtailed (*Reduced Summer Spill* measure), and overall TDG in the lower
5703 Columbia River would be reduced as compared to the No Action Alternative, which calls for fish
5704 spill through the end of August. This would result in TDG effects at John Day, The Dalles and
5705 Bonneville dams to be minor to negligible, as compared to the No Action Alternative.

5706 **6.5.3 Multiple Objective Alternative 3 Results – Other Water Quality Impacts**

5707 In general, MO3 would result in little to no change on other water quality parameters at Hungry
5708 Horse, Albeni Falls, and Chief Joseph dams and reservoirs, as compared to the No Action
5709 Alternative. Due to lower winter reservoir elevations at Libby, resulting from the *Modified Draft*
5710 *at Libby* measure combined with the change in the *December Libby Target Elevation* measure,
5711 which allows for an additional draft of 20 feet (a bit different from the end-of-December draft
5712 target described in MO1), reductions in lake productivity may occur. This could result in
5713 reduced growth rate of fish in the reservoir and downstream of Libby Dam. Changes to Grand
5714 Coulee water levels include higher elevations in January in below-average years, lower
5715 elevations in spring during wet years, and similar elevations the rest of the year. Most of the
5716 changes in Lake Roosevelt elevation are due to the drawdown draft rate that is built into the
5717 SRD shape (*Planned Draft Rate at Grand Coulee* measure) from January to April. The Update
5718 *System FRM Calculations* measure may also impact elevation by changing the end of April
5719 and/or May FRM requirement. The hydraulic capacity reduction for maintenance (*Grand Coulee*
5720 *Maintenance Operations* measure), and *Lake Roosevelt Additional Water Supply* measure do
5721 not have an effect on elevation, but do affect outflow and spill. The earlier and longer
5722 drawdown of the reservoir could lead to increased mercury methylation, while the *Planned*
5723 *Draft Rate at Grand Coulee* measure, which slows the reservoir draft rate to 0.8 feet per day,
5724 could result in a decrease in bank erosion, sloughing, and overall turbidity in the reservoir.

5725 The MO3 lower Snake River dam breach measure would have considerable impacts on water
5726 quality in the lower Snake River in the near term; these impacts would be largest during
5727 reservoir drawdown and immediately following breaching. Based on sediment transport
5728 modeling conducted by the River Mechanics Team, reservoir drawdown and dam breaching will
5729 result in large amounts of suspended sediment moving downstream under both years of breach
5730 (Lower Granite and Little Goose in the first year of breaching, followed by Lower Monumental
5731 and Ice Harbor in the second year of breaching). This suspended sediment would result in high
5732 turbidity and low to anoxic dissolved oxygen conditions. This is of particular concern under the
5733 first year of breaching as there are few tributaries to dilute and re-oxygenate the river as it
5734 moves into Lower Monumental Reservoir. Analysis suggests that the upstream end of the
5735 Lower Monumental Reservoir could experience reduced dissolved oxygen (DO <2.5 mg/L) for 15
5736 to 29 days, while the downstream end of the reservoir (near the dam) could see DO < 2.5 mg/L

5737 for 4 to 17 days, creating expansive dissolved oxygen problems for aquatic organisms. It is
5738 anticipated that during year two of breaching, dissolved oxygen conditions in McNary Reservoir
5739 would remain more oxygenated due to the influence of the Columbia River, which converges
5740 with the lower Snake River upstream of McNary Reservoir. Additional near-term impacts to
5741 dam breaching include the release of nutrients, metals, dioxins, PCBs, and pesticides, which
5742 may bioaccumulate. Smothering of benthics, amocetes, and plants could also occur. In the long-
5743 term, these impacts would lessen over time, and fish tissue concentrations of pollutants would
5744 be reduced over the long term to lower than No Action Alternative levels because
5745 contaminated sediments would no longer be present in the lower Snake River (contaminants
5746 would move downstream). The lower Snake River would revert back to a riverine system with
5747 water quality processes and species transitioning to more riverine in nature, as well. Longer-
5748 term impacts associated with the return to a riverine system may include impacts to
5749 groundwater discharges and impacts to point (National Pollutant Discharge Elimination System)
5750 dischargers along the river.

5751 The lower Columbia River, particularly above McNary Reservoir, will experience some impacts
5752 from the lower Snake River dam breach. Dissolved oxygen, light attenuation, phytoplankton,
5753 zooplankton, and productivity would likely be depressed, while suspended sediments,
5754 nutrients, organics, and metals would likely increase in the near term. These effects would
5755 diminish considerably moving downstream toward Bonneville Dam.

5756 **6.5.4 Multiple Objective Alternative 3 Results – Sediment Quality**

5757 MO3 is not expected to affect land use along the Columbia River, including upland recreation,
5758 flood management, agricultural, timber, or mining activities, and it is not expected to change
5759 population growth patterns in the area of any of the Columbia River reservoirs. Land use and
5760 industries along the lower Snake River would potentially be impacted by the removal of the
5761 dams, particularly in industries that rely on navigation through the impounded river system.

5762 Sediment released from the lower Snake River dams will move downstream and is anticipated
5763 to be mostly trapped within McNary Reservoir. Initially, released sediment will move
5764 downstream but may form temporary shoals along the end of the Snake River and into the
5765 Columbia River, including near the confluence. The sediment will continue to move for a
5766 number of years in response to seasonal high flows until the sediment reaches a more stable
5767 configuration.

5768 The sediment released to McNary Reservoir will carry any sorbed pollutants along with it. This
5769 material will at least temporarily cover downstream areas, including habitat areas, with the
5770 result that initially McNary Reservoir will likely experience higher surficial pollutant
5771 concentrations. Over time, the released sediment will be covered with newer material that
5772 enters the system and covers the older material. The surficial pollutant concentrations may be
5773 reflected in aquatic organism tissue concentrations, for at least a period of several years.

5774

CHAPTER 7 - MULTIPLE OBJECTIVE ALTERNATIVE 4

5775 Multiple Objective Alternative 4 (MO4) was developed with the goal to examine an additional
5776 combination of measures to benefit ESA-listed fish species that were integrated with measures
5777 for water management flexibility for flood risk management and to adapt to changing
5778 environmental conditions, hydropower generation, and additional water supply. The
5779 alternative includes structural measures as well as operational measures (Chapter 2). The
5780 structural measures are related to powerhouse, turbine, spillway, and fish passage features,
5781 and do not include the removal of any dams or major structures. The operational measures
5782 include a long list of changes to current flow and power operations, including increasing the
5783 irrigation to authorized amounts.

5784 **7.1 UPPER COLUMBIA RIVER BASIN**

5785 **7.1.1 Water Temperature**

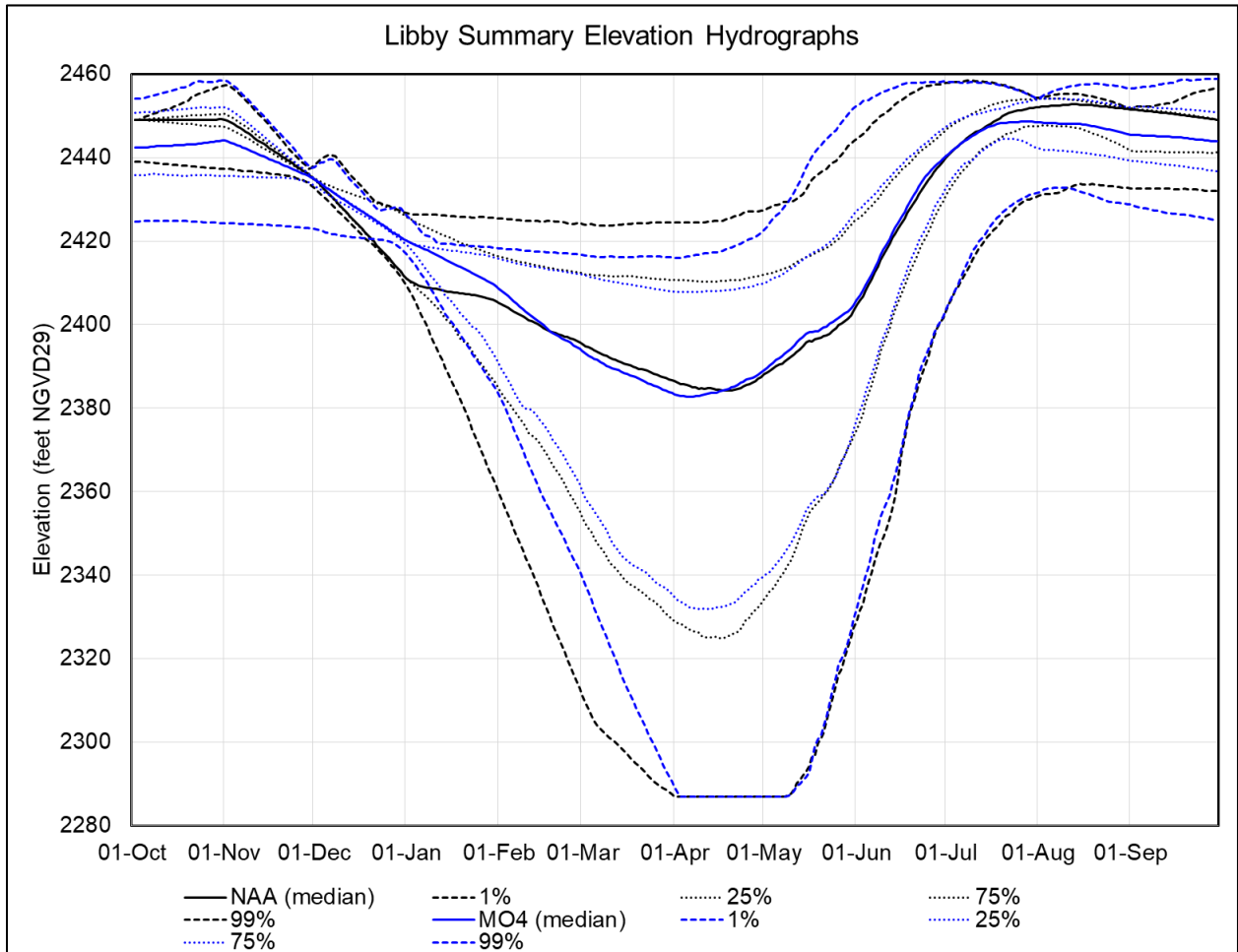
5786 There are a few measures within MO4 that are expected to modify reservoir storage and
5787 outflow rates at some of the upper Columbia River Basin projects. Although these measures
5788 would not greatly impact downstream water temperature, some change is expected as
5789 compared to the No Action Alternative. These effects are described below.

5790 **7.1.1.1 Libby and Hungry Horse Dams and Reservoirs**

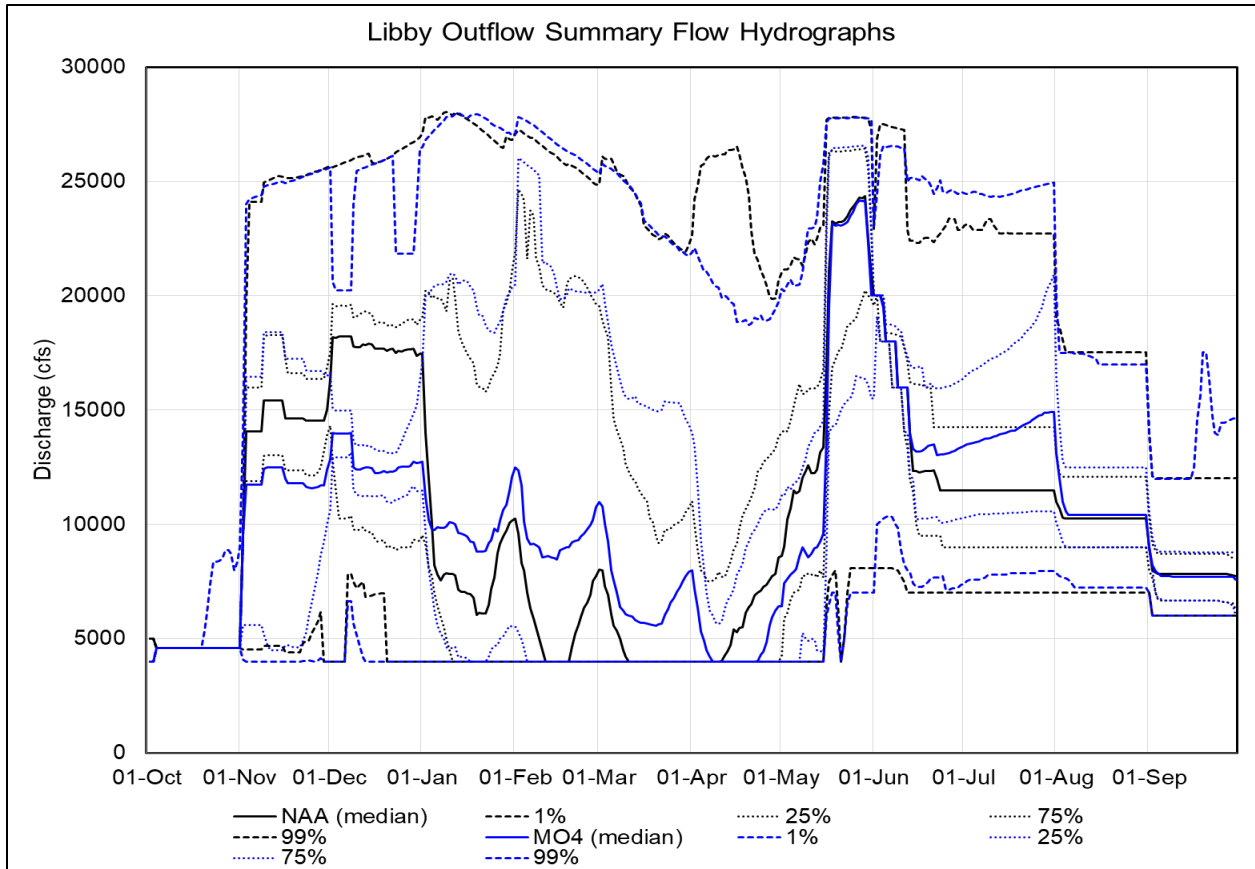
5791 MO4 would modify Libby Dam's draft and refill operations. The end of December sliding scale
5792 variable draft would be eliminated and replaced with a single draft target of 2,420 feet
5793 NGVD29, about 9 feet higher than with no action. The driest 25 percent of years would have
5794 about a 5-foot-deeper draft, and for most years, the reservoir would be lower from mid-July
5795 through the end of September due to the *McNary Dam Flow Target* measure. In general, MO4
5796 would result in lower water elevations in Lake Kooconusa for most of the year, but the
5797 elevations would be higher for those years with a high water forecast in April. It should be
5798 noted that these changes do vary by water year, water forecast, and time of year. A summary
5799 hydrograph for Lake Kooconusa, representing the probability of the reservoir elevation on any
5800 given day under MO4 and the No Action Alternative is shown in Figure 7-1.. Under MO4,
5801 median elevations in Lake Kooconusa are similar to No Action Alternative elevations from
5802 October through the end of November, held higher in December, and drafted down more
5803 aggressively through the end of March. In general, elevations are drafted slightly deeper in the
5804 spring, from March through mid-April, and increased in May and June. Full pool elevation is not
5805 held as high or for as long under MO4 as compared to the No Action Alternative due to
5806 increasing outflows in late June and July for McNary flow augmentation. Given this, by the end
5807 of September, the median MO4 elevation is about 9 feet lower than under the No Action
5808 Alternative.

5809 In general, MO4 largely impacts Libby Dam outflows and Kootenai River flows from about
5810 November through April and again in late June and July (Figure 7-2.). When compared to the No
5811 Action Alternative, median MO4 outflows are about 20 to 26 percent less in November and

5812 December, respectively; 18, 52, and 29 percent greater in January, February, and March,
 5813 respectively; about 21 percent less in April; and about 25 percent greater in July. Modeled
 5814 outflows presented in Figure 7-2. show that the greatest difference between MO4 and No
 5815 Action Alternative flows occur from December through May. Typically, MO4 and No Action
 5816 Alternative outflows follow a similar patten, albeit with much different flows, except for June
 5817 and July when the McNary Dam flow augmentation measure under MO4 results in a substantial
 5818 flow pattern change and increase in outflows.



5819 **Figure 7-1. Libby Dam–Lake Kocanusa Summary Forebay Elevations for Multiple Objective**
 5820 **Alternative 4 Versus No Action Alternative.**
 5821



5822
 5823 **Figure 7-2. Libby Dam–Lake Kootenusa Summary Outflows for Multiple Objective Alternative**
 5824 **4 Versus No Action Alternative.**

5825 Similar to the No Action Alternative, Libby Dam’s SWS provides some ability to adjust where in
 5826 the water column water is drawn from. The range of the SWS bulkheads are from elevation
 5827 2,409 to 2,200 feet, NGVD29. Because SWS protocol maintains at least 30 feet of submergence
 5828 over the top row of the bulkheads for hydraulic stability, the SWS has the ability to perform
 5829 under the full range of possible MO4 drawdown operations with a similar efficiency as under
 5830 the No Action Alternative. Modeled forebay elevations under MO4 are predicted to be well
 5831 within the operating range of the SWS and similar to the ranges observed in the historical years
 5832 described in Section 3.1.1.1 .

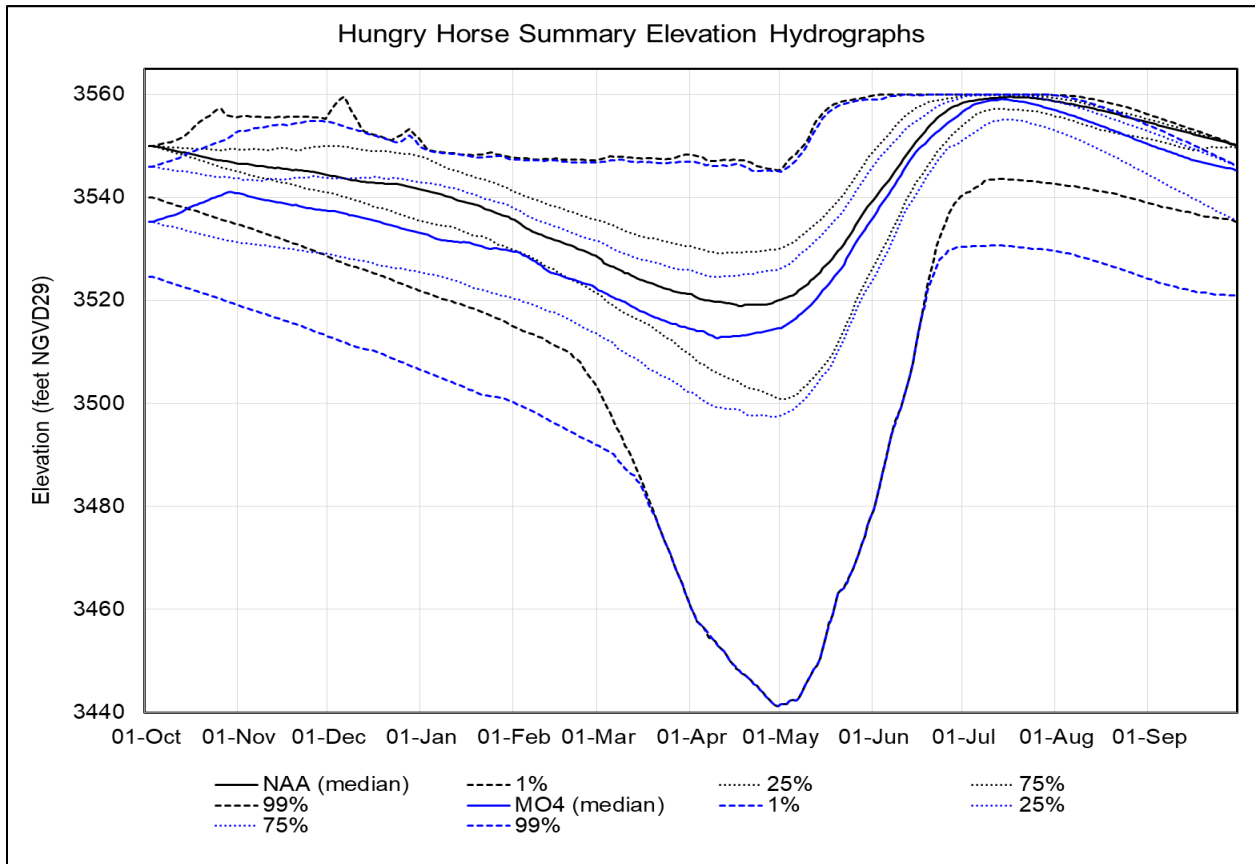
5833 Changes in downstream temperatures from Libby Dam to Bonners Ferry may result from MO4
 5834 increasing the median monthly flows in January through March to draft the pool at a more
 5835 aggressive rate. During the cold winter months, Kootenai River water can cool by several
 5836 degrees between Libby Dam and Bonners Ferry if flows are held low. By increasing the flows to
 5837 draw the pool down aggressively in the winter, MO4 may prevent the natural cooling of the
 5838 river as it moves downstream. These higher winter temperatures in the Kootenai River may be
 5839 an issue for certain fish species, such as burbot.

5840 Hungry Horse Reservoir thermally stratifies in the summer and can provide some downstream
 5841 water temperature management through use of the SWS. The SWS at Hungry Horse Dam is

5842 operated from approximately from June to the end of September. The selective withdrawal
 5843 structure can be made/modified to operate over a pool elevation range from full (3,560 feet,
 5844 NGVD29) down 160 feet (3,400 feet< NGVD29); however, major modification to the structure(s)
 5845 is required to enable function over the lower 60 feet of this range, including removal of the
 5846 upper and intermediate stationary gates. Three MO4 operational measures that apply to
 5847 Hungry Horse Dam and influence the pool elevation in the reservoir and outflows to the river
 5848 below the dam include:

- 5849 • Sliding Scale at Libby and Hungry Horse
- 5850 • Hungry Horse Additional Water Supply
- 5851 • McNary Flow Target

5852 These changes are not anticipated to affect the ability to operate the SWS, so downstream
 5853 water temperatures in the South Fork Flathead River below the dam are expected to be similar
 5854 to under the No Action Alternative. This conclusion is based on a comparison of the range of
 5855 water levels in MO4 (Figure 7-3.) with the range that the SWS can operate under (3,560 to
 5856 3,400 feet, NGVD29).

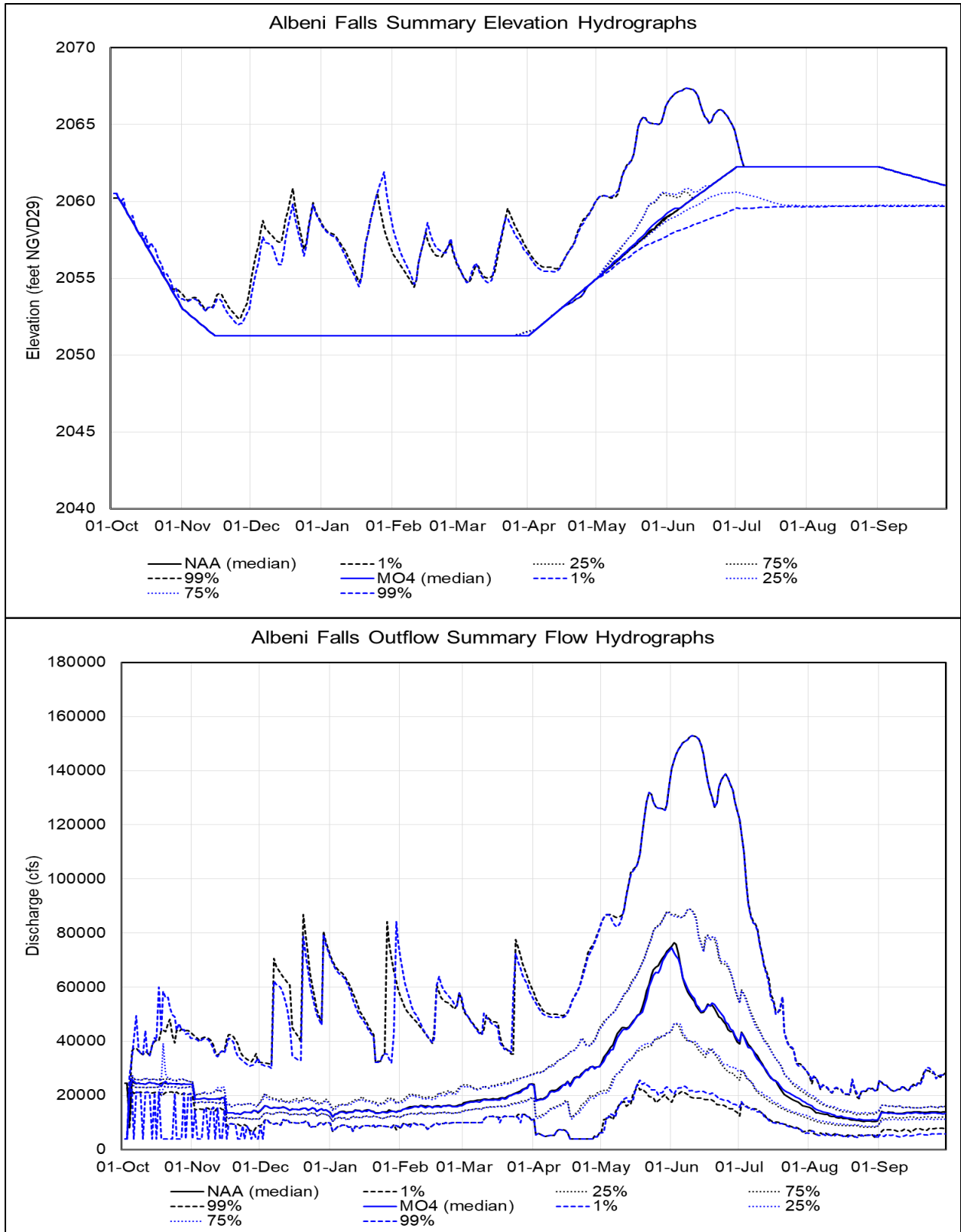


5857
 5858 **Figure 7-3. Hungry Horse Summary Forebay Elevations for Multiple Objective Alternative 4**
 5859 **Versus No Action Alternative**

5860 **7.1.1.2 Albeni Falls Dam and Reservoir**

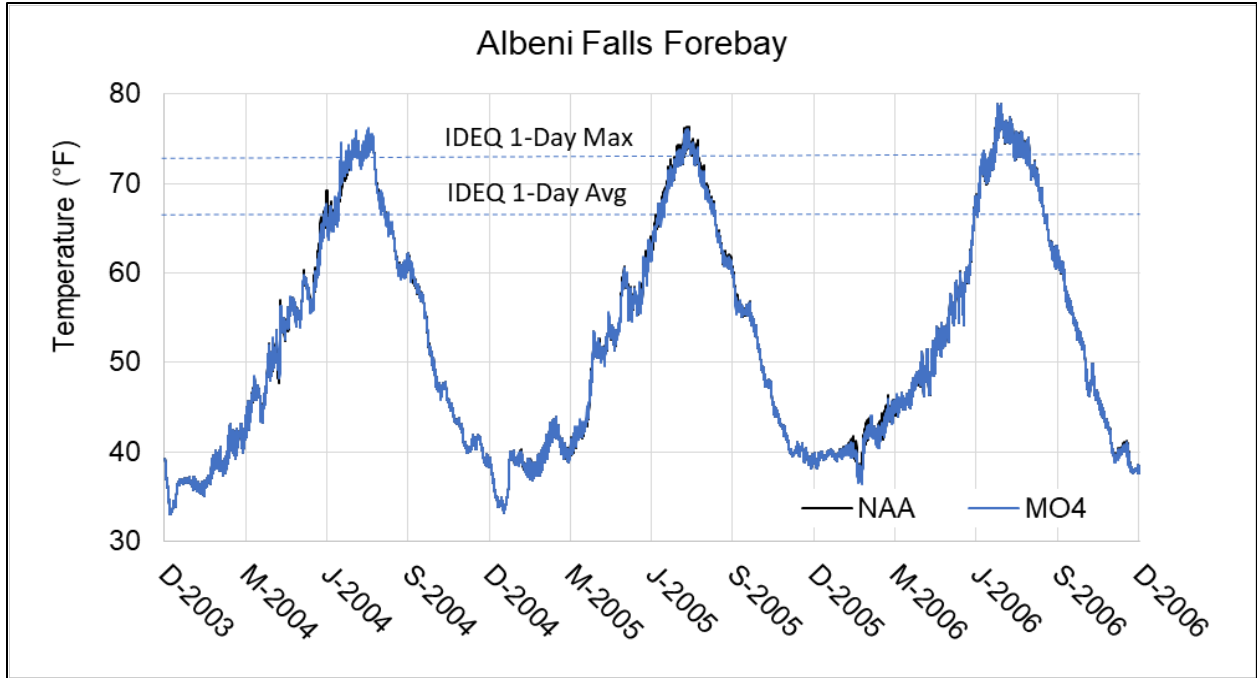
5861 Under MO4, Lake Pend Oreille and the Pend Oreille River will experience elevation changes
5862 during drier water years. For the median and wetter water years, elevations will remain similar
5863 to the No Action Alternative. However, for the drier 40 percent of water years, the elevation of
5864 Lake Pend Oreille will be up to 2.6 feet lower from about mid-June through the end of
5865 September (Figure 7-4.). This decrease is the result of increased outflows from Albeni Falls Dam
5866 to meet the McNary *Flow Target* measure.

5867 Because of the size and depth of Lake Pend Oreille, and the depth of the Pend Oreille River
5868 upstream of Albeni Falls Dam, decreasing the lake elevation by up to 2.6 feet during the
5869 summer would not likely result in a large change in water temperature. However, increasing the
5870 flow through the Pend Oreille River during the summer might result in some cooling of the river
5871 during hot weather conditions but also some warming of the river during cool weather
5872 conditions. W2 model results indicate some of these changes in water temperatures below
5873 Albeni Falls Dam. The largest temperature differences between the MO4 and the No Action
5874 Alternative are about ± 0.9 to 1.8 degrees Fahrenheit (± 0.5 to 1.0 degrees Celsius) with
5875 increases and decreases evenly distributed (Figure 7-5. and Figure 7-6.). Even with this potential
5876 cooling effect, water temperatures would continue to exceed the IDEQ Pend Oreille River
5877 temperature criteria (1-Day Maximum of 71.6°F and 1-Day Average of 66.2°F) during the
5878 summer.



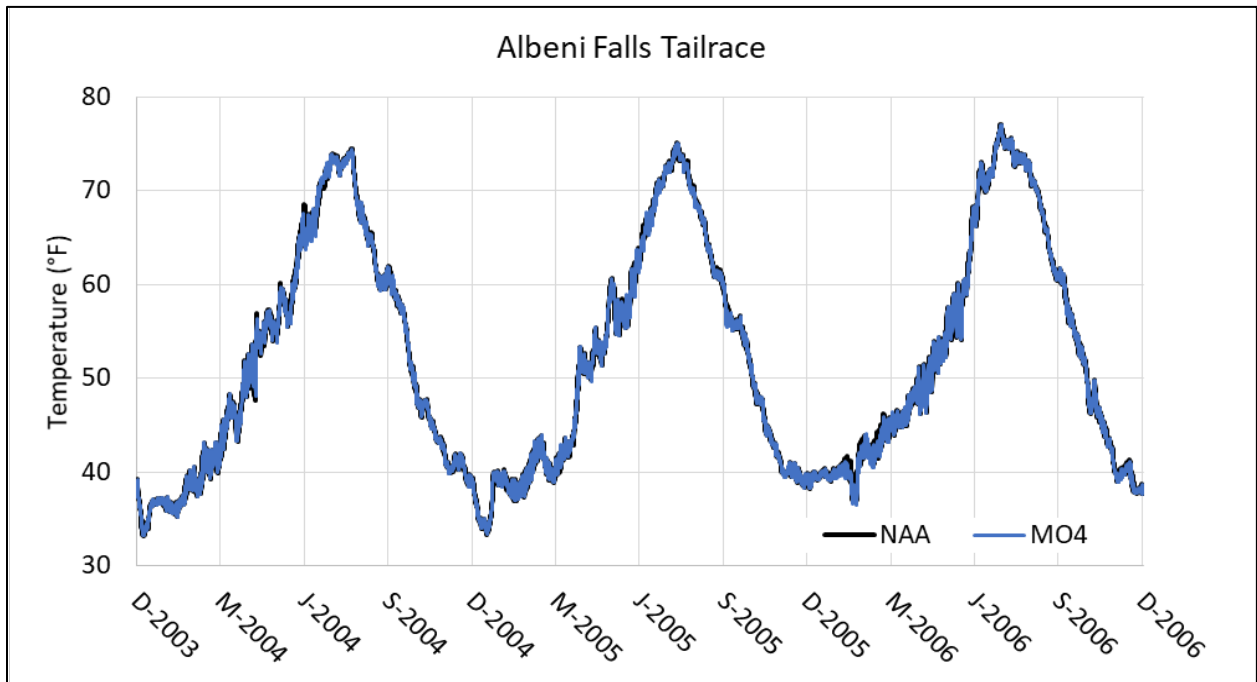
5879
 5880
 5881

Figure 7-4. Albeni Falls Dam Summary Elevation Hydrographs and Outflows for Multiple Objective Alternative 4 Versus the No Action Alternative



5882
 5883 **Figure 7-5. Modeled Forebay Temperatures for Multiple Objective Alternative 4 and No**
 5884 **Action Alternative at Albeni Falls for 2004 to 2006**

5885 Note: IDEQ 1-Day Maximum temperature standard of 22°C and 1-Day Average standard of 19°C shown for
 5886 comparison.



5887
 5888 **Figure 7-6. Modeled Tailwater Temperatures for Multiple Objective Alternative 4 and No**
 5889 **Action Alternative at Albeni Falls for 2004–2006**

5890 Note: IDEQ 1-Day Maximum temperature standard of 22°C and 1-Day Average standard of 19°C are shown for
 5891 comparison.

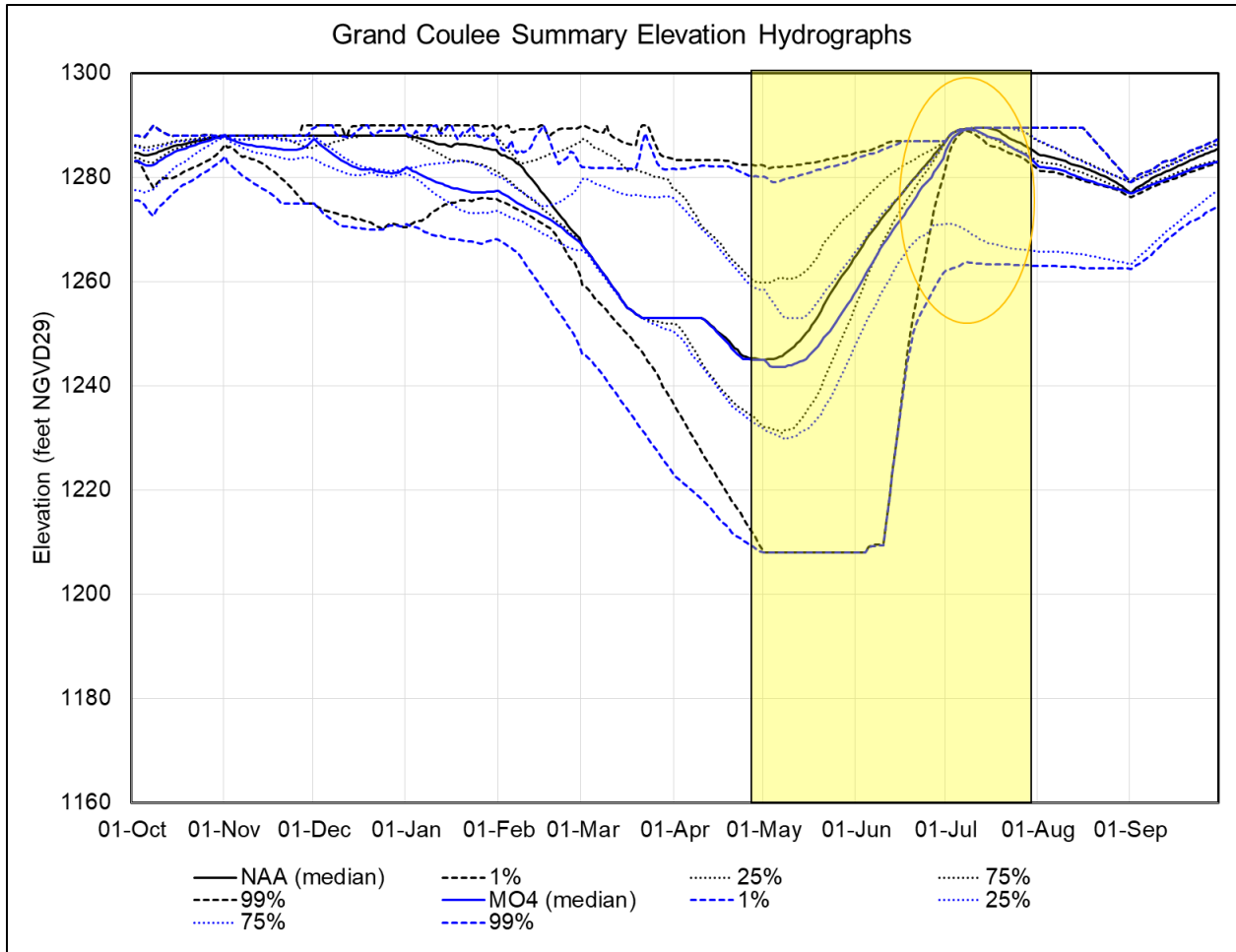
5892 **7.1.1.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

5893 Water temperature below Grand Coulee Dam has the potential to be affected by six
5894 operational measures:

- 5895 • Update System FRM Calculation
- 5896 • Grand Coulee Maintenance Operations
- 5897 • Planned Draft Rate at Grand Coulee
- 5898 • Winter System FRM Space
- 5899 • Lake Roosevelt Additional Water Supply
- 5900 • McNary Flow Target

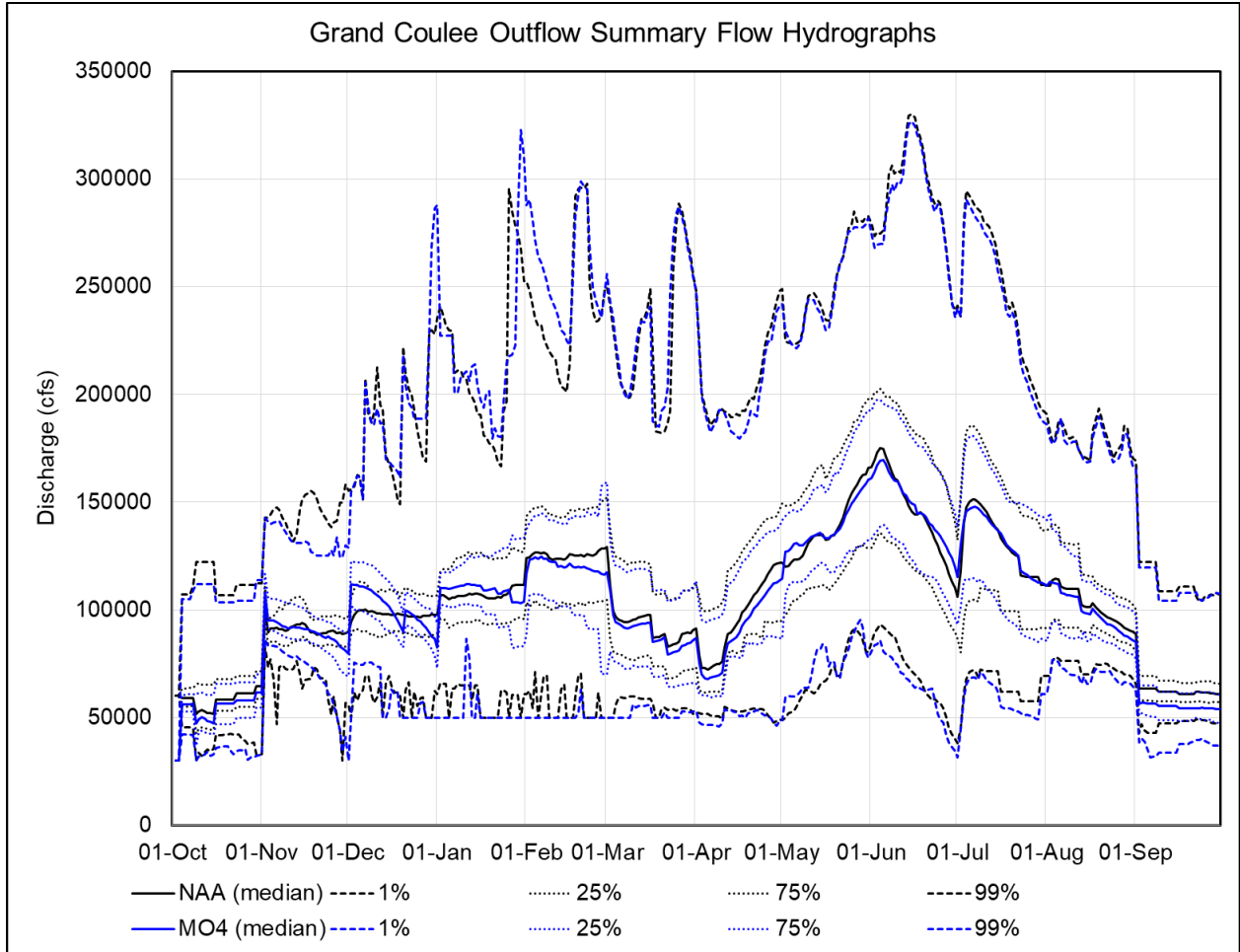
5901 Under MO4, Winter System FRM Space drafts Grand Coulee in December to provide dedicated
5902 650 kaf of space (Figure 7-7.), resulting in a larger outflow (Figure 7-8.). From January through
5903 March, more FRM space would be reserved in Lake Roosevelt for *Winter System FRM Space*,
5904 *Update System FRM Space*, and *Planned Draft Rate at Grand Coulee*. Similar to under the No
5905 Action Alternative, Lake Roosevelt would refill in July in average to wet years; however, in drier
5906 years, when Grand Coulee is managed to support operational measure *McNary Flow Target*,
5907 refill may be delayed or not occur (Figure 7-7.). In these below-average years the outflows are
5908 larger than under the No Action Alternative for the *McNary Flow Target*.

5909 Overall, temperatures in the reservoir are predicted to remain largely the same as under the No
5910 Action Alternative. The changes that do occur are short in duration or low in magnitude. In
5911 general, impacts are greatest at Grand Coulee Dam and are reduced towards the U.S.-Canada
5912 border, where the impacts are almost unnoticeable at Hall Creek. Overall, an increase of
5913 temperature at depth in the late summer/fall of all years is the most pronounced difference
5914 from the No Action Alternative near the dam; this is likely due to operational changes and
5915 potentially due to some modeling assumptions that warrants further investigation. Figure 7-9.
5916 shows predicted Grand Coulee tailwater temperatures under MO4. In wet years, there are
5917 almost no downstream temperature differences between MO4 and the No Action Alternative;
5918 however, during average or dry years, changes to downstream water temperature may occur.
5919 Temperature response under MO4 varies and appears to be dependent on a variety of factors
5920 such as reservoir elevation, total outflow, and powerhouse operations. Additional factors that
5921 impact the model results include the water year type (for example the LF/HT year may be more
5922 reactive to operational changes than a HF/LT year), operational changes resulting in reduced
5923 outflows (FRM and Water Supply measures), and potentially simplifying assumptions in the
5924 modeling. An additional factor may be winter and spring operations that decrease storage
5925 during that period, which could potentially reduce the cold water mass that would dilute or
5926 cool the inflowing temperature signal from upstream through the spring and early summer
5927 months.



5928
 5929 **Figure 7-7. Grand Coulee Reservoir Summary Elevation Hydrograph for Multiple Objective**
 5930 **Alternative 4 Versus No Action Alternative**

5931 In the dry years, the implementation of the *McNary Flow Target* measure prevents Grand
 5932 Coulee Dam from refilling due to additional downstream flow requirements. Rather than being
 5933 stored, warm water is passed through the reservoir in May and June, which can result in cooler
 5934 summer water temperatures in some (LF/HT), but not all (LF/AT) cases. In most years, there
 5935 tends to be a rise in water temperature in September under MO4, which coincides with a
 5936 marked reduction in total project outflows that are lower under MO4 as compared to the No
 5937 Action Alternative (Figure 7-8.). Similar water temperatures can be seen downstream of Wells
 5938 Dam (Figure 7-10.), but the temperature signal, created by the operation of Grand Coulee Dam,
 5939 is diluted by the time that water is discharged from Rocky Reach Dam, located approximately
 5940 115 miles downstream (Figure 7-11.).

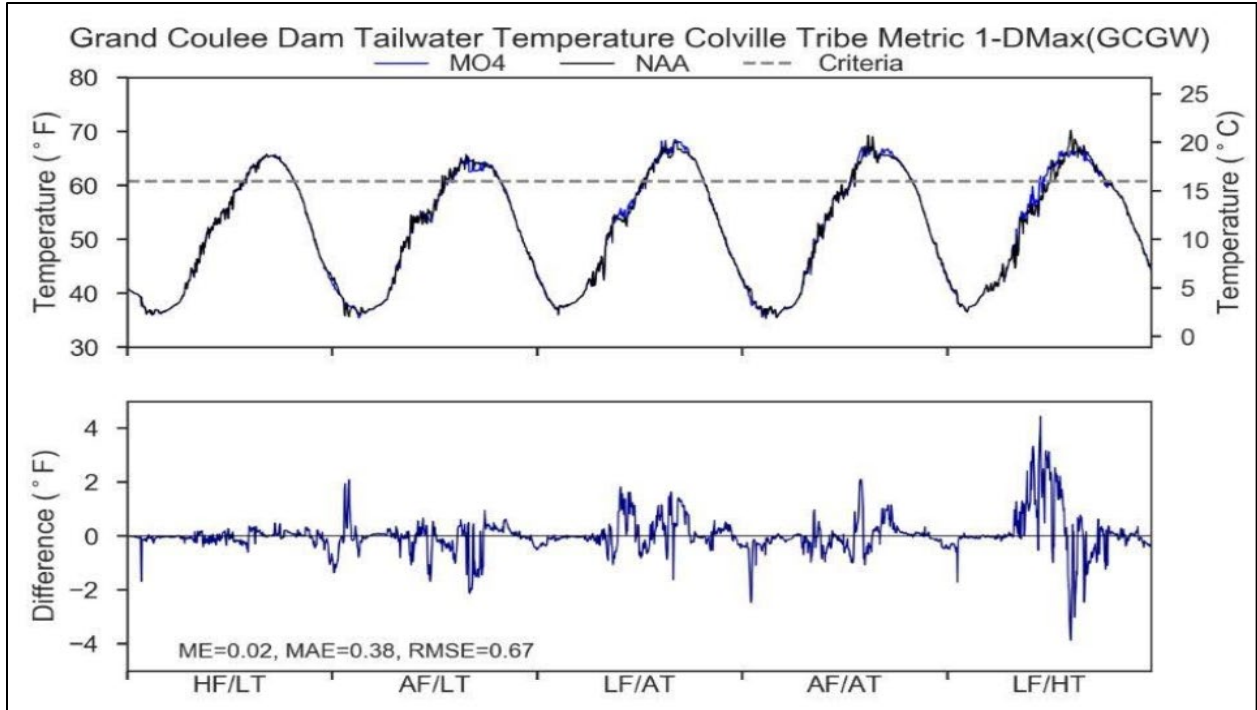


5941

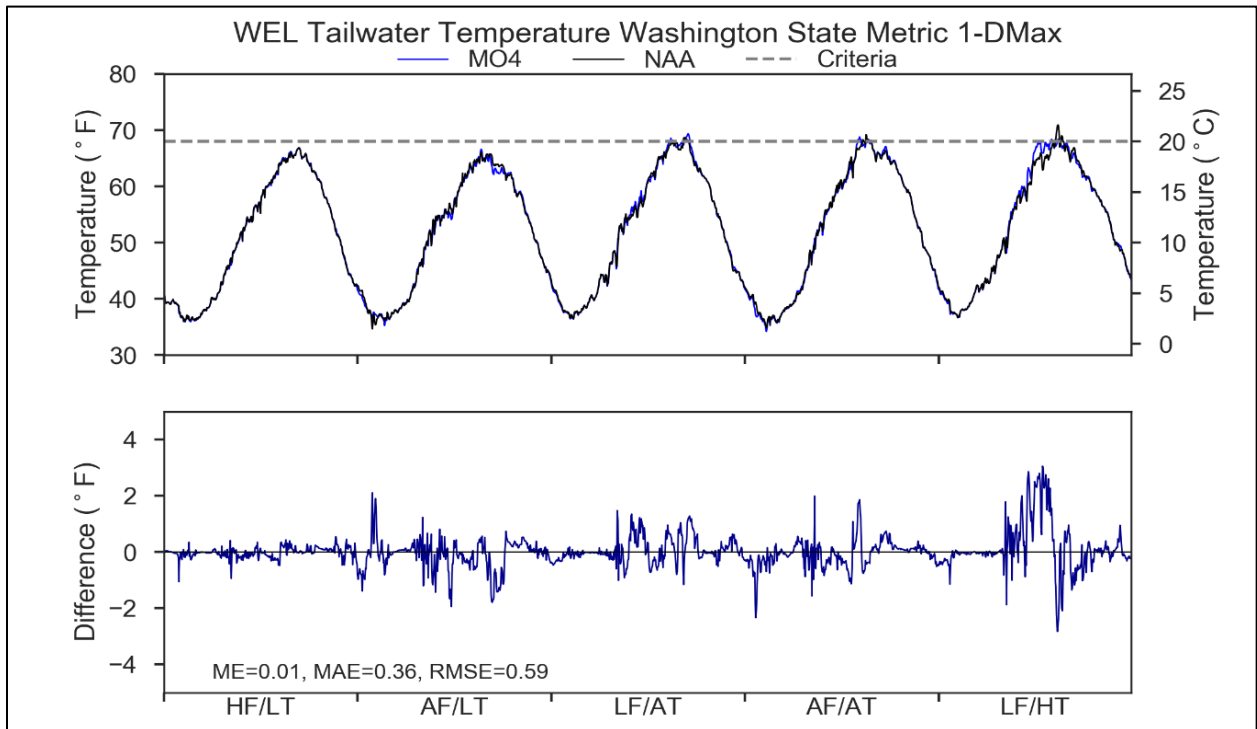
5942

5943

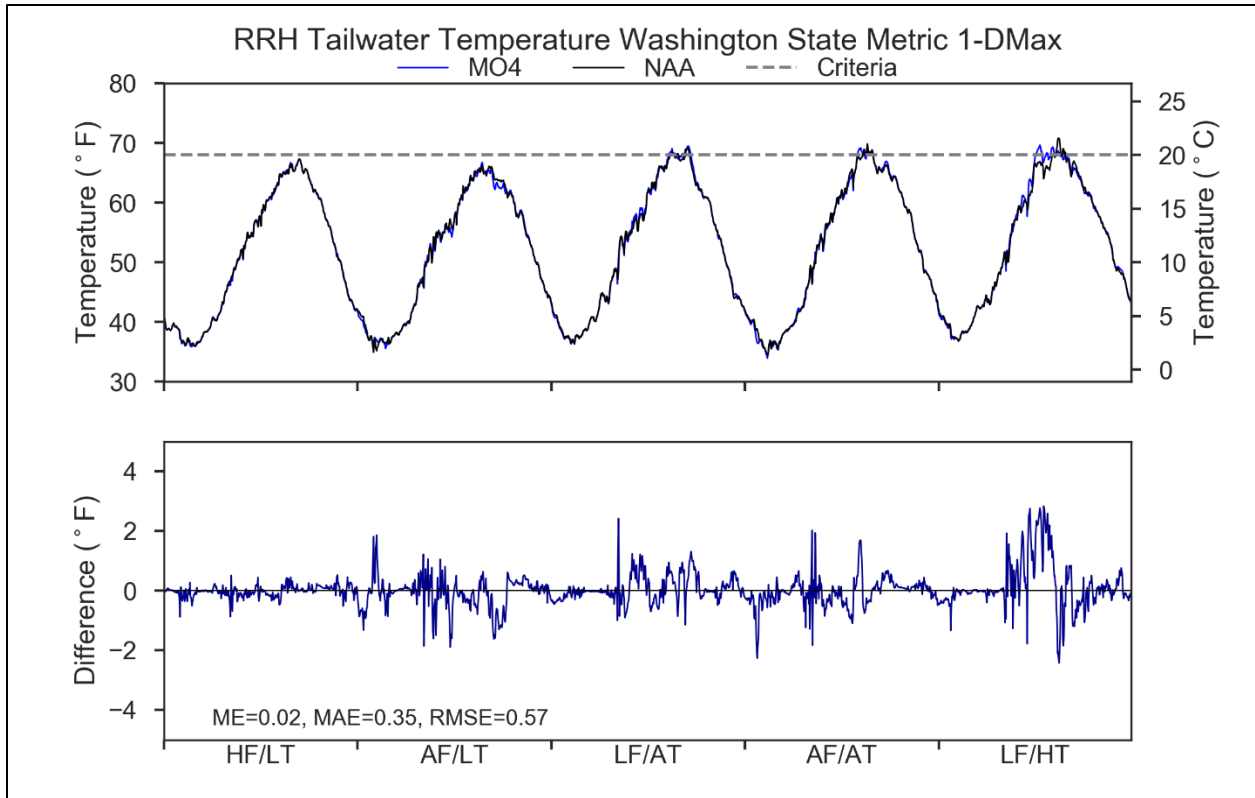
Figure 7-8. Grand Coulee Dam Summary Outflows for Multiple Objective Alternative 4 Versus No Action Alternative



5944
 5945 **Figure 7-9. Modeled Tailwater Temperature for Multiple Objective Alternative 4 and No**
 5946 **Action Alternative at Grand Coulee Dam Under a 5-year Range of River and Meteorological**
 5947 **Conditions Compared to the Confederated Colville Tribe 1-D Maximum Water Quality**
 5948 **Standard**

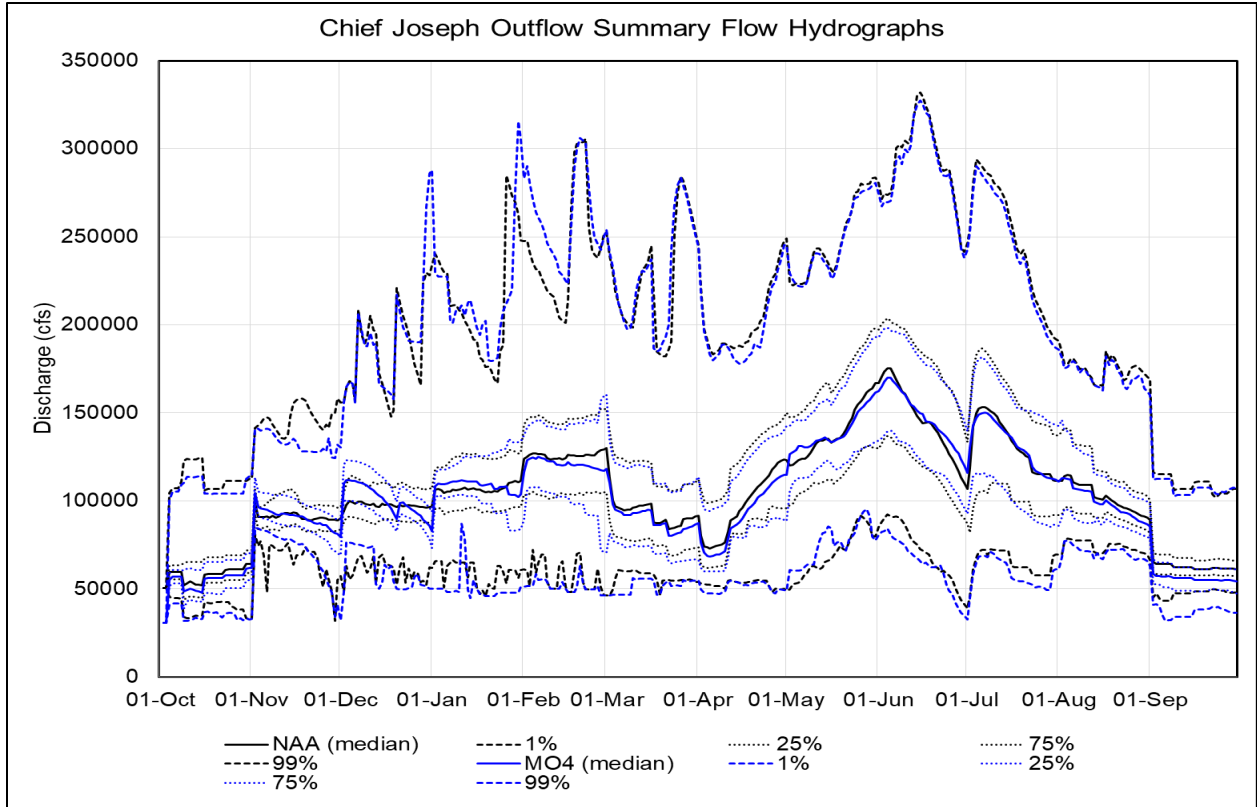


5949
 5950 **Figure 7-10. Modeled Tailwater Temperature for Multiple Objective Alternative 4 and No**
 5951 **Action Alternative at Wells Dam Under a 5-year Range of River and Meteorological**



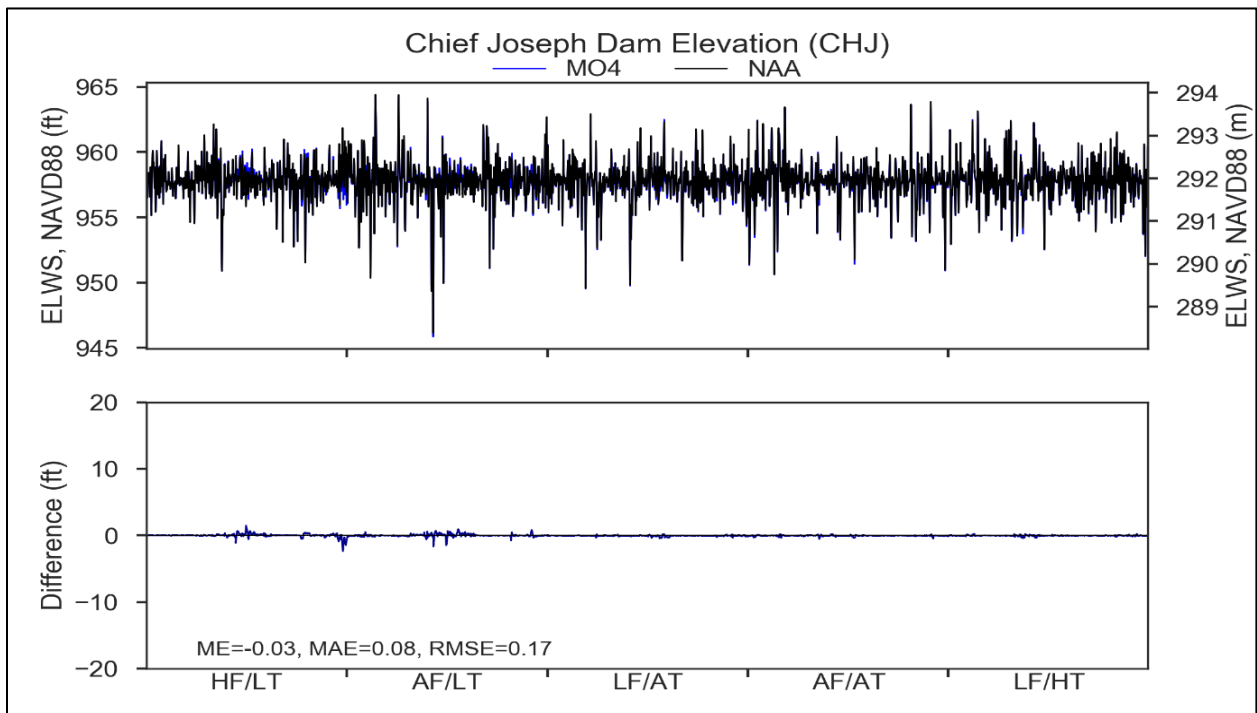
5952
5953 **Figure 7-11. Modeled Tailwater Temperature for Multiple Objective Alternative 4 and No**
5954 **Action Alternative at Rocky Reach Dam Under a 5-year Range of River and Meteorological**
5955 **Conditions**

5956 Under MO4, reservoir elevation changes and corresponding project outflow changes predicted
5957 at Grand Coulee Dam would carry downstream through Rufus Woods Lake, Chief Joseph Dam,
5958 and downstream. In general, monthly outflows out of Chief Joseph Dam would be similar to the
5959 No Action Alternative except in September and October. Chief Joseph Dam outflows would be
5960 reduced in September and October by about 9 and 8 percent, respectively (Figure 7-12.). Since
5961 Chief Joseph Dam is a run-of-river project, little change to forebay elevations would occur for
5962 MO4 when compared to the No Action Alternative (Figure 7-13.). Tailwater temperatures under
5963 both MO4 and the No Action Alternative are predicted to exceed the Washington State and
5964 Tribal water quality standards regardless of water year type or meteorological condition.



5965
 5966
 5967

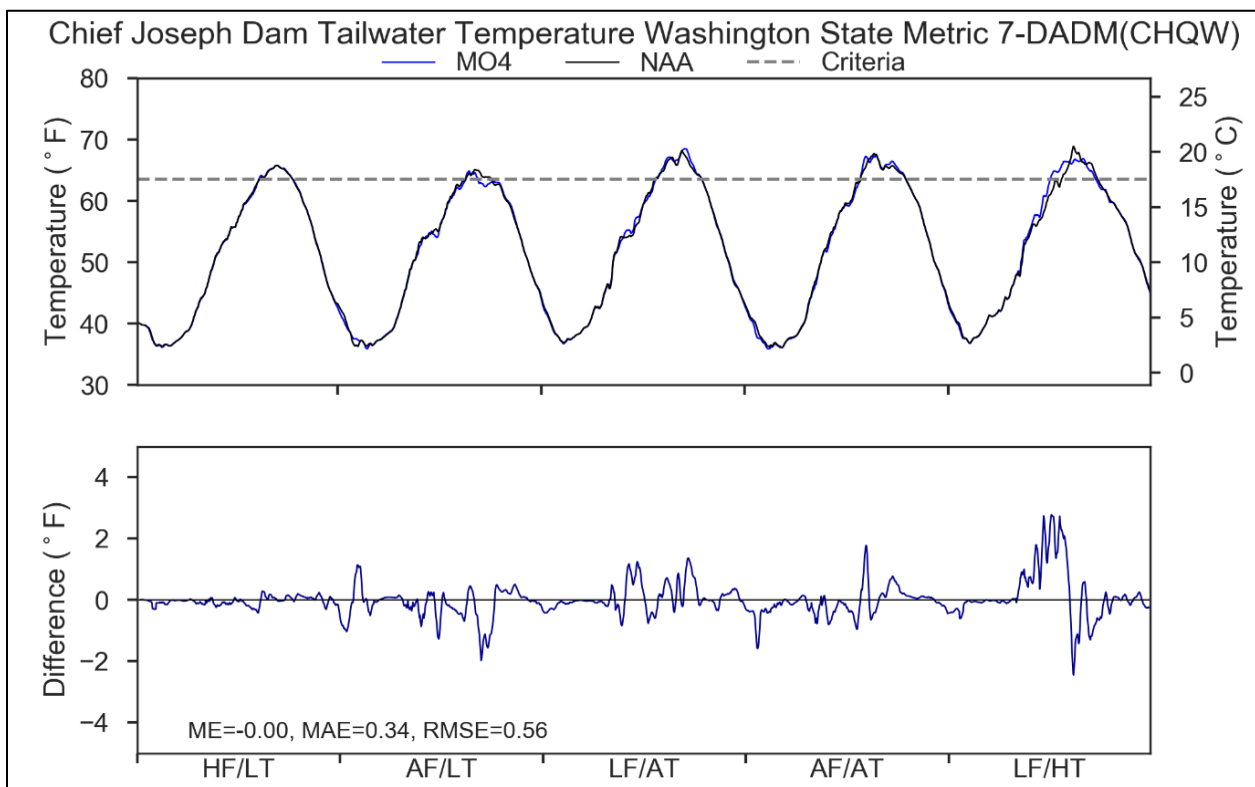
Figure 7-12. Chief Joseph Dam–Rufus Woods Lake Outflows for Multiple Objective Alternative 4 Versus No Action Alternative



5968
 5969
 5970

Figure 7-13. Chief Joseph Dam–Rufus Woods Lake Forebay Elevations for Multiple Objective Alternative 4 Versus No Action Alternative

5971 Water temperatures under MO4 at Chief Joseph Dam tailwater are similar to or slightly warmer
5972 than under the No Action Alternative with the majority of temperature differences in the ± 1
5973 degree Fahrenheit range (Figure 7-14.). In general, temperatures modeled for MO4 are similar
5974 to the No Action Alternative for most river and meteorological conditions. An exception is for
5975 the low-flow scenarios (LF/AT and LF/HT) where river temperatures in the spring and summer
5976 are expected to be up to 1.5 degrees Fahrenheit (LF/AT) and 3 degrees Fahrenheit (LF/HT)
5977 greater under MO4. Tailwater temperatures under both the MO4 and No Action Alternative are
5978 predicted to exceed the Washington State standard of 17.5°C (63.5°F) as measured by the 7-day
5979 average of the daily maximum temperature in August and September. Similar to the No Action
5980 Alternative, there is little difference in temperature between Grand Coulee Dam tailwater
5981 (Figure 7-9.) and Chief Joseph Dam tailwater (Figure 7-14.) under MO4, showing that water
5982 temperatures released from Lake Roosevelt are passed through Rufus Woods Lake unchanged.



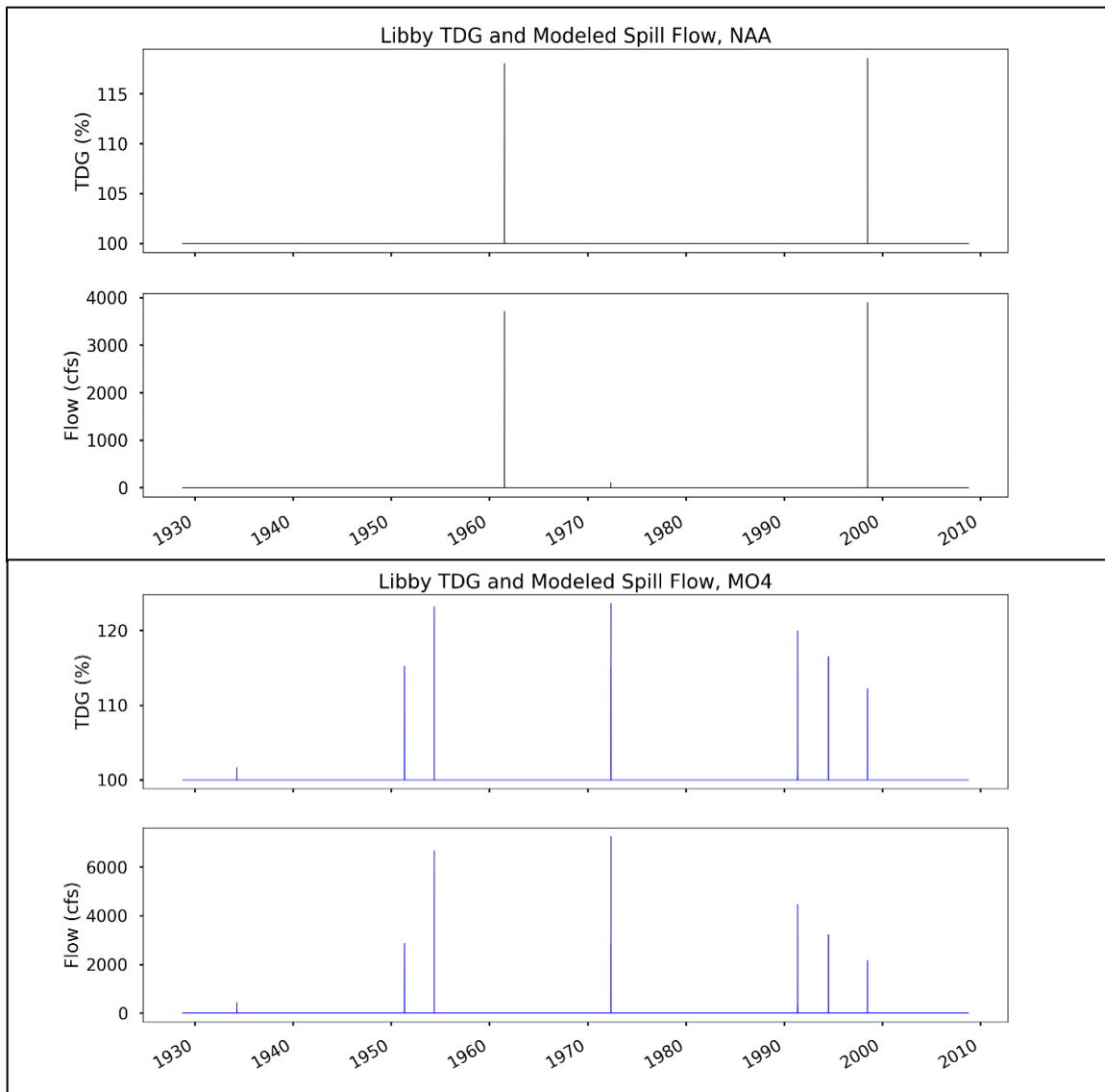
5983
5984 **Figure 7-14. Modeled tailwater temperature for Multiple Objective Alternative 4 and No**
5985 **Action Alternative at Chief Joseph Dam Under a 5-year Range of River and Meteorological**
5986 **Conditions**

5987 7.1.2 Total Dissolved Gas

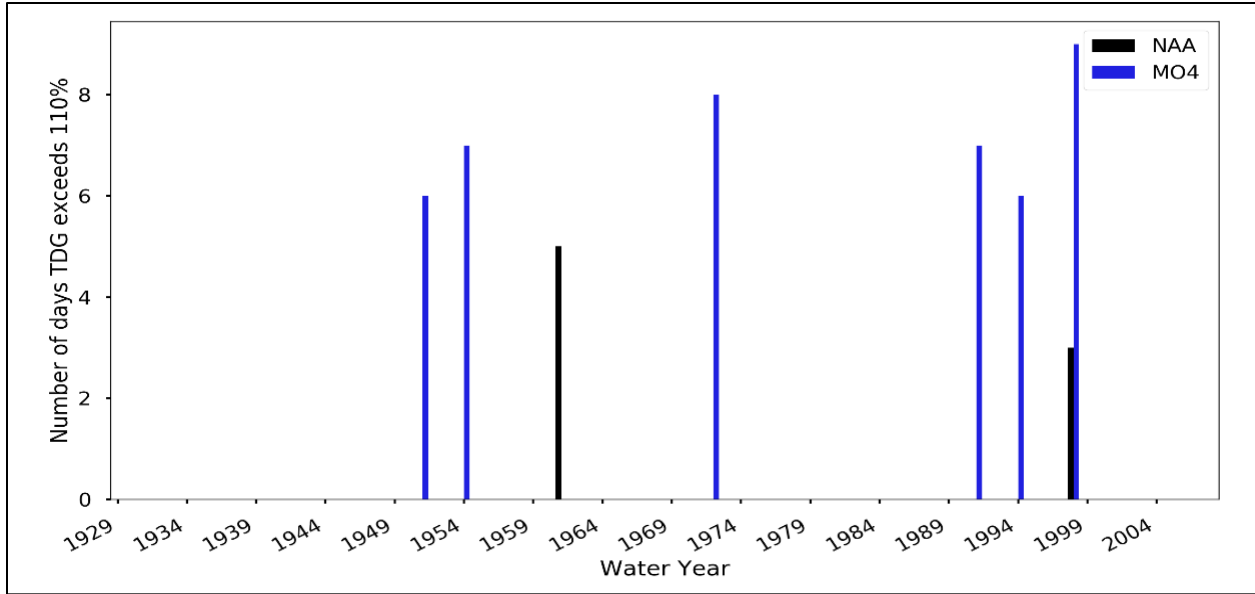
5988 There are a few measures within MO4 that are expected to modify reservoir storage and
5989 outflow rates at the upper Columbia River Basin projects. Although these measures would not
5990 greatly affect downstream TDG, some change is expected as compared to the No Action
5991 Alternative. These effects are described below.

5992 **7.1.2.1 Libby and Hungry Horse Dams and Reservoirs**

5993 Libby Dam is typically operated to minimize spill due to associated water quality concerns such
5994 as elevated TDG. Under MO4, Libby Dam’s draft and refill operations will be modified, resulting
5995 in an increase in the highest releases from the dam. This operational change is predicted to
5996 increase the chance of spill at Libby Dam. The 80-year period of record flows (1928 to 2008)
5997 were used to predict TDG, as presented in Figure 7-15.. This shows that under MO4, the
5998 number of years where spill could occur increases threefold, as compared to the No Action
5999 Alternative over the 80-year period. The number of days exceeding 110 percent would increase
6000 as well, from 8 days for the No Action Alternative to 43 days for MO4 (Figure 7-16.). Although
6001 spill from Libby Dam for the 80-year model period is predicted to increase under MO4, the
6002 frequency of spill is still very small.

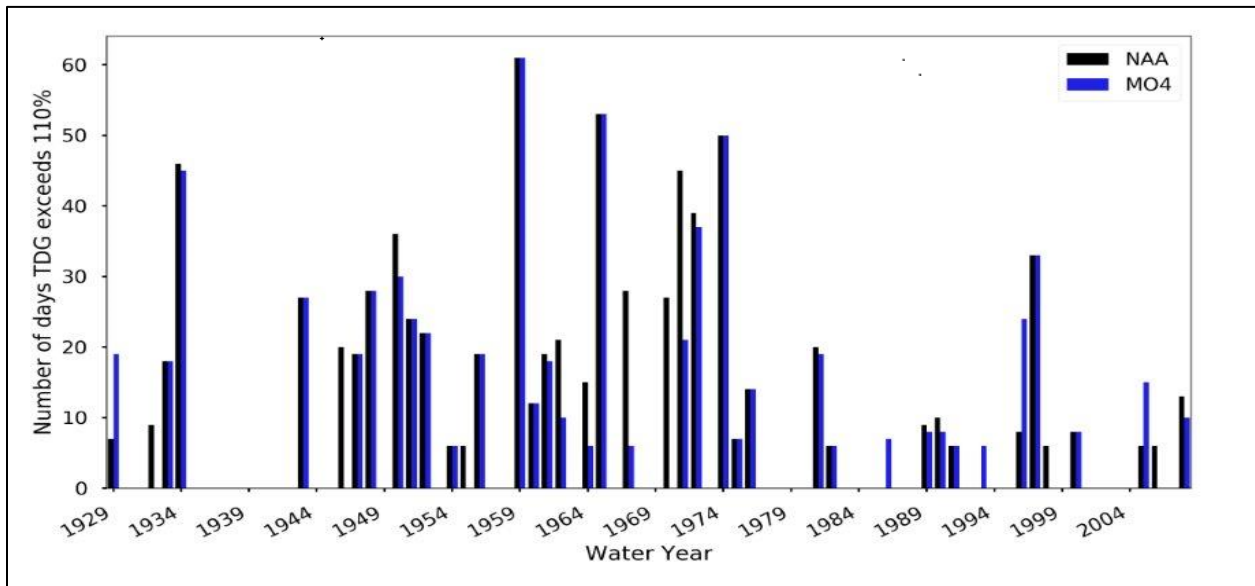


6003 **Figure 7-15. Modeled Tailwater Total Dissolved Gas and Spillway Flows for Multiple Objective**
6004 **Alternative 4 and No Action Alternative at Libby Dam over an 80-year period.**
6005



6006
6007 **Figure 7-16. Number of Days Modeled Tailwater Total Dissolved Gas Exceeds the 110 percent**
6008 **State Water Quality Standards for Multiple Objective Alternative 4 and No Action Alternative**
6009 **at Libby Dam over an 80-year Period**

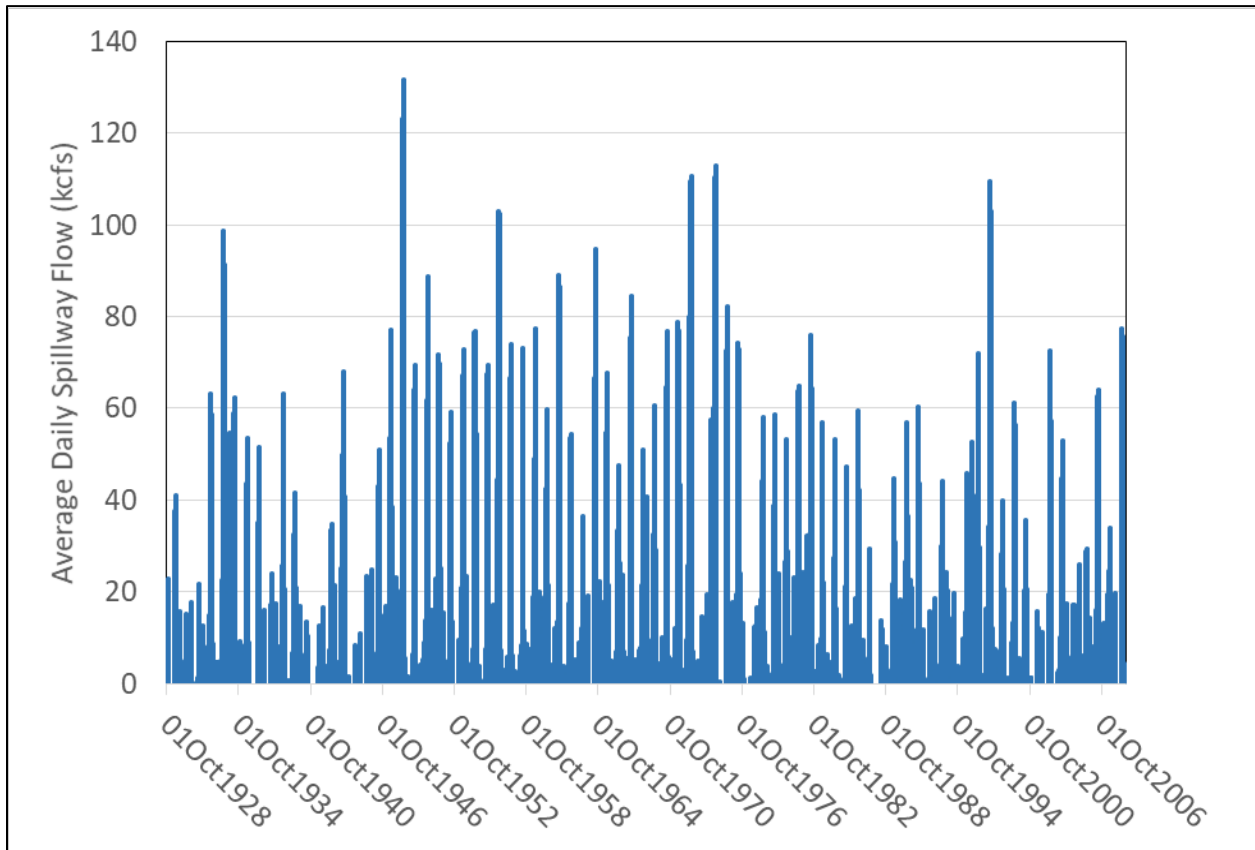
6010 In general, the number of days that TDG is anticipated to exceed 110 percent below Hungry
6011 Horse Dam under MO4 is similar to what is expected under No Action Alternative (Figure 7-17.).
6012 That said, MO4 operations could lead to reductions in TDG in the winter and spring following a
6013 dry year due to changes in pool elevations at the end of September. The reduced elevation
6014 would provide additional storage to capture runoff, thereby resulting in less spill and associated
6015 TDG.



6016
6017 **Figure 7-17. Number of Days Modeled Tailwater Total Dissolved Gas Exceeds the 110 percent**
6018 **State Water Quality Standards for Multiple Objective Alternative 4 and No Action Alternative**
6019 **at Hungry Horse Dam over an 80-year Period**

6020 **7.1.2.2 Albeni Falls Dam and Reservoir**

6021 TDG in the Pend Oreille River upstream of Albeni Falls Dam can be greater than 110 percent
6022 largely because of spillway releases from Cabinet Gorge Dam located on the Clark Fork River
6023 about 55 miles upstream of Albeni Falls Dam. During most years, Albeni Falls Dam spills during
6024 high-flow spring runoff. In general, spillway discharges up to about 10 kcfs can increase TDG
6025 saturations over forebay levels by about 1 to 2 percent, while spill between 10 to 50 kcfs can
6026 increase TDG saturations downstream of Albeni Falls by about 5 to 9 percent. When Pend
6027 Oreille River flows exceed about 50 to 60 kcfs, Albeni Falls Dam powerhouse operations are
6028 suspended and the spillway gates are raised, allowing the river to flow relatively un-impounded
6029 across the dam. Under these high-flow conditions Albeni Falls Dam produces no TDG as the
6030 river is essentially free flowing. Spillway flows at Albeni Falls Dam were modeled under MO4
6031 and the No Action Alternative for the 80-year period from 1928 to 2008 using the ResSim model
6032 (Figure 7-18.). There was little difference in spillway flows under MO4 and the No Action
6033 Alternative. For both alternatives, spillway flows were predicted to range between 1 and 50
6034 kcfs in nearly every year at Albeni Falls Dam, with many years having spill exceed about 60 kcfs,
6035 resulting in free-flowing conditions. The similar spillway flows under MO4 and No Action
6036 Alternative are expected to result in no change in TDG saturations downstream of Albeni Falls
6037 Dam.



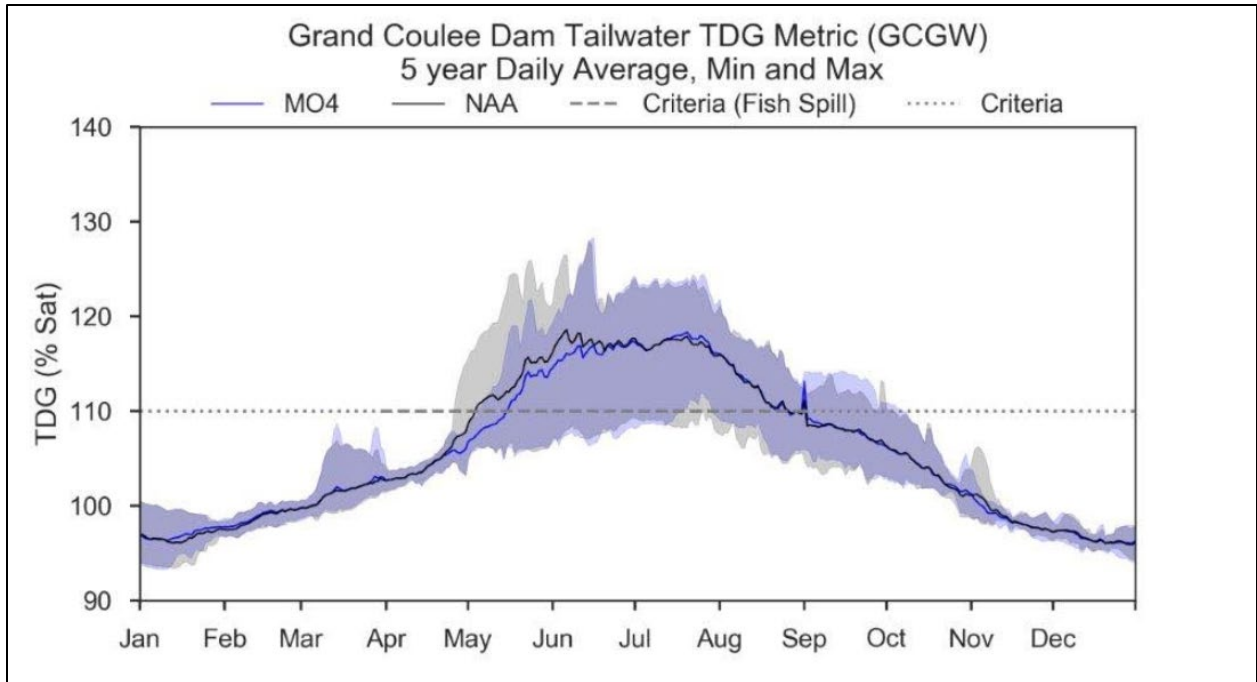
6038 **Figure 7-18. Modeled Tailwater Spillway Flows for Multiple Objective Alternative 4 and No**
6039 **Action Alternative at Albeni Falls Dam over an 80-year Period**
6040

6041 **7.1.2.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

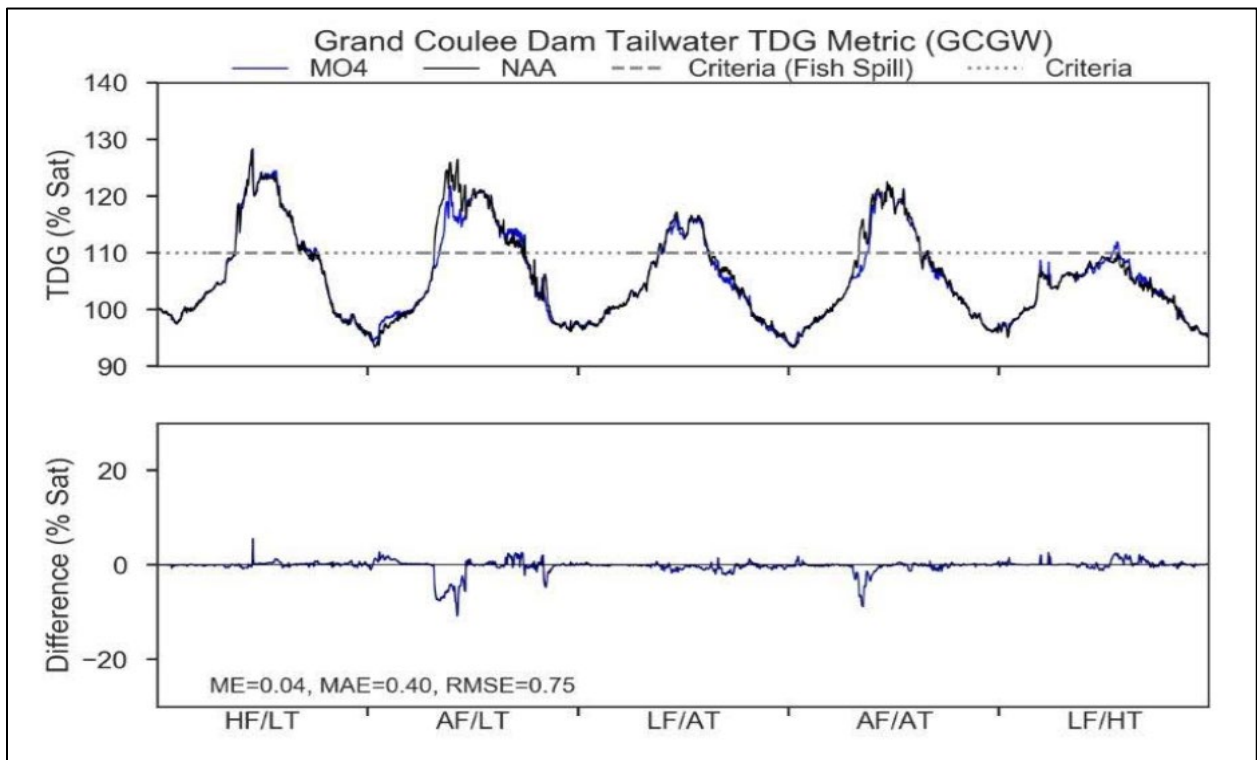
6042 There are multiple measures under MO4 that result in changed operations at Grand Coulee
6043 Dam: *Update System FRM Calculation, Planned Draft Rate at Grand Coulee, Grand Coulee*
6044 *Maintenance Operations, Winter System FRM Space, Lake Roosevelt Additional Water Supply,*
6045 *and McNary Flow Target.*

6046 In addition to the measures listed above, changes in operations of upstream projects result in
6047 changes to inflows at Grand Coulee, which may have minor impacts on inflowing TDG but are
6048 not captured by the system modeling.

6049 During drier years, operational measure *McNary Flow Target* may require the release of an
6050 additional 2 Maf (up to 1 Maf of water will be released from upstream projects to offset part of
6051 these releases) of water from Grand Coulee Dam to help maintain fish flow objectives in the
6052 lower river. *Winter System FRM Space* could result in a deeper draft and larger outflow in the
6053 month of December, however TDG responses under MO4 and the No Action Alternative are not
6054 all that different this time of year (Figure 7-19.). From January through March, because the
6055 reservoir is lower for the FRM measures, including the *Winter System FRM* measure, there are
6056 typically lower outflows and in some situations less spill (and corresponding TDG) is predicted in
6057 those following few months (mid-April to mid-June). *Grand Coulee Maintenance Operations*
6058 measure has the potential to increase spill through the reduction in the hydraulic capacity of
6059 the powerhouse at Grand Coulee; however, the other actions tend to minimize effects and
6060 higher TDG associated with this measure is not reflected in modeled results (Figure 7-19. and
6061 Figure 7-20.). The Grand Coulee Maintenance Operations in isolation could result in significant
6062 increases in spill and TDG, in some cases producing TDG in excess of 130 percent for a limited
6063 duration. An additional impact that is expected from Grand Coulee Maintenance Operations is
6064 the potential for slightly deeper spill over the drum gates (when the forebay elevation is greater
6065 than 1,267 feet, NGVD29). Information to assess the magnitude of water quality impacts is
6066 unavailable but would likely result in small increases in TDG. In wet conditions, potential
6067 maintenance activities could be delayed in advance of spill, to allow spill over more gates.
6068 Another factor not considered in the analysis is that as maintenance occurs there would be an
6069 increase in hydraulic capacity as more units become available. This would result in reduced spill
6070 and TDG in some cases; however, the other actions would have a larger impact on outflows and
6071 associated spill.



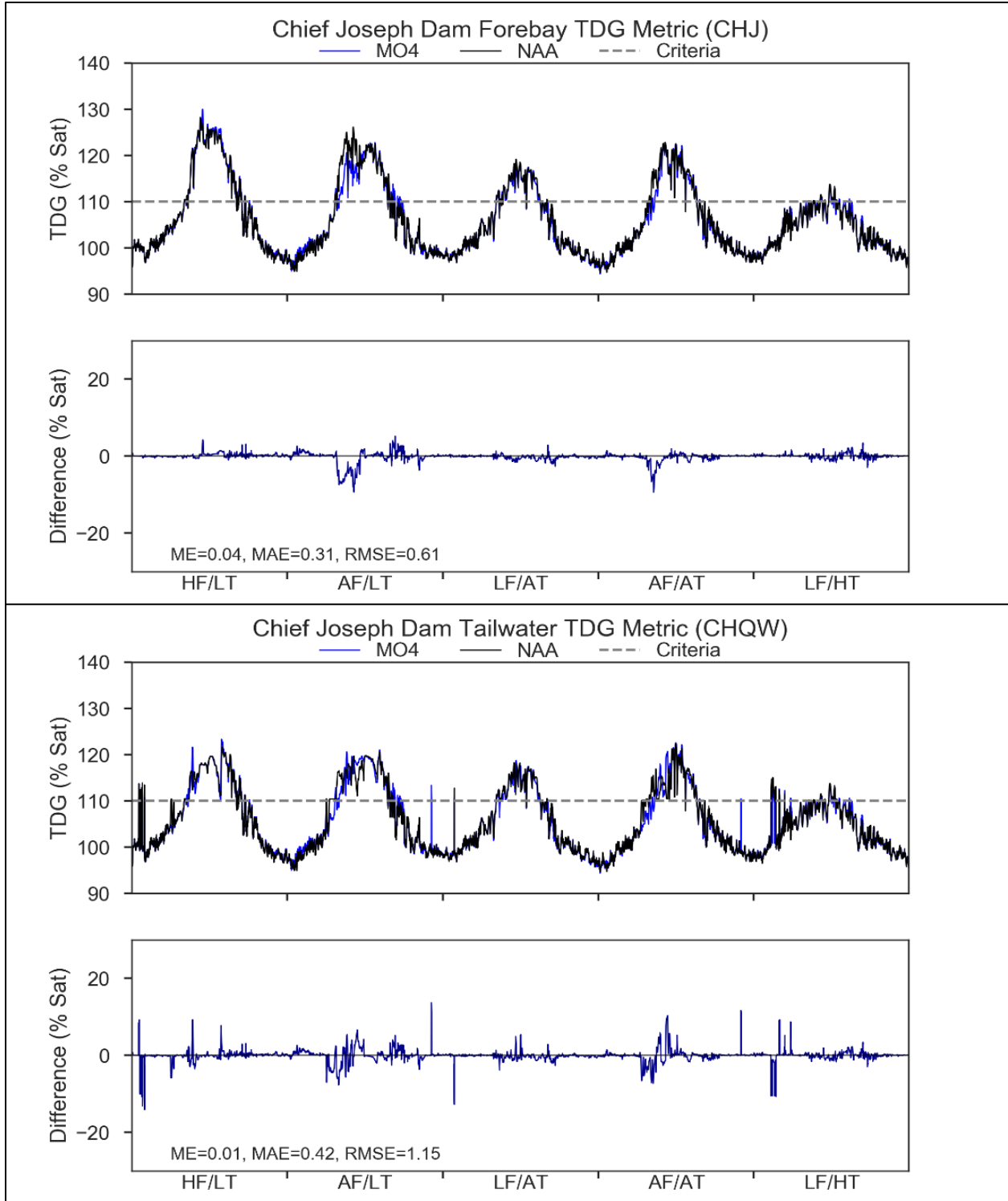
6072
 6073 **Figure 7-19. Modeled Tailwater Total Dissolved Gas 5-year Daily Average, Minimum, and**
 6074 **Maximum for Multiple Objective Alternative 4 and No Action Alternative at Grand Coulee**
 6075 **Dam**



6076
 6077 **Figure 7-20. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4 and**
 6078 **No Action Alternative at Grand Coulee Dam Under a 5-year Range of River and**
 6079 **Meteorological Conditions**

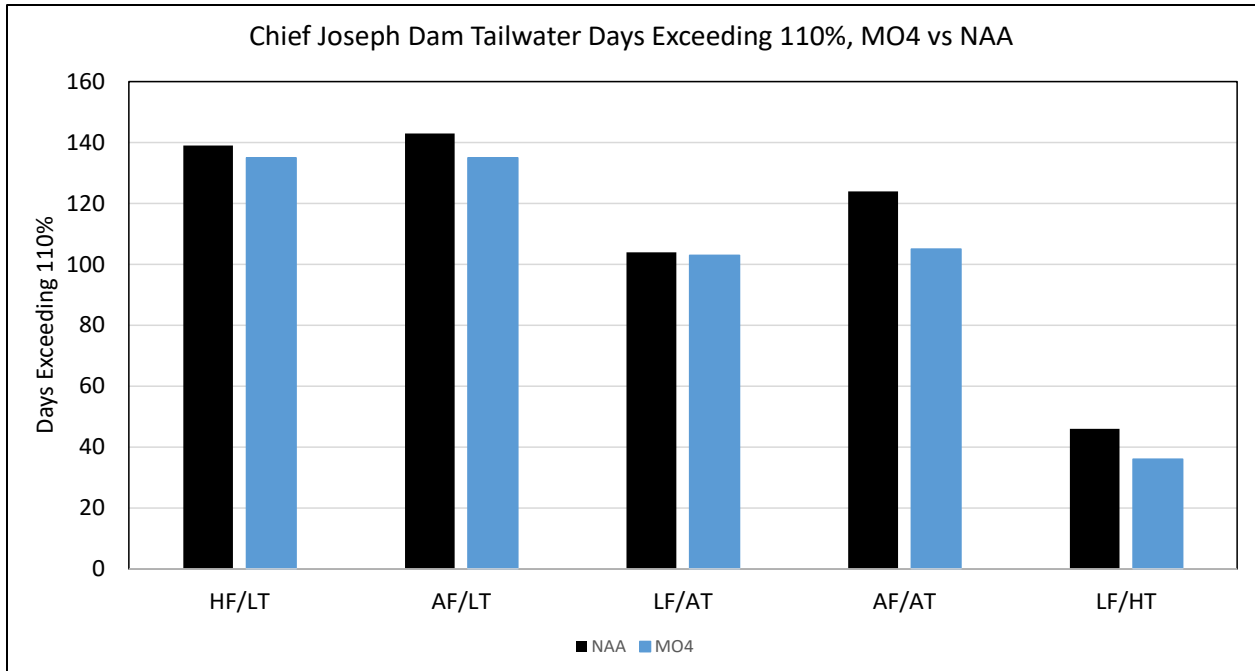
6080 TDG at the forebay of Chief Joseph Dam is largely a function of the TDG released upstream from
6081 Lake Roosevelt and Grand Coulee Dam, because little degassing occurs in Rufus Woods Lake.
6082 High inflowing TDG to Lake Roosevelt from Canada as well as spill from Grand Coulee Dam via
6083 the outlet tubes can increase TDG saturations in Rufus Woods Lake at the Chief Joseph Dam
6084 forebay to over 130 percent for a limited time. During periods when incoming TDG levels are
6085 above approximately 120 percent, spilling at Chief Joseph Dam over the spillway deflectors can
6086 degas the water and reduce downstream system TDG loading. Therefore, Chief Joseph Dam is
6087 often used to help manage overall system TDG production in the mainstem Columbia River. In
6088 addition, to avoid spilling through the outlet tubes at Grand Coulee Dam, spill is often shifted
6089 from Grand Coulee to Chief Joseph Dam to take advantage of the lower TDG produced by
6090 spilling over the deflectors. These operational strategies are expected to continue under MO4.

6091 Chief Joseph Dam TDG saturations at the forebay and tailwater modeled under MO4 were
6092 compared to the No Action Alternative (Figure 7-21.). In general, MO4 forebay TDG saturations
6093 are predicted to be similar to the No Action Alternative under a wide range of flow and air
6094 temperature conditions. Tailwater TDG saturations under MO4 are predicted to be both lower
6095 and higher than the No Action Alternative depending on flow and meteorological conditions.
6096 The number of days the tailwater exceeds the 110 percent TDG criteria is predicted to be
6097 slightly lower under MO4 for all flow and meteorological conditions (Figure 7-22.). Decreased
6098 TDG saturations between the forebay and tailwater during high-flow and high-spill years
6099 (HF/LT) modeled under the No Action Alternative would continue under MO4. It is expected
6100 that under MO4, Chief Joseph Dam would continue to decrease TDG during high-flow years
6101 when elevated TDG saturations occur in the forebay.



6102
6103
6104
6105

Figure 7-21. Modeled forebay and tailwater Total Dissolved Gas saturations for Multiple Objective Alternative 4 and No Action Alternative at Chief Joseph Dam Under a 5-year Range of River and Meteorological Conditions



6106
6107 **Figure 7-22. Days Exceeding the 110 percent Total Dissolved Gas Criteria for Multiple**
6108 **Objective Alternative 4 and No Action Alternative at Chief Joseph Dam Tailwater Under a 5-**
6109 **year Range of River and Meteorological Conditions**

6110 **7.1.3 Other Physical, Chemical, and Biological Processes**

6111 MO4 operations do have an impact on storage (reservoir elevation) and retention time (flow) in
6112 many of the upper basin CRSO projects. These changes may create shifts in nutrient dynamics
6113 and food availability for resident fish species. Details are discussed below.

6114 **7.1.3.1 Libby and Hungry Horse Dams and Reservoirs**

6115 Retention time, which is the inverse of the flushing rate, refers to the length of time water
6116 remains in a water-body. Water quality chemical and biological parameters of concern in Lake
6117 Kooconusa that may be impacted by changes in the reservoir elevation and retention times,
6118 under MO4, include nutrients such as phosphorus and nitrogen, trace metals such as selenium,
6119 and phytoplankton such as cyanobacteria and diatoms. Water quality concerns for MO4 would
6120 be similar to those discussed for MO1. The MO4 median water year retention time would likely
6121 be slightly less than under the No Action Alternative. For a long, narrow, deep water-body like
6122 Lake Kooconusa, a shorter retention time may allow certain chemical constituents in inflowing
6123 waters to move further down reservoir towards the forebay and outflow before settling out or
6124 transforming.

6125 Median reservoir elevations under MO4 would be up to 9 feet lower from mid-June through the
6126 end of September when compared to the No Action Alternative. These lower MO4 summer
6127 pool elevations correspond to about a 4 percent decrease in the volume of the reservoir's
6128 photic/productive zone. In addition, the increased outflow under MO4 from Libby Dam would

6129 create a moving, increasing hydrograph, which may reduce variability of (periodically wetted)
6130 zone productivity by moving the photic zone with increasing flow. Because water quality
6131 parameters in Lake Kootenai and the Kootenai River were not modeled, the potential
6132 decreases in productivity from a lower reservoir pool elevation and an increasing river
6133 hydrograph are a hypothesis and additional studies may be needed.

6134 The MO4 operational measures *McNary Flow Target*, *Hungry Horse Additional Water Supply*,
6135 and *Sliding Scale at Libby and Hungry Horse* could result in deeper drafts and lower reservoir
6136 elevations, stratification and thermocline depths in the reservoir. These elevations combined
6137 with higher outflows in late spring/early summer could reduce in-lake productivity and food
6138 availability for resident fish species (ISAB 1997, Fraley et. al 1989).

6139 Water level fluctuations in reservoirs may increase methyl-mercury concentrations in the
6140 waterbody as seasonally inundated areas of a reservoir have higher rates of methylation
6141 activity when compared to permanently inundated areas of a reservoir (Willacker 2016).
6142 Studies suggest that methyl-mercury has a greater probability of entering the food web during
6143 the spring and summer growing seasons (January to July) (Willacker 2016). Under MO4 the
6144 measures do not change the cyclic occurrence of inundation and exposure but do result in
6145 earlier and longer exposure of sediments that may have some impact on mercury methylation
6146 in Hungry Horse Reservoir. However, unlike other downstream locations such as Lake
6147 Roosevelt, mercury has not been recorded as a concern at Hungry Horse Reservoir as the only
6148 likely mercury input at this location is through airborne pollution deposition.

6149 **7.1.3.2 Albeni Falls Dam and Reservoir**

6150 Under MO4 there are only proposed changes to operations at Albeni Falls Dam for the drier 40
6151 percent of years when the elevation of Lake Pend Oreille would be up to 2.6 feet lower in the
6152 summer. The change in summer elevation of Lake Pend Oreille during drier years would not
6153 likely impact the physical, chemical, or biological water quality in the open water areas of Lake
6154 Pend Oreille. However, shallow nearshore areas that currently have a nutrient TMDL in place
6155 would become substantially shallower, which might allow for more growth of periphyton and
6156 macrophytes in these bays. Such an increase in macrophytes and periphyton may impact
6157 nutrient cycling, dissolved oxygen concentrations, and pH levels in these shallow bays.
6158 Additionally, nearshore areas used for recreation may be more difficult to access due to the
6159 lower lake level, as well as due to greater macrophyte and periphyton growth.

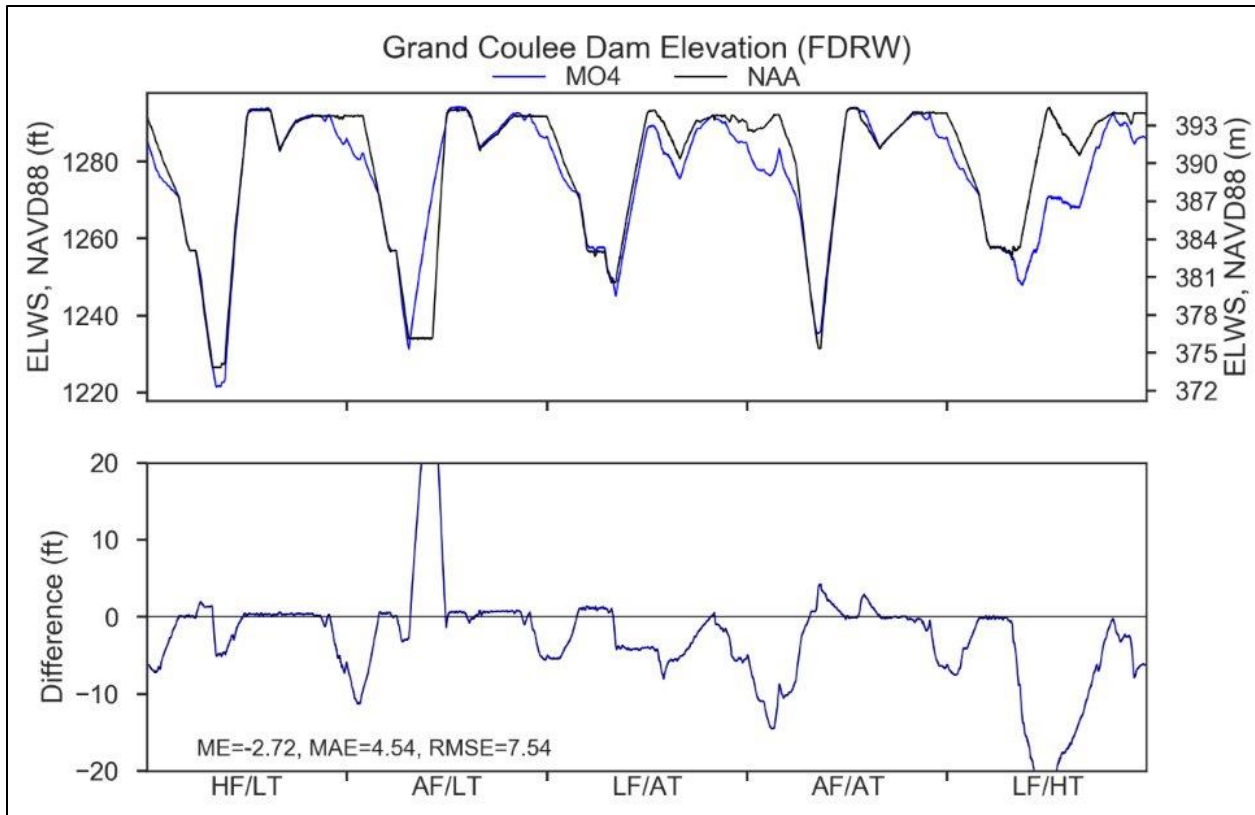
6160 **7.1.3.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

6161 Lake Roosevelt tends to display relatively low primary productivity throughout the year.
6162 However, with slightly longer water retention times in the spring due to greater volumes of
6163 water being stored for refill, some locations in the reservoir may experience algal blooms.
6164 These blooms have the potential to increase pH and decrease dissolved oxygen when they
6165 decay. Under MO4, retention time of water in through the reservoir could decrease slightly
6166 from March through May and in the fall of low-flow years, and sharply increase for a short
6167 period of time in late December and early January. In the section of reservoir where the

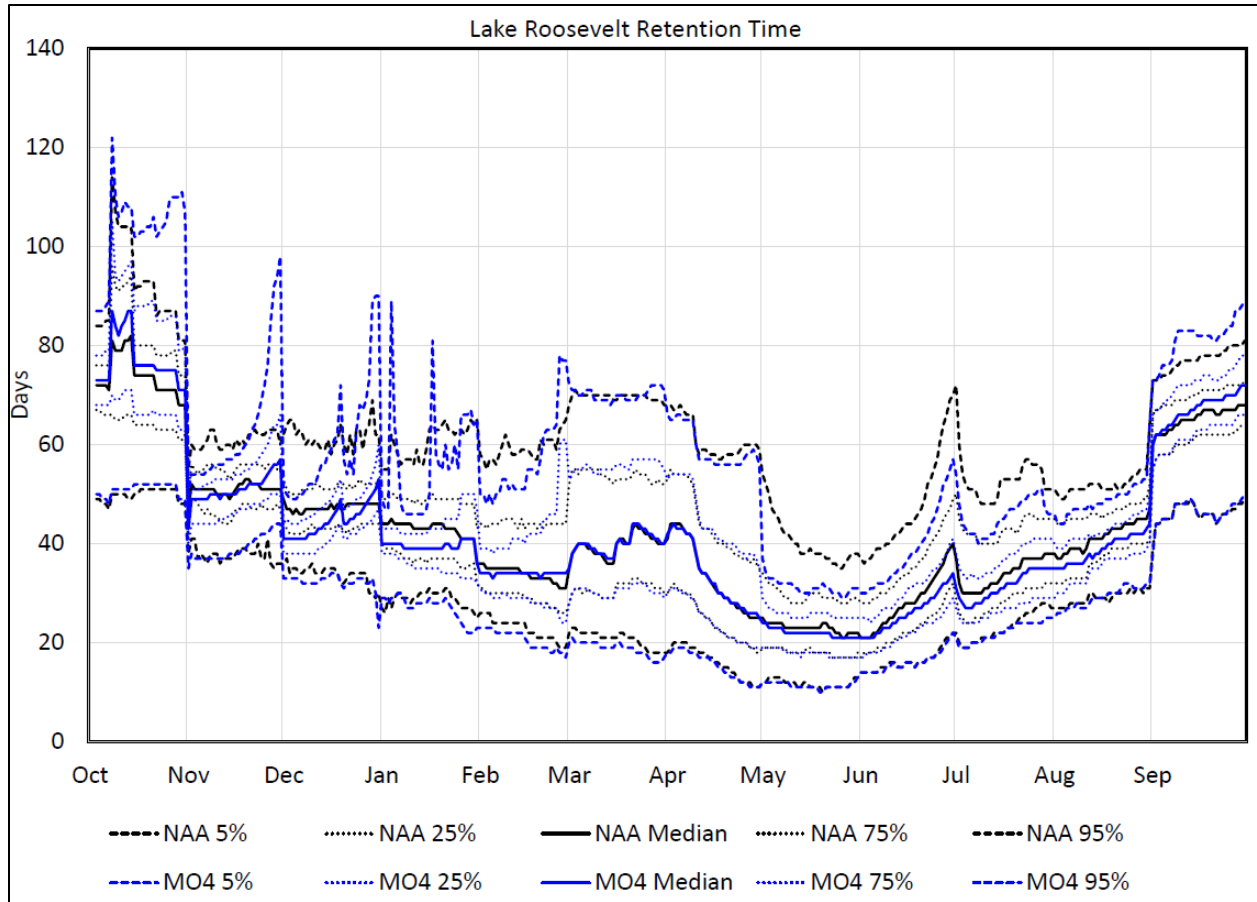
6168 Spokane River flows in, anoxic conditions may be greater under the LF/HT year for MO4 as
 6169 compared to the No Action Alternative. This may be related to water retention time and
 6170 temperature conditions in that year.

6171 Turbidity generated from local landslides along Lake Roosevelt has been related to the rate of
 6172 drawdown and refill at Grand Coulee Dam. Operational measure *Winter System FRM Space*
 6173 changes the planning draft rate to a target of 0.8 feet per day. A slower drawdown rate may
 6174 result in lower turbidity throughout the reservoir as a byproduct of a reduced likelihood of
 6175 mass wasting events.

6176 Water level fluctuations in Lake Roosevelt may have an impact on mercury cycling within the
 6177 reservoir, especially when the lowest lake levels occur during peak fish growing season, which
 6178 typically occurs from April through July. Studies suggest that methyl-mercury has a greater
 6179 probability of entering the food web, especially fish, when growth is greatest. Effects such as
 6180 this under some MO4 measures—particularly the release of an additional 2 Maf under the
 6181 operational measure *McNary Flow Target*—could be expected since larger variations in water
 6182 elevation are predicted. This variation may promote a higher rate of mercury cycling in Lake
 6183 Roosevelt under MO4 than is seen in the No Action Alternative.



6184 **Figure 7-23. Modeled Forebay Elevations for Multiple Objective Alternative 4 and No Action**
 6185 **Alternative Grand Coulee Dam Under a 5-year Range of River and Meteorological Conditions**
 6186



6187
 6188 **Figure 7-24. Modeled Retention Times at Lake Roosevelt for No Action Alternative and**
 6189 **Multiple Objective Alternative 4**

6190 MO4 includes modified operations at Grand Coulee Dam, which would result in some changes
 6191 in monthly outflows to Rufus Woods Lake and Chief Joseph Dam. However, only minor changes
 6192 to operational conditions at Chief Joseph Dam are expected. Given this, the physical, chemical,
 6193 and biological water quality of Rufus Woods Lake and the Columbia River downstream of Chief
 6194 Joseph Dam under MO4 are expected to remain relatively unchanged from under the No Action
 6195 Alternative.

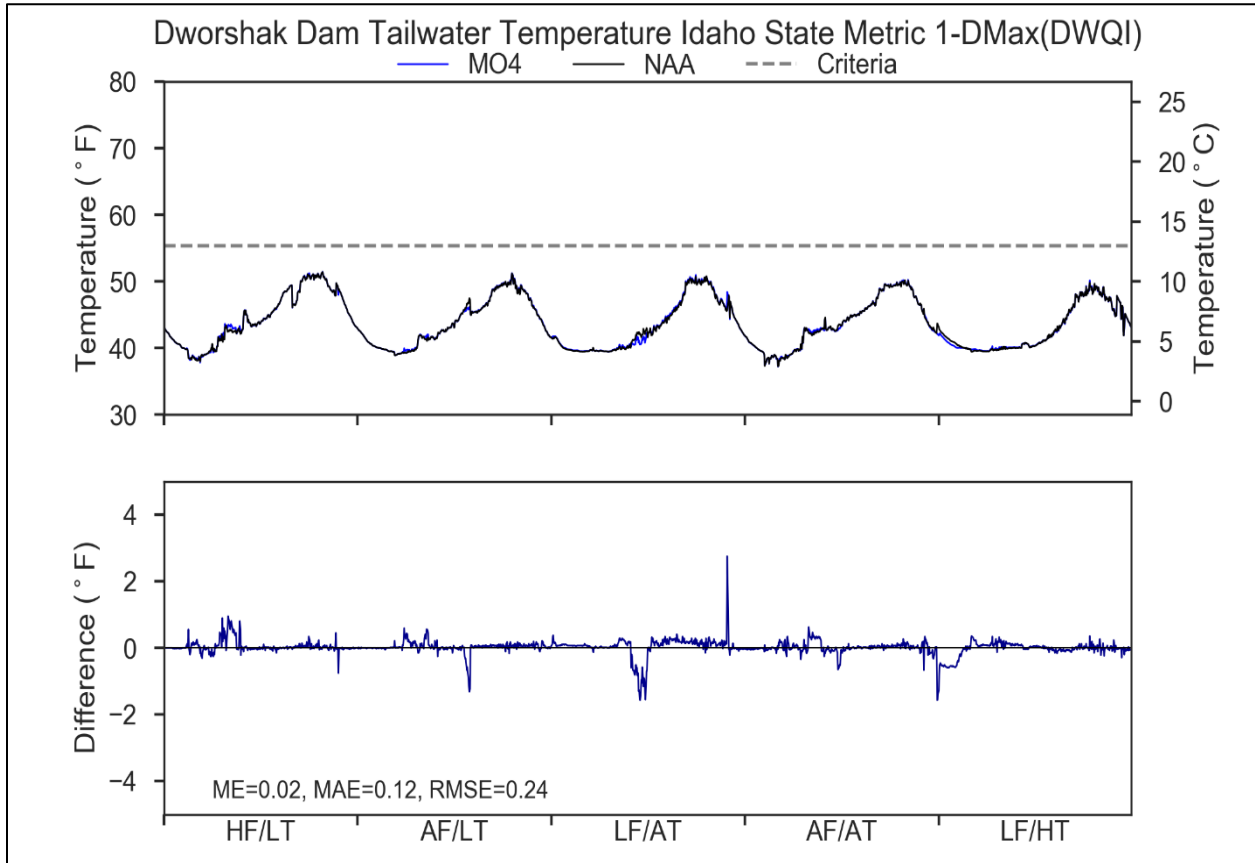
6196 **7.2 LOWER SNAKE RIVER BASIN**

6197 **7.2.1 Water Temperature**

6198 There are no measures within MO4 directed at changing water temperature management in
 6199 the lower Snake River. It is not anticipated that fish ladder water temperature improvements at
 6200 Lower Monumental and Ice Harbor Dams (*Lower Snake Ladder Pumps* measure) would have
 6201 any meaningful impact to downstream river water temperatures. These structural changes are
 6202 anticipated to affect fish ladder conditions only.

6203 **7.2.1.1 Dworshak Dam and Reservoir**

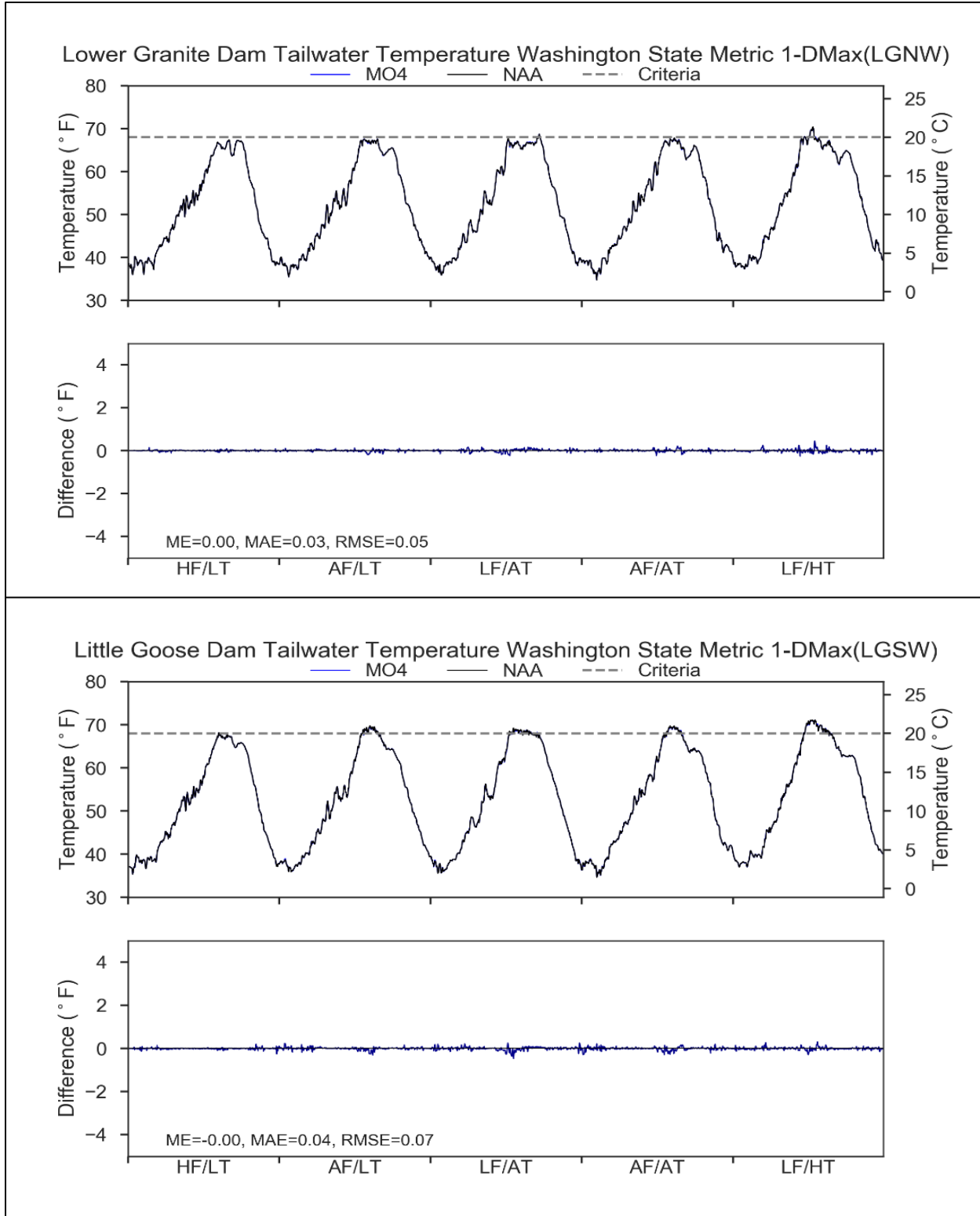
6204 Outflow temperatures from Dworshak Dam, modeled for MO4, would be very similar to the
6205 modeled results for the No Action Alternative, with temperatures remaining less than 52°F
6206 throughout the year (Figure 7-25.).



6207 **Figure 7-25. Modeled Tailwater Temperature for Multiple Objective Alternative 4 and No**
6208 **Action Alternative at Dworshak Dam Under a 5-year Range of River and Meteorological**
6209 **Conditions**
6210

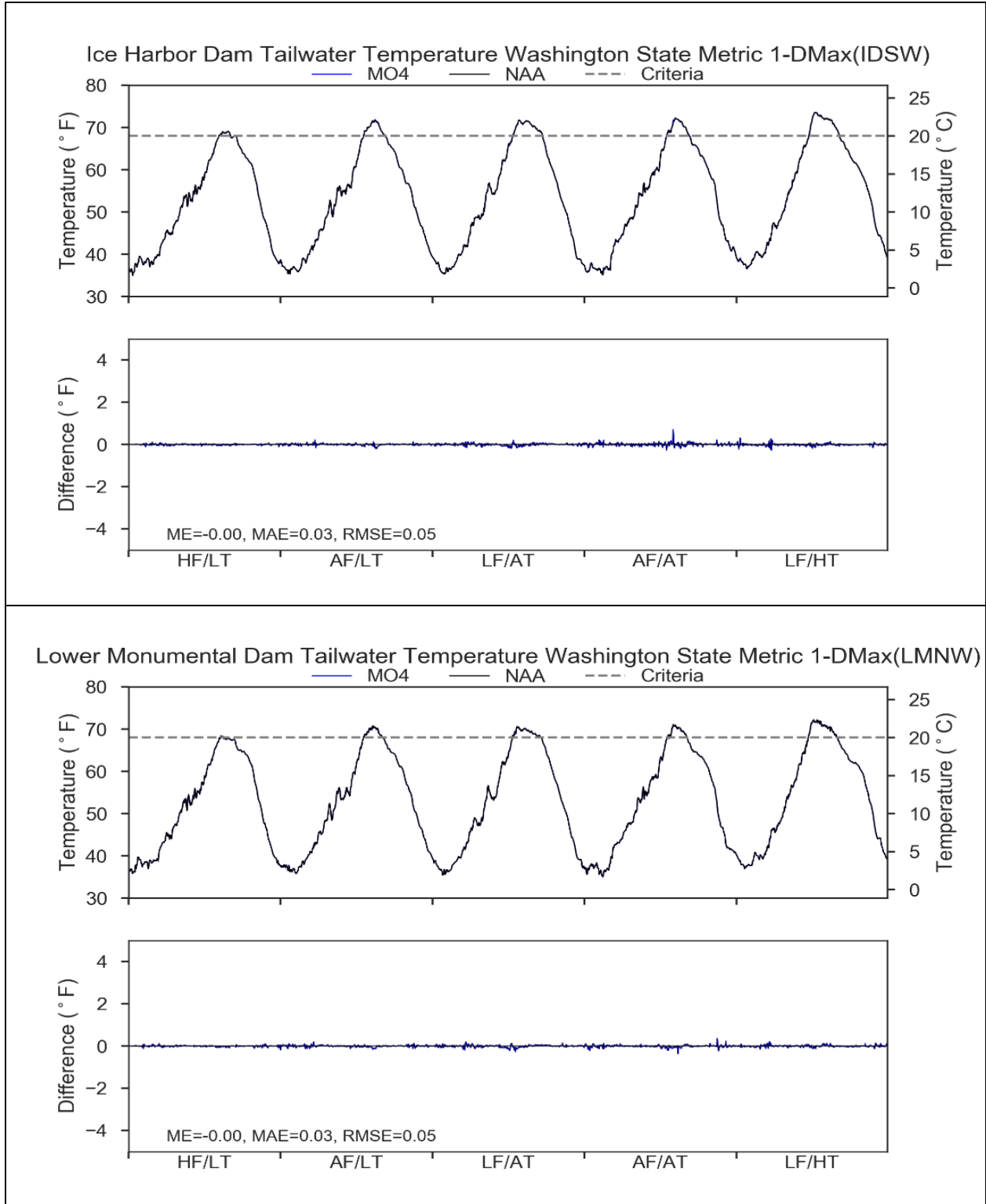
6211 **7.2.1.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
6212 **Reservoirs**

6213 Modeled tailwater temperatures at the four lower Snake River dams would be very similar
6214 under MO4 and No Action Alternative (Figure 7-26. and Figure 7-27.) as well. The differences
6215 that would occur are expected to be less than 0.5 degree Fahrenheit, which is within the margin
6216 of error for the model. This suggests that water temperatures are not sensitive to increased
6217 spill on the lower Snake River, as called for in MO4.



6218
 6219
 6220
 6221

Figure 7-26. Modeled Tailwater Temperatures for Multiple Objective Alternative 4 and No Action Alternative at Lower Granite and Little Goose Dams Under a 5-year Range of River and Meteorological Conditions



6222
 6223
 6224
 6225

Figure 7-27. Modeled Tailwater Temperatures for Multiple Objective Alternative 4 and No Action Alternative at Lower Monumental and Ice Harbor Dams Under a 5-year Range of River and Meteorological Conditions

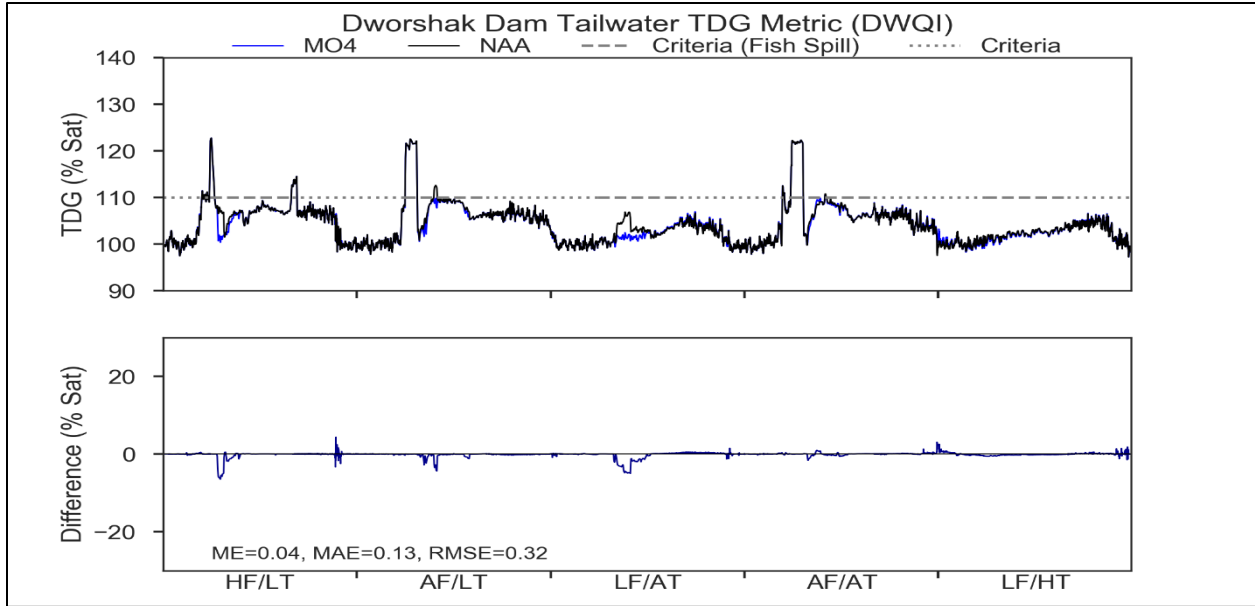
6226 **7.2.2 Total Dissolved Gas**

6227 There are four measures in MO4 that would modify fish passage spill operations in the lower
6228 Snake River; no fish spill operations are included in MO4 for Dworshak Dam. The *Spill to 125%*
6229 *TDG* measure increases the tailwater gas cap at all four lower Snake River projects from 120
6230 percent to 125 percent when sufficient flow is available. This operational measure does not call
6231 on additional upstream storage to meet the 125 percent TDG target when total river flows are
6232 low. To implement this measure, a change in the State water quality standard from the baseline
6233 No Action Alternative would be required⁴. Results from this measure, as shown in the sections
6234 below, are compared to the 2016 water quality standards and the No Action Alternative
6235 standard to make comparisons among all MO measures easier. The *Spill to 125%* TDG measure
6236 extends the implementation of juvenile fish passage spill operations by 1 month as compared
6237 to the No Action Alternative, with fish spill under MO4 running from March through August.
6238 Structural measure *Spillway Weir Notch Inserts* calls for the modification of one existing
6239 spillway weir, with a notch gate, at each lower Snake River dam, while operational measure,
6240 *Spill for Adult Steelhead*, calls for around 2 kcfs of spill through these notch gates to increase
6241 adult steelhead survival from October 1 to November 31.

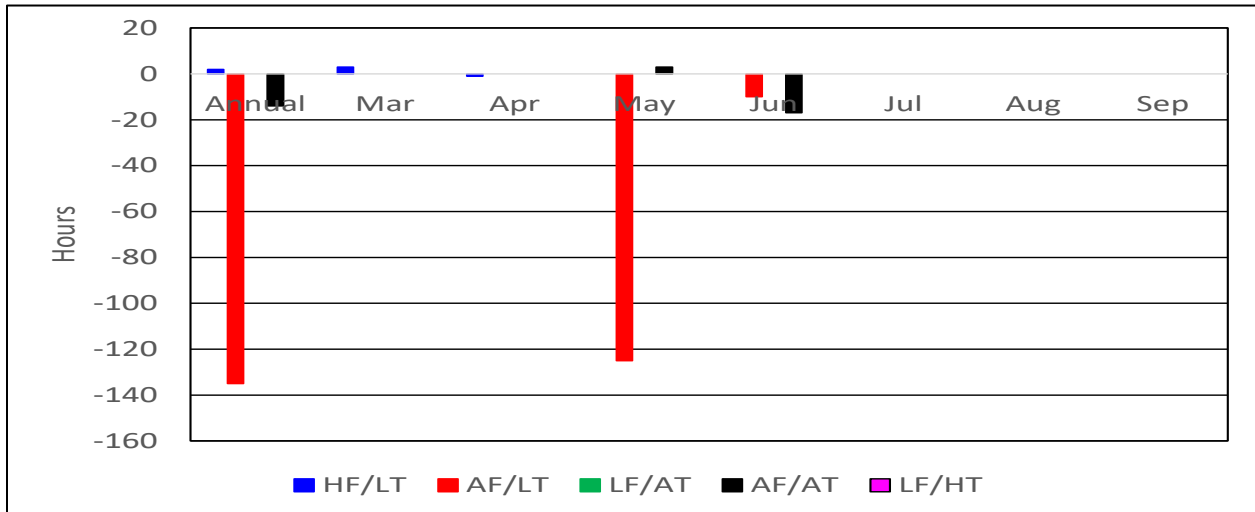
6242 **7.2.2.1 Dworshak Dam and Reservoir**

6243 TDG below Dworshak Dam under MO4 would be very similar to the No Action Alternative
6244 model results (Figure 7-28.), with a few notable exceptions. First, there would be 135 fewer
6245 hours during late May and early June of an AF/LT year when the TDG would exceed 110 percent
6246 (Figure 7-29.). Second, there are two additional periods when the TDG is already less than 110
6247 percent under No Action Alternative, but would be even lower under MO4 for an extended
6248 period of time. The one instance would occur during April of a HF/LT year when the TDG would
6249 be approximately 6 percent less for about 300 hours during April. The second instance would
6250 occur during May and June of a LF/AT year when there would be over 1,300 hours when the
6251 average TDG would be 2.6 percent less during MO4, but the difference could be as high as 5
6252 percent for several days (Figure 7-28.).

⁴ Washington and Oregon are currently undergoing standard revision to potentially revise the standards for TDG in the four lower Snake and four lower Columbia River dams.



6253
 6254 **Figure 7-28. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4 and**
 6255 **No Action Alternative at Dworshak Dam Under a 5-year Range of River and Meteorological**
 6256 **Conditions**

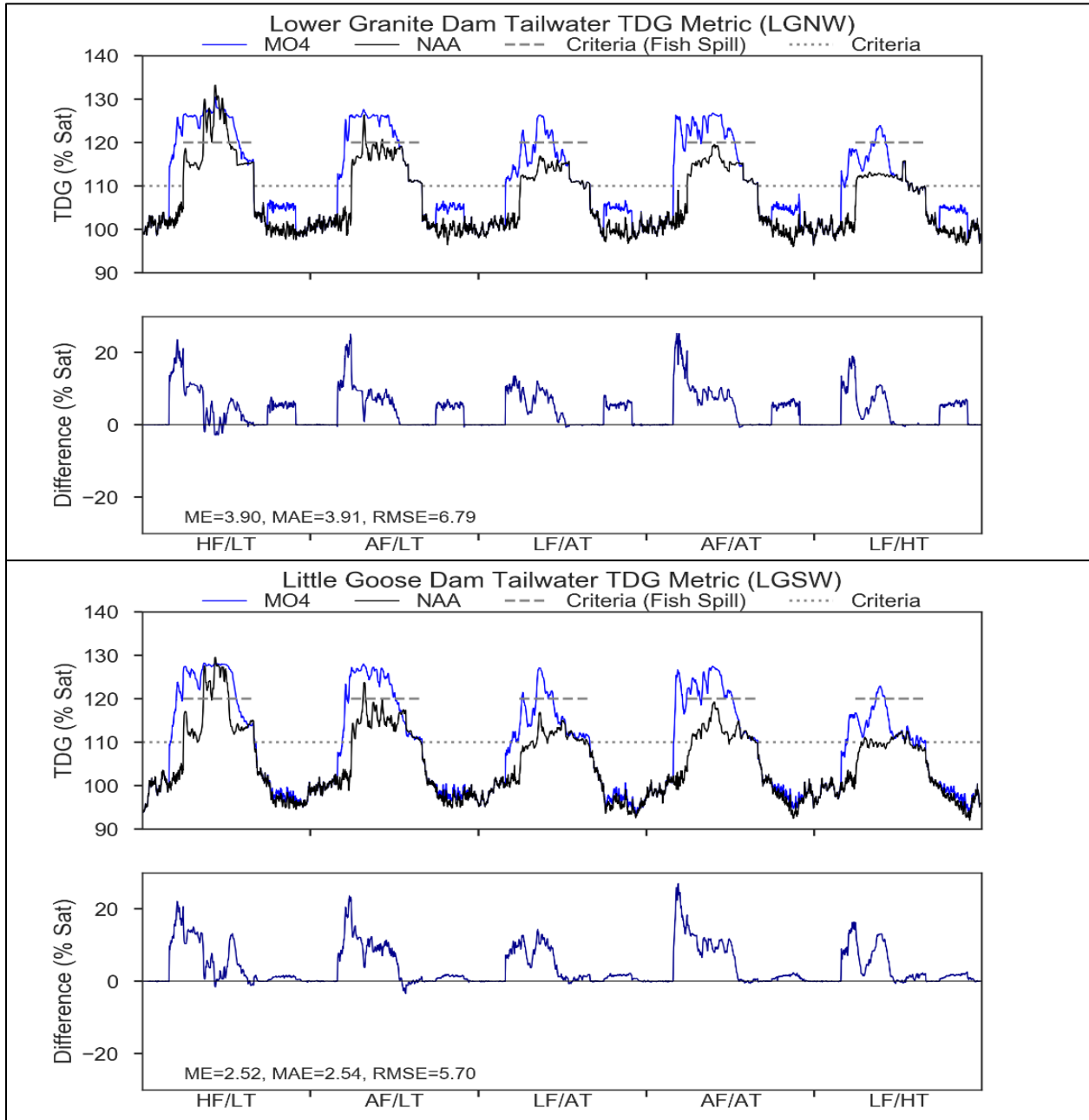


6257
 6258 **Figure 7-29. Difference in the Number of Hours each Year when Total Dissolved Gas Would**
 6259 **Violate Idaho's 110 percent Water Quality Standard at the Dworshak Dam Tailwater Fixed**
 6260 **Monitoring Station, for Each Flow/Temperature Condition, Under Multiple Objective**
 6261 **Alternative 4 and No Action Alternative**

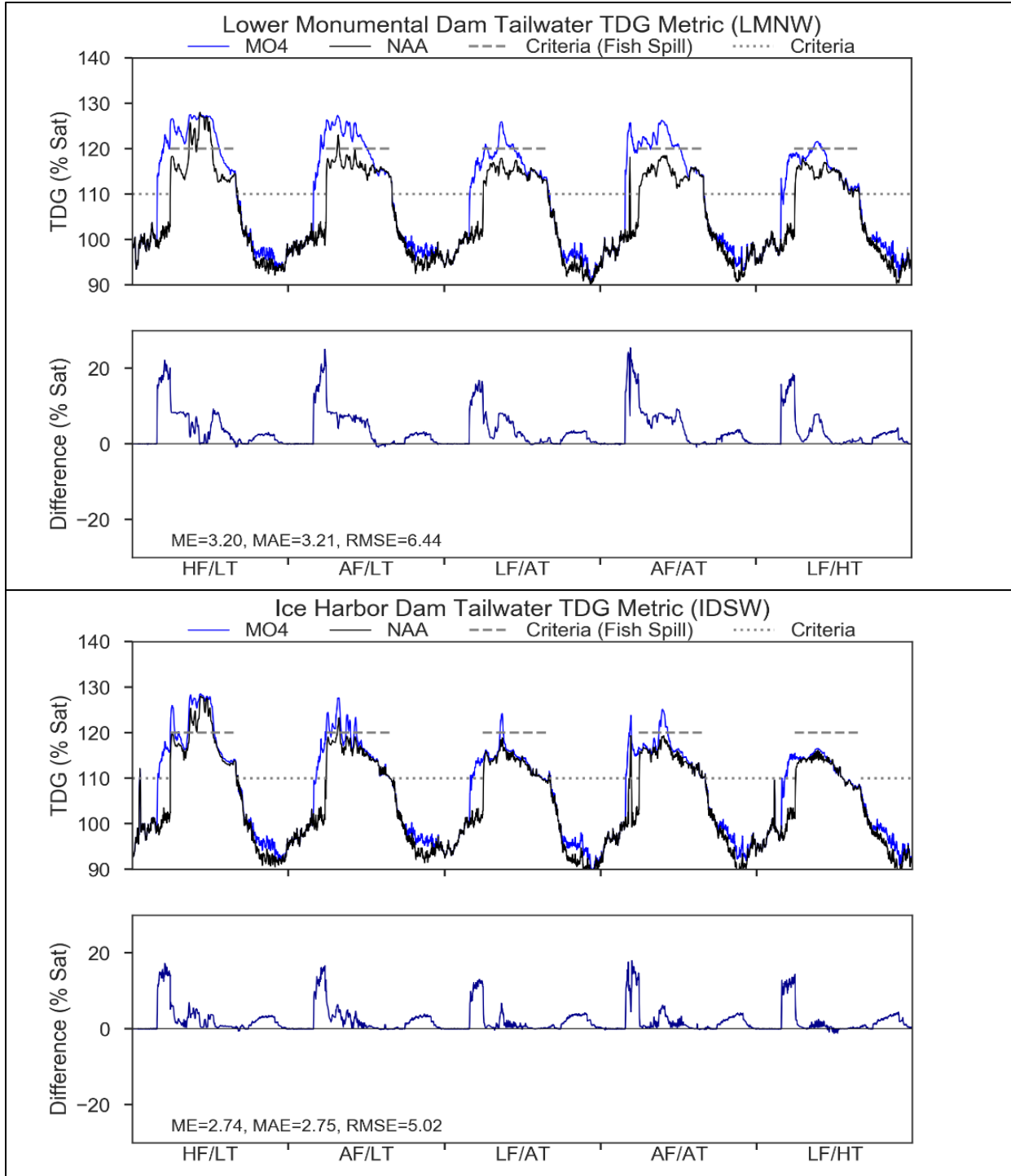
6262 **7.2.2.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
 6263 **Reservoirs**

6264 Tailwater TDG would increase at the four lower Snake River projects under MO4 because the
 6265 gas cap would be 125 percent rather than the 120 percent considered for the No Action
 6266 Alternative, and fish spill would begin March 1 instead of April 1 (Figure 7-30. and Figure 7-31.).

6267 The 125 percent TDG target would be achievable in the high-flow and average-flow years, but
 6268 less achievable in the low-flow years. This is because in the low-flow years there is not enough
 6269 total river flow to meet both minimum hydropower generation and spill enough water to reach
 6270 the 125 percent TDG target. A small increase in TDG would also be expected in the fall due to
 6271 spill for adult steelhead migration. This increase would be minimal and well below state water
 6272 quality standards for TDG.



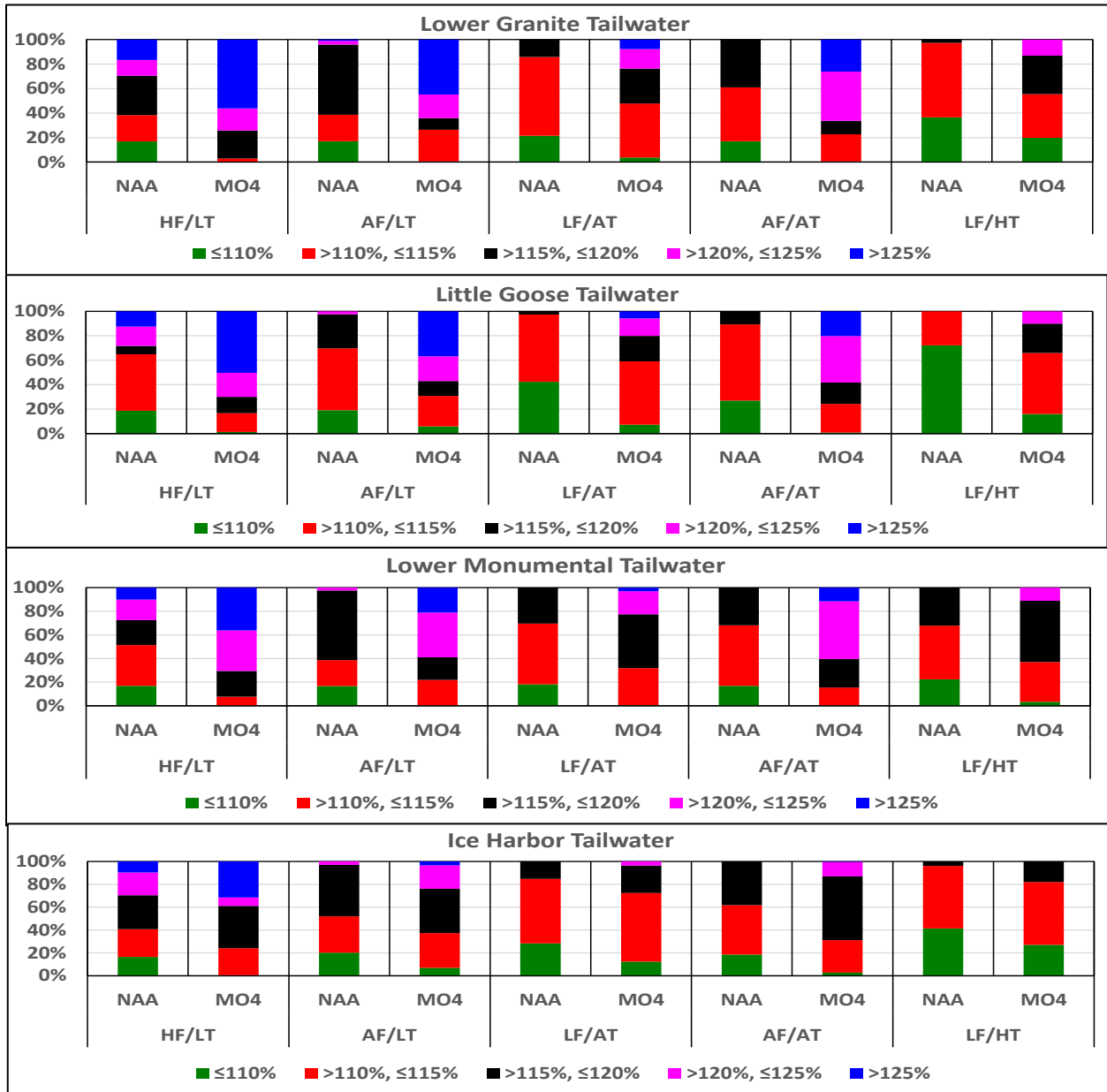
6273 **Figure 7-30. Modeled Tailwater Total Dissolved Gas for the Multiple Objective Alternative 4**
 6274 **and No Action Alternative at Lower Granite and Little Goose Dams Under a 5-year Range of**
 6275 **River and Meteorological Conditions**
 6276



6277
 6278 **Figure 7-31. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4 and**
 6279 **No Action Alternative at Lower Monumental and Ice Harbor Dams Under a 5-year Range of**
 6280 **River and Meteorological Conditions**

6281 Since the number of days when fish spill would occur increases from 153 to 184, and the gas
 6282 cap increases from 120 to 125 percent under MO4, the comparison of tailwater TDG under
 6283 MO4 relative to No Action Alternative is presented in two ways. First, the frequency

6284 distributions of March through August TDG for selected intervals for both alternatives is shown
 6285 in Figure 7-32.. The general pattern is that the percentage of time when TDG would be less than
 6286 115 percent is higher under the No Action Alternative, and the percentage of time when it is
 6287 greater than 120 percent is higher under MO4. For example, during HF/LT conditions at Lower
 6288 Granite Dam, 38 percent of the data would be less than 115 percent TDG under the No Action
 6289 Alternative, but only 3 percent would be less than this value under MO4. There would also
 6290 typically be a higher percentage of values greater than 120 percent during high flows, followed
 6291 by average flows, and then low flows under MO4.



6292
 6293 **Figure 7-32. No Action Alternative and Multiple Objective Alternative 4 March through**
 6294 **August Frequency Distributions for Selected Tailwater Total Dissolved Gas Intervals at the**
 6295 **Four Lower Snake River Projects**

6296 A further evaluation of the differences between the No Action Alternative and MO4 was
 6297 completed by comparing tailwater TDG to the current and proposed criteria on a monthly basis
 6298 (Table 7-1.). Changes in the number of days that TDG would be greater than the 110 percent
 6299 March standard and the 120 percent April through August waiver if MO4 is implemented are
 6300 shown in the column identified as "Curr." The difference in the number of days that the
 6301 proposed 125 percent criteria would be exceeded if MO4 is implemented compared to the No
 6302 Action Alternative are shown in the column labeled "Prop." Several trends are apparent in the
 6303 table. First, the number of days when the 110 percent criteria would be exceeded increases in
 6304 most instances simply because the spill cap would be increased to 125 percent under MO4.
 6305 Second, the largest changes occur in the March through May/June period at all of the projects
 6306 and for most flow/temperature conditions. This is related to the higher river flow during those
 6307 months since there are fewer changes, and in several cases, no change during July/August and
 6308 low-flow conditions. Third, changes in the number of daily exceedances would be lower at Ice
 6309 Harbor Dam than at the three upstream projects.

6310 **Table 7-1. Changes in the Number of Days Total Dissolved Gas Would be Greater or Less Than**
 6311 **the 2016 Tailwater Criteria Under Multiple Objective Alternative 4 Relative to No Action**
 6312 **Alternative**

	Flow and Air Temperature Conditions									
	HF/LT		AF/LT		LF/AT		AF/AT		LF/HT	
	Curr	Prop	Curr	Prop	Curr	Prop	Curr	Prop	Curr	Prop
Lower Granite										
March	30	4	30	7	31	0	30	11	30	0
April	30	30	24	27	6	0	29	3	0	0
May	13	14	30	27	26	15	31	23	22	0
June	1	8	28	19	12	0	30	13	4	0
July	21	15	11	0	0	0	11	0	0	0
August	0	0	0	0	0	0	0	0	0	0
Little Goose										
March	29	1	21	5	20	0	31	8	0	0
April	30	24	25	30	3	0	27	0	0	0
May	13	20	31	22	25	11	30	19	16	0
June	1	10	30	12	10	0	29	12	3	0
July	17	14	3	0	0	0	7	0	0	0
August	0	0	0	0	0	0	0	0	0	0
Lower Monumental										
March	31	0	30	1	31	0	28	4	29	0
April	30	9	26	24	6	0	29	0	0	0
May	16	18	31	11	26	7	31	14	18	0
June	1	12	30	4	13	0	30	5	4	0
July	15	9	3	0	0	0	6	0	0	0
August	0	0	0	0	0	0	0	0	0	0

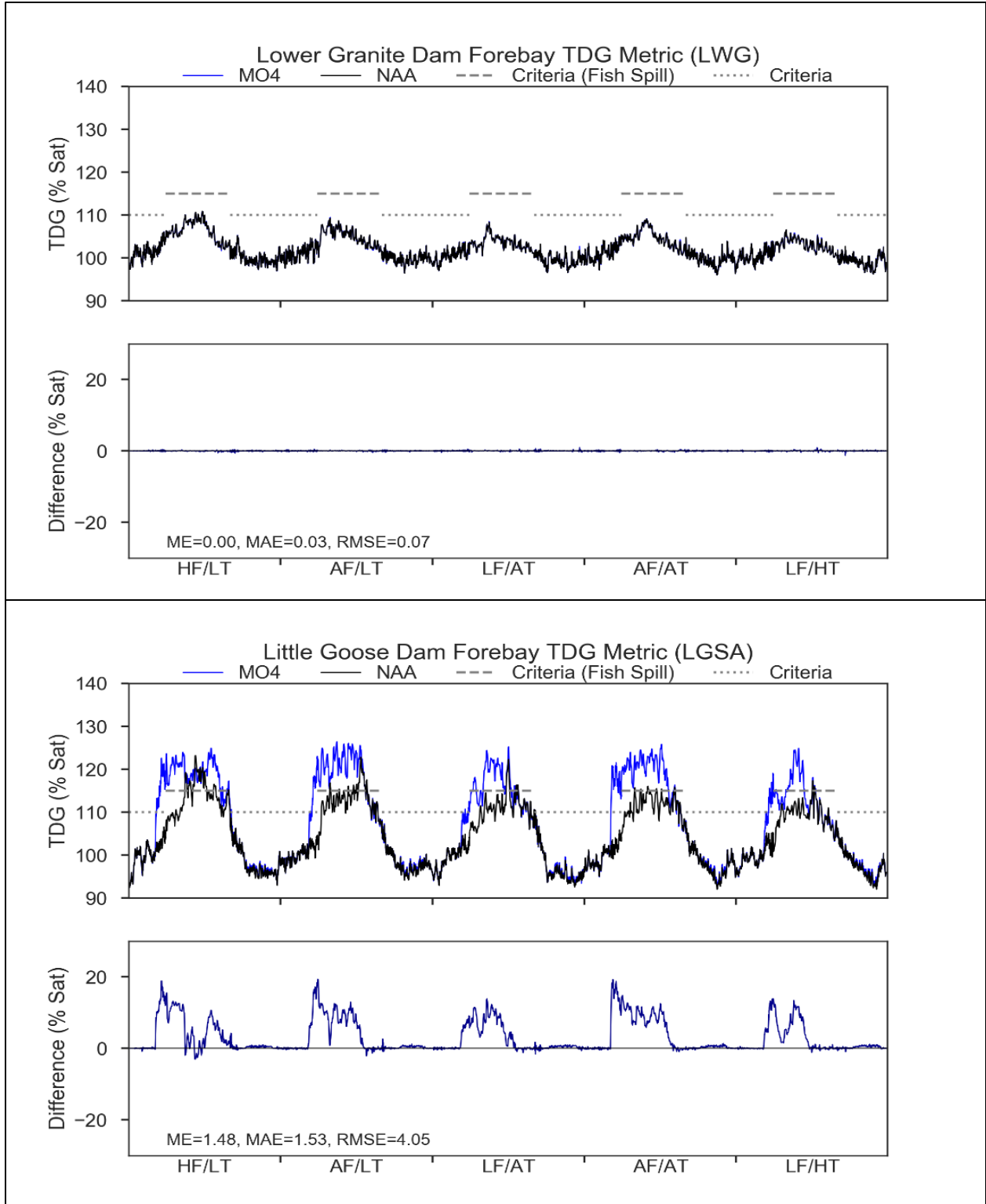
Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

	Flow and Air Temperature Conditions									
	HF/LT		AF/LT		LF/AT		AF/AT		LF/HT	
	Curr	Prop	Curr	Prop	Curr	Prop	Curr	Prop	Curr	Prop
Ice Harbor										
March	30	0	21	0	28	0	27	0	26	0
April	11	4	19	7	0	0	0	0	0	0
May	3	17	14	0	7	0	14	2	0	0
June	0	14	5	0	0	0	6	0	0	0
July	3	6	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0

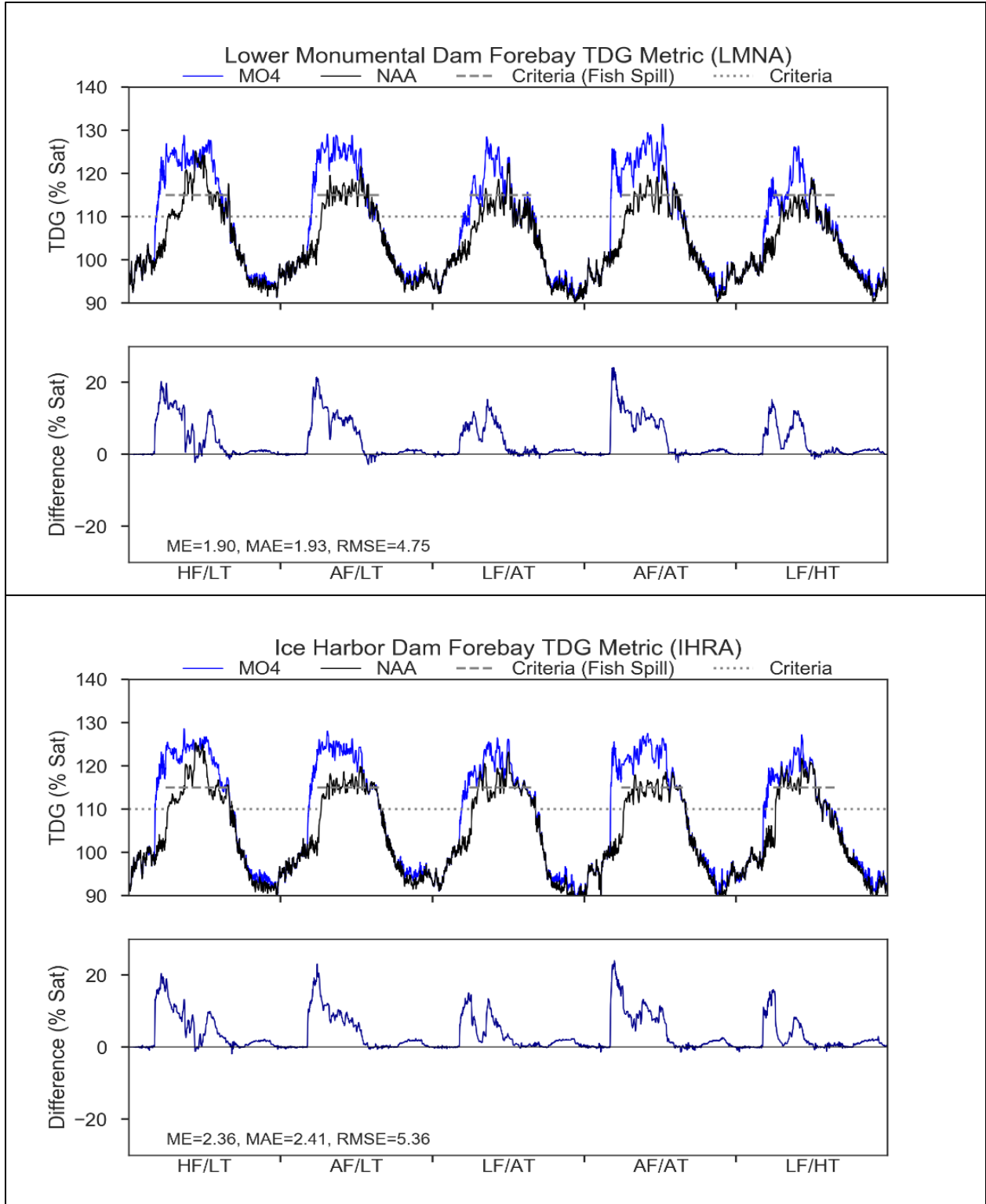
6313 Note: Curr = Change in the number of days TDG would be greater than 110 percent during March and greater than
6314 120 percent from April through August if MO4 was implemented when compared to No Action Alternative
6315 operations. Prop = Change in the number of days TDG would be greater than 125 percent between March through
6316 August if MO4 was implemented when compared to the No Action Alternative.

6317 Since tailwater TDG would be increased to 125 percent under MO4, downstream forebay TDG
6318 would also increase at the three downstream lower Snake River projects when compared to the
6319 No Action Alternative (Figure 7-33. and Figure 7-34.). Lower Granite Dam forebay TDG would
6320 remain less than 115 percent since there are no changes in upstream operations (Figure 7-35.).
6321 TDG at the three remaining forebay locations would reach maximum values ranging from 126
6322 to 131 percent. The frequency of time when forebay TDG would be above 115 percent between
6323 March and August is very similar at Little Goose and Lower Monumental Dams. During LF/HT
6324 conditions this level of saturation would be surpassed about 26 percent of the time, increasing
6325 to almost 80 percent of the time during HF/LT conditions. During average flow conditions the
6326 115 percent criteria would be surpassed 62 to 72 percent of the time. The frequency of TDG
6327 greater than 115 percent under MO4 would be greater at the Ice Harbor Dam forebay. During
6328 LF/HT and LF/AT conditions 60 and 64 percent of the measurements would be above 115
6329 percent, respectively. During AF/AT and HF/LT conditions the frequencies would increase to 82
6330 and 86 percent of the time, respectively.

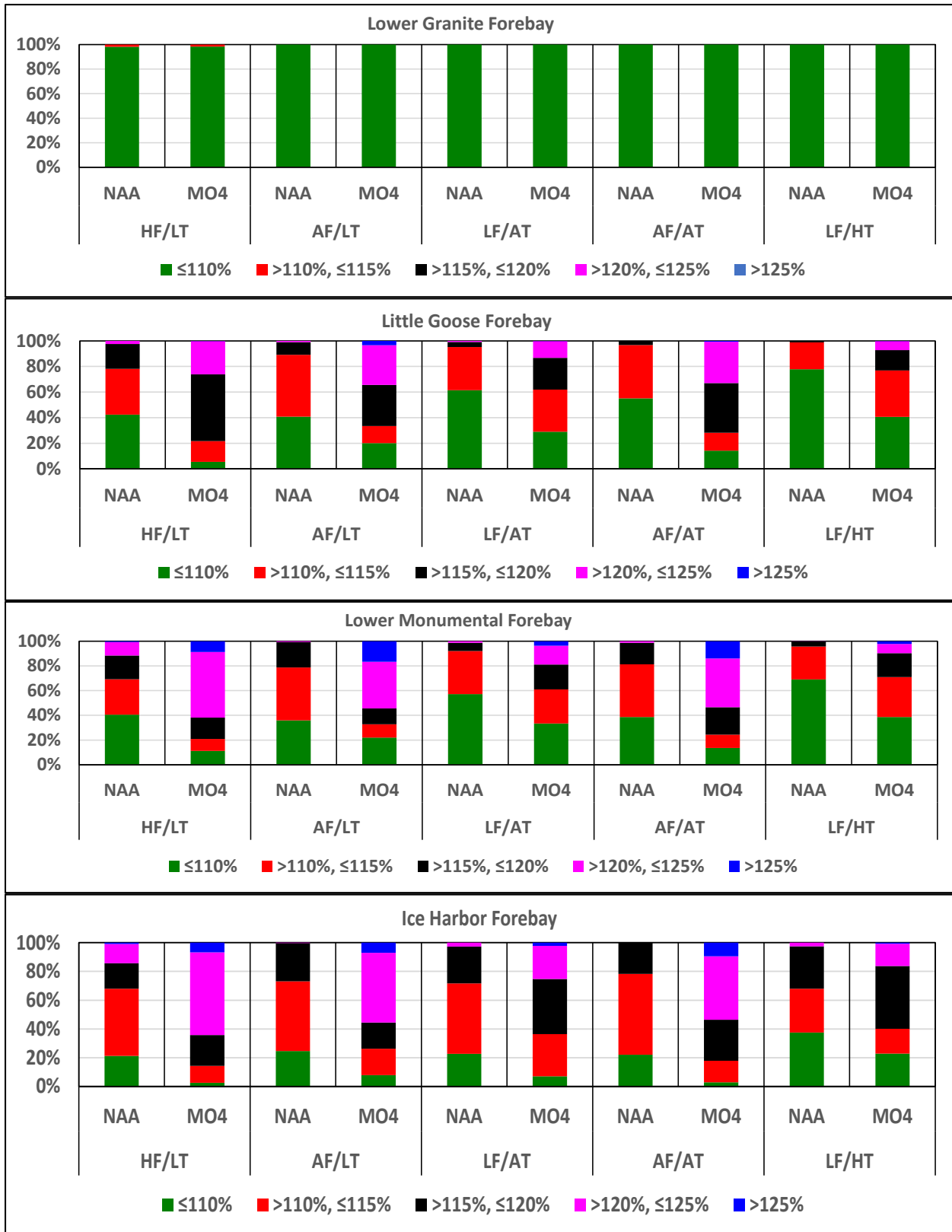
6331 A request to “eliminate forebay standards” would be made under MO4. Given this, a
6332 comparison between MO4 and No Action Alternative forebay TDG exceedances similar to the
6333 one made for the tailwater cannot be completed. However, a comparison to the 12-hour
6334 average 115 percent standard was made to show the changes in the number of days that
6335 standard would be exceeded if MO4 was implemented (Table 7-2.). As was the case for the
6336 tailwater stations, the largest changes occur between March and May and taper off through
6337 August regardless of the flow/temperature conditions.



6338
 6339 **Figure 7-33. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 4 and No**
 6340 **Action Alternative at Lower Granite and Little Goose Dams Under a 5-year Range of River and**
 6341 **Meteorological Conditions**



6342
 6343 **Figure 7-34. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 4 and No**
 6344 **Action Alternative at Lower Monumental and Ice Harbor Dams Under a 5-year Range of River**
 6345 **and Meteorological Conditions**



6346
 6347
 6348

Figure 7-35. No Action Alternative and Multiple Objective Alternative 4 March through August Frequency Distributions for Selected Forebay Total Dissolved Gas Intervals

6349 **Table 7-2. Change in the Number of days Total Dissolved Gas Would be Greater or Less Than**
6350 **the 2016 Forebay Criteria Under Multiple Objective Alternative 4 Relative to No Action**
6351 **Alternative**

	Flow and Air Temperature Conditions									
	HF/LT		AF/LT		LF/AT		AF/AT		LF/HT	
	Curr	Prop	Curr	Prop	Curr	Prop	Curr	Prop	Curr	Prop
Lower Granite										
March	0	0	0	0	0	0	0	0	0	0
April	0	-	0	-	0	-	0	-	0	-
May	0	-	0	-	0	-	0	-	0	-
June	0	-	0	-	0	-	0	-	0	-
July	0	-	0	-	0	-	0	-	0	-
August	0	-	0	-	0	-	0	-	0	-
Little Goose										
March	24	16	18	13	6	0	27	22	14	6
April	28	-	29	-	8	-	30	-	1	-
May	30	-	31	-	27	-	31	-	28	-
June	25	-	27	-	22	-	30	-	13	-
July	11	-	18	-	9	-	20	-	3	-
August	11	-	0	-	-1	-	2	-	0	-
Lower Monumental										
March	24	18	18	14	12	0	27	26	17	10
April	30	-	25	-	14	-	30	-	3	-
May	16	-	13	-	27	-	20	-	25	-
June	2	-	11	-	14	-	12	-	14	-
July	15	-	4	-	1	-	5	-	-1	-
August	8	-	0	-	1	-	2	-	0	-
Ice Harbor										
March	27	23	24	19	21	7	28	27	24	14
April	30	-	25	-	18	-	30	-	16	-
May	15	-	16	-	23	-	21	-	10	-
June	1	-	8	-	7	-	12	-	4	-
July	18	-	8	-	1	-	13	-	0	-
August	13	-	-1	-	1	-	1	-	0	-

6352 Note: Curr = Change in the number of days TDG would be greater than 110 percent during March and greater than
6353 115 percent from April through August if MO4 was implemented when compared to No Action Alternative
6354 operations Prop = Change in the number of days TDG would be greater than 115 percent during March if MO4 was
6355 implemented when compared to the No Action Alternative.

6356 **7.2.3 Other Physical, Chemical, and Biological Processes**

6357 **7.2.3.1 Dworshak Dam and Reservoir**

6358 The remaining water quality parameters considered for the No Action Alternative would not
6359 change if MO4 was implemented.

6360 **7.2.3.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
6361 **Reservoirs**

6362 The remaining water quality parameters considered for the No Action Alternative would not
6363 change if MO4 was implemented.

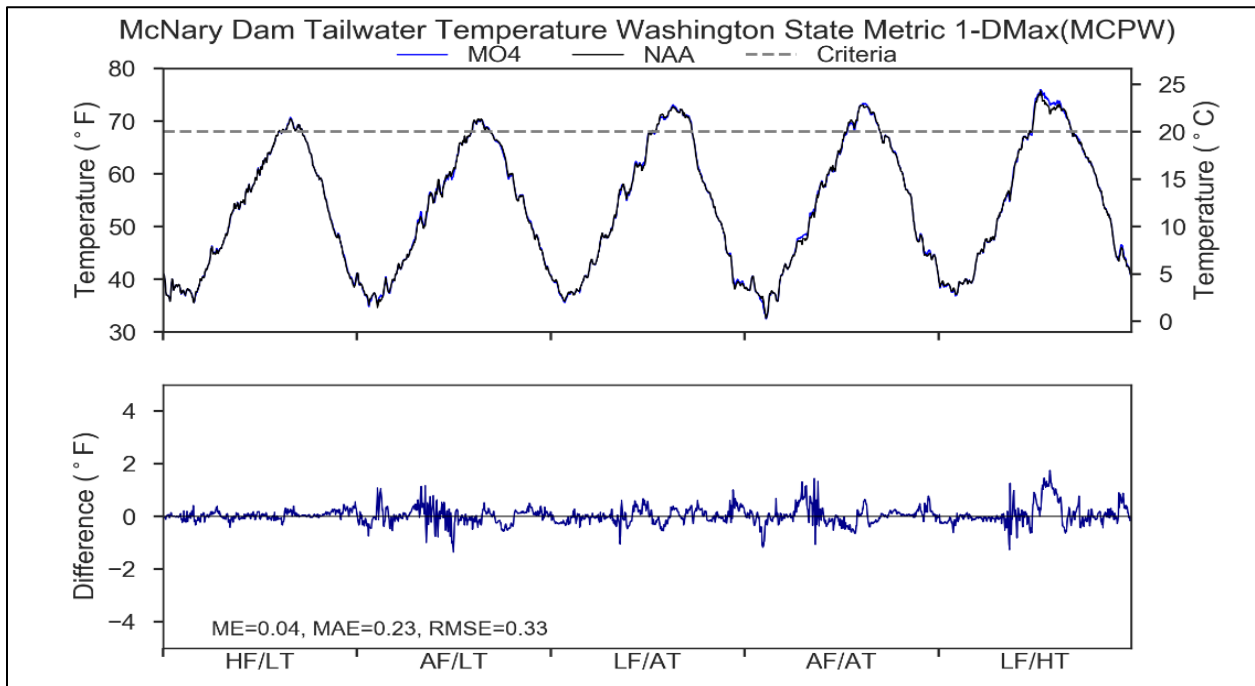
6364 **7.3 LOWER COLUMBIA RIVER**

6365 **7.3.1 Water Temperature**

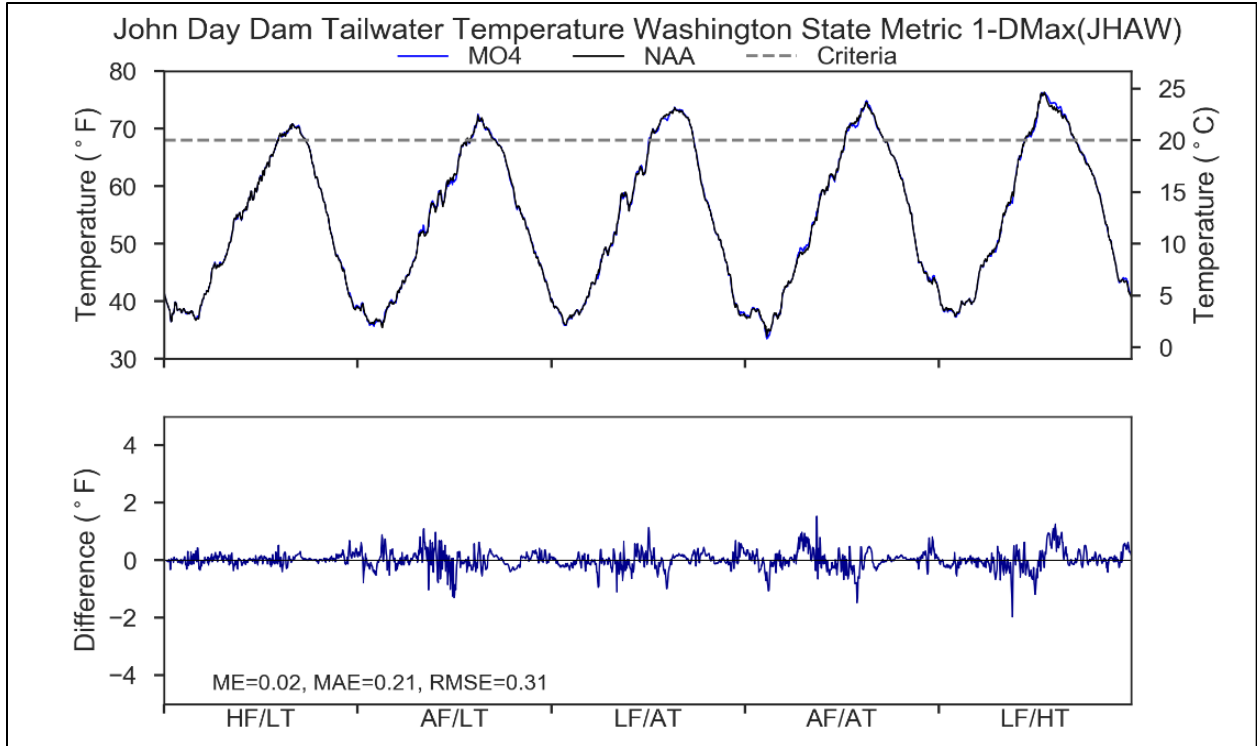
6366 There are no specific structural or operational measures in MO4 that are expected to influence
6367 water temperatures in the lower Columbia River. Details are provided below.

6368 **7.3.1.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

6369 The tailwater temperatures for MO4 at McNary, John Day, The Dalles, and Bonneville Dams
6370 were modeled under a 5-year range of river and meteorological conditions, and compared to
6371 the modeled results for the No Action Alternative (Figure 7-36. to Figure 7-39.). Just as with the
6372 No Action Alternative model results, MO4 model results show that tailwater temperatures can
6373 exceed 68°F at all four dams during any of the years and conditions presented, and maximum
6374 water temperatures and the frequency of water temperature violations of state water quality
6375 standards would be higher during a year when river flows are lower than normal and summer
6376 ambient air temperatures are higher (as in LF/HT). The average frequency of water temperature
6377 violations of the state water quality standards would be nearly identical for the No Action
6378 Alternative and MO4 for all four lower Columbia River dams (Figure 7-40.), even with the
6379 *McNary Flow Target* measure in place.

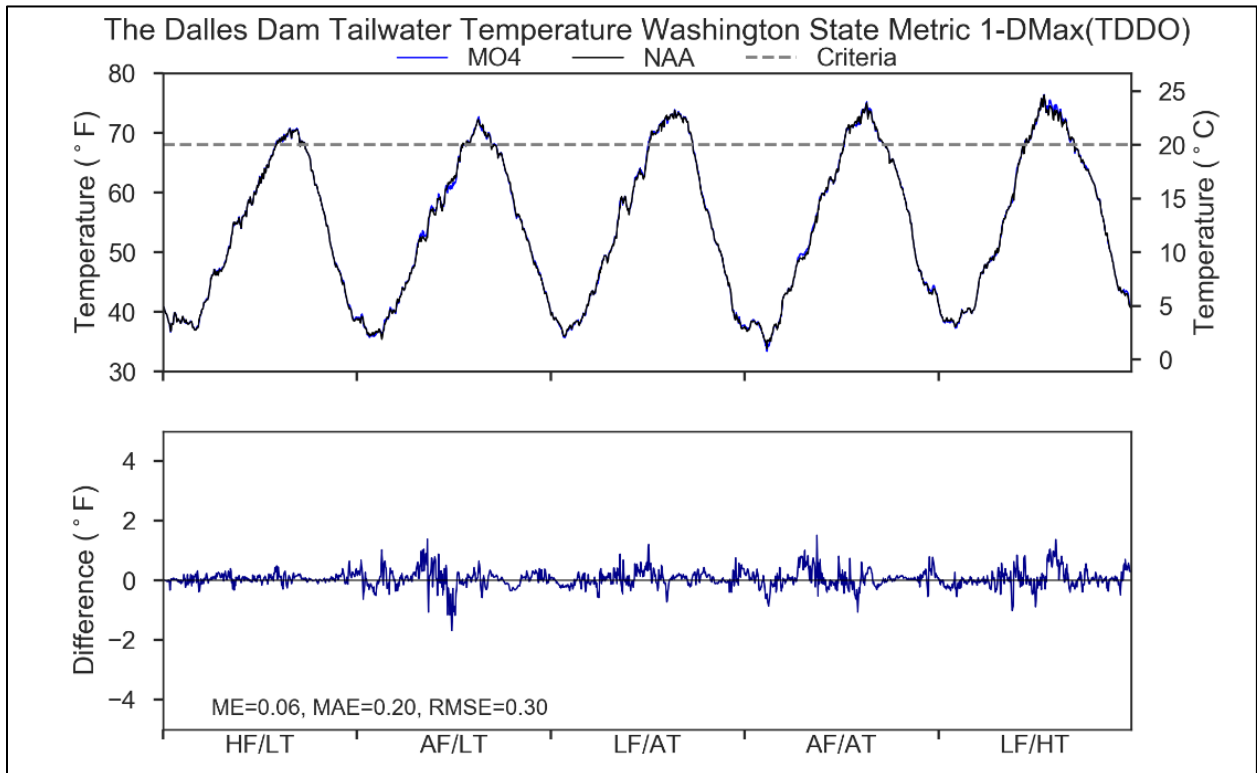


6380 **Figure 7-36. Modeled Tailwater Temperature for Multiple Objective Alternative 4 at McNary**
6381 **Dam Under a 5-year Range of River and Meteorological Conditions**
6382



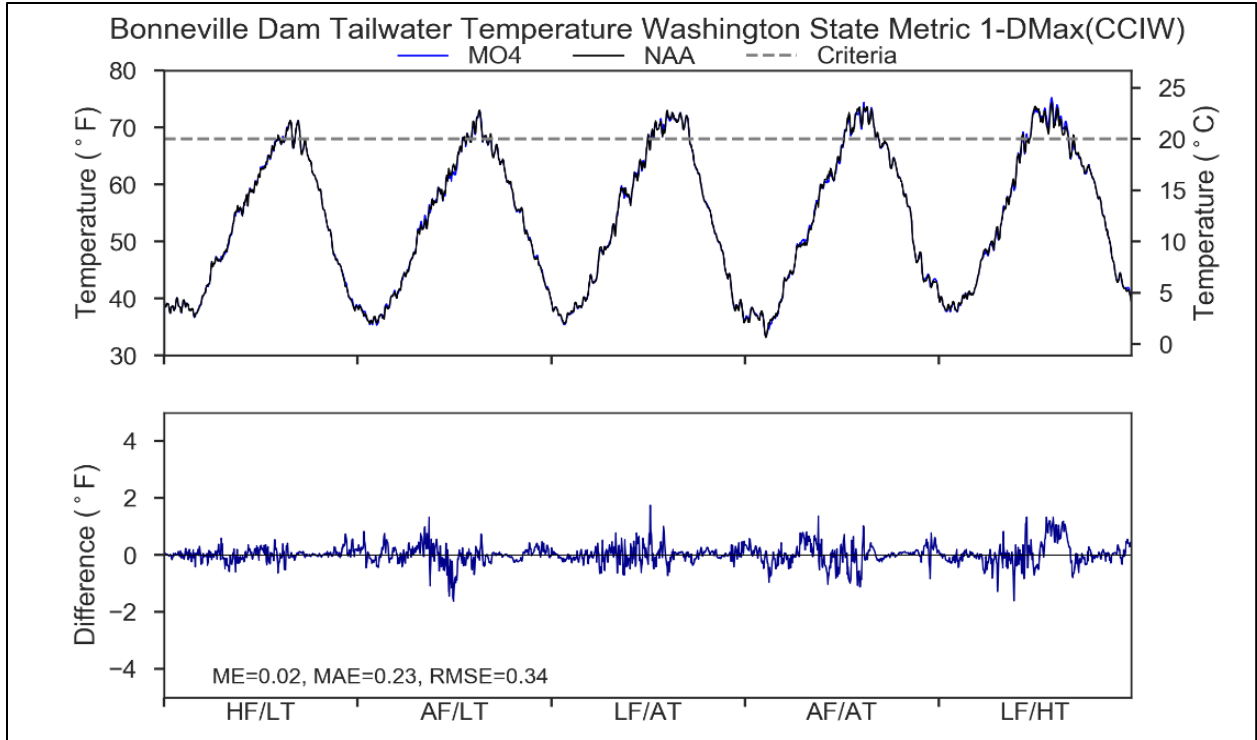
6383
 6384
 6385

Figure 7-37. Modeled Tailwater Temperature for Multiple Objective Alternative 4 at John Day Dam Under a 5-year Range of River and Meteorological Conditions

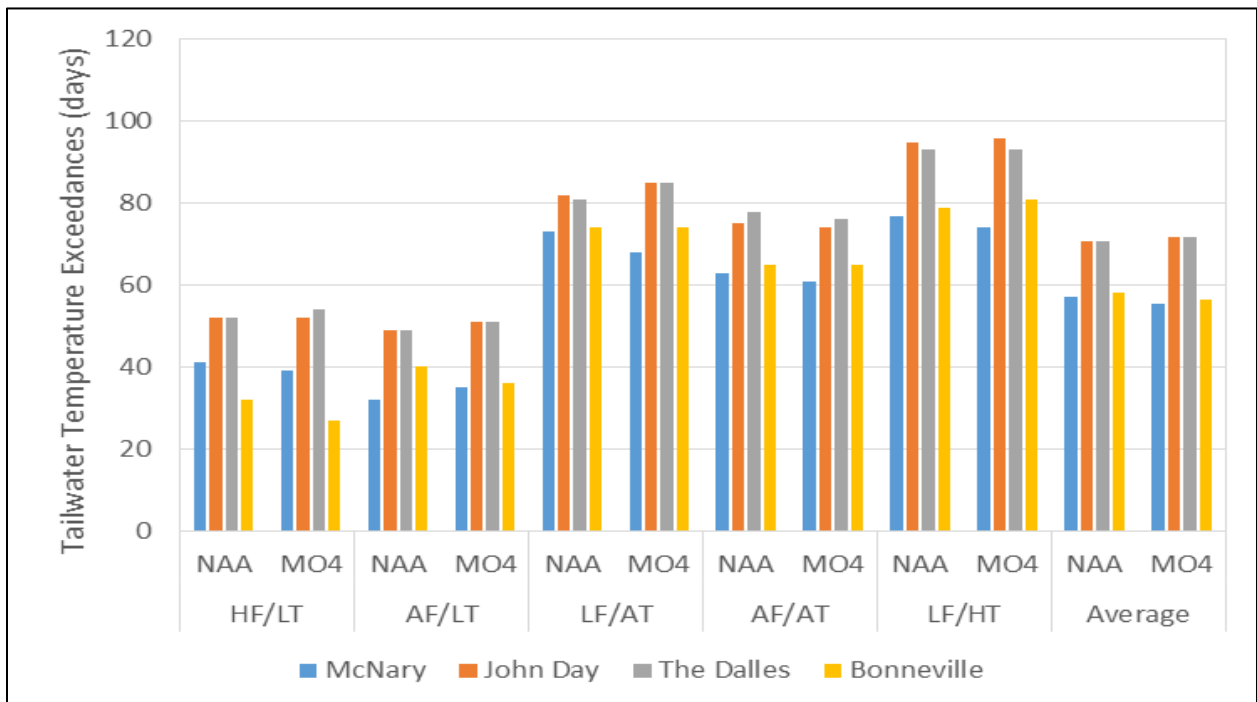


6386
 6387
 6388

Figure 7-38. Modeled Tailwater Temperature for Multiple Objective Alternative 4 at The Dalles Dam Under a 5-year Range of River and Meteorological Conditions



6389
 6390 **Figure 7-39. Modeled Tailwater Temperature for Multiple Objective Alternative 4 at**
 6391 **Bonneville Dam Under a 5-year Range of River and Meteorological Conditions**



6392
 6393 **Figure 7-40. Frequency of Modeled Tailwater Temperature Violations of State Water Quality**
 6394 **Standards for Multiple Objective Alternative 4 and No Action Alternative at McNary, John**
 6395 **Day, The Dalles, and Bonneville Dams Under a 5-year Range of River and Meteorological**
 6396 **Conditions**

6397 **7.3.2 Total Dissolved Gas**

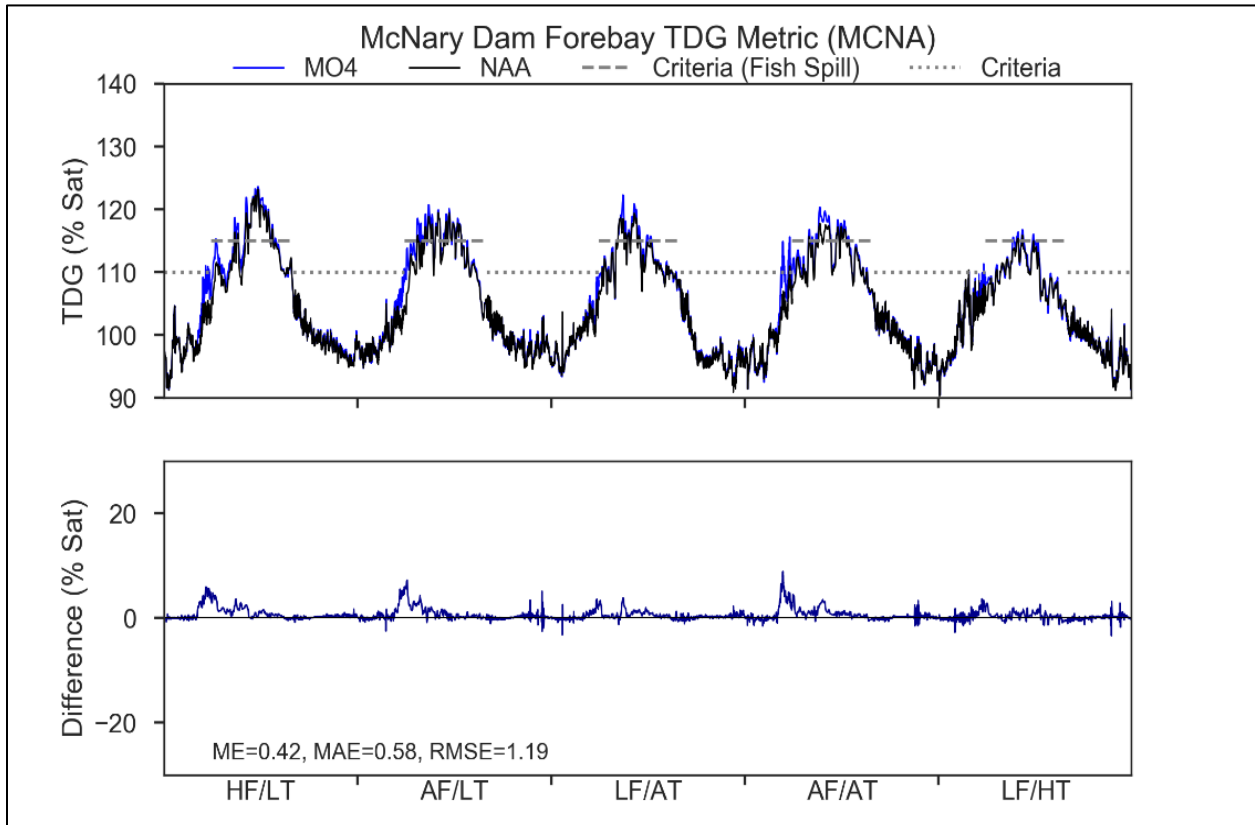
6398 The *Spill to 125%* TDG measure sets juvenile fish passage spill to not exceed 125 percent TDG
6399 saturation, as measured at the tailrace, at all lower Columbia River projects from March 1 to
6400 August 31. Due to the earlier start of fish passage spill and the higher tailwater TDG target,
6401 MO4 model results show notable increases in forebay and tailwater TDG saturations and the
6402 frequency of violations of 2016 state TDG standards as compared to the No Action Alternative.
6403 Additionally, at McNary and John Day Dams, structural measure *Spillway Weir Notch Inserts*
6404 includes the addition of spillway weir notch gate inserts while the *Spill for Adult Steelhead*
6405 measure uses spill through existing surface passage structures from October 1 to November 30
6406 to address adult steelhead passage. These measures would result in higher TDG in the McNary
6407 and John Day Dam tailwaters. Details are described below.

6408 **7.3.2.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

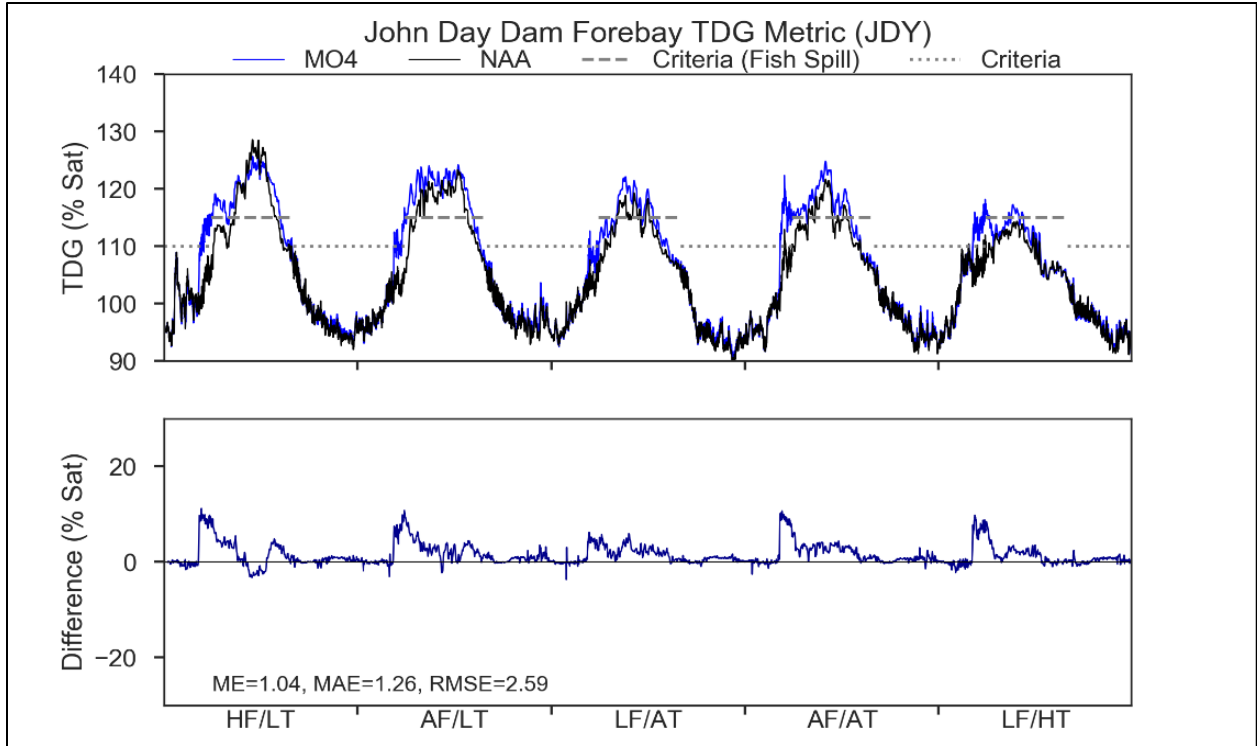
6409 Forebay TDG saturations for MO4 at McNary, John Day, The Dalles, and Bonneville Dams were
6410 modeled under a 5-year range of river and meteorological conditions, and compared to the
6411 modeled results for the No Action Alternative (Figure 7-41. to Figure 7-44.). The MO4 model
6412 results show that forebay TDG saturations can exceed the 115 percent spill season TDG
6413 standard at all four dams during all of the years and conditions presented. Maximum forebay
6414 TDG saturation would be higher during a year when river flows were higher than normal (as in
6415 2011). Forebay TDG saturations would be higher in MO4 as compared to No Action Alternative
6416 for all four dams during spill season, and high TDG saturations would start earlier (beginning in
6417 March) due to the earlier fish spill start in MO4 as compared to the No Action Alternative.
6418 Generally, the frequency of 110% TDG exceedances outside of current fish passage spill seasons
6419 would be greater under MO4 than the No Action Alternative, though not at all or only slightly
6420 greater for a small number dam/condition combinations (e.g., McNary and John Day under
6421 LF/AT conditions; Figure 7-45.). At all four dam forebays, the frequency of 115% TDG
6422 exceedances during current fish passage spill season would be greater under MO4 than the No
6423 Action Alternative under all modeled river and meteorological conditions (Figure 7-46.).

6424 Tailwater TDG saturations for MO4 at McNary, John Day, The Dalles, and Bonneville Dams can
6425 be found in Figure 7-47. to Figure 7-50.. The MO4 model results show that tailwater TDG
6426 saturations can exceed the 120 percent TDG standard at all four dams during all of the years
6427 and conditions presented. Maximum tailwater TDG saturation would be higher during a year
6428 when river flows were higher than normal and summer ambient air temperatures were lower
6429 (as in 2011). Tailwater TDG saturations would be higher in MO4 as compared to No Action
6430 Alternative for all four dams during spill season, and high TDG saturations would start earlier
6431 (beginning of March) due to the earlier fish spill start in MO4 as compared to the No Action
6432 Alternative. Generally, the frequency of 110% TDG exceedances outside of current fish passage
6433 spill seasons would be greater under MO4 than the No Action Alternative, except at Bonneville,
6434 where TDG is expected to exceed 110% at nearly all times for both alternatives (Figure 7-51.).
6435 During the current fish passage spill season, the frequency of 120% TDG exceedances at all four
6436 dams would be substantially greater under MO4 than the No Action Alternative under all

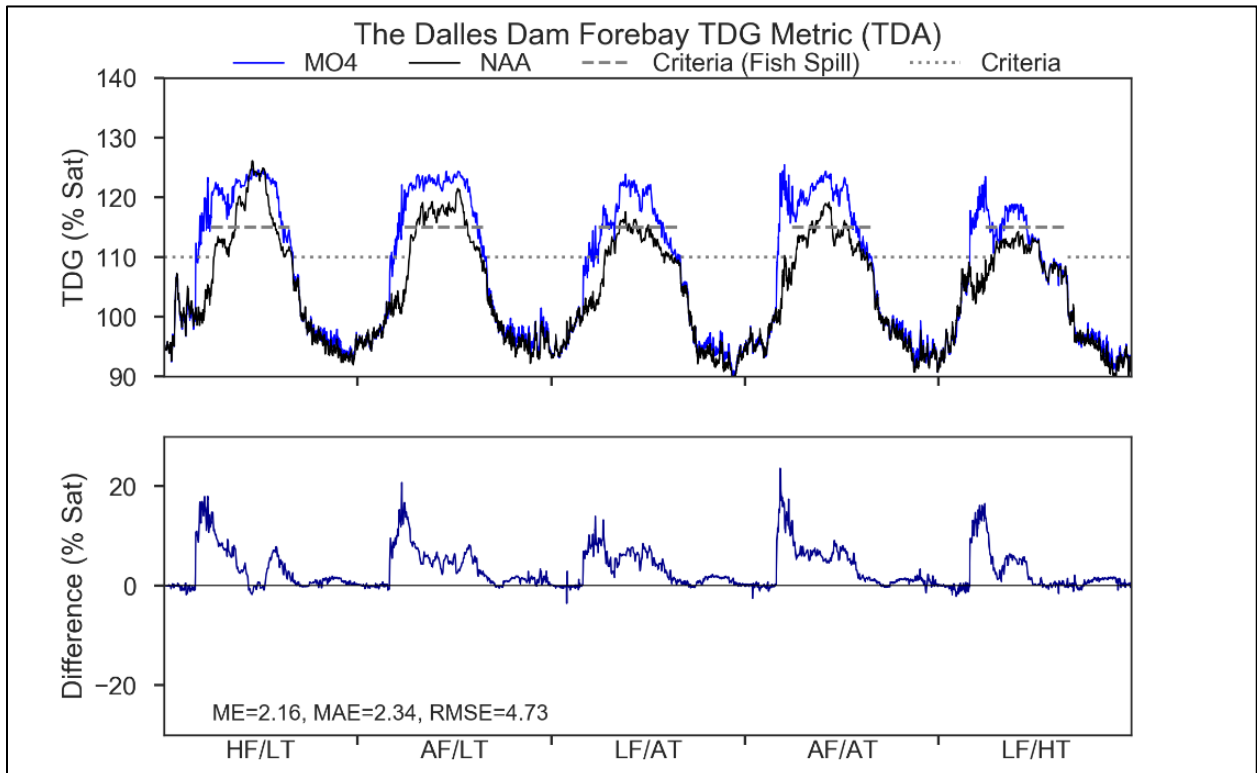
6437 modeled river and meteorological conditions (Figure 7-52.). Additionally, at McNary and John
 6438 Day, structural measure *Spillway Weir Notch Inserts* includes the addition of spillway weir notch
 6439 gate inserts while the *Spill for Adult Steelhead* measure uses spill through existing surface
 6440 passage structures from October 1 to November 30 to address adult steelhead passage. These
 6441 measures would result in significantly higher October and November TDG in the McNary
 6442 tailwater (Figure 7-47.), though the effect in the John Day Dam tailwater would be far less
 6443 pronounced (Figure 7-48.).



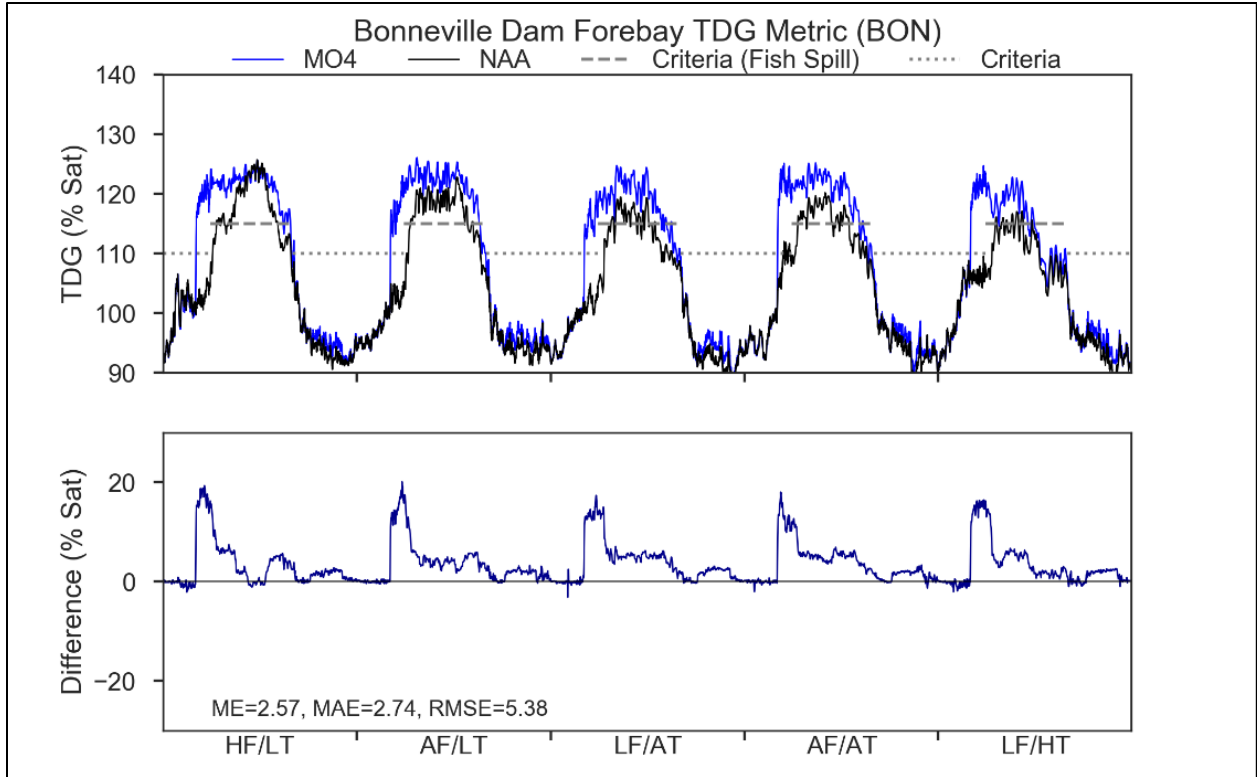
6444
 6445 **Figure 7-41. Modeled Forebay Total Dissolved Gas for the Multiple Objective Alternative 4 at**
 6446 **McNary Dam Under a 5-year Range of River and Meteorological Conditions**



6447
 6448 **Figure 7-42. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 4 at John**
 6449 **Day Dam Under a 5-year Range of River and Meteorological Conditions**

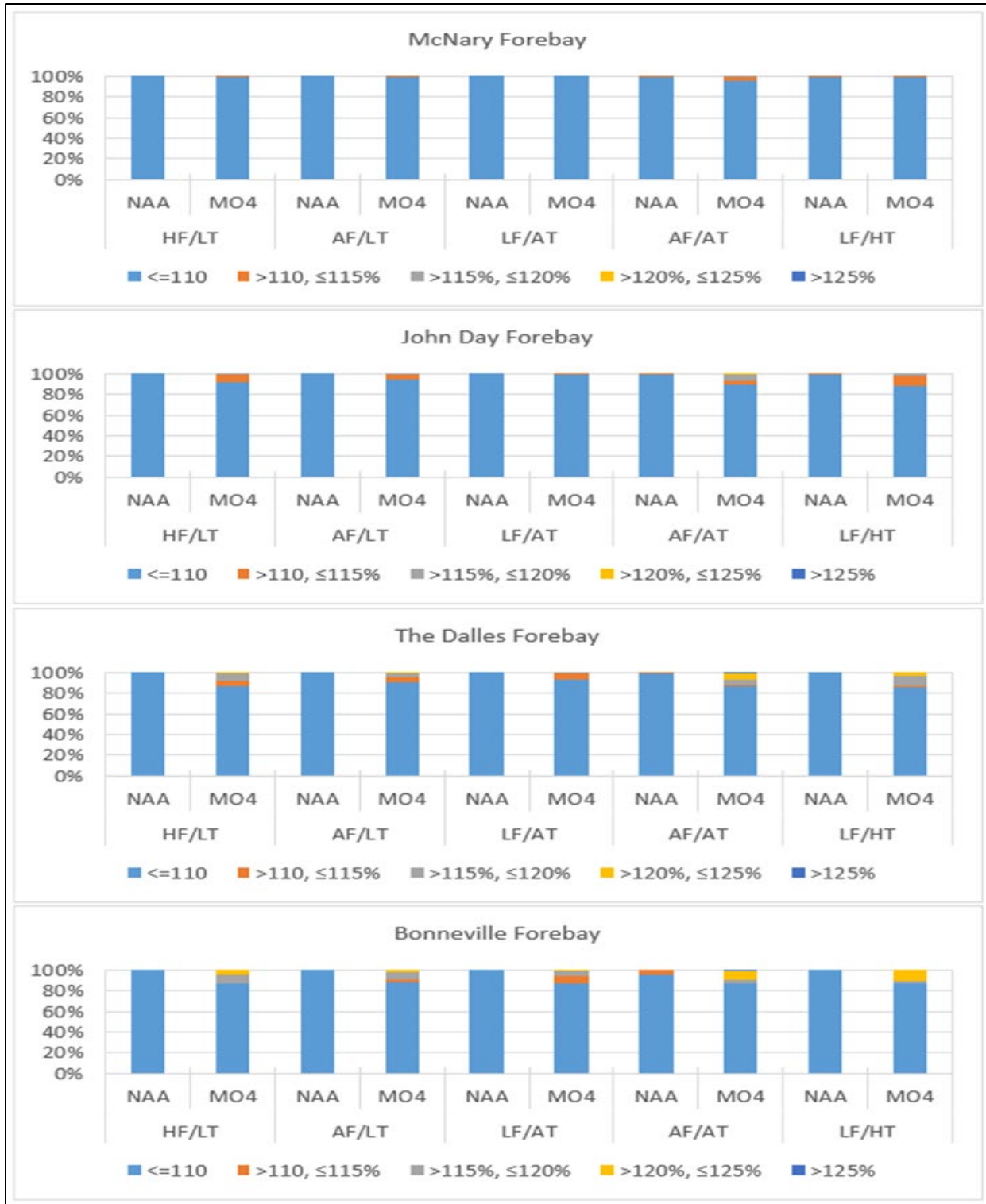


6450
 6451 **Figure 7-43. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 4 at The**
 6452 **Dalles Dam Under a 5-year Range of River and Meteorological Conditions**



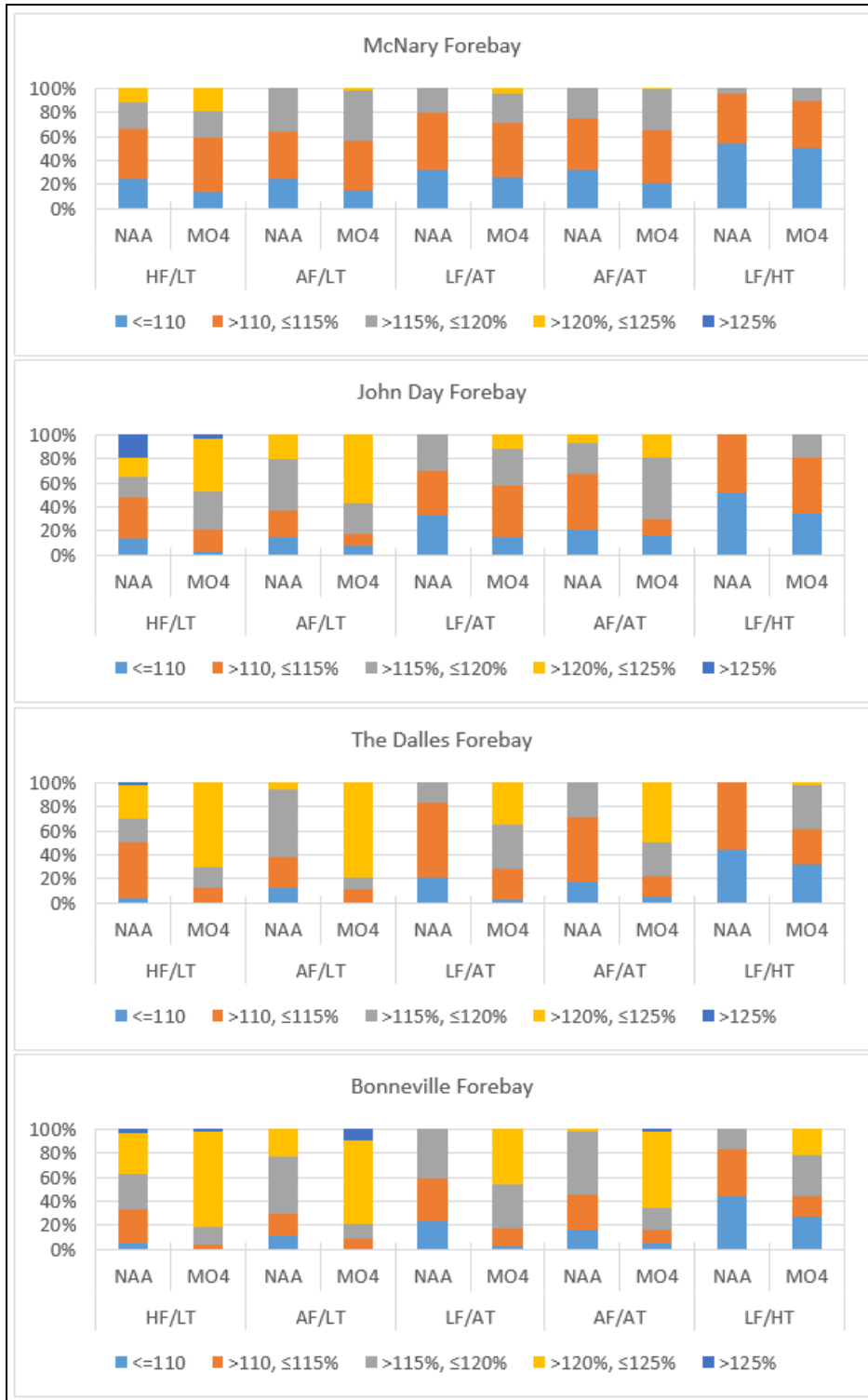
6453
6454
6455

Figure 7-44. Modeled Forebay Total Dissolved Gas for Multiple Objective Alternative 4 at Bonneville Dam Under a 5-year Range of River and Meteorological Conditions



6456
 6457 **Figure 7-45. Frequency of Modeled Forebay Total Dissolved Gas Outside of Current Fish**
 6458 **Passage Spill Season for Multiple Objective Alternative 4 and No Action Alternative at**
 6459 **McNary, John Day, The Dalles, and Bonneville Dams Under a 5-year Range of River and**
 6460 **Meteorological Conditions**

6461 Note: Current fish passage spill season is April 1 to August 31



6462

6463

6464

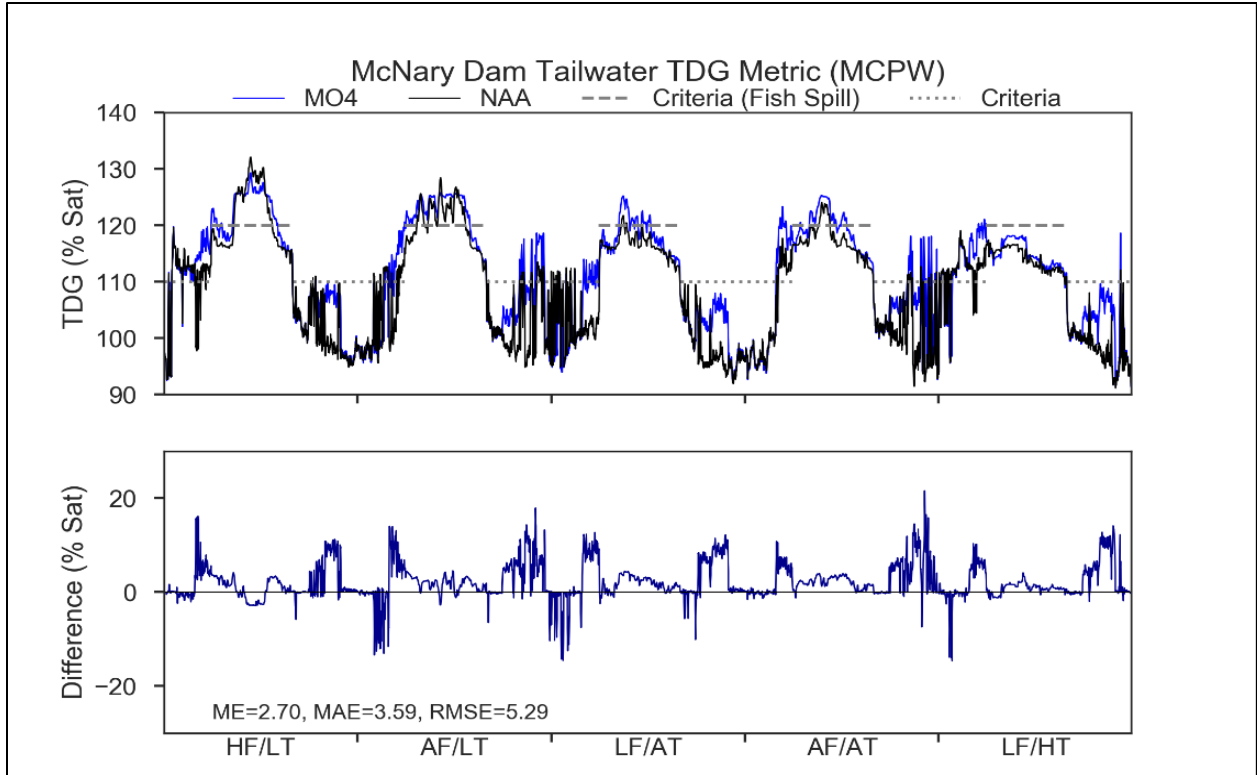
6465

6466

6467

Figure 7-46. Frequency of Modeled Forebay Total Dissolved Gas During Current Fish Passage Spill Season for Multiple Objective Alternative 4 and No Action Alternative at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-year Range of River and Meteorological Conditions

Note: Current fish passage spill season is April 1 to August 31

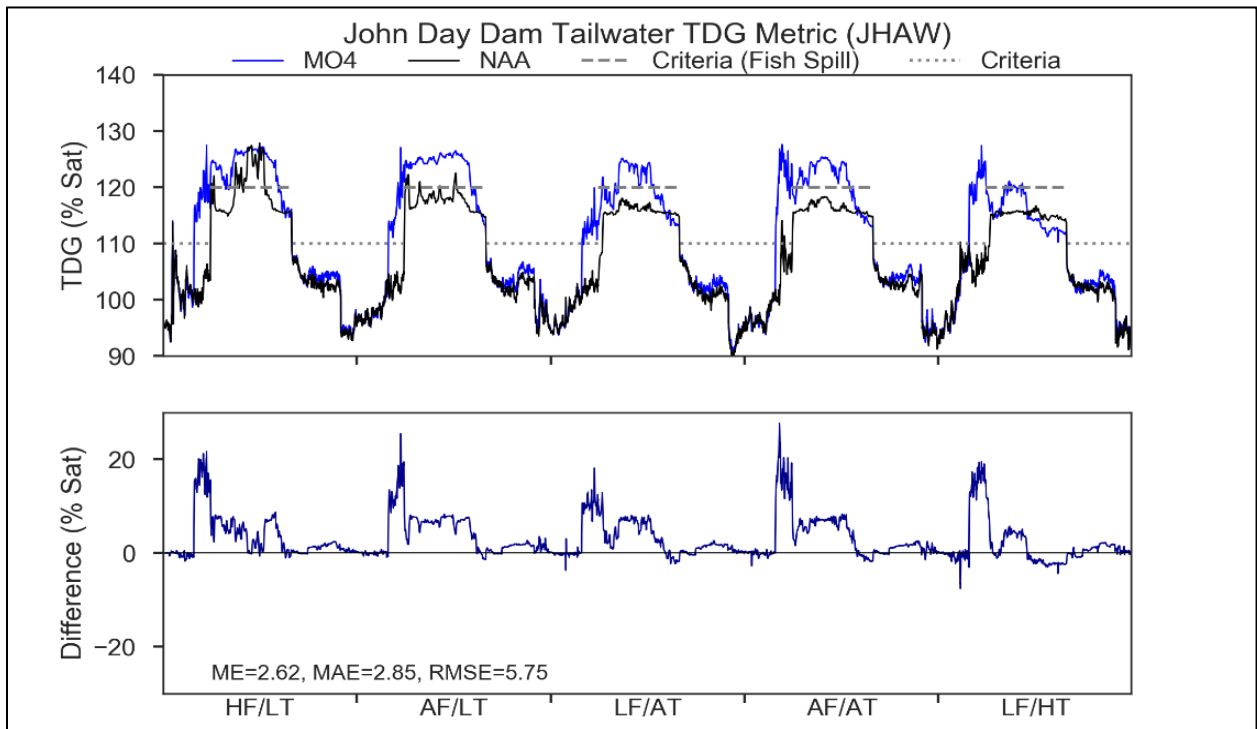


6468

6469

6470

Figure 7-47. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4 at McNary Dam Under a 5-year Range of River and Meteorological Conditions

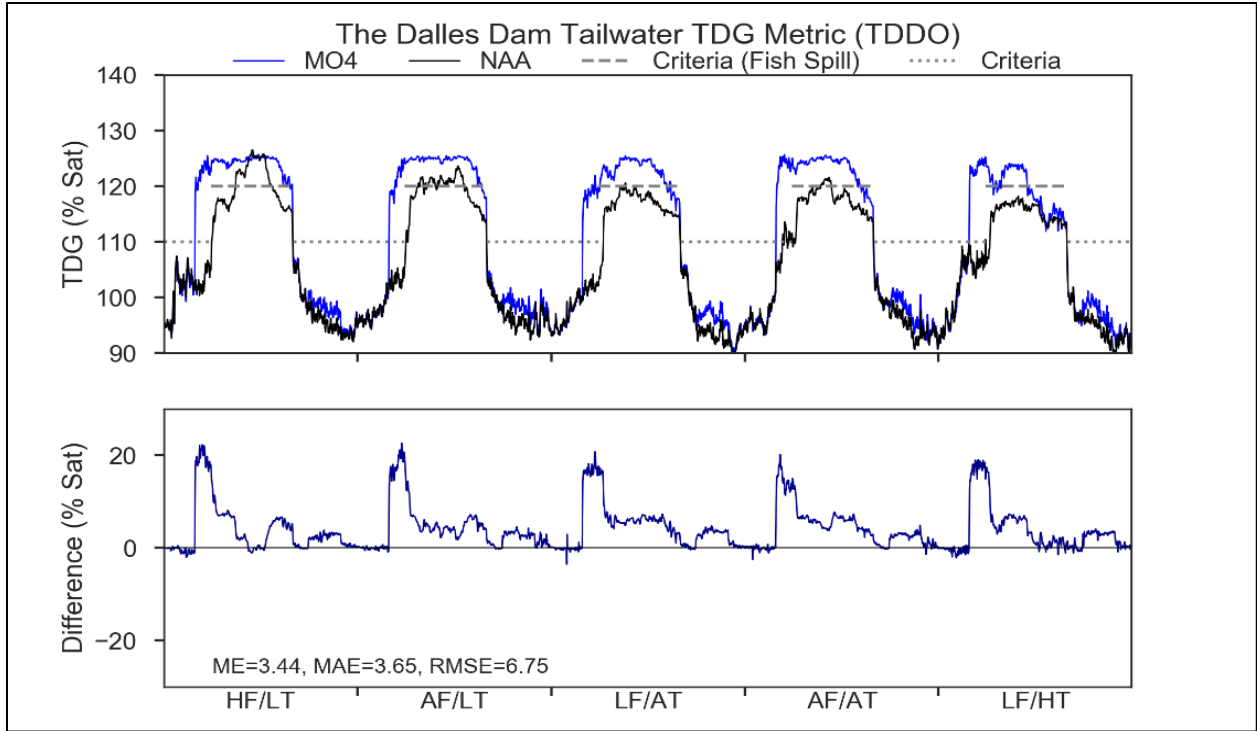


6471

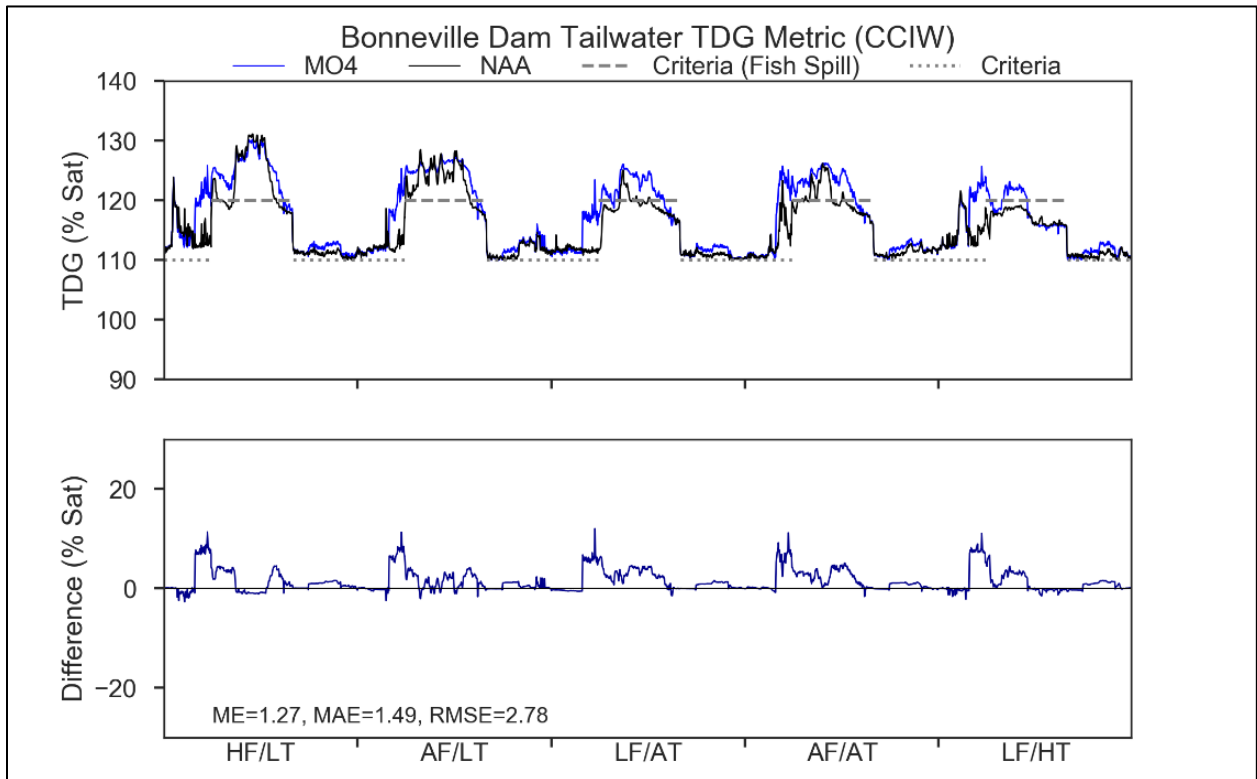
6472

6473

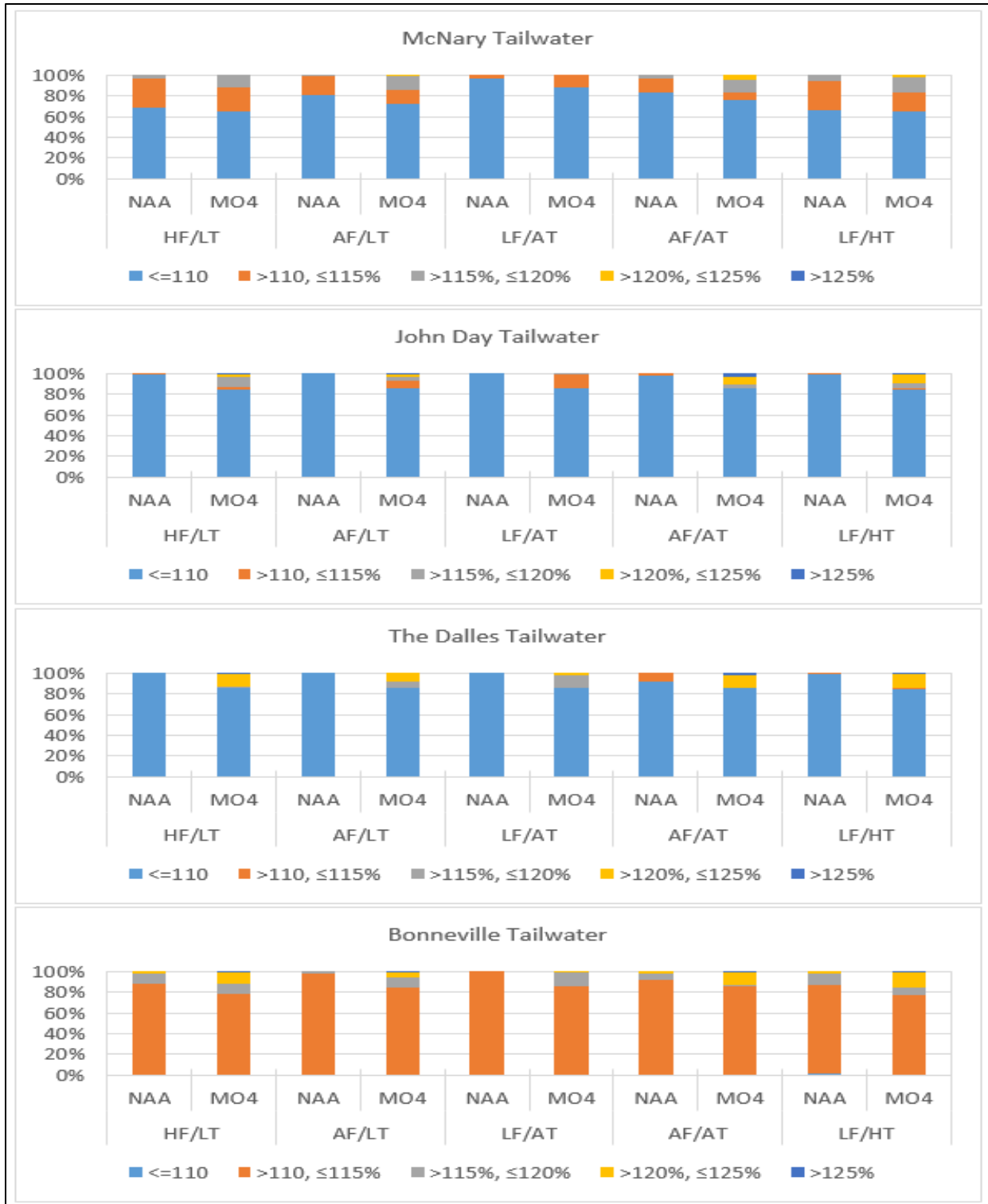
Figure 7-48. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4 at John Day Dam Under a 5-year Range of River and Meteorological Conditions



6474
 6475 **Figure 7-49. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4 at**
 6476 **The Dalles Dam Under a 5-year Range of River and Meteorological Conditions**

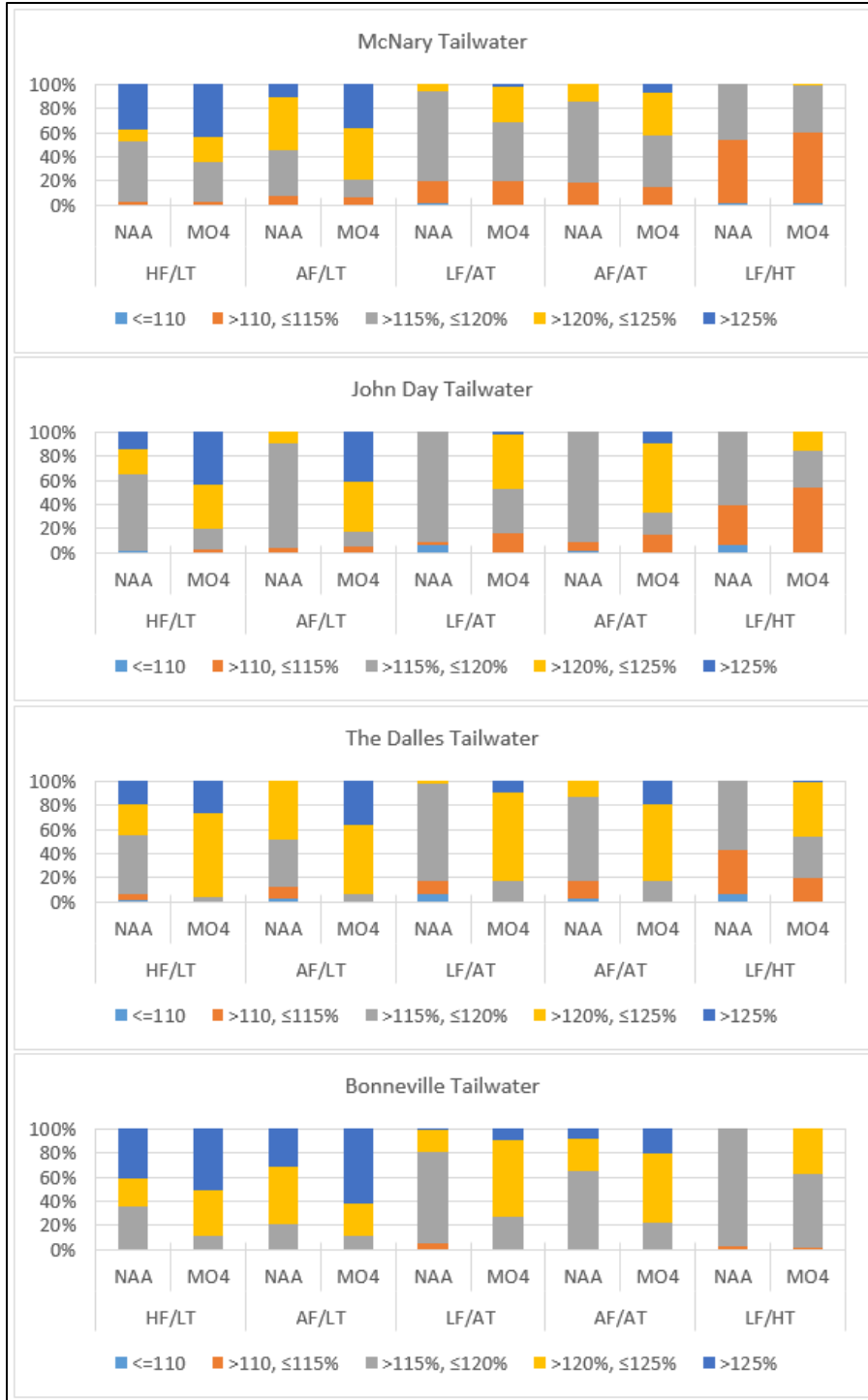


6477
 6478 **Figure 7-50. Modeled Tailwater Total Dissolved Gas for Multiple Objective Alternative 4 at**
 6479 **Bonneville Dam Under a 5-year Range of River and Meteorological Conditions**



6480
 6481 **Figure 7-51. Frequency of Modeled Tailwater Total Dissolved Gas Outside of Current Fish**
 6482 **Passage Spill Season for Multiple Objective Alternative 4 and No Action Alternative at**
 6483 **McNary, John Day, and The Dalles Dams Under a 5-year Range of River and Meteorological**
 6484 **Conditions**

6485 Note: Current fish passage spill season is April 1 to August 31



6486
 6487
 6488
 6489
 6490
 6491

Figure 7-52. Frequency of Modeled Forebay Total Dissolved Gas During Current Fish Passage Spill Season for Multiple Objective Alternative 4 and No Action Alternative at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-year Range of River and Meteorological Conditions

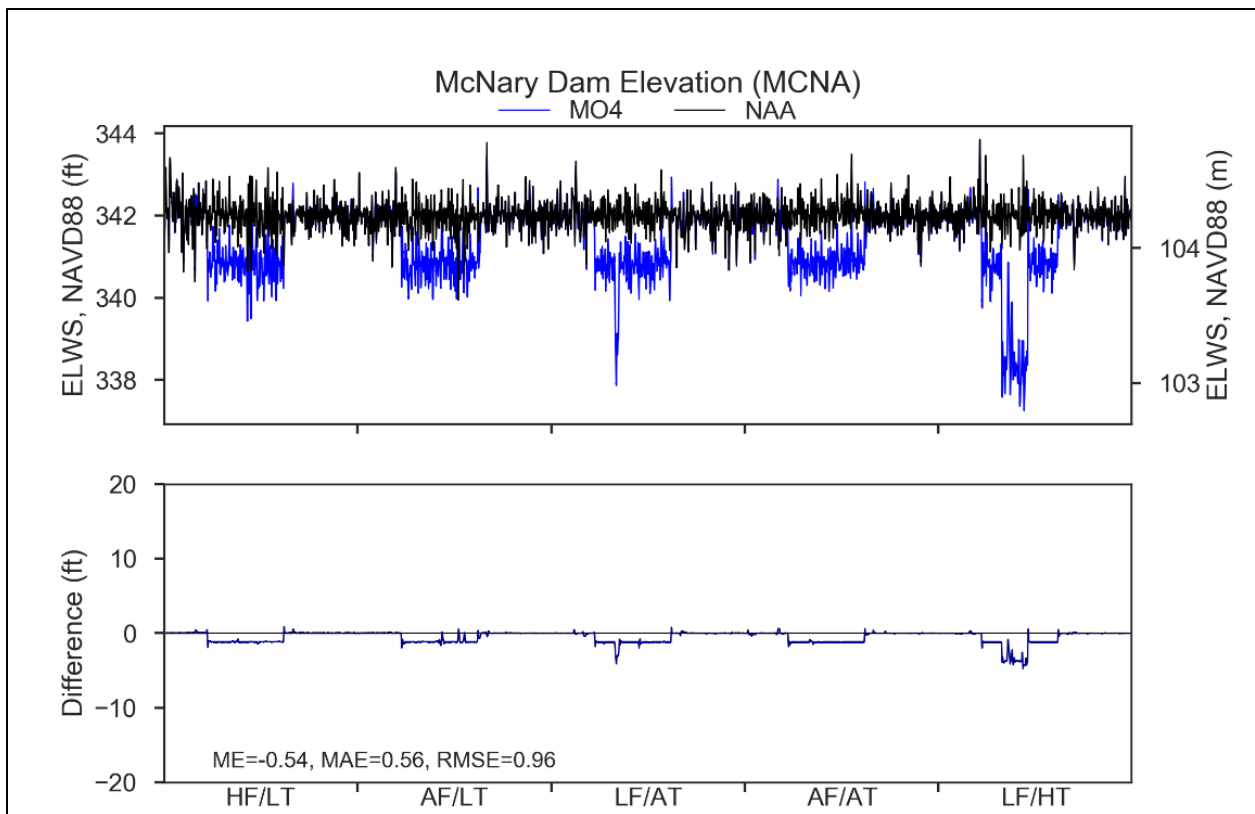
Note: Current fish passage spill season is April 1 to August 31

6492 **7.3.3 Other Physical, Chemical, and Biological Processes**

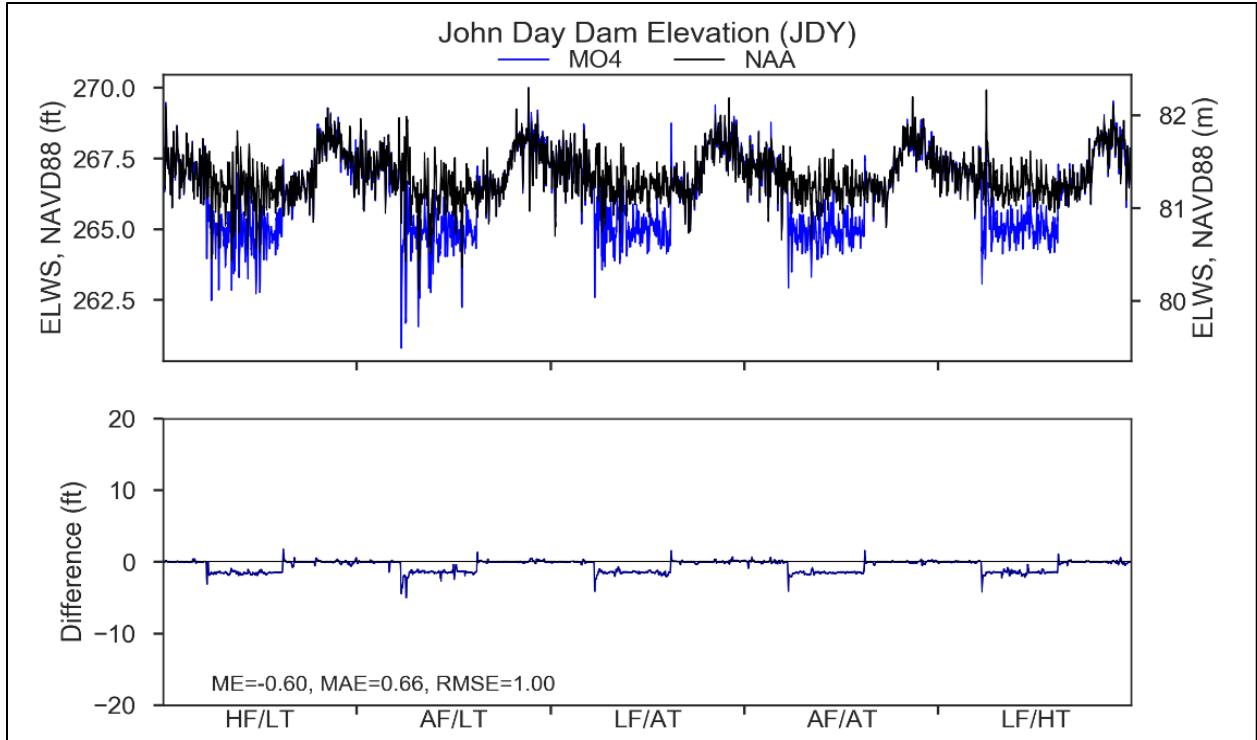
6493 **7.3.3.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

6494 Under the MO4 Drawdown to MOP measure, the McNary, John Day, The Dalles, and Bonneville
6495 Reservoir elevations would be drawn down to minimum operating pool from March 25 through
6496 August 15 to reduce travel times for anadromous fish outmigration (Figure 7-53. to
6497 Figure 7-56.). Lowering the reservoir elevations could lead to minor total suspended solids (TSS)
6498 increases and associated impacts (turbidity, light attenuation, and/or chemicals that may be
6499 associated with TSS like nutrients, metals, and organics). However, the impacts are expected to
6500 be negligible in the large lower Columbia River reservoirs.

6501 Otherwise, the introduction of pollutants and excess nutrients from farming and industrial
6502 activities as well as urban runoff is expected to continue under MO4. As with the No Action
6503 Alternative, emerging contaminants such as pharmaceuticals and new pesticides will also likely
6504 become more prevalent. The lower Columbia River contains a wide variety of human-sourced
6505 compounds, including trace metals and organic compounds. This condition is expected to
6506 remain generally unchanged, and it is expected that current water quality impairments would
6507 continue.

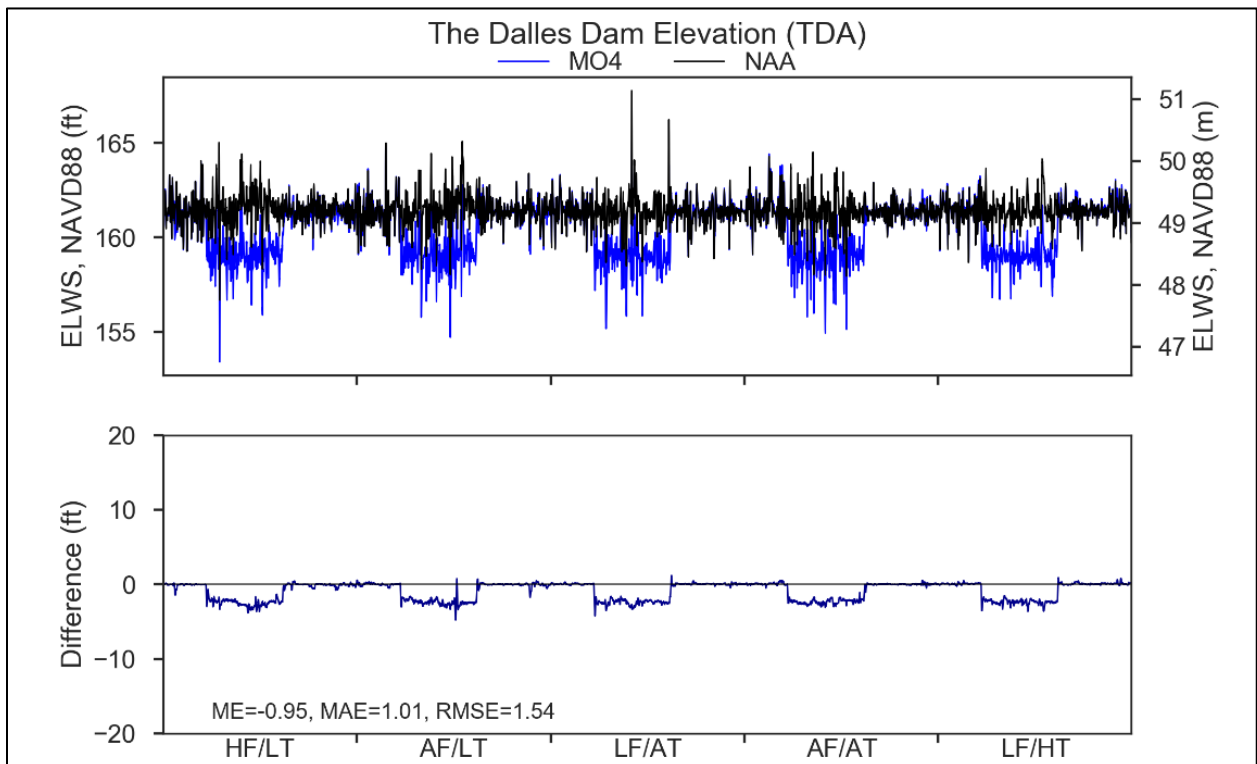


6508 **Figure 7-53. Modeled Forebay Elevation for Multiple Objective Alternative 4 at McNary Dam**
6509 **Under a 5-year Range of River and Meteorological Conditions**
6510



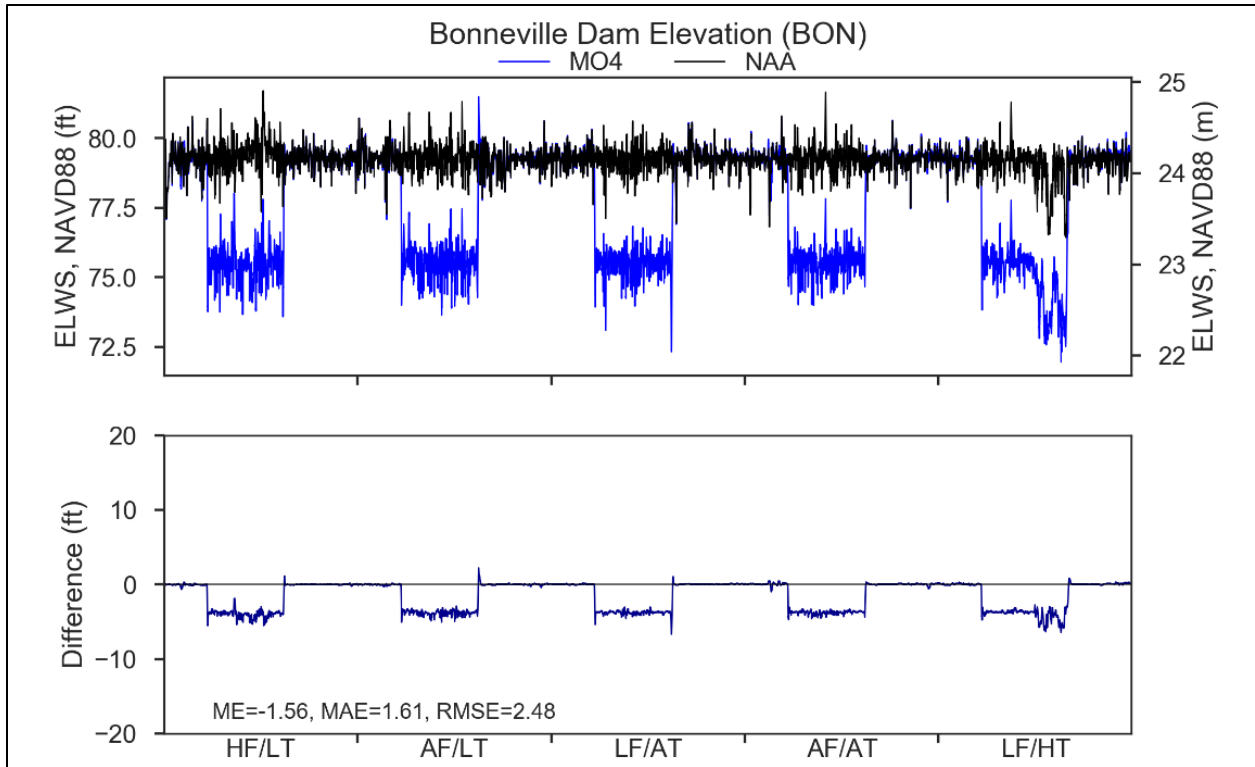
6511
6512
6513

Figure 7-54. Modeled Forebay Elevation for Multiple Objective Alternative 4 at John Day Dam Under a 5-year Range of River and Meteorological Conditions



6514
6515
6516

Figure 7-55. Modeled Forebay Elevation for Multiple Objective Alternative 4 at The Dalles Dam Under a 5-year Range of River and Meteorological Conditions



6517
 6518 **Figure 7-56. Modeled Forebay Elevation for Multiple Objective Alternative 4 at Bonneville**
 6519 **Dam Under a 5-year Range of River and Meteorological Conditions**

6520 **7.4 SEDIMENT PROCESSES**

6521 **7.4.1 Sediment Sources**

6522 MO4 includes structural changes aimed at improving fish passage as well as hydropower
 6523 operation; these proposed measures would not affect sediment sources or movement. The
 6524 proposed operational changes include a wide range of hydropower and fish related measures;
 6525 many of the operational changes do not affect sediment sources or movement. Increasing the
 6526 irrigation volume to authorized levels could cause changes in sediment sources for the upper
 6527 Columbia River. Sediment sources for the upper Columbia River Basin include erosion from bare
 6528 lands (deforested or fallow agricultural lands) and landslides due to fluctuating water levels,
 6529 especially in Lake Roosevelt. Since MO4 includes providing up to the authorized volume of
 6530 irrigation water, the alternative would potentially increase agricultural land acreage and would
 6531 likely increase erosion from agricultural land (simply because there would be more of it.)
 6532 Increased irrigation from Lake Roosevelt would result in many thousands of additional acres of
 6533 irrigable land for agricultural development. An additional 90,000 acre-feet of water from
 6534 Hungry Horse reservoir has no specific purpose identified but could be used for either irrigation
 6535 or municipal purposes. Increased irrigation from Chief Joseph would allow for an additional
 6536 several thousand acres of land for agricultural development. Agricultural erosion could contain
 6537 nutrients and pesticides that would affect sediment quality. The use of additional water from
 6538 Lake Roosevelt could cause water level fluctuations which could exacerbate landslide

6539 conditions along the shores. These changes would affect the upper Columbia River portion of
6540 the project, however the changes in sediment sources would not be felt through the entire
6541 system since sediment downstream movement is disrupted by dams. The measures included in
6542 MO4 would not cause changes to land use near the lower Columbia River and Snake River
6543 projects including upland recreation, flood management, agricultural, timber, or mining
6544 activities, and would not be expected to change population growth patterns in those areas.
6545 Overall, sediment loading to Lake Roosevelt, Chief Joseph Reservoir, and Hungry Horse
6546 Reservoir could be increased due to the increased irrigation proposed in MO4.

6547 **7.4.2 Chemicals of Concern**

6548 No change is predicted to the list of sediment chemicals of concern, compared to the existing
6549 conditions and under the No Action Alternative. Higher loading of agriculturally sourced
6550 pollutants may occur on the upper Columbia River due to the increase in irrigated agricultural
6551 lands. Changes in reservoir water levels due to changes in operations could affect the mobility
6552 and bioavailability of some pollutants such as mercury (Willacker et al. 2016). Throughout the
6553 basin, the contaminants of concern would remain metals, polycyclic aromatic hydrocarbons
6554 (PAHs), volatile organic compounds (VOCs), pesticides and pesticide degradation products,
6555 PCBs, dioxins, and nutrients (ammonia).

6556 **7.5 CONCEPTUAL SITE MODEL**

6557 The conceptual site model for dredging under MO4 is the same as the conceptual site model(s)
6558 for the existing conditions and under the No Action Alternative. Areas that are currently not
6559 dredged (such as Chief Joseph Reservoir) would not be dredged in the future, in spite of
6560 potential changes in sediment loading in the upper Columbia River Basin, since there are no
6561 navigational features maintained by dredging. Sediment management operations in the Snake
6562 and lower Columbia Rivers would remain as they currently are since sediment sources for those
6563 reaches are not affected. Where dredging is needed (such as at the confluence of the Snake and
6564 Clearwater Rivers), it is assumed that dredged materials would be of sufficient quality for either
6565 in-water or upland beneficial use, as habitat creation areas or as upland fill. Sediment
6566 characterization following the Sediment Evaluation Framework (RSET 2018) or other applicable
6567 guidance would continue to be required for any new dredging or sediment related projects.

6568 **7.6 WATER AND SEDIMENT QUALITY CONCLUSIONS**

6569 The most notable MO4 measures that affect water quality are as follows:

- 6570 • *Spillway Weir Notch Inserts and Spill for Adult Steelhead*: Modify spillway weir with notch
6571 gate inserts at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, and
6572 John Day; provide 2 kcfs of spill for steelhead and kelt downstream passage; October to
6573 November
- 6574 • *Spill to 125% TDG*: Set juvenile fish passage spill not to exceed 125 percent TDG as
6575 measured in the tailrace at all lower Snake River and lower Columbia River projects

- 6576 • *McNary Flow Target*: Maintain 220/200-kcfs spring spill objectives at McNary through use of
6577 water in upper Columbia River Basin storage projects
- 6578 • *Hungry Horse Additional Water Supply, Lake Roosevelt Additional Water Supply, Chief*
6579 *Joseph Dam Project Additional Water Supply*: Modify operations to meet existing
6580 contractual water supply obligations
- 6581 • *Modified Draft at Libby, December Libby Target Elevation, Update System FRM Calculation,*
6582 *Winter System FRM Space*: Modify operations for FRM at Libby and Grand Coulee
- 6583 • *Grand Coulee Maintenance Operation*: Perform major maintenance at Grand Coulee

6584 **7.6.1 Multiple Objective Alternative 4 Results – Water Temperature**

6585 In general, MO4 would result in little to no change to water temperature downstream of
6586 Hungry Horse Dam. Some minor changes in water temperatures could be expected at Libby,
6587 Albeni Falls, Grand Coulee, and Chief Joseph Dams and Reservoirs, as compared to the No
6588 Action Alternative. Higher winter reservoir elevations at Libby from the change in the end-of-
6589 December draft target measure (*December Libby Target Elevation*), followed by higher outflows
6590 (aggressive drafting) in late winter/early spring, could result in warmer water temperatures
6591 downstream of the dam in the winter and colder downstream water temperatures in the early
6592 spring and summer as compared to under the No Action Alternative. This could result in various
6593 negative impacts to resident fish species. The largest changes in flow from the No Action
6594 Alternative to MO4 on the Pend Oreille River downstream of Albeni Falls Dam would occur in
6595 June and September during lower flow years, both of which months are associated with
6596 changes in Albeni Falls Dam operations for McNary Dam augmentation (*McNary Flow Target*).
6597 This is expected to result in warmer downstream water temperatures in the summer months.
6598 The *McNary Flow Target* measure combined with the Winter System FRM and the spring FRM
6599 system operations at Grand Coulee Dam (*Update System FRM Calculation* and *Planned Draft*
6600 *Rate at Grand Coulee*), result in lower Lake Roosevelt elevations year-round. These reductions
6601 in storage would result in warmer water temperatures downstream of Grand Coulee Dam in
6602 the spring and summer and cooler water temperatures in the fall and winter, which would be
6603 passed down and through Chief Joseph Dam.

6604 Negligible impacts in water temperature are expected at Dworshak Dam and Reservoir or in the
6605 lower Snake and Columbia Rivers under MO4, with the exception of McNary, which could
6606 experience some warming due to the *McNary Flow Target* measure.

6607 **7.6.2 Multiple Objective Alternative 4 Results – Total Dissolved Gas**

6608 There are no anticipated impacts to TDG expected downstream of Hungry Horse or Albeni Falls
6609 under MO4. For Libby, negligible increases to TDG are expected in the spring due to higher
6610 flows from aggressive drafting of Libby Reservoir following the *December Libby Target Elevation*
6611 *measure*. Downstream of Grand Coulee Dam, major reductions in TDG are likely due to *Lake*
6612 *Roosevelt Additional Water Supply* and multiple FRM measures which results in a decrease in
6613 outflow from May through September. TDG effects downstream of Chief Joseph Dam are

6614 anticipated to be negligible. Under MO4, TDG would be higher at the lower Snake and Columbia
6615 River dams due to the *Spill to 125% TDG* measure, which sets tailwater TDG limits to 125
6616 percent TDG with no forebay TDG limit. This results in higher TDG production as compared to
6617 under the No Action Alternative, which has TDG limits of 115 percent in the forebay and 120
6618 percent in the tailrace. Overall, major increases in TDG are anticipated in the lower Snake River
6619 and moderate increases in TDG are anticipated in the lower Columbia River.

6620 **7.6.3 Multiple Objective Alternative 4 Results – Other Water Quality Impacts**

6621 In general, MO4 would result in little to no change on other water quality parameters at most
6622 CRSO projects as compared to the No Action Alternative. The exceptions include potential
6623 changes at Libby and Grand Coulee. Due to higher winter reservoir elevations at Libby, resulting
6624 from the change in the *December Libby Target* measure, followed by higher outflows
6625 (aggressive drafting) in late winter/early spring due to the *Modified Draft at Libby* measure,
6626 operations could reduce overall lake productivity, effecting the growth rate in fish within and
6627 downstream of the reservoir. At Grand Coulee, the deeper draft of the reservoir elevation,
6628 associated with the carryover effects of the *McNary Flow Target*, the *Winter System FRM*
6629 *Space*, the system FRM operations at Grand Coulee (*Update System FRM Calculation* and
6630 *Planned Draft Rate at Grand Coulee*) and the *Lake Roosevelt Additional Water Supply* could lead
6631 to increased mercury methylation due to prolonged sediment exposure. The *Planned Draft Rate*
6632 *at Grand Coulee* measure would slow the reservoir draft rate to 0.8 feet/day, which could result
6633 in a decrease in bank erosion, sloughing, and overall turbidity in the reservoir.

6634 **7.6.4 Multiple Objective Alternative 4 Results – Sediment Quality**

6635 MO4 is not expected to affect land use throughout the Columbia River Basin, including upland
6636 recreation, flood management, agricultural, timber, or mining activities, and is not expected to
6637 change population growth patterns in the area of any of the affected reservoirs. Overall, MO4 is
6638 not expected to affect sediment movement within the system.

6639

CHAPTER 8 - PREFERRED ALTERNATIVE

6640 The Preferred Alternative (PA) includes a complete description of measures that would be
6641 implemented to operate the CRS to better meet the Purpose and Need and objectives of the
6642 study. Several measures, from the alternatives in Chapter 2, were refined or added for inclusion
6643 into the Preferred Alternative. Operations, maintenance and programs that were ongoing or
6644 planned as of 2016 are carried forward into the Preferred Alternative unless described
6645 otherwise. Ongoing operations and maintenance measures are described in more detail in
6646 Chapter 2.3.2.1. Further details regarding the Preferred Alternative measures can be found in
6647 Chapter 7.

6648 **8.1 UPPER COLUMBIA RIVER BASIN**

6649 **8.1.1 Water Temperature**

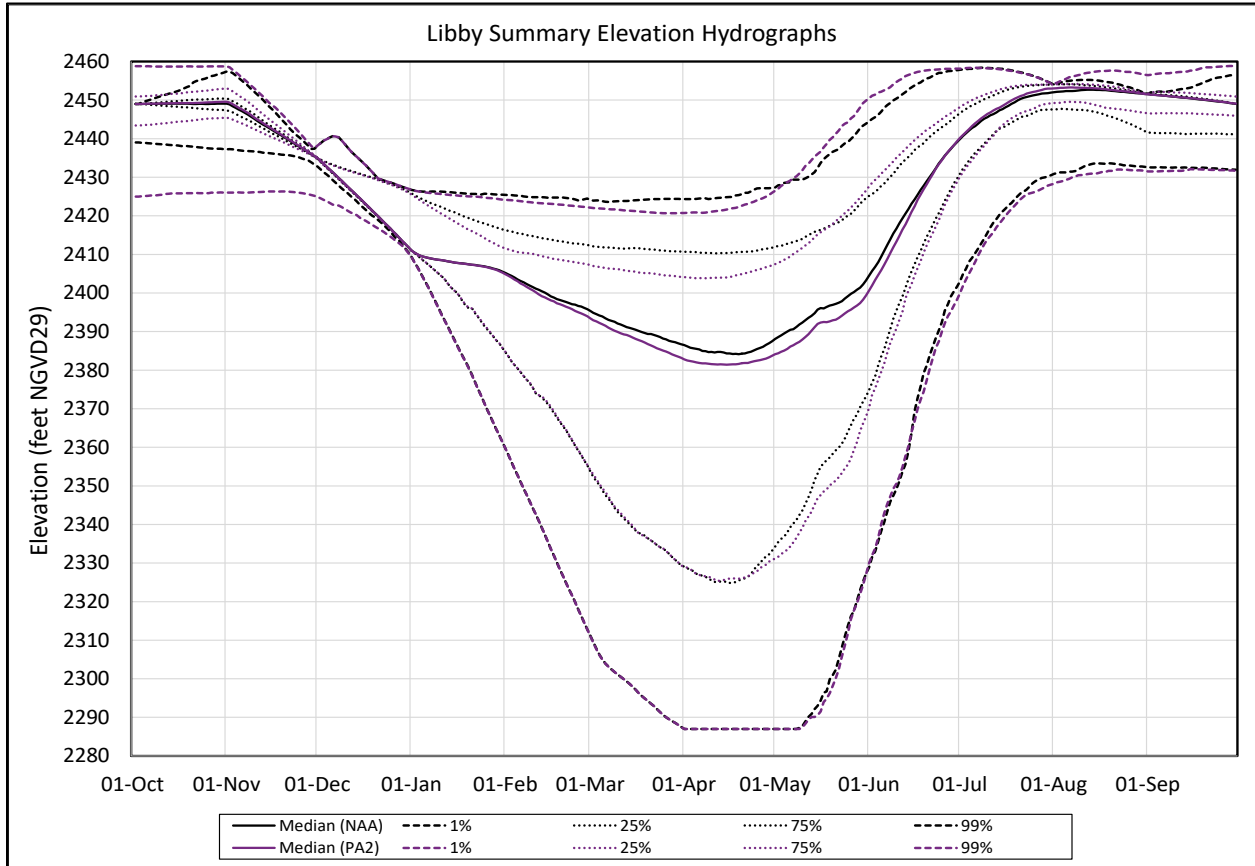
6650 ***8.1.1.1 Libby and Hungry Horse Dams and Reservoirs***

6651 The PA would modify Libby Dam’s draft and refill operations after December 31. The *Modified*
6652 *Draft at Libby* measure results in mid-April reservoir elevations lower than the No Action
6653 Alternative when the water supply forecast is less than 6.9 Maf (median to low water supply
6654 forecast). Refill operations would be adjusted for the water supply forecast with peak reservoir
6655 elevations being achieved in late July or August. Peak reservoir elevations under the PA would
6656 be about 1 to 5 feet higher than under the No Action Alternative depending on the water year.
6657 A summary hydrograph for Lake Kootenai, representing the probability of the reservoir
6658 elevation on any given day under PA and the No Action Alternative, is shown in Figure 8-1.
6659 Under the PA, median elevations in Lake Kootenai are similar to the No Action Alternative
6660 elevations from October through the end of January, about 5 feet lower by mid-April, slightly
6661 higher by the end of July, and held at similar elevations in August and September. In years with
6662 high water supply forecasts (represented by the 75 percent and 99 percent non-exceedance
6663 lines in Figure 8-1) mid-April draft elevations are similar but the reservoir is refilled and held
6664 slightly higher (1 to 4 feet) in August and September. In years with low water supply forecasts
6665 (the 25 percent and 1 percent non-exceedance lines in Figure 8-1), the PA drafts the reservoir
6666 deeper than the No Action Alternative by about 5 to 8 feet, and the reservoir is refilled at a
6667 more rapid rate and held higher by about 5 feet in August and September.

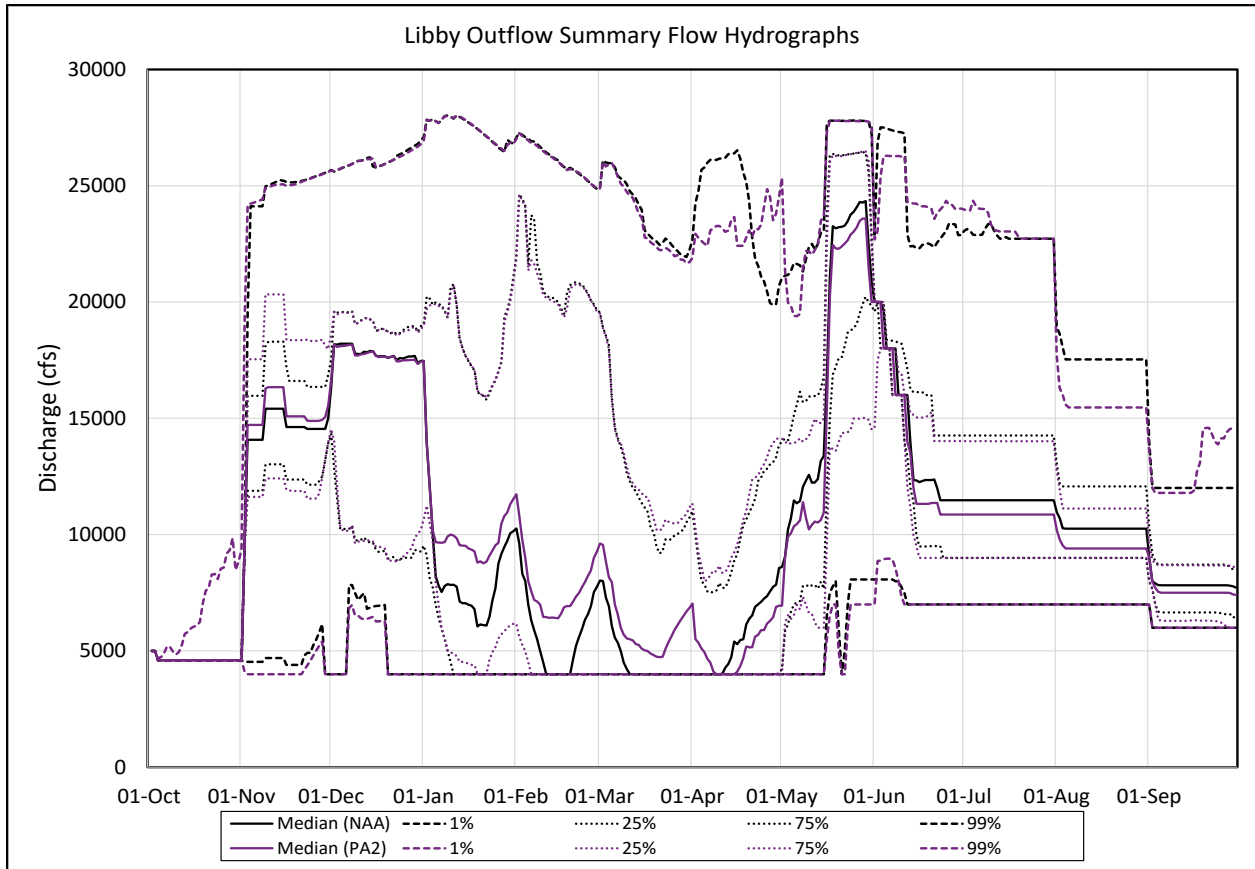
6668 Historical temperature data suggests that holding the pool higher in the winter results in colder
6669 spring and summer reservoir temperatures and difficulty for the SWS to achieve downstream
6670 temperatures objectives. When the pool is drafted deeper in the winter, as is the case under
6671 the PA, the pool volume is less, thereby allowing for greater warming in the spring from warmer
6672 inflows and ambient air temperatures. Hence, the SWS has a greater ability to achieve desired
6673 water temperatures downstream in the Kootenai River.

6674 In general, the PA impacts Libby Dam outflows and Kootenai River flows from January through
6675 April and again in June, July, and August (Figure 8-2). When compared to the No Action
6676 Alternative, median PA outflows are similar from October through December; 19, 26, and 18

6677 percent greater in January, February, and March, respectively; 14 percent less in April; and
 6678 about 5 to 8 percent greater from June through September. High water year flows (1 and 25
 6679 percent exceedance flows) do not follow the same pattern, and are 11 to 40 percent greater
 6680 than the No Action Alternative in October and November, similar from December through June,
 6681 and 1 to 12 percent less from June through September. Low water year flows (75 and 99
 6682 percent exceedance flows) follow a similar pattern as median flows, except for a 15 and 43
 6683 percent decrease in May for the 75 and 99 percent flows, respectively, and an increase in the
 6684 June through August period (9 to 14 percent) for the 99 percent flows.



6685 **Figure 8-1. Libby Dam–Lake Koocanusa Summary Elevations for Preferred Alternative Versus**
 6686 **No Action Alternative**
 6687



6688
 6689
 6690

Figure 8-2. Libby Dam–Lake Kootenusa Summary Outflows for Preferred Alternative Versus No Action Alternative

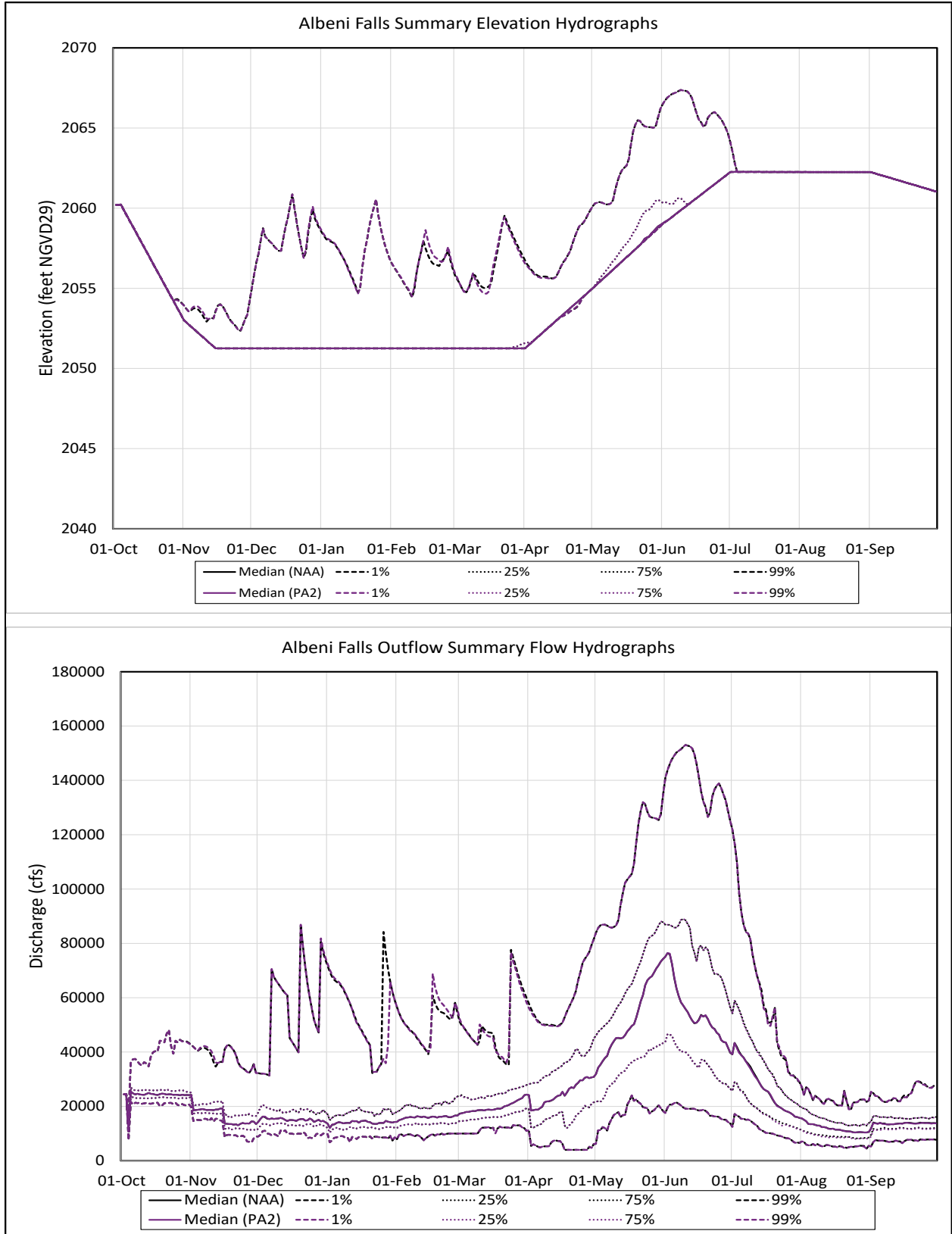
6691 Under the PA, Libby Dam’s SWS provides some ability to adjust where in the water column
 6692 water entering the powerhouse penstocks is drawn from. The range of the SWS bulkheads are
 6693 from elevation 2,409 to 2,200 feet, NGVD29. Because SWS protocol maintains at least 30 feet of
 6694 submergence over the top row of the bulkheads for hydraulic stability, the SWS has the ability
 6695 to perform under the full range of possible PA operations with a similar efficiency as under the
 6696 No Action Alternative. Modeled forebay elevations under PA are predicted to be well within the
 6697 operating range of the SWS and similar to the ranges observed in the historical years described
 6698 in Section 3.1.1.1.

6699 Changes in downstream temperatures from Libby Dam to Bonners Ferry may result from PA
 6700 operations increasing the median monthly outflow from January through March to draft the
 6701 reservoir deeper. During the cold winter months, Kootenai River water can cool by several
 6702 degrees between Libby Dam and Bonners Ferry if flows are held low. By increasing winter flows
 6703 to draw the pool down deeper, the PA may prevent the natural cooling of the river as it moves
 6704 downstream. These higher winter temperatures in the Kootenai River may be an issue for
 6705 certain fish species, such as burbot, which require near freezing river temperatures (<35°F or
 6706 <2°C) to spawn. Overall, the PA is expected to results in negligible to minor changes in water
 6707 temperature as compared to the No Action Alternative.

6708 Under the PA, water temperatures in the South Fork of the Flathead River below Hungry Horse
6709 Dam would be similar to those under the No Action Alternative. Only one operational measure,
6710 *Sliding Scale and Libby and Hungry Horse*, applies to Hungry Horse. This measure would result
6711 in negligible changes to summer operations at Hungry Horse Dam in dry years; these changes
6712 are not anticipated to impact the ability of Hungry Horse to utilize the selective withdrawal
6713 structure and meet water temperature objectives downstream in the South Fork Flathead
6714 River. As presented in the Hungry Horse Selective Withdrawal System Evaluation Report
6715 (Reclamation 2006), temperatures between 50°F and 59°F (10°C and 15°C) are optimal for trout
6716 growth and the SWS has been successful in maintaining these water temperatures during the
6717 summer months. Epilimnion thickness and thermocline strength is relatively stable from year-
6718 to-year in the reservoir despite drastically different hydrological conditions (Reclamation,
6719 2006).

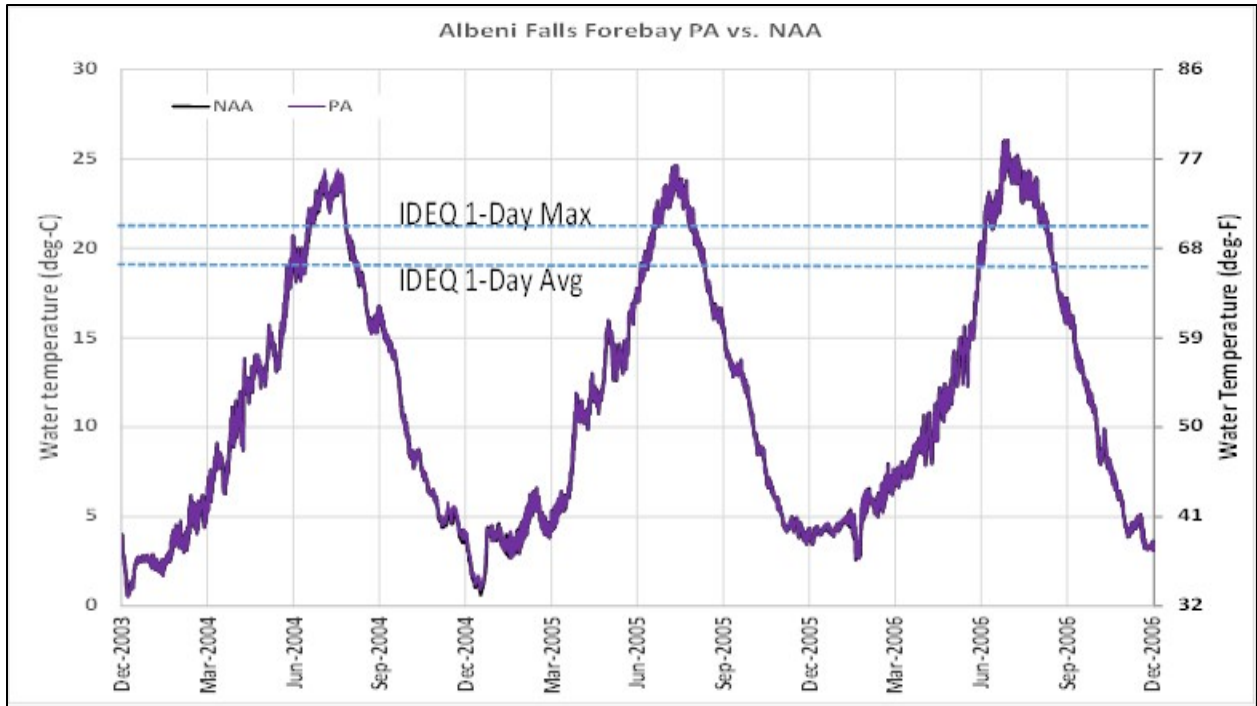
6720 **8.1.1.2 Albeni Falls Dam and Reservoir**

6721 Under the PA, there are no changes to operations at Albeni Falls Dam. Any changes in flow from
6722 Hungry Horse Dam under PA that move downstream through the basin are insignificant by the
6723 time they enter the Pend Oreille River Basin. As such, there are no expected changes in Lake
6724 Pend Oreille elevations and only minor changes in Pend Oreille River flows between the PA and
6725 the No Action Alternative (Figure 8-3). Median and high water supply year outflows from Albeni
6726 Falls Dam under the PA are expected to be the same as the No Action Alternative, while low
6727 water supply years would be up to several hundred cfs lower. Model results show a negligible
6728 change in temperature at Albeni Falls Dam between the PA and No Action Alternative with the
6729 majority of temperature differences between the two alternatives of about ± 0.35 degree
6730 Fahrenheit (± 0.2 degree Celsius) (Figure 8-4 and Figure 8-5). Modeled temperatures under
6731 both the PA and the No Action Alternative would continue to exceed the IDEQ Pend Oreille
6732 River temperature criteria (1-Day Maximum of 71.6°F [22°C] and 1-Day Average of 66.2°F
6733 [19°C]) during the summer.



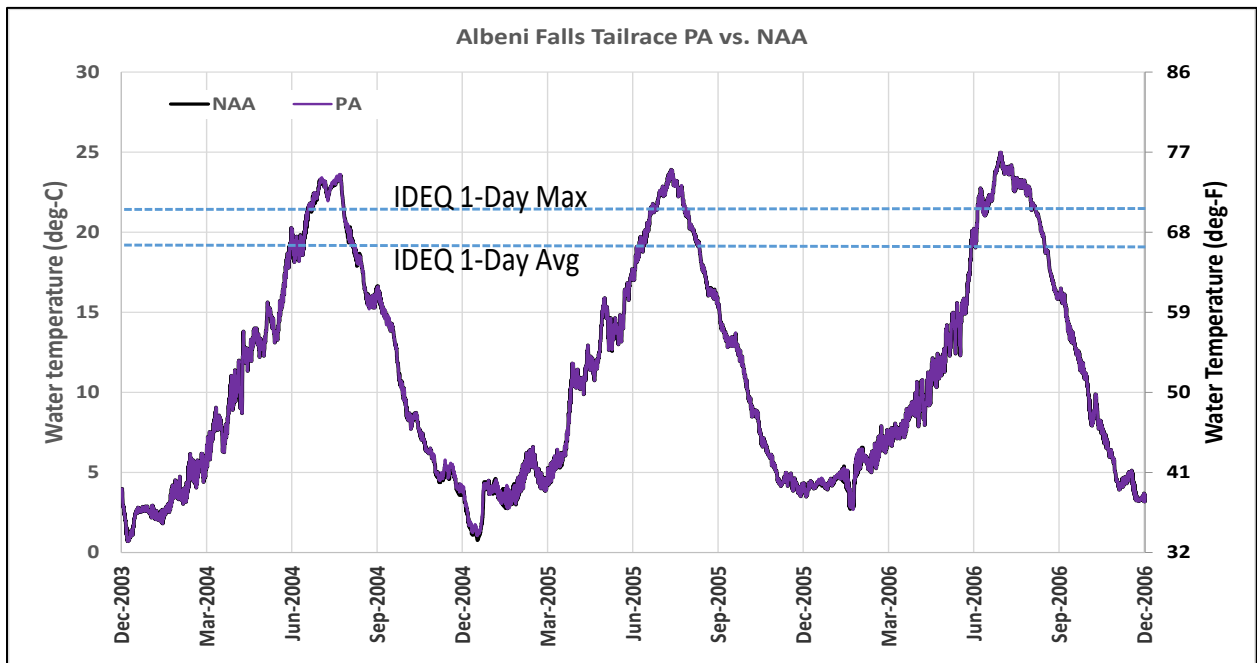
6734
6735
6736

Figure 8-3. Albeni Falls Dam Summary Elevation Hydrographs and Outflows for Preferred Alternative Versus the No Action Alternative



6737
 6738 **Figure 8-4. Modeled Forebay Temperatures for Preferred Alternative and No Action**
 6739 **Alternative at Albeni Falls for 2004 to 2006**

6740 Note: IDEQ 1-Day Maximum temperature standard of 22°C and 1-Day Average standard of 19°C shown for
 6741 comparison.



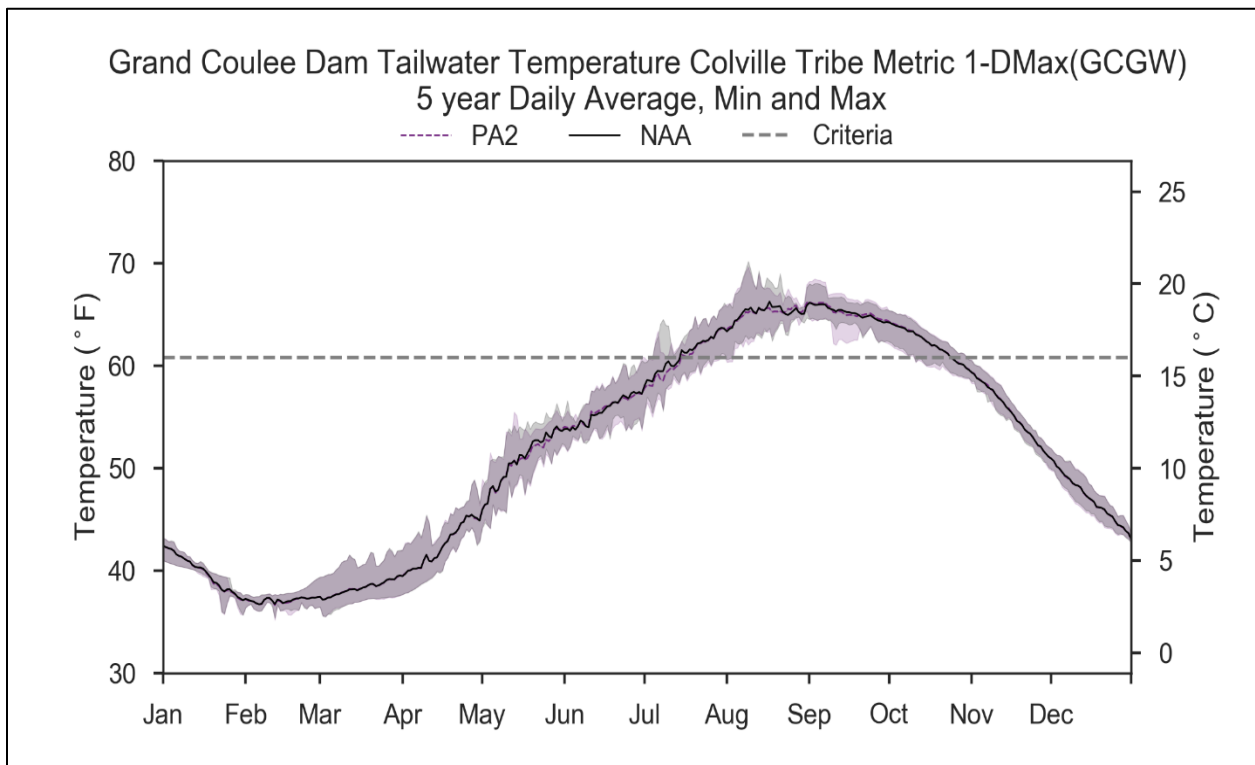
6742
 6743 **Figure 8-5. Modeled Tailwater Temperatures for Preferred Alternative and No Action**
 6744 **Alternative at Albeni Falls for 2004–2006**

6745 Note: IDEQ 1-Day Maximum temperature standard of 22°C and 1-Day Average standard of 19°C are shown for
 6746 comparison.

6747 **8.1.1.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

6748 Under the PA, the *Update System FRM Calculation, Planned Draft Rate at Grand Coulee, Fall*
6749 *Operational Flexibility for Hydropower (Grand Coulee), and Lake Roosevelt Additional Water*
6750 *Supply* measures relate directly to Grand Coulee Dam, and all of these (with the exception of
6751 *Lake Roosevelt Additional Water Supply*) would influence reservoir elevations at Lake Roosevelt.
6752 Operational changes in Region A upstream may also have a slight effect on Lake Roosevelt
6753 water levels. The *Grand Coulee Maintenance Operations* measure would not impact reservoir
6754 elevations or total outflows.

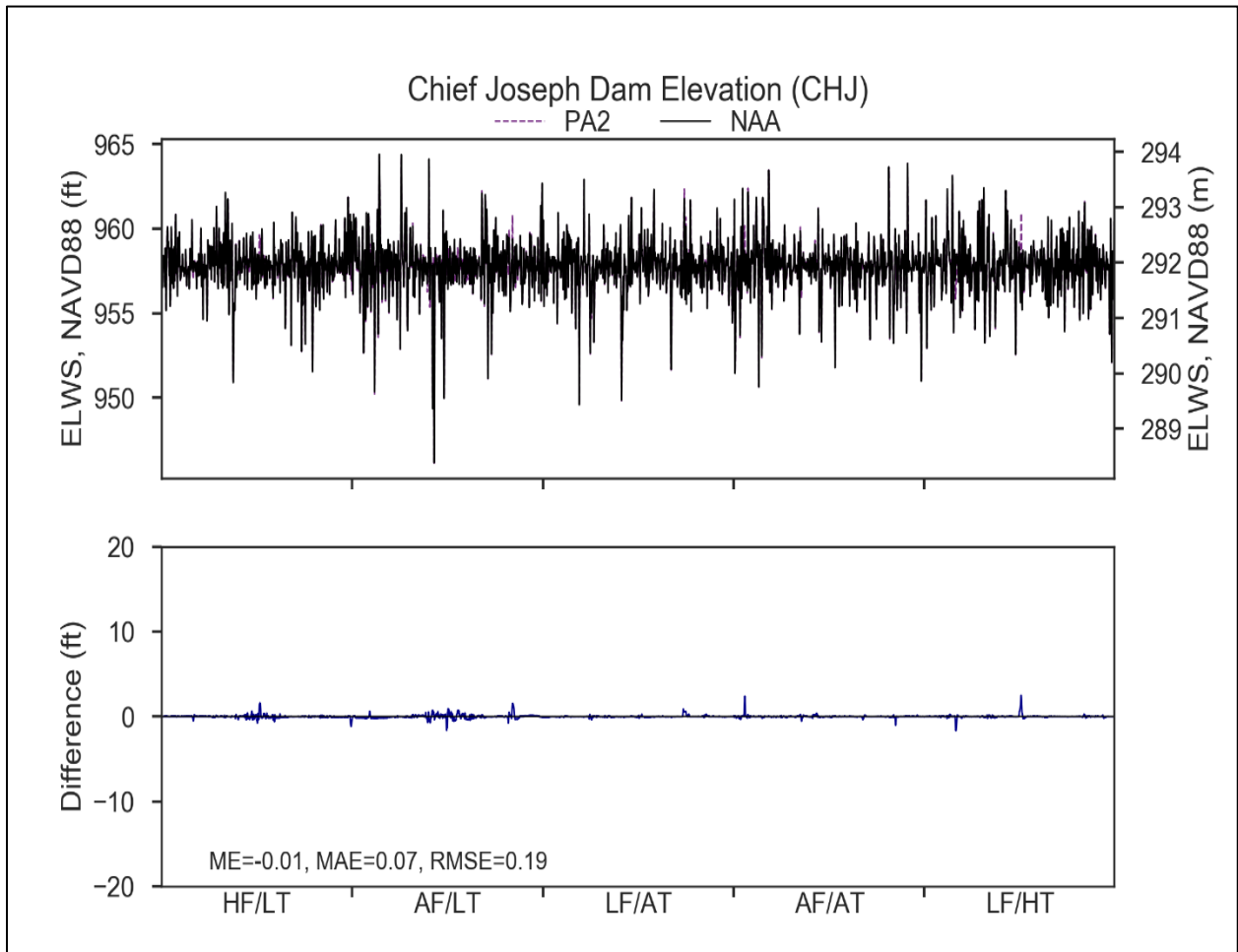
6755 The changes in operations from these measures have negligible impacts to temperature.
6756 Figure 8-6 shows the PA versus the No Action Alternative modeled water temperatures below
6757 Grand Coulee Dam. As shown, the PA water temperatures are very similar to the No Action
6758 Alternative.



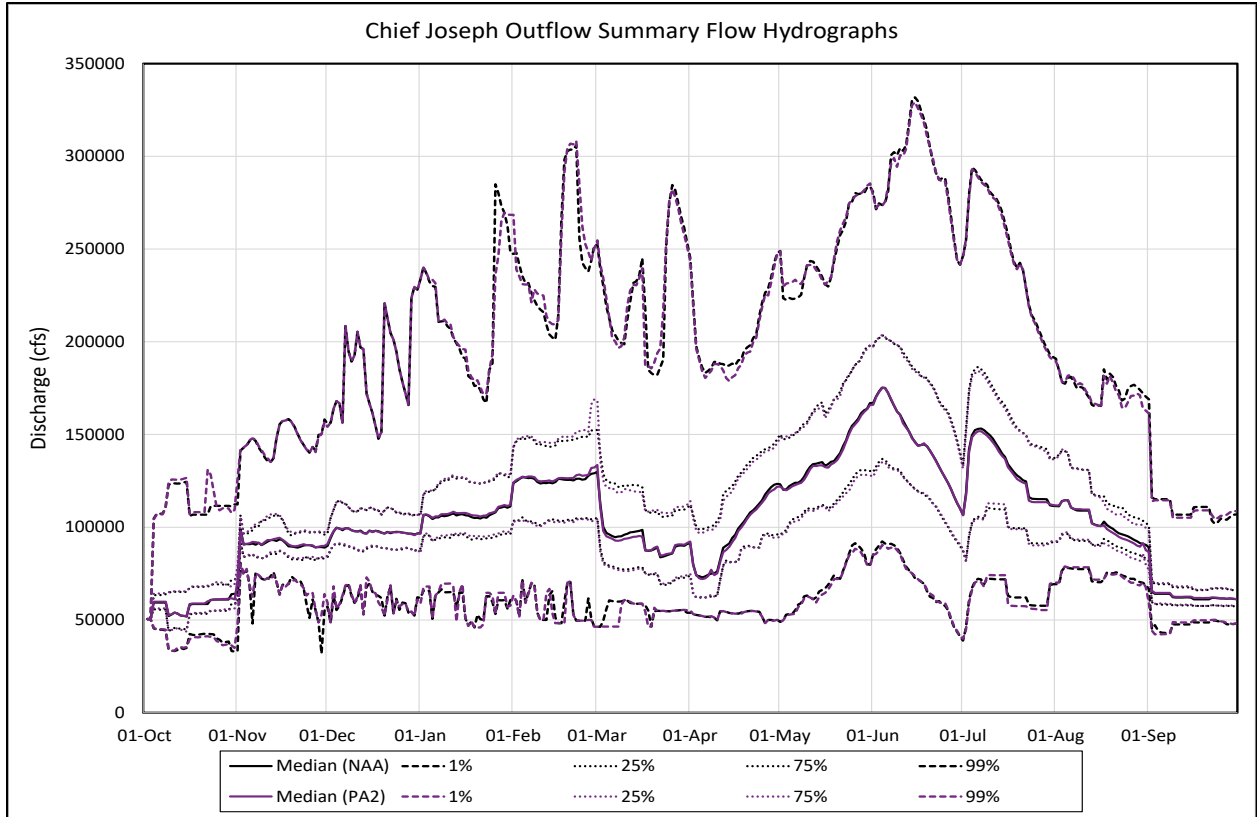
6759 **Figure 8-6. Modeled Range of Tailwater Total Dissolved Gas for the No Action Alternative and**
6760 **Multiple Objective Alternative 2 at Grand Coulee Dam Under a 5-Year Range of River and**
6761 **Meteorological Conditions**
6762

6763 Model results predict little change in Rufus Woods Lake forebay elevations for the PA when
6764 compared to the No Action Alternative (Figure 8-7). Monthly outflows from Chief Joseph Dam
6765 are predicted to be similar to or about 1 percent less than the No Action Alternative for all
6766 types of water years (Figure 8-8). Consequently, modeled temperatures under the PA
6767 downstream of Chief Joseph Dam are similar to the No Action Alternative with the majority of
6768 temperature differences in the ± 1 degree Fahrenheit range (Figure 4-8.). In general,

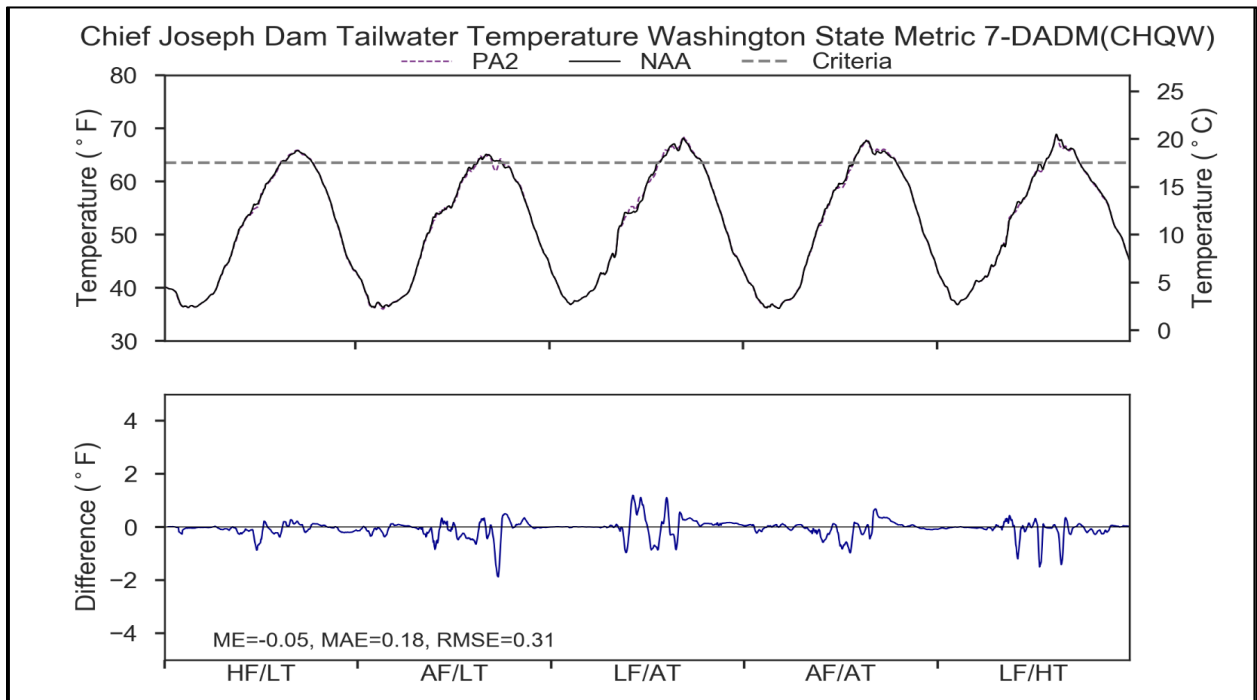
6769 temperatures modeled for PA are similar or slightly cooler than the No Action Alternative for
 6770 most river and climate conditions. An exception is for the low flow/average temperature
 6771 (LF/AT) scenario where river temperatures in the spring are expected to be up to 1 degree
 6772 Fahrenheit greater under the PA alternative. Tailwater temperatures under both the PA and No
 6773 Action Alternative are predicted to exceed the Washington State standard of 63.5F (17.5°C) as
 6774 measured by the 7-day average of the daily maximum temperature in August and September.
 6775 Similar to the No Action Alternative, there is little difference in temperature between Grand
 6776 Coulee Dam (Figure 8-6) and Chief Joseph Dam (Figure 8-9) under the PA, showing that water
 6777 temperatures released from Lake Roosevelt are passed through Rufus Woods Lake unchanged.



6778 **Figure 8-7. Chief Joseph Dam–Rufus Woods Lake Forebay Elevations for Preferred Alternative**
 6779 **Versus No Action Alternative**
 6780



6781
 6782 **Figure 8-8. Chief Joseph Dam–Rufus Woods Lake Outflows for Preferred Alternative Versus**
 6783 **No Action Alternative**



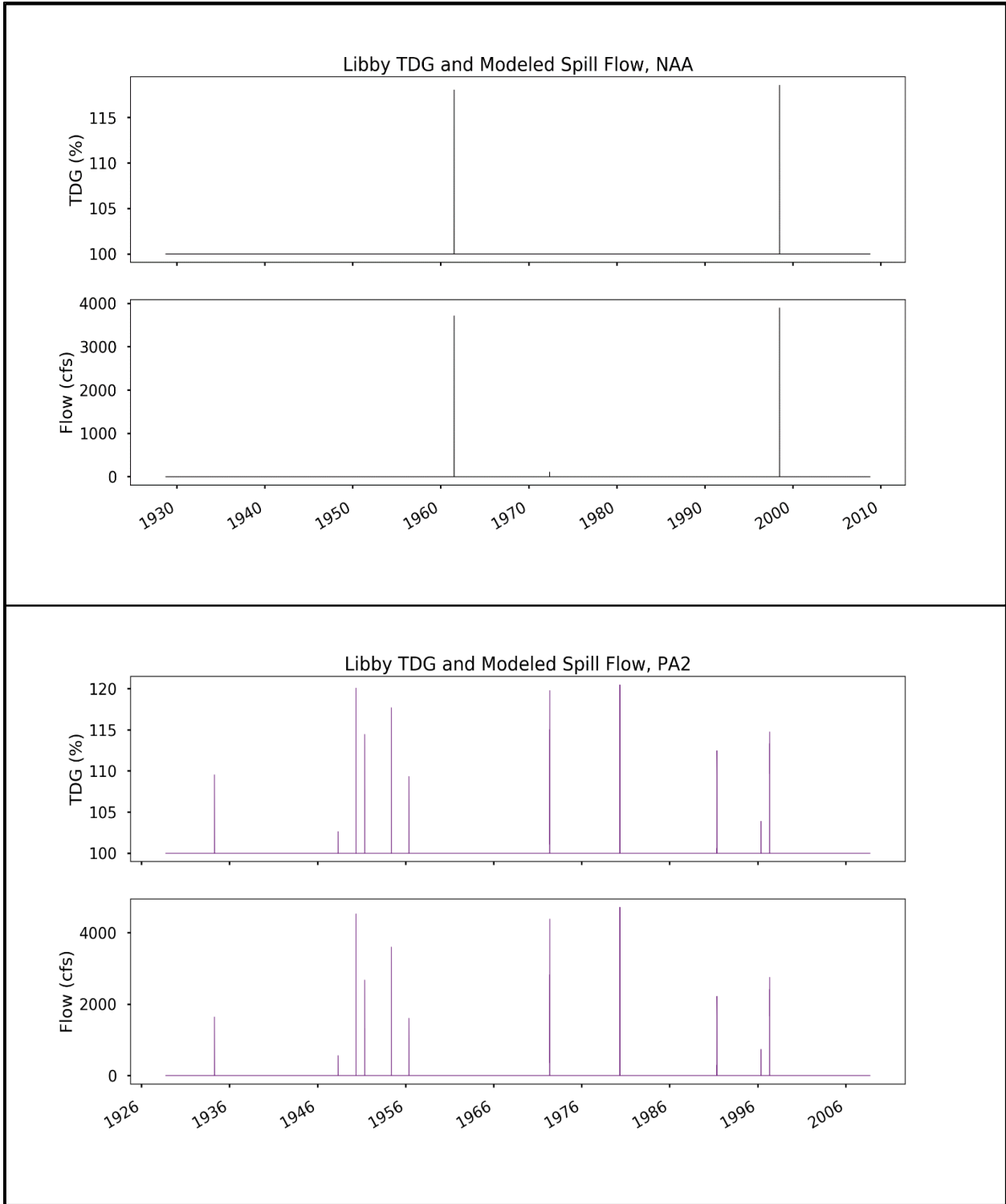
6784
 6785 **Figure 8-9. Modeled tailwater temperature for Preferred Alternative and No Action**
 6786 **Alternative at Chief Joseph Dam Under a 5-year Range of River and Meteorological Conditions**

6787 **8.1.2 Total Dissolved Gas**

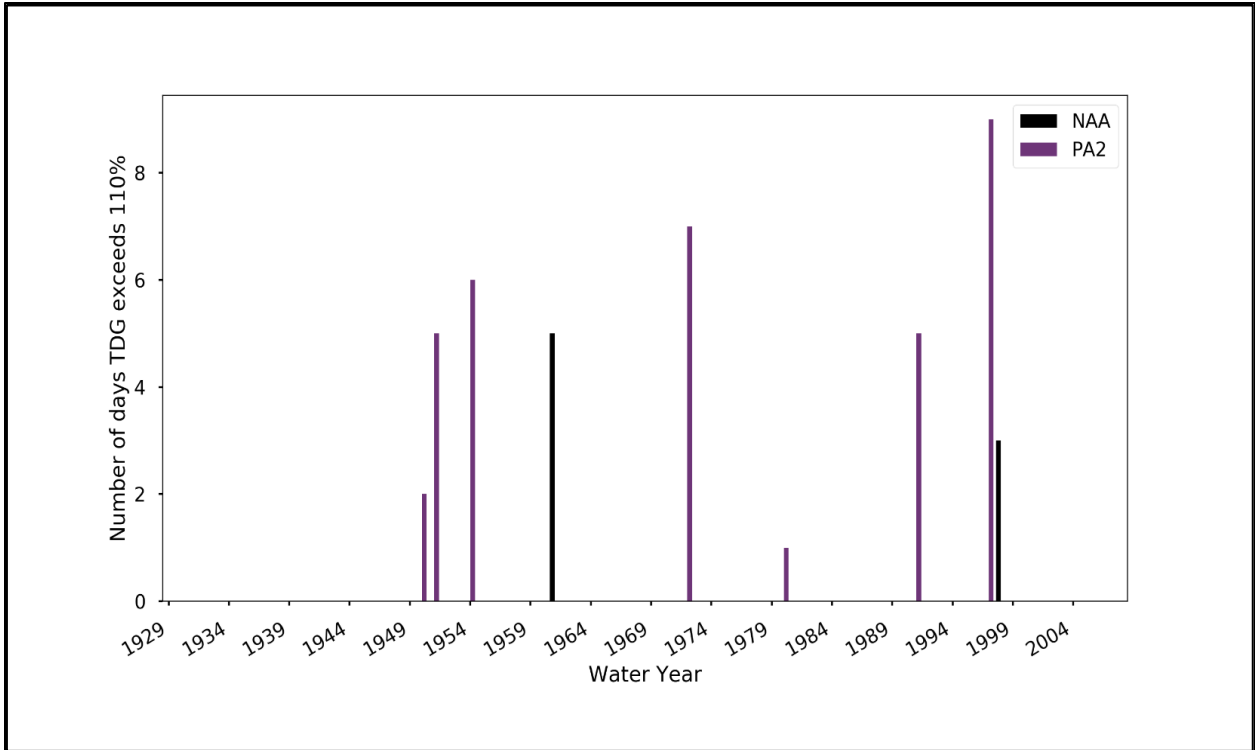
6788 **8.1.2.1 Libby and Hungry Horse Dams and Reservoirs**

6789 Libby Dam is typically operated to minimize spill to minimize elevated TDG and related impacts.
6790 Under the PA, Libby Dam's draft and refill operations will be modified, resulting in an increase
6791 in the highest releases from the dam. This operational change is predicted to increase the
6792 chance of spill at Libby Dam. The 80-year period of record flows (1928 to 2008) were used to
6793 predict TDG, as presented in Figure 8-10. The model predicts 11 years with spill for PA versus
6794 only two years with spill for the No Action Alternative over the 80-year period. However, of
6795 those 11 years of spill, only 7 years were predicted to spill enough volume to increase tailwater
6796 TDG saturations to greater than 110 percent. The number of days exceeding 110 percent
6797 increased from 8 days for the No Action Alternative to 35 days for PA (Figure 8-11). Although
6798 spill from Libby Dam for the 80-year model period is predicted to increase under the PA, the
6799 frequency of spill with TDG exceeding 110 percent is still small and effects are considered
6800 negligible.

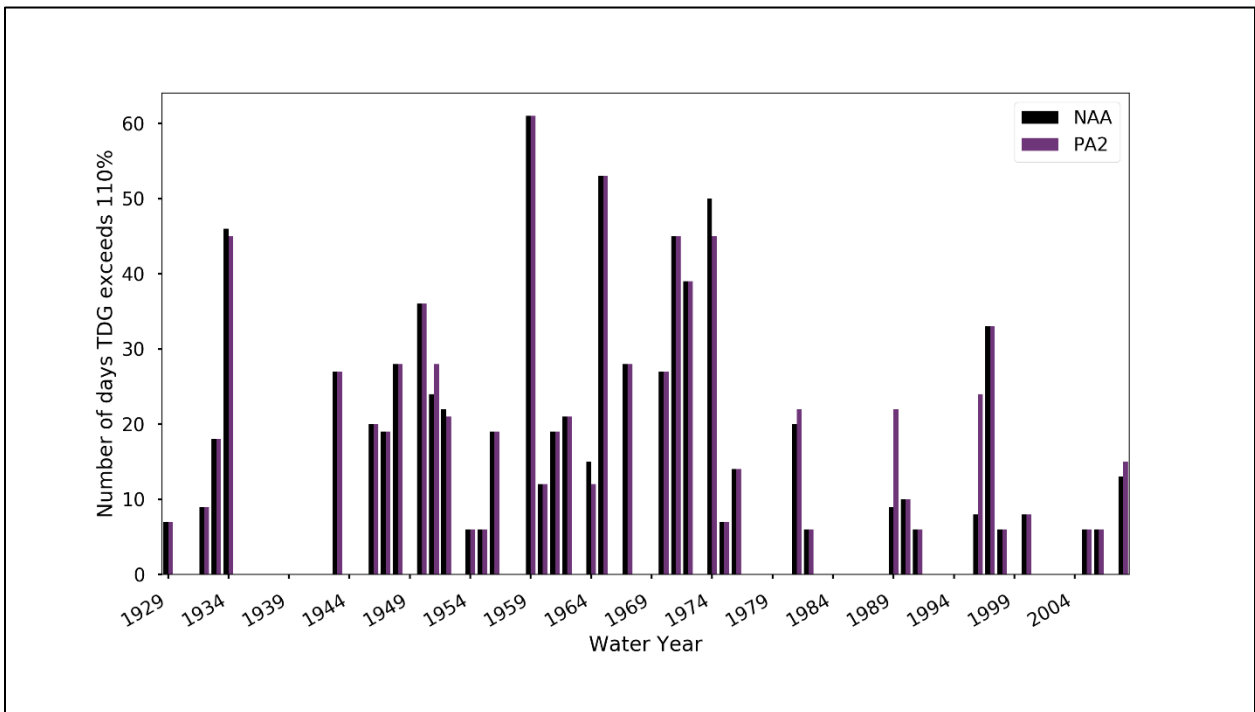
6801 TDG below Hungry Horse Dam under the PA is expected to be relatively similar to the No Action
6802 Alternative in most years (Figure 8-12). Spill at Hungry Horse Dam, which is already infrequent,
6803 would increase slightly in a few years given the increase in carryover in some dry years due to
6804 the *Sliding Scale and Libby and Hungry Horse* measure, but the duration of spill would decrease
6805 in most years compared to the No Action Alternative. The PA would results in 64 days
6806 exceeding the standard in a single year. On average, spill would exceed 110% approximately 10
6807 days per year when including years with zero days of spill. Overall, the PA and No Action
6808 alternatives are similar in the number of exceedance days; the effects are considered negligible.



6809
 6810 **Figure 8-10. Modeled Tailwater Total Dissolved Gas and Spillway Flows for Preferred**
 6811 **Alternative and No Action Alternative at Libby Dam over an 80-year period**



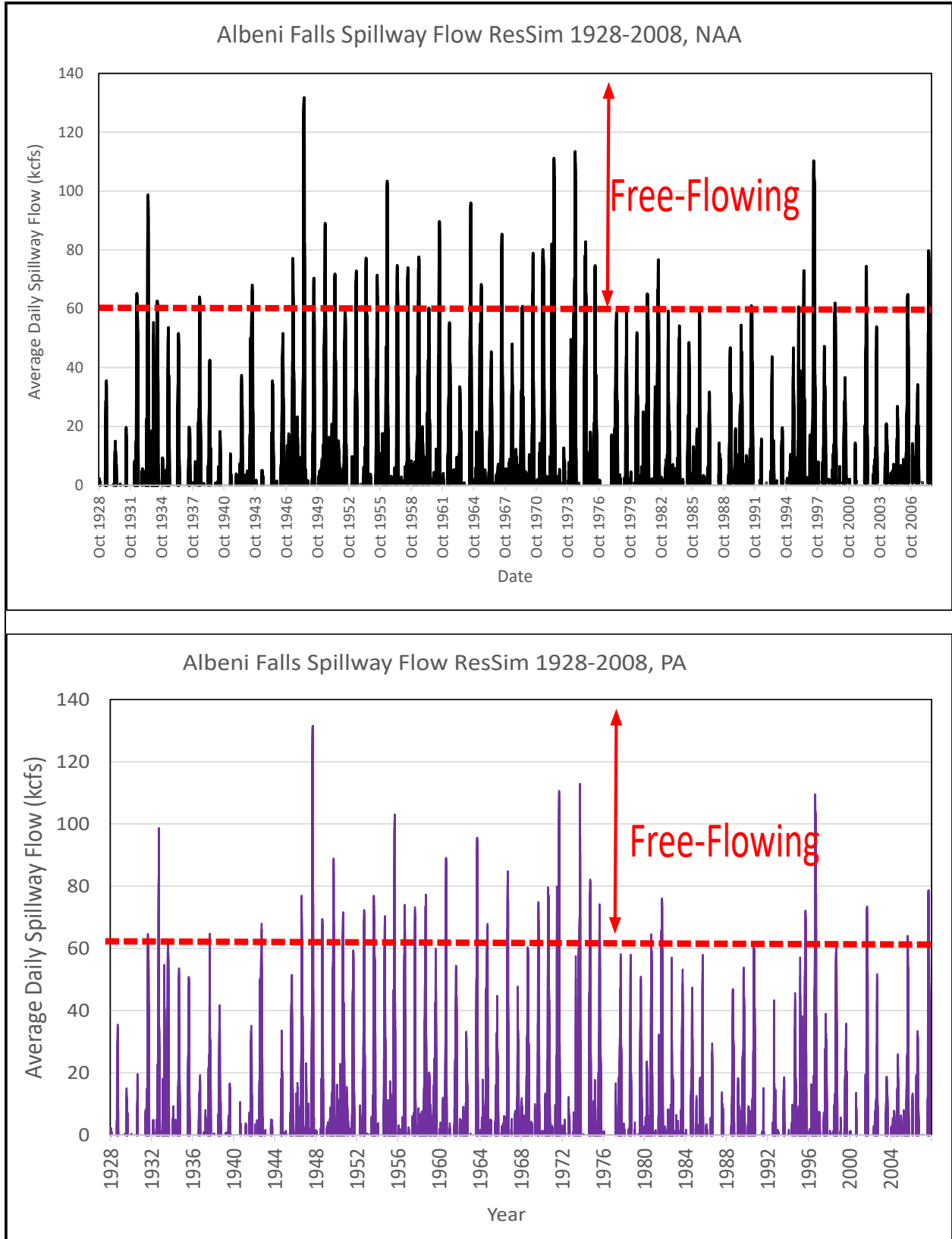
6812
 6813 **Figure 8-11. Number of Days Modeled Tailwater Total Dissolved Gas Exceeds the 110 percent**
 6814 **State Water Quality Standards for Preferred Alternative and No Action Alternative at Libby**
 6815 **Dam over an 80-year Period**



6816
 6817 **Figure 8-12. Modeled Tailwater Total Dissolved Gas and Spillway Flows for Preferred**
 6818 **Alternative and No Action Alternative at Hungry Horse Dam over an 80-year period**

6819 **8.1.2.2 Albeni Falls Dam and Reservoir**

6820 TDG in the Pend Oreille River upstream of Albeni Falls Dam can be greater than 110 percent
6821 largely because of spillway releases from Cabinet Gorge Dam located on the Clark Fork River
6822 about 55 miles upstream of Albeni Falls Dam. During most years, Albeni Falls Dam spills during
6823 high-flow spring runoff. In general, when spill is spread evenly across the spillway, spillway
6824 discharges up to about 10 kcfs can increase TDG saturations over forebay levels by about 1 to 2
6825 percent, while spill between 10 to 50 kcfs can increase TDG saturations downstream of Albeni
6826 Falls by about 5 to 9 percent. When Pend Oreille River flows exceed about 50 to 60 kcfs, Albeni
6827 Falls Dam powerhouse operations are suspended and the spillway gates are raised, allowing the
6828 river to flow relatively un-impounded across the dam. Under these high-flow conditions Albeni
6829 Falls Dam produces no TDG as the river is essentially free flowing. Spillway flows at Albeni Falls
6830 Dam were modeled under the PA and the No Action Alternative for the 80-year period from
6831 1928 to 2008 (Figure 8-13). In general, there were no differences in spillway flows under the PA
6832 and the No Action Alternative. For both alternatives, spillway flows were predicted to range
6833 between 1 and 50 kcfs in nearly every year at Albeni Falls Dam, with many years having spill
6834 exceed about 60 kcfs, resulting in free-flowing conditions. The similar spillway flows under the
6835 PA and No Action Alternative are expected to result in no change in TDG saturations
6836 downstream of Albeni Falls Dam.



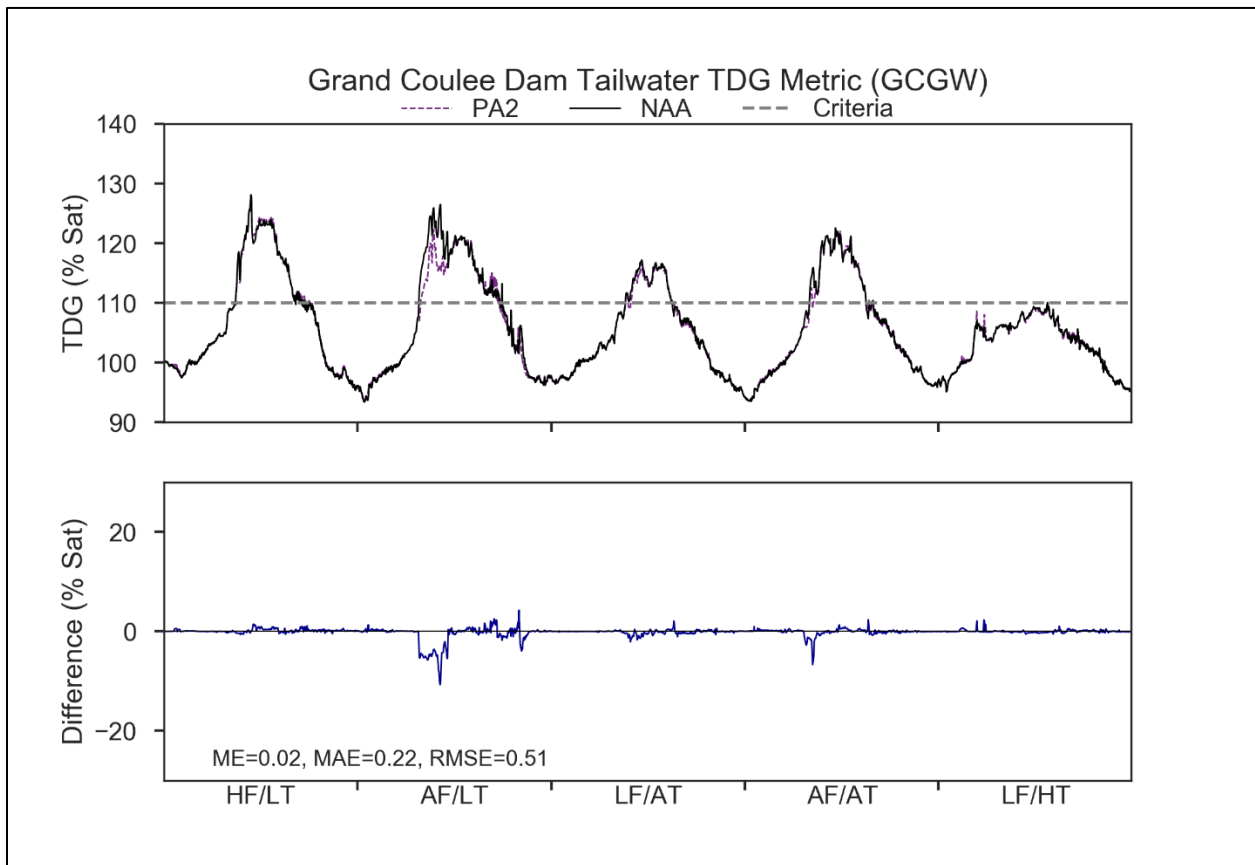
6837
 6838
 6839

Figure 8-13. Modeled Tailwater Spillway Flows for Preferred Alternative and No Action Alternative at Albeni Falls Dam over an 80-year Period

6840 **8.1.2.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

6841 The Update System FRM Calculation, Planned Draft Rate at Grand Coulee, Fall Operational
6842 Flexibility for Hydropower (Grand Coulee), and Lake Roosevelt Additional Water Supply
6843 measures relate directly to Grand Coulee Dam under the PA, and all of these (with the
6844 exception of Lake Roosevelt Additional Water Supply) would influence reservoir elevations at
6845 Lake Roosevelt. Operational changes in Region A (upstream) may also have a slight effect on
6846 Lake Roosevelt water levels. The Grand Coulee Maintenance Operations measure would not
6847 impact reservoir elevations or total outflows, but would affect power generation, frequency of
6848 spill, and potentially TDG generation.

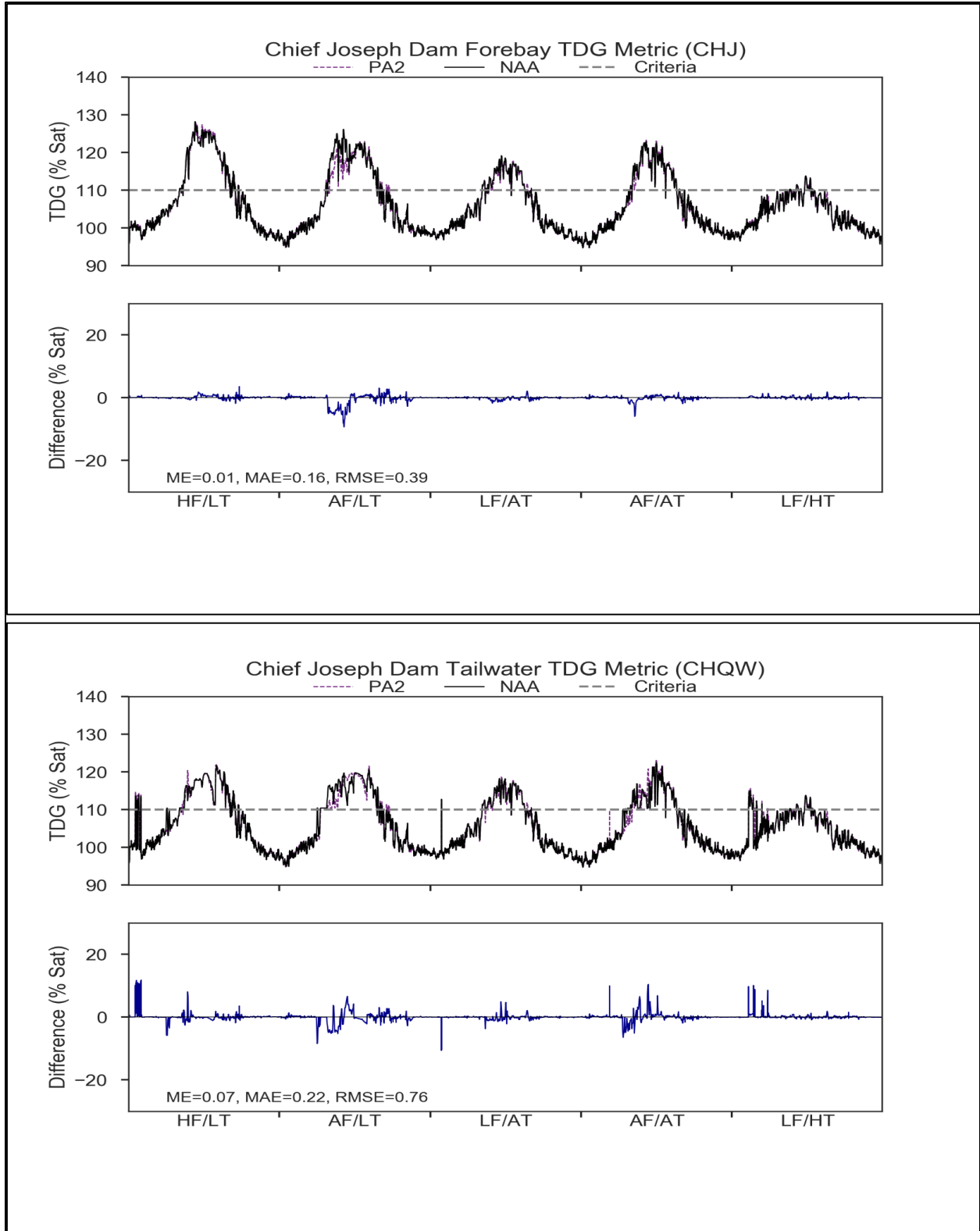
6849 Under the PA, TDG downstream of Grand Coulee Dam ranges from 95% to 125%; historically
6850 TDG in excess of 125% has been recorded and is still a possibility under the PA depending on
6851 inflowing TDG and flow conditions. The Grand Coulee Maintenance Operations and Planned
6852 Draft Rate at Grand Coulee measures, could affect TDG below the dam, but these measures
6853 tend to partially offset each other in this analysis. In general, these measure result in TDG very
6854 similar to the No Action Alternative (Figure 8-14). These differences are considered negligible.



6855 **Figure 8-14. Modeled forebay and tailwater Total Dissolved Gas saturations for Preferred**
6856 **Alternative and No Action Alternative at Grand Coulee Dam Under a 5-year Range of River**
6857 **and Meteorological Conditions**
6858

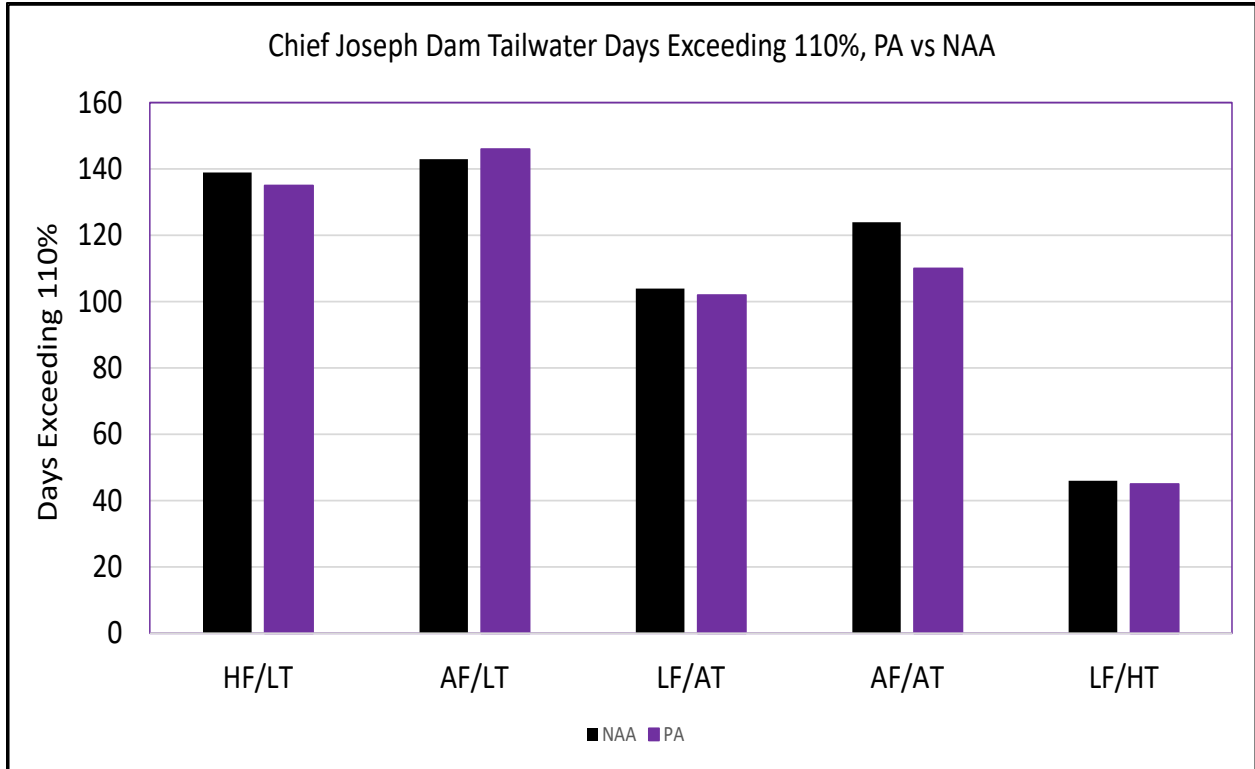
6859 TDG at the forebay of Chief Joseph Dam is largely a function of the TDG released upstream from
6860 Lake Roosevelt and Grand Coulee Dam, because little degassing occurs in Rufus Woods Lake.
6861 High inflowing TDG to Lake Roosevelt from Canada, as well as spill from Grand Coulee Dam via
6862 the outlet tubes, can increase TDG saturations in Rufus Woods Lake at the Chief Joseph Dam
6863 forebay to over 130 percent. During periods when incoming TDG levels are above
6864 approximately 120 percent, spilling at Chief Joseph Dam over the spillway deflectors can degas
6865 the water and reduce downstream system TDG loading. Therefore, Chief Joseph Dam is often
6866 used to help manage overall system TDG production in the mainstem Columbia River. In
6867 addition, to avoid spilling through the outlet tubes at Grand Coulee Dam, spill is often shifted
6868 from Grand Coulee to Chief Joseph Dam to take advantage of the lower TDG produced by
6869 spilling over the deflectors. These operational strategies are expected to continue under the
6870 PA.

6871 Chief Joseph Dam TDG saturations at the forebay and tailwater modeled under the PA for a
6872 range of flow and meteorological conditions were compared to the No Action Alternative
6873 Figure 8-15). In general, predicted PA forebay TDG saturations are similar to the No Action
6874 Alternative for the different flow and air temperature conditions. Tailwater TDG saturations
6875 under the PA are predicted to be both lower and higher than the No Action Alternative
6876 depending on flow and meteorological conditions. The number of days the tailwater exceeds
6877 the 110 percent TDG criteria is predicted to be similar between the No Action Alternative and
6878 PA for all flow and meteorological conditions (Figure 8-16). Decreased TDG saturations between
6879 the forebay and tailwater during high-flow and high-spill years (HF/LT) modeled under the No
6880 Action Alternative would continue under the PA. It is expected that under PA, Chief Joseph Dam
6881 would continue to decrease TDG during years when elevated TDG saturations occur in the
6882 forebay. TDG impacts at Chief Joseph Dam are expected to be negligible.



6883
6884
6885
6886

Figure 8-15. Modeled forebay and tailwater Total Dissolved Gas saturations for Preferred Alternative and No Action Alternative at Chief Joseph Dam Under a 5-year Range of River and Meteorological Conditions



6887
 6888 **Figure 8-16. Days Exceeding the 110 percent Total Dissolved Gas Criteria for Preferred**
 6889 **Alternative and No Action Alternative at Chief Joseph Dam Tailwater Under a 5-year Range of**
 6890 **River and Meteorological Conditions**

6891 **8.1.3 Other Physical, Chemical and Biological Processes**

6892 **8.1.3.1 Libby and Hungry Horse Dams and Reservoirs**

6893 The PA modifies operations at Libby Dam resulting in changes in the drafting depth and refill
 6894 elevations of Lake Kooconusa that may impact physical, chemical, and biological water quality
 6895 parameters when compared to the No Action Alternative. The PA reservoir elevations and
 6896 outflows during median and high water supply years will be relatively similar to the No Action
 6897 Alternative, and water quality changes are not anticipated. However, for low water supply
 6898 years, the reservoir would be drafted deeper with mid-April water elevations up to 8 feet lower
 6899 in the driest 40 percent of years. Reservoir refill and summer pool elevations for all water
 6900 supply years are improved over the No Action Alternative with the reservoir reaching full pool
 6901 by the end of July and maintaining higher elevations (about 1 to 4 feet higher) in August and
 6902 September. For water quality concerns, of particular interest are the 8 foot lower mid-April
 6903 water elevations for low water supply years because they equate to less volume of water in
 6904 Lake Kooconusa during the spring runoff and a shorter water retention time.

6905 Retention time, which is the inverse of the flushing rate, refers to the length of time water
 6906 remains in a waterbody. Water quality chemical and biological parameters of concern in Lake
 6907 Kooconusa that may be impacted by changes in the reservoir elevation and retention times,

6908 under the PA, include suspended sediments, nutrients such as phosphorus and nitrogen, metals
6909 such as selenium, and phytoplankton such as cyanobacteria and diatoms. It is possible that
6910 shorter retention times may allow certain chemical constituents in inflowing waters to move
6911 farther down-reservoir toward the forebay and outflow before settling out or transforming.

6912 Historical data show that Lake Kootenai is a sink for phosphorus and sediments, with up to 93
6913 percent of inflow total phosphorus retained in the reservoir (Yassien and Ward 2018). Under
6914 the PA, the lower reservoir elevations for the driest 40 percent of years may allow sediments
6915 and total phosphorus from the inflow to move farther down-reservoir. Conversely, Lake
6916 Kootenai does not appear to be a sink for nitrogen with most of the inflow nitrate passing
6917 down-reservoir to the forebay and Kootenai River.

6918 Increased nitrate loadings to Lake Kootenai, largely due to coal mining operations in British
6919 Columbia, and low phosphorus concentrations have created a large imbalance in the nitrogen-
6920 to-phosphorus ratio resulting in strong phosphorus limitation. Despite rising nitrate
6921 concentrations in Lake Kootenai, phytoplankton blooms appear to have been kept in check by
6922 the strong phosphorus limitation under existing conditions and the No Action Alternative. It is
6923 possible that the operational changes proposed for the PA may increase total phosphorus
6924 concentrations in Lake Kootenai, which could result in changes in phytoplankton densities and
6925 functional types. However, these changes in retention times are small and only occur during
6926 more extreme water years (low water supply), which likely would reduce potential nutrient and
6927 phytoplankton impacts from PA on Lake Kootenai.

6928 Increasing selenium concentrations over the next 25 years in Lake Kootenai from coal mining
6929 operations in British Columbia are a concern and were previously discussed for the No Action
6930 Alternative. Although there does not yet appear to be an increasing trend in water column
6931 selenium concentrations in the reservoir, there is concern that without water quality
6932 treatment, the continued selenium loadings to Lake Kootenai may lead to additional selenium
6933 contamination. It is possible that the lower mid-April reservoir elevations for the driest 40
6934 percent of years under PA may alter the movement, cycling, and transformation of selenium in
6935 the reservoir and downstream in the Kootenai River, possibly resulting in water and sediment
6936 quality impacts.

6937 Low water year reservoir elevations under the PA would be up to 8 feet lower in the spring, but
6938 mid-June through September growing season reservoir elevations would be 1 to 4 feet higher
6939 as compared to the No Action Alternative. As such, Lake Kootenai should not experience
6940 substantial changes to in-lake productivity under the PA. Additionally, changes in the median
6941 average monthly outflows from Libby Dam during the mid-June through September time frame
6942 are relatively minor (reduction of 5 to 8 percent when compared to the No Action Alternative),
6943 which result in only about a 0.3-foot decrease in median monthly elevation in the Kootenai
6944 River downstream of Libby Dam, and should not greatly impact the varial (periodically wetted)
6945 zone productivity. Overall, changes to water quality in Lake Kootenai are anticipated to be
6946 negligible under the PA.

6947 As previously stated, there no known sources of contamination in Hungry Horse Reservoir or in
6948 the South Fork of the Flathead River. Based on the very minor changes to operations at Hungry
6949 Horse there are no anticipated changes to water quality conditions anticipated under the PA as
6950 compared to the No Action Alternative.

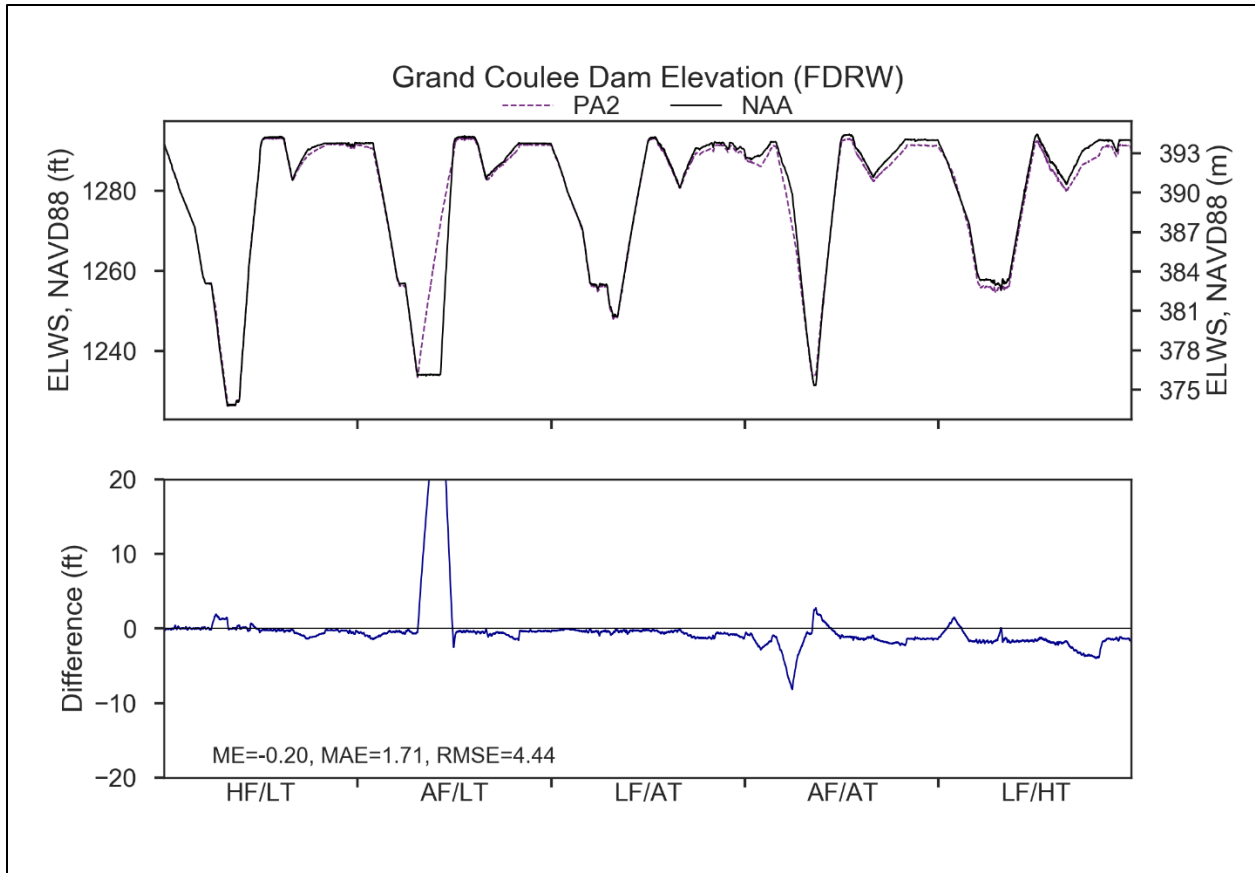
6951 **8.1.3.2 Albeni Falls Dam and Reservoir**

6952 Under the PA, there are no changes to operations at Albeni Falls Dam. The physical, chemical,
6953 and biological water quality of Lake Pend Oreille and the Pend Oreille River described under the
6954 No Action Alternative are expected to remain unchanged.

6955 **8.1.3.3 Grand Coulee and Chief Joseph Dams and Reservoirs**

6956 Turbidity from mass wasting, such as small local landslides, within Lake Roosevelt, is correlated
6957 to the rate of drawdown and refill at Grand Coulee Dam. The operational measure to decrease
6958 the *Planned Draft Rate at Grand Coulee* changes the target maximum drawdown from 1.0
6959 ft/day to a target of 0.8 ft/day. A slower drawdown rate may result in lower turbidity
6960 throughout the reservoir.

6961 Water level fluctuations in Lake Roosevelt may have an impact on mercury cycling within the
6962 reservoir, especially when the lowest lake levels occur from April through June. As previously
6963 stated, studies have suggested that methylmercury has a greater probability of entering the
6964 food web. Under the PA, the *Update System FRM Calculation, Planned Draft Rate at Grand*
6965 *Coulee, and Fall Operational Flexibility for Hydropower* measures are all predicted to influence
6966 Lake Roosevelt water surface elevations. However, as shown in Figure 8-17, changes in water
6967 surface elevation are small and are not predicted to impact mercury cycling. Overall, impacts to
6968 water quality within Lake Roosevelt are anticipated to be negligible as compared to the No
6969 Action Alternative.



6970
 6971 **Figure 8-17. Modeled Forebay Elevations for the No Action Alternative and the Preferred**
 6972 **Alternative at Grand Coulee Dam Under a 5-Year Range of River and Meteorological**
 6973 **Conditions**

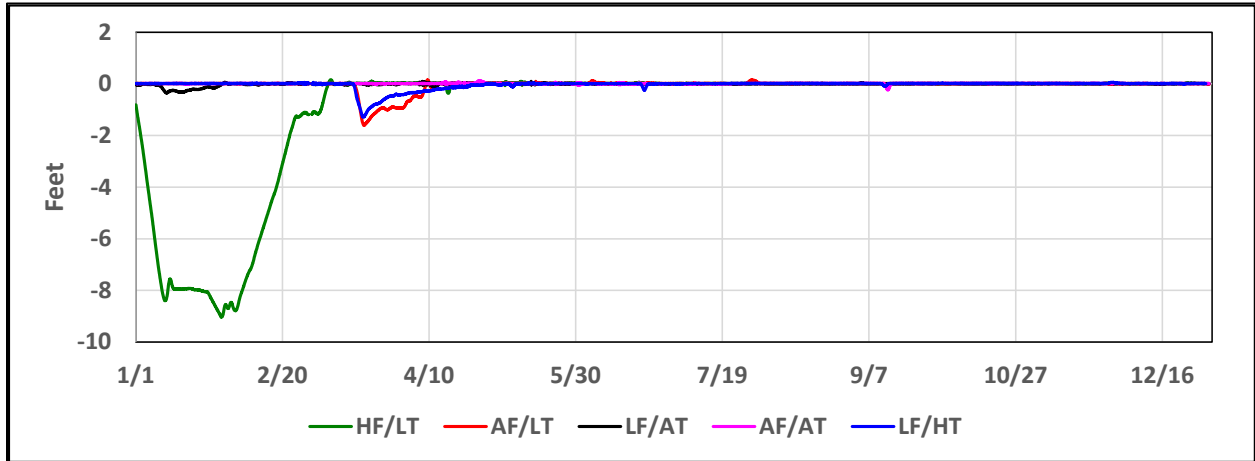
6974 Under the PA, only minor changes to operations, reservoir elevations, and flows at Chief Joseph
 6975 Dam are expected. Given this, the physical, chemical, and biological water quality of Rufus
 6976 Woods Lake and the Columbia River downstream of Chief Joseph Dam under the PA are
 6977 expected to remain relatively unchanged from the No Action Alternative. The harmful algae
 6978 blooms at this location, as described in the No Action Alternative (Section 3.1.3), would
 6979 continue in the future under the PA.

6980 **8.2 LOWER SNAKE RIVER BASIN**

6981 Under the PA, a slightly deeper draft in the Dworshak Dam reservoir would occur between
 6982 January and March during years with a higher flow forecast. Additional spill up to 125% would
 6983 occur at the four lower Snake River projects from the beginning of April through the third week
 6984 of June. Structural measures that include adult fish trap modifications at Lower Granite Dam
 6985 and installation of entrance weir caps at each of the four lower Snake River dams are not
 6986 anticipated to affect water quality conditions in the river.

6987 The reservoir elevation differences that would occur at Dworshak Reservoir under the PA are
 6988 shown in Figure 8-18. The largest difference would occur during January and February of a

6989 HF/LT (high flow/lower air temperature) year when the reservoir would be lower by a
 6990 maximum of about 9 feet. Average January and February differences during the same flow and
 6991 air temperature conditions would be 7.1 and 4.9 feet, respectively. The maximum and average
 6992 differences during the other four flow and air temperature conditions would only range from
 6993 0.0 to 0.3 feet. Smaller elevation changes would occur during March ranging from a maximum
 6994 of 1.2 to 1.6 feet during HF/LT, AF/LT, and LF/HT conditions. Average differences during the
 6995 same month and conditions would range from 0.1 to 0.5 feet. Maximum and average
 6996 conditions during LF/AT and AF/LT would be zero.

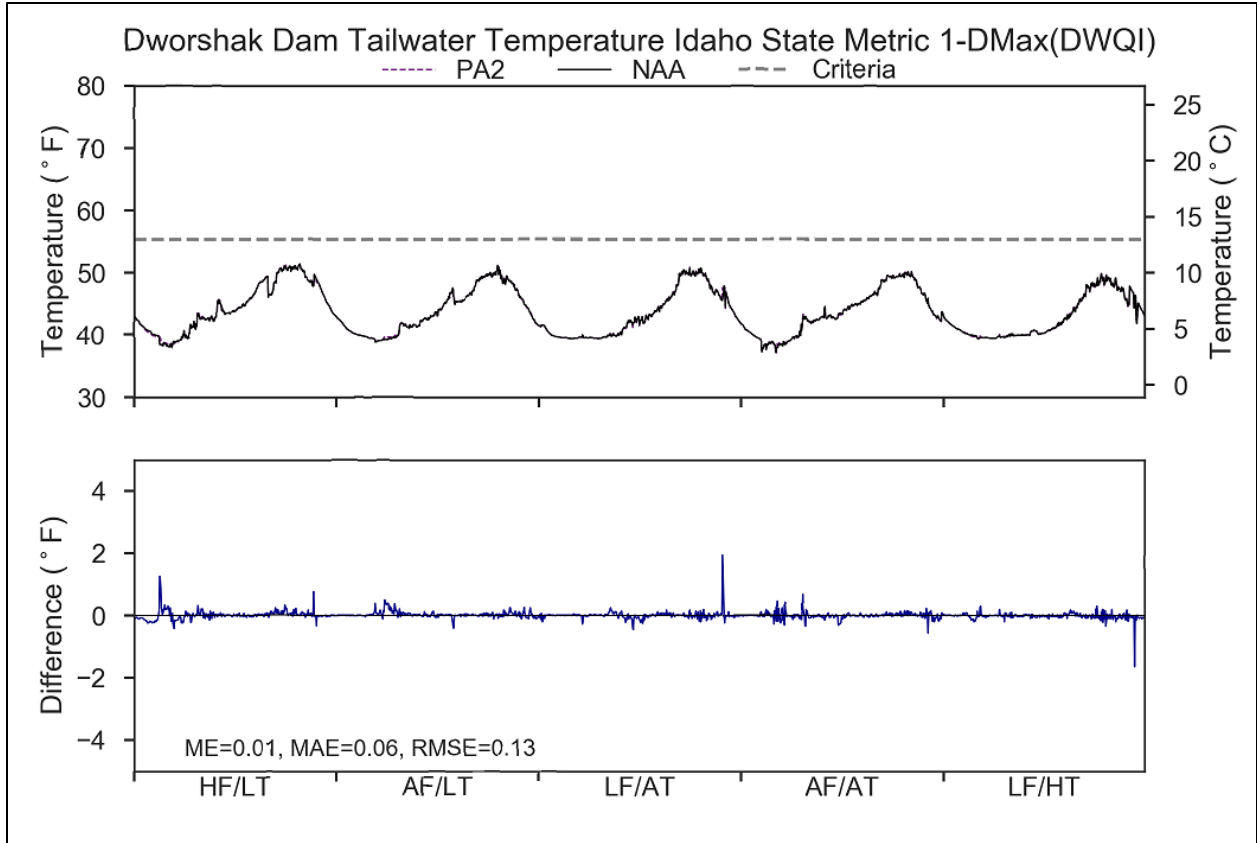


6997 **Figure 8-18. Differences Between Dworshak Reservoir Pool Elevations for the Preferred**
 6998 **Alternative and the No Action Alternative for the 5-Year Range of Flow and Meteorological**
 6999 **Conditions Modeled**
 7000

7001 **8.2.1 Water Temperature**

7002 **8.2.1.1 Dworshak Dam and Reservoir**

7003 Outflow water temperatures from Dworshak Dam under the PA would be very similar to No
 7004 Action Alternative conditions (Figure 8-19). Daily average and maximum temperatures would
 7005 be less than 52°F throughout the year. The average monthly temperature differences between
 7006 January and September would not exceed 0.1°F (Table 8-1). Maximum daily differences could
 7007 reach 1.7°F during February of a HF/LT year and 0.8°F during February, March, and April of a
 7008 AF/AT year, but each of these events would only last one day.



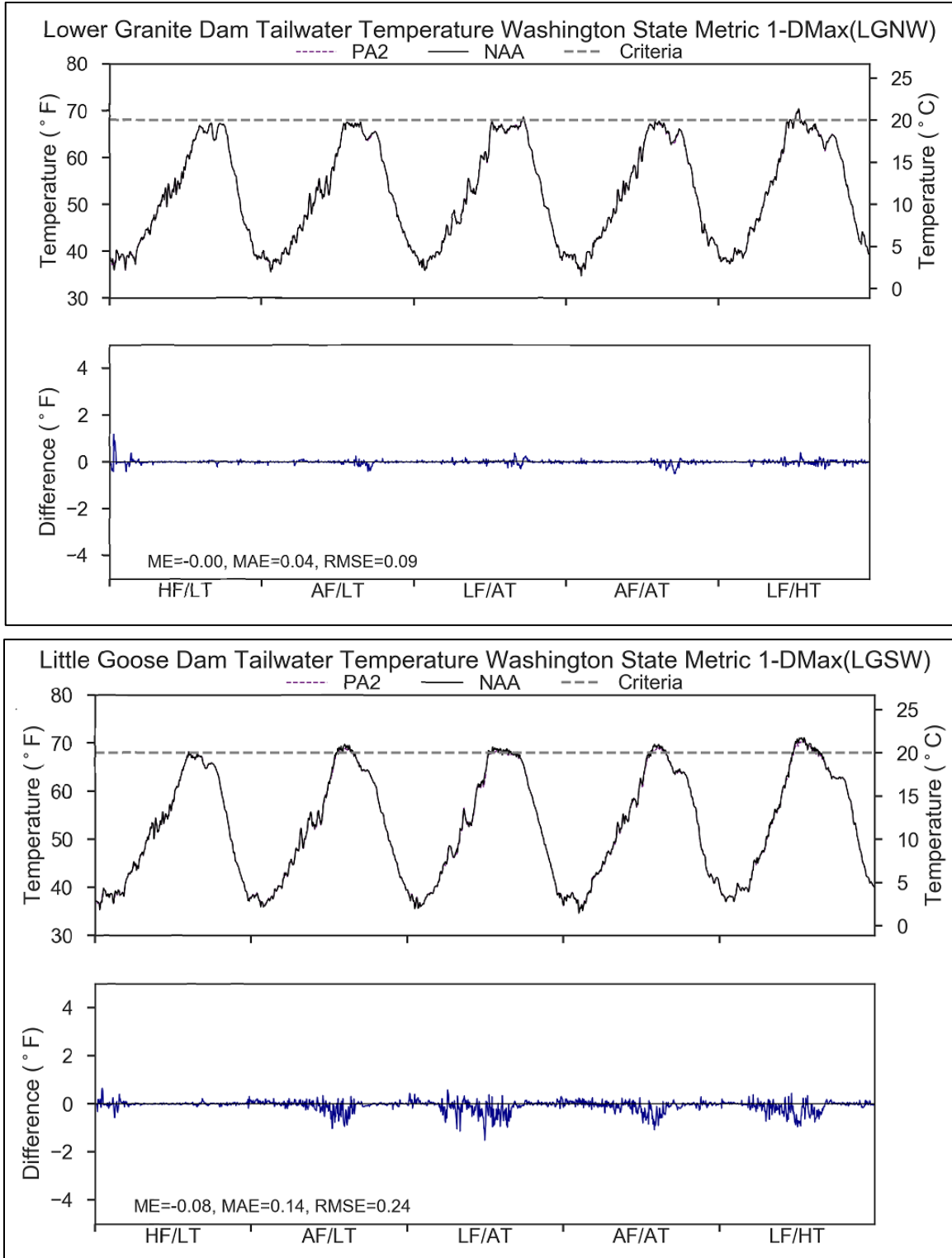
7009
 7010 **Figure 8-19. Modeled Tailwater Temperature for the Preferred Alternative and No Action**
 7011 **Alternative at Dworshak Dam Under a 5-year Range of River and Meteorological Conditions**

7012 **Table 8-1. Monthly Average Temperature Differences (°F) Between the Preferred Alternative**
 7013 **and the No Action Model Results at Dworshak Dam for Five Flow and Meteorological**
 7014 **Conditions**

Month	Flow and Air Temperature Conditions				
	HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
January	-0.1	0.0	0.0	0.0	0.0
February	0.1	0.0	0.0	0.0	0.0
March	-0.1	0.1	0.0	0.0	0.0
April	0.0	0.1	0.0	0.0	0.0
May	0.0	0.0	0.1	0.0	0.0
June	0.0	0.0	-0.1	0.0	0.0
July	0.0	0.0	-0.1	0.0	0.0
August	0.0	0.0	0.0	0.0	0.1
September	0.1	0.0	0.0	0.0	0.0

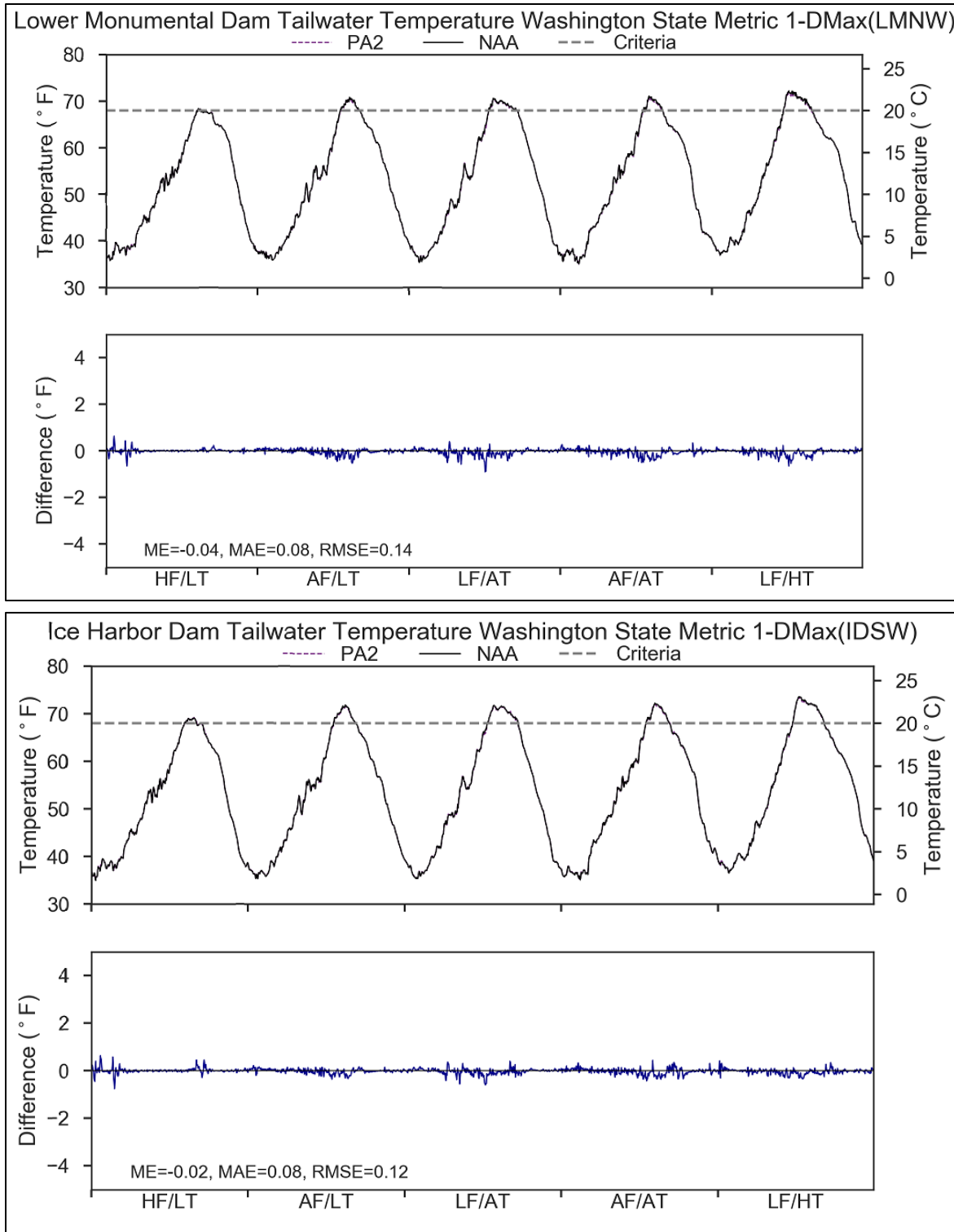
7015 **8.2.1.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
7016 **Reservoirs**

7017 Water temperatures in the lower Snake River under the PA would be very similar to the No
7018 Action Alternative (Figure 8-20 and Figure 8-21). Maximum daily temperatures would be less
7019 than 68°F most of the time between April and September downstream of Lower Granite Dam.
7020 The two exceptions would occur during LF/AT and LF/HT conditions when maximum
7021 temperatures would reach 68.8°F and 70.2°F, respectively. Maximum daily temperatures
7022 would increase downstream and range from 70.1°F to 73.4°F during July and August. However,
7023 the average monthly differences under the PA would be cooler than the No Action Alternative
7024 at all four projects with the largest differences occurring in July and August (Figure 8-22). The
7025 number of days when water temperatures would exceed 68°F would be similar under the PA as
7026 compared to the No Action Alternative (Table 8-2). Overall, water temperature impacts are
7027 expected to be negligible under the PA.



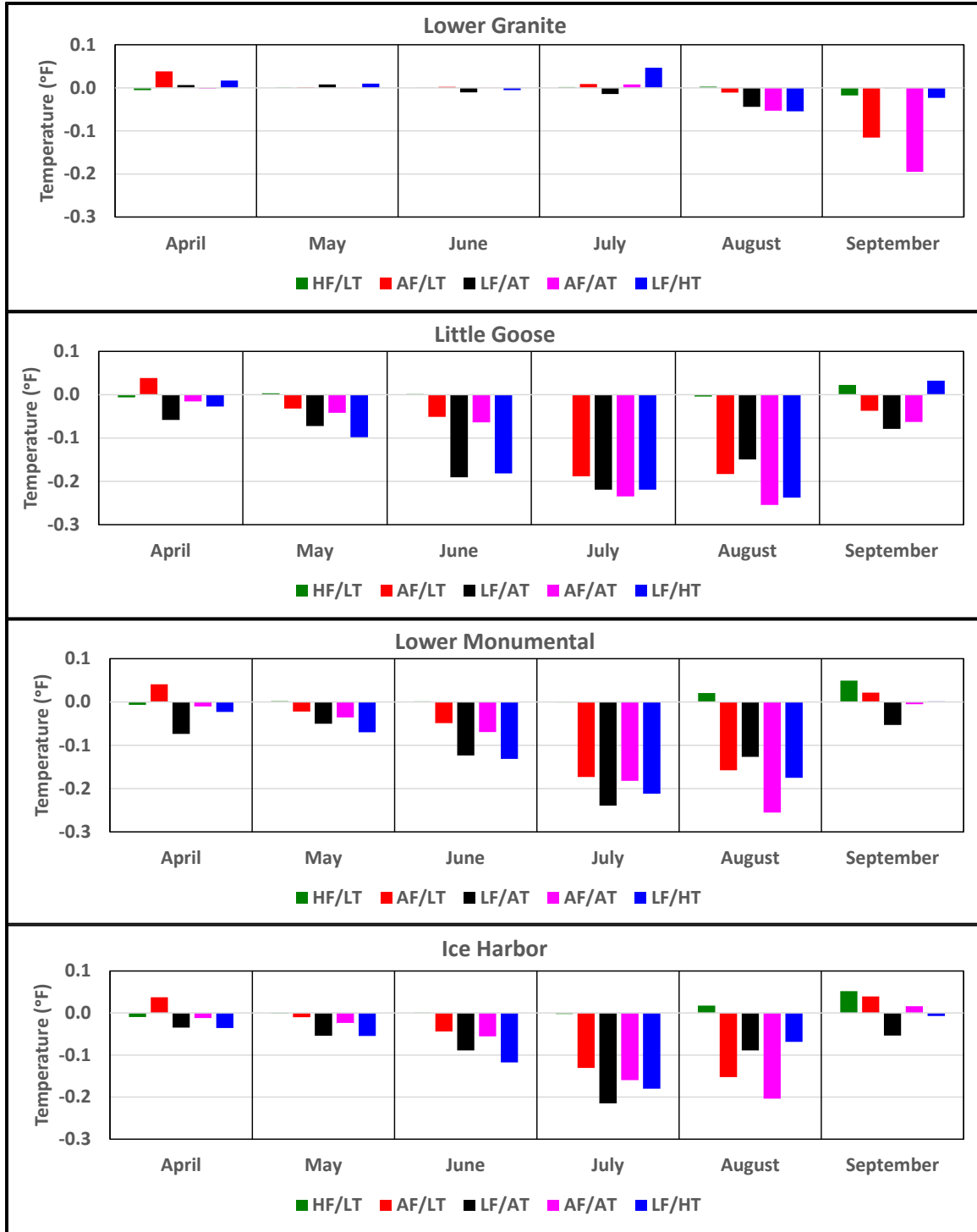
7028
 7029
 7030
 7031

Figure 8-20. Modeled Tailwater Temperatures for the Preferred Alternative and No Action Alternative at Lower Granite and Little Goose Dams Under a 5-year Range of River and Meteorological Conditions



7032
 7033
 7034
 7035

Figure 8-21. Modeled Tailwater Temperatures for the Preferred Alternative and No Action Alternative at Lower Monumental and Ice Harbor Dams Under a 5-year Range of River and Meteorological Conditions



7036
 7037
 7038
 7039

Figure 8-22. Average Temperature Differences Between the Preferred Alternative and the No Action Alternative for April Through September at the Four Lower Snake River Dam Tailwater Locations for the Five Flow and Air Temperature Conditions

7040 **Table 8-2. Changes in the Number of Days During the Month when Maximum Tailwater**
7041 **Temperatures Would be Greater than 68°F Under the Preferred Alternative when compared**
7042 **to the No Action Alternative for the Five Flow and Air Temperature Conditions at the Four**
7043 **Lower**

Project	Month	Flow and Air Temperature Conditions				
		HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
Lower Granite	June	0	0	0	0	0
	July	0	0	0	0	2
	August	0	0	0	0	0
	September	0	0	-1	0	0
Little Goose	June	0	0	0	0	-1
	July	0	-1	-4	-4	0
	August	0	-2	-16	-1	-5
	September	0	0	0	0	0
Lower Monumental	June	0	0	0	0	0
	July	0	-2	0	-2	0
	August	1	0	0	0	0
	September	0	1	0	0	-1
Ice Harbor	June	0	0	0	0	0
	July	0	0	-1	-1	0
	August	0	0	0	0	0
	September	0	1	-1	2	0

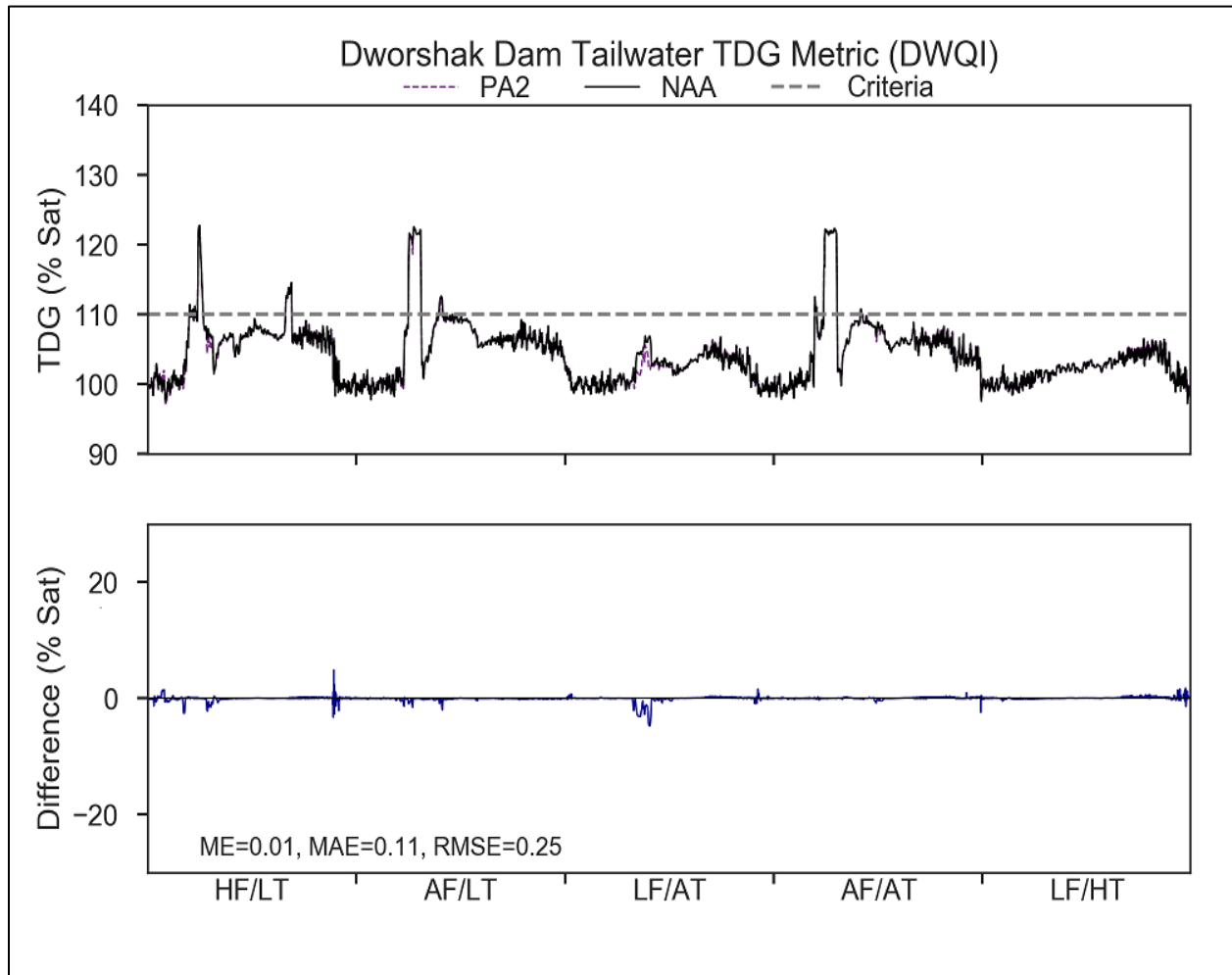
7044 **8.2.2 Total Dissolved Gas**

7045 The PA contains the *Juvenile Fish Passage Spill* measure, which is based on the results of the
7046 spring 2019 Flexible Spill Test Operation and analyses of the four MO Alternatives. The *Juvenile*
7047 *Fish Passage Spill* measure would be implemented during the spring juvenile salmonid
7048 migration season at the lower Snake River and involve 16 hours of spill operations up to the
7049 125% TDG gas cap at most projects for juvenile outmigration. For the remaining 8 hours, the
7050 projects would spill at a lower level (this level is referred to as performance standard spill).
7051 These performance standard spill levels are slightly variable depending on the project, and may
7052 be slightly higher or lower depending on river conditions and the opportunity to spill. This
7053 operation would allow hydropower generation during times of peak demand, while still
7054 providing for high spill for fish when it is expected to be most important (generally in the
7055 evenings and very early morning hours). These operations would be implemented during the
7056 spring juvenile migration, which at the lower Snake River projects occurs from April 3 through
7057 June 20. When *Juvenile Fish Passage Spill* ceases, the projects would transition to summer spill
7058 operations.

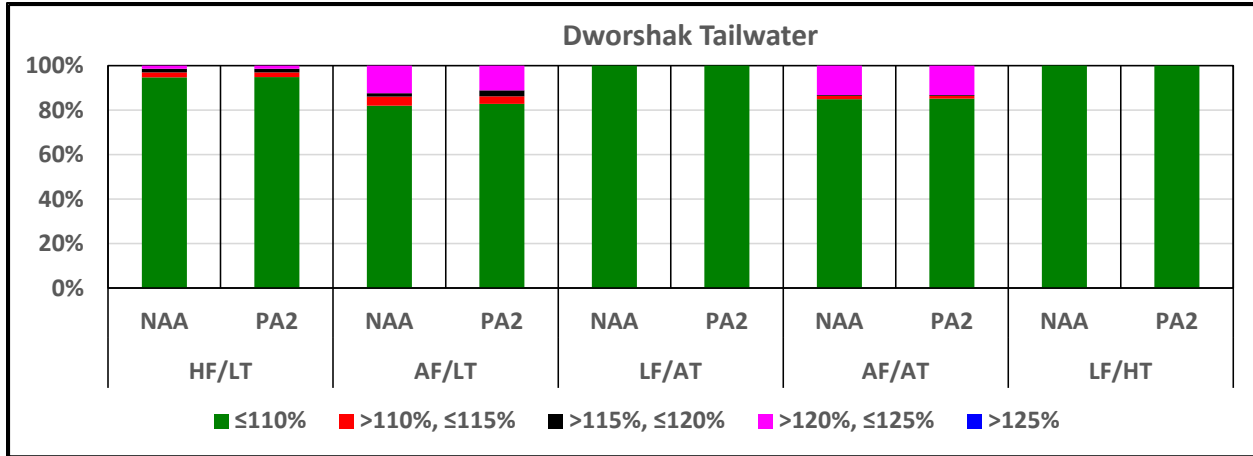
7059 **8.2.2.1 Dworshak Dam and Reservoir**

7060 TDG downstream from Dworshak Dam under the PA would be very similar to the No Action
7061 Alternative model results (Figure 8-23 and Figure 8-24). TDG would remain below the 110

7062 percent standard the majority of the time for each of the five flow and air temperature
7063 combinations. Gas saturation greater than 120 percent would still occur during April under
7064 HF/LT, AF/LT, and AF/AT conditions. However, the percent of time that TDG would be greater
7065 than 120 percent under the PA would not differ from the No Action Alternative under HF/LT
7066 and AF/AT conditions (Table 8-3). During April of AF/LT conditions, there would be a 6.4
7067 percent decrease in the amount of time TDG would be greater than 120 percent. Finally, the
7068 additional release of water during January of HF/LT conditions would increase downstream TDG
7069 by up to 1.5 percent, but TDG in the river would still be less than 110 percent. Overall, TDG
7070 impacts downstream of Dworshak Dam are negligible.



7071
7072 **Figure 8-23. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative and No**
7073 **Action Alternative at Dworshak Dam Under a 5-Year Range of River and Meteorological**
7074 **Conditions**



7075
7076 **Figure 8-24. Frequency Distributions for Dworshak Tailwater Total Dissolved Gas for the No**
7077 **Action Alternative and Preferred Alternative for April through August during the five flow and**
7078 **air temperature conditions**

7079 **Table 8-3. Changes in the percent of time Dworshak Tailwater TDG saturation would occur**
7080 **within selected ranges if PA2 would be implemented compared to the NAA for the five flow**
7081 **and air temperature conditions by month**

Month	Percent Range	Flow and Air Temperature Conditions				
		HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
JANUARY	≤ 110%	0.0	0.0	0.0	0.0	0.0
	> 110%, ≤ 115%	0.0	0.0	0.0	0.0	0.0
	> 115%, ≤ 120%	0.0	0.0	0.0	0.0	0.0
	> 120%, ≤ 125%	0.0	0.0	0.0	0.0	0.0
FEBRUARY	≤ 110%	0.0	0.0	0.0	0.0	0.0
	> 110%, ≤ 115%	0.0	0.0	0.0	0.0	0.0
	> 115%, ≤ 120%	0.0	0.0	0.0	0.0	0.0
	> 120%, ≤ 125%	0.0	0.0	0.0	0.0	0.0
MARCH	≤ 110%	-1.3	0.0	0.0	0.0	0.0
	> 110%, ≤ 115%	1.3	0.0	0.0	0.0	0.0
	> 115%, ≤ 120%	0.0	0.0	0.0	0.0	0.0
	> 120%, ≤ 125%	0.0	0.0	0.0	0.0	0.0
APRIL	≤ 110%	0.1	0.3	0.0	0.0	0.0
	> 110%, ≤ 115%	-0.1	0.0	0.0	0.0	0.0
	> 115%, ≤ 120%	0.0	6.1	0.0	0.0	0.0
	> 120%, ≤ 125%	0.0	-6.4	0.0	0.0	0.0
MAY	≤ 110%	0.0	2.3	0.0	0.0	0.0
	> 110%, ≤ 115%	0.0	-2.3	0.0	0.0	0.0
	> 115%, ≤ 120%	0.0	0.0	0.0	0.0	0.0
	> 120%, ≤ 125%	0.0	0.0	0.0	0.0	0.0
JUNE	≤ 110%	0.0	1.1	0.0	1.3	0.0
	> 110%, ≤ 115%	0.0	-1.1	0.0	-1.3	0.0
	> 115%, ≤ 120%	0.0	0.0	0.0	0.0	0.0
	> 120%, ≤ 125%	0.0	0.0	0.0	0.0	0.0

*Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix*

Month	Percent Range	Flow and Air Temperature Conditions				
		HF/LT	AF/LT	LF/AT	AF/AT	LF/HT
JULY	≤ 110%	0.0	0.0	0.0	0.0	0.0
	> 110%, ≤ 115%	0.0	0.0	0.0	0.0	0.0
	> 115%, ≤ 120%	0.0	0.0	0.0	0.0	0.0
	> 120%, ≤ 125%	0.0	0.0	0.0	0.0	0.0
AUGUST	≤ 110%	0.0	0.0	0.0	0.0	0.0
	> 110%, ≤ 115%	0.0	0.0	0.0	0.0	0.0
	> 115%, ≤ 120%	0.0	0.0	0.0	0.0	0.0
	> 120%, ≤ 125%	0.0	0.0	0.0	0.0	0.0

7082 **8.2.2.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
7083 **Reservoirs**

7084 Tailwater TDG would increase at the four lower Snake River projects under the PA due to the
7085 *Juvenile Fish Passage Spill* measure that would allow for spill up to 125% TDG 16 hours per day,
7086 from the beginning of April through the third week of June. Under the No Action Alternative,
7087 spill was limited to 120 percent TDG (Figure 8-25 and Figure 8-26). During the April through
7088 August fish passage season, there would be increases in the percent of time that TDG would be
7089 between 120 percent and 125 percent during each of the five flow and air temperature
7090 conditions modeled (Figure 8-27).

7091 The number of days during the month that TDG conditions would exceed 120 percent would
7092 increase, primarily during April, May and June, under the PA (Table 8-4). The changes in the
7093 number of days would be larger at the Lower Granite, Little Goose, and Lower Monumental
7094 projects. During April, the increases in the number of days exceeding 120 percent during HF/LT,
7095 AF/LT, and AT/AT conditions would range from 17 to 29. Changes during LF/AT and LF/HT
7096 conditions would be less, ranging from zero to an additional 6 days. TDG would be greater than
7097 120 percent during May at Lower Granite and Mower Monumental dams 100 percent of the
7098 time during AF/LT and AF/AT conditions. The percent of time at this level during the same
7099 flow/air temperature conditions would be less at Little Goose Dam, but still range from 88 to 93
7100 percent. TDG would drop off sharply in June under HF/LT and LF/HT conditions, resulting in only
7101 1 to 4 additional days of exceedances. In contrast, the number of days of exceedances would
7102 still increase by 10 to 19 days during AF/LT, LF/AT, and AF/AT conditions.

7103 The change in the number of days of exceedance that would occur downstream of Ice Harbor
7104 Dam would be smaller than at the three upstream projects since more degassing occurs in that
7105 reach. The model results show that for the majority of the time during AF/LT, LF/AT, AF/AT,
7106 and LF/HT conditions, 120 percent would not be exceeded. Under the PA, the largest changes
7107 at this project would be increases of 10 and 12 days during May of AF/LT and AT/AT conditions,
7108 respectively. This means that TDG would be greater than 120 percent for 23 to 35 percent of
7109 the time under the PA for that month and flow-air temperature conditions when no
7110 exceedances occur under the No Action Alternative. The remainder of the increases would be 8
7111 days or less.

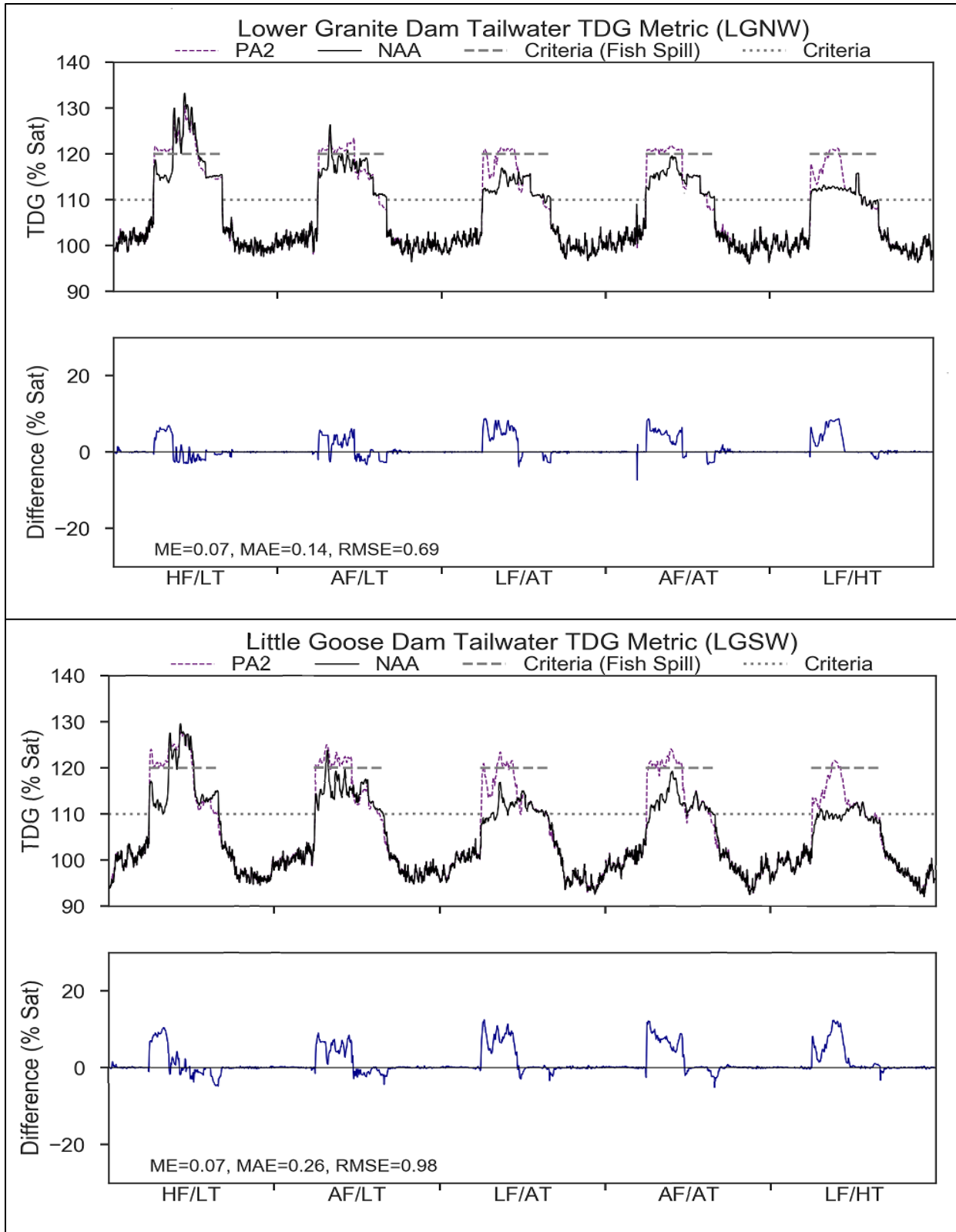
Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

7112 Maximum tailwater TDG would change under the PA (Figure 8-28). The highest TDG would still
7113 occur during HF/LT conditions, but the TDG under the PA would often be less than under the No
7114 Action Alternative conditions. TDG would peak to 128 percent at Little Goose, Lower
7115 Monumental, and Ice Harbor during June and 131 percent at Lower Granite tailwater.
7116 However, these maximums, as well as the ones predicted for May, July, and August are the
7117 same, or often less than the No Action Alternative. The largest decreases, up to almost 3
7118 percent, would occur at Lower Granite Dam followed by Little Goose Dam. TDG increases
7119 greater than 8 percent would occur at Lower Granite Dam during April of a LF/AT year as well as
7120 May and June of a LF/HT year. At Little Goose Dam, similar increases would occur during April
7121 of LF/AT and AF/AT conditions, May of LF/HT conditions, and June of LF/AT and LF/HT
7122 conditions. Remaining increases at the three upper projects between April and June would be
7123 6 percent or less. April through June increases in gas saturation downstream from Ice Harbor
7124 Dam would be less than at the upstream projects, typically ranging from zero to less than 3
7125 percent. Maximum TDG during July and August would either not change, decrease by up to 2
7126 percent, or in the case of LF/HT conditions increase by up to 1 percent.

7127 Overall, moderate changes to TDG in the lower Snake River would occur under the PA as
7128 compared to the No Action Alternative due to the *Juvenile Fish Passage Spill* measure.

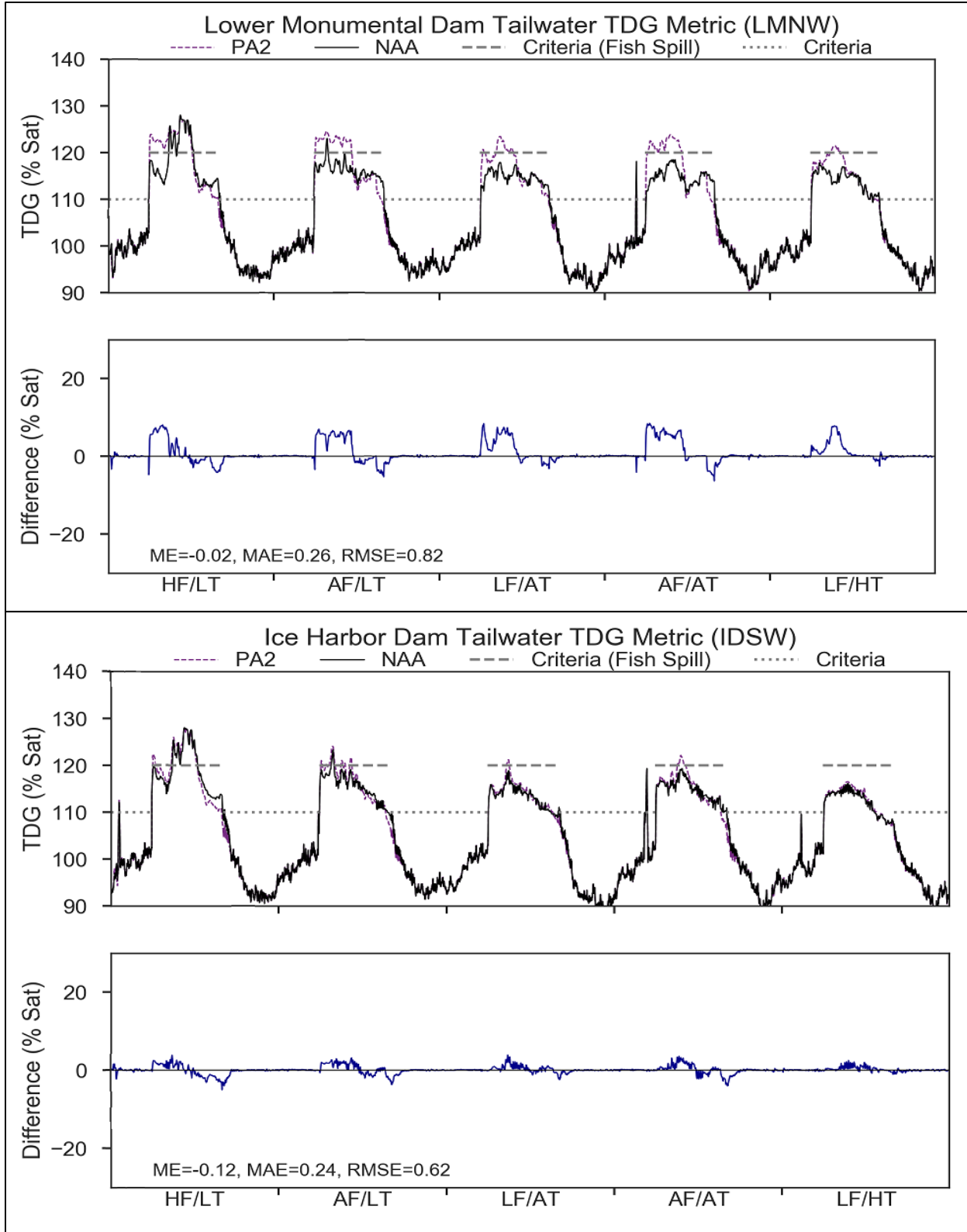
7129 Since the water entering Lower Granite forebay travels through free-flowing reaches before
7130 entering the reservoir, forebay TDG would remain less than 110 percent most of the time
7131 (Figure 8-29). The only exceptions would occur during a HF/LT year when TDG would be
7132 greater than 110 percent about 1 percent of the time during May and July, and 8 percent of the
7133 time in June. These occurrences, however, are not substantially different from the No Action
7134 Alternative.

7135 Since tailwater TDG would be increased to 125 percent under the PA, downstream forebay TDG
7136 would also increase at the lower Snake River projects when compared to the No Action
7137 Alternative (Figure 8-29, Figure 8-30, and Table 8-5). The general downstream trend from
7138 Lower Granite Dam would be a primary increase in the amount of time TDG would be in the
7139 115 to 120 percent range at Little Goose Dam, an increase in the 115 to 120 percent range at
7140 Lower Monumental Dam, and an increase in the 120 to 125 percent range at Ice Harbor Dam
7141 (Figure 8-32).



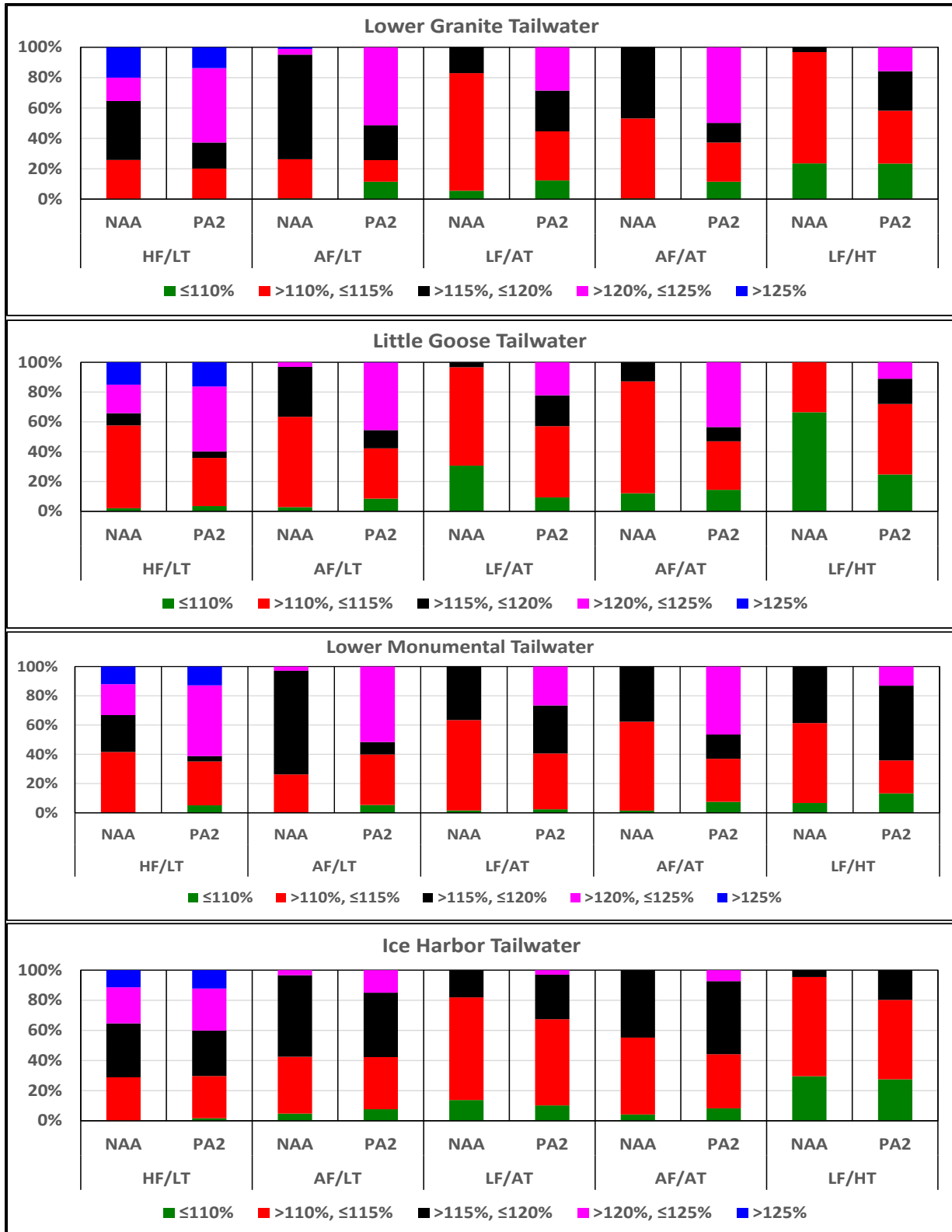
7142
 7143
 7144
 7145

Figure 8-25. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative and No Action Alternative at Lower Granite and Little Goose Dams Under a 5-year Range of River and Meteorological Conditions



7146
 7147
 7148
 7149

Figure 8-26. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative and No Action Alternative at Lower Monumental and Ice Harbor Dams Under a 5-year Range of River and Meteorological Conditions



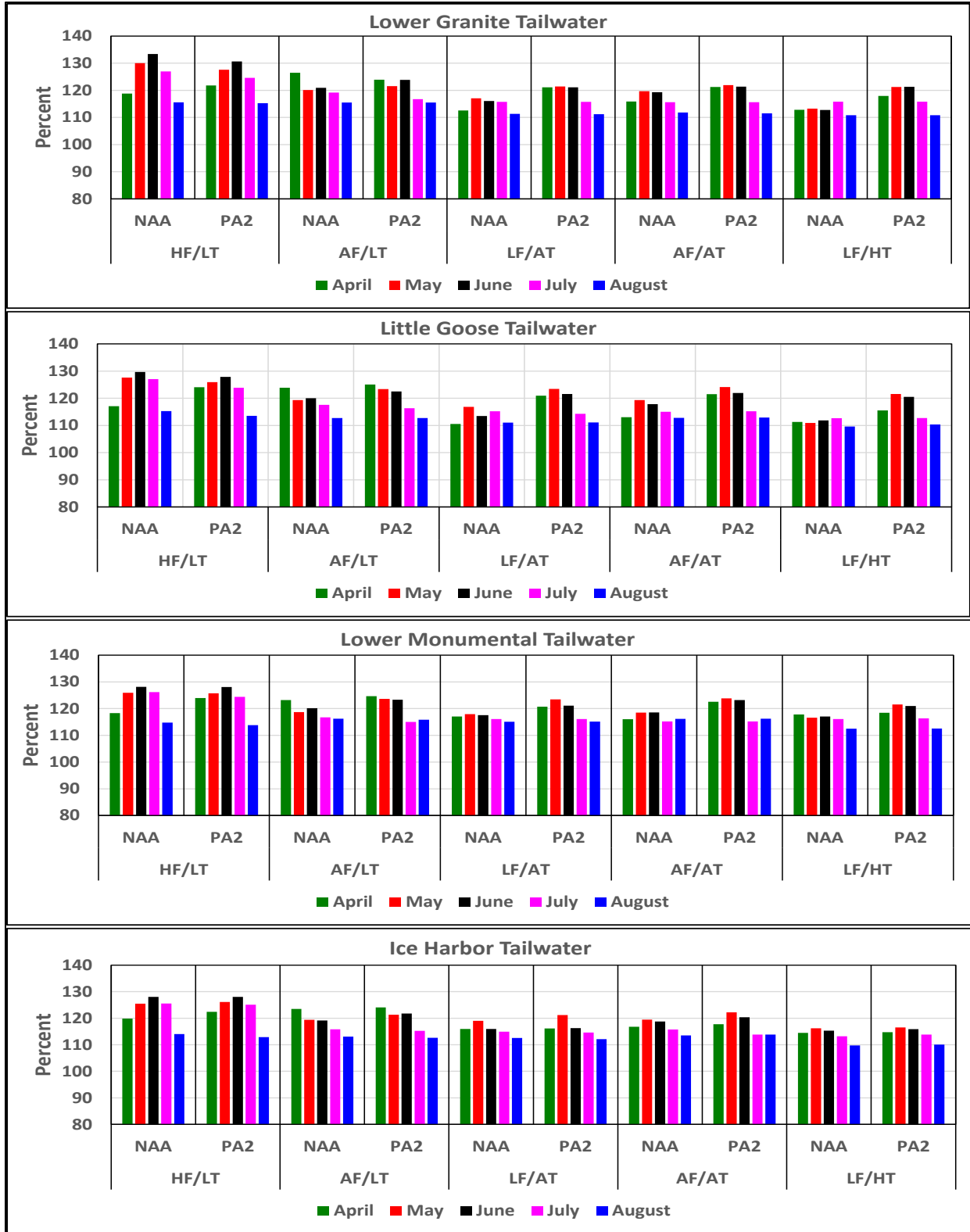
7150
 7151
 7152
 7153

Figure 8-27. No Action Alternative and Preferred Alternative April through August Frequency Distributions for Selected Tailwater Total Dissolved Gas Intervals at the Four Lower Snake River Projects

7154 **Table 8-4. Number of days that the tailwater 12-hour TDG would be greater the current 120**
7155 **percent for the No Action Alternative and the Preferred Alternative**

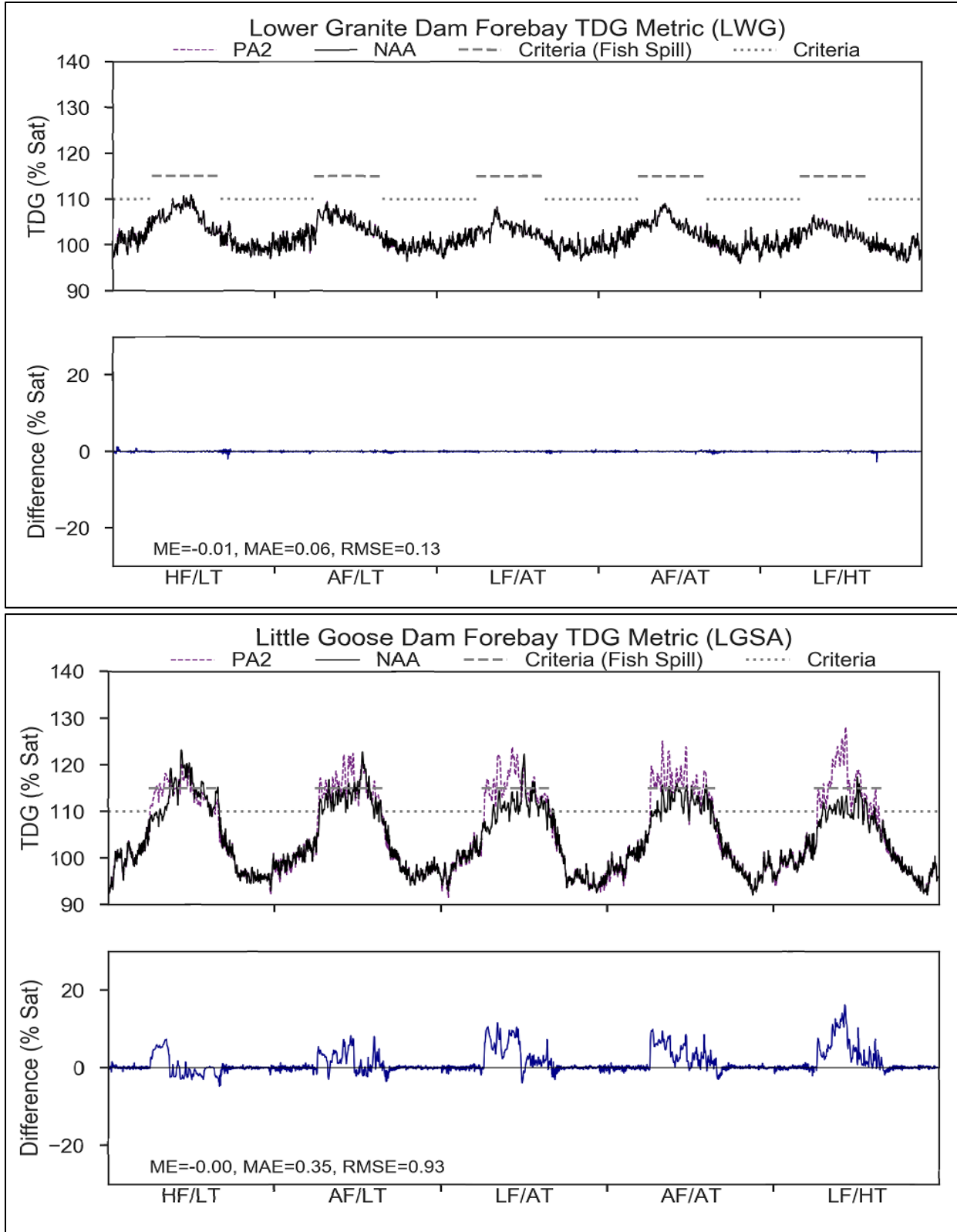
	Flow and Air Temperature Conditions									
	HF/LT		AF/LT		LF/AT		AF/AT		LF/HT	
	NAA	PA2	NAA	PA2	NAA	PA2	NAA	PA2	NAA	PA2
Lower Granite										
Apr	0	28	6	28	0	6	0	27	0	0
May	18	31	1	31	0	26	0	31	0	22
Jun	29	30	2	20	0	12	0	19	0	4
Jul	8	7	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0
Little Goose										
Apr	0	27	5	22	0	2	0	21	0	0
May	18	31	0	28	0	25	0	30	0	14
Jun	29	30	0	19	0	10	0	18	0	3
Jul	7	6	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0
Lower Monumental										
Apr	0	29	4	29	0	5	0	23	0	0
May	15	31	0	31	0	26	0	31	0	18
Jun	29	30	0	20	0	13	0	19	0	3
Jul	7	4	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0
Ice Harbor										
Apr	0	6	6	14	0	0	0	0	0	0
May	17	19	0	10	0	5	0	12	0	0
Jun	30	30	0	4	0	0	0	1	0	0
Jul	8	7	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0

7156 Note: Bold and highlighted cells indicate increases from the No Action Alternative



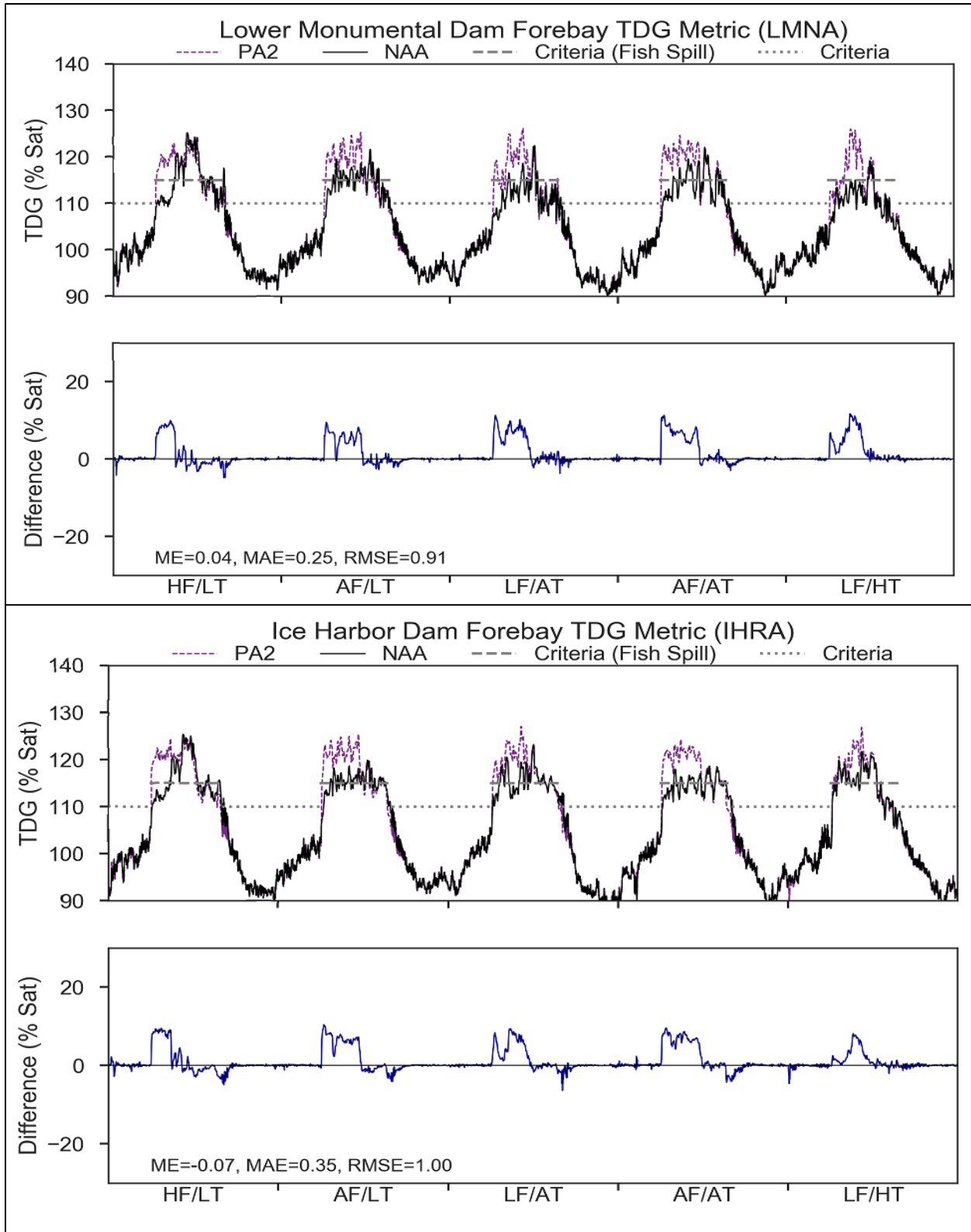
7157
 7158
 7159

Figure 8-28. Maximum monthly tailwater TDG modeled for the No Action and Preferred Alternatives for the 5 flow and air temperature conditions



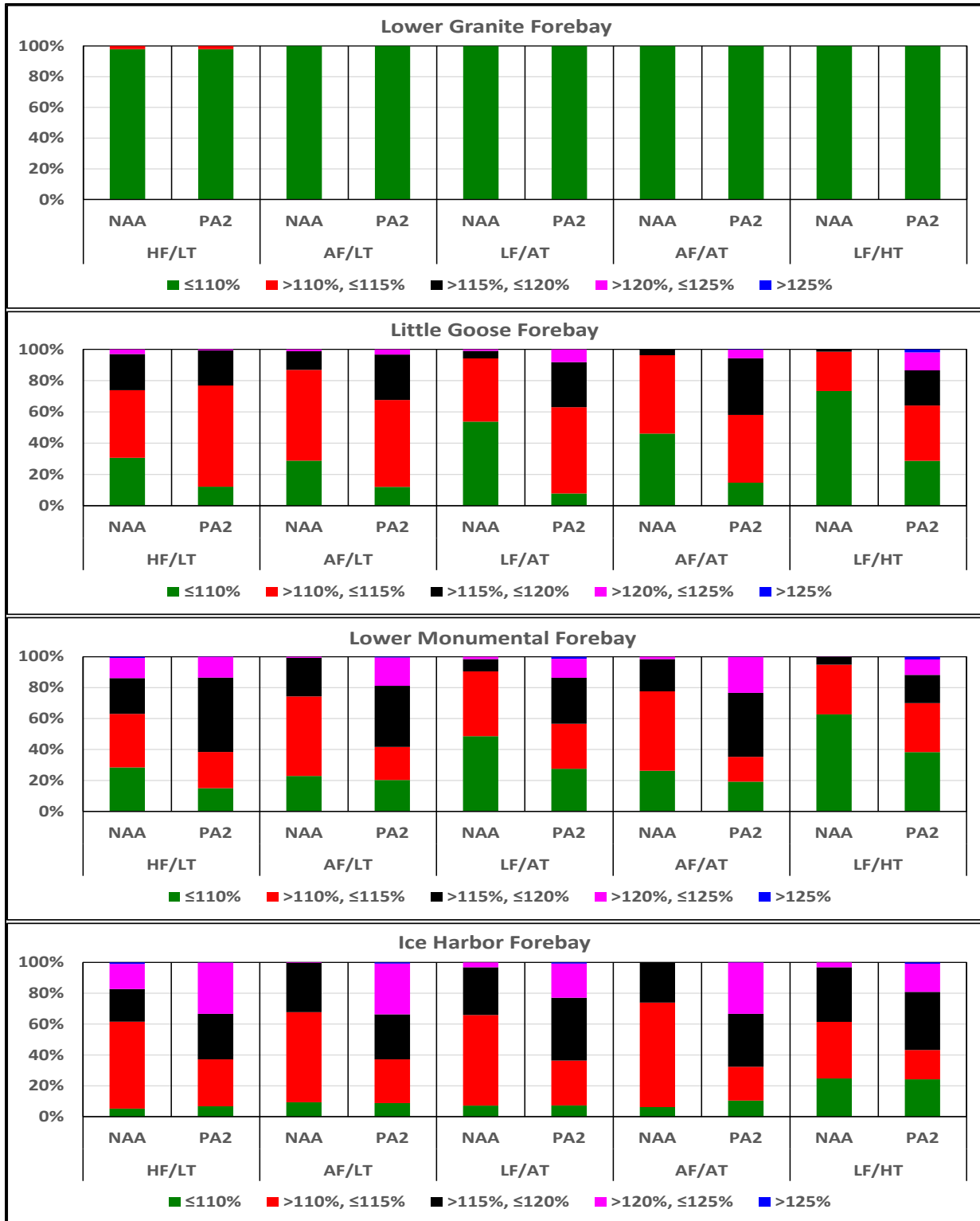
7160
 7161
 7162
 7163

Figure 8-29. Modeled Forebay Total Dissolved Gas for Preferred Alternative and No Action Alternative at Lower Granite and Little Goose Dams Under a 5-year Range of River and Meteorological Conditions



7164
 7165
 7166
 7167

Figure 8-30. Modeled Forebay Total Dissolved Gas for Preferred Alternative 4 and No Action Alternative at Lower Monumental and Ice harbor Dams Under a 5-year Range of River and Meteorological Conditions



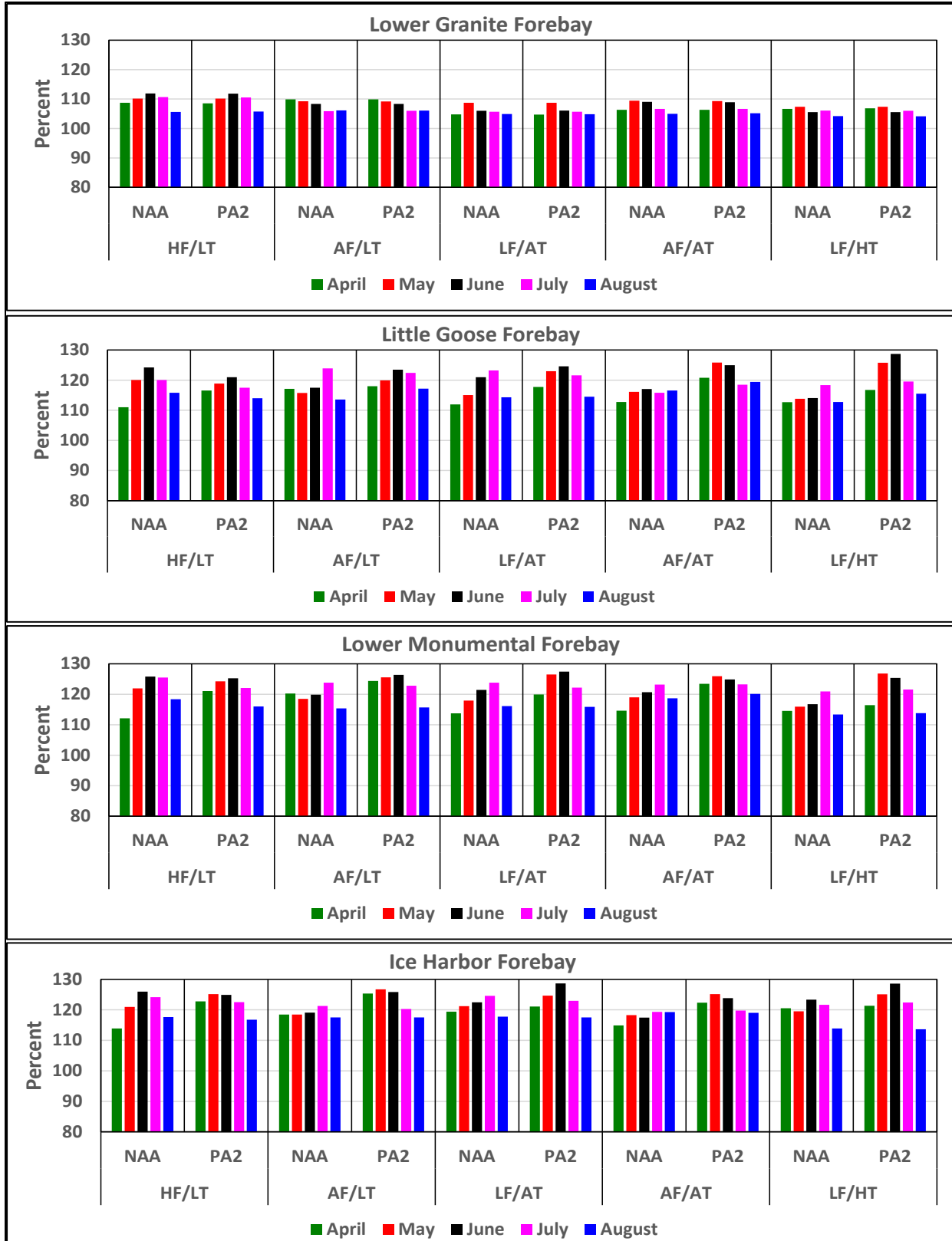
7168
 7169
 7170
 7171

Figure 8-31. No Action Alternative and Preferred Alternative April through August Frequency Distributions for Selected Forebay Total Dissolved Gas Intervals at the Four Lower Snake River Projects

7172 **Table 8-5. Number of days that the forebay 12-hour TDG would be greater the current 115**
7173 **percent for the No Action Alternative and the Preferred Alternative.**

	Flow and Air Temperature Conditions									
	HF/LT		AF/LT		LF/AT		AF/AT		LF/HT	
	NAA	PA2	NAA	PA2	NAA	PA2	NAA	PA2	NAA	PA2
Lower Granite										
Apr	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0
Little Goose										
Apr	0	5	2	5	0	8	0	18	0	1
May	11	14	1	13	0	18	2	21	0	30
Jun	24	24	4	18	3	26	4	24	0	14
Jul	12	2	20	17	6	11	1	12	1	12
Aug	1	0	0	3	0	0	1	6	0	0
Lower Monumental										
Apr	0	25	5	24	0	12	0	26	0	1
May	15	31	18	31	3	30	11	31	2	21
Jun	28	30	19	28	10	24	18	27	2	18
Jul	16	7	17	13	7	7	15	14	9	10
Aug	3	0	0	0	0	1	6	9	0	0
Ice Harbor										
Apr	0	27	5	26	10	22	0	26	13	18
May	16	31	15	31	8	31	10	31	21	31
Jun	29	30	22	29	22	28	18	28	26	30
Jul	13	8	17	13	24	22	15	14	10	11
Aug	6	2	10	8	6	6	10	14	0	0

7174 Note: Bold and highlighted cells indicate increases from the No Action Alternative



7175
 7176
 7177

Figure 8-32. Maximum monthly forebay TDG modeled for the No Action and Preferred Alternatives for the 5 flow and air temperature conditions.

7178 **8.2.3 Other Physical, Chemical and Biological Processes**

7179 **8.2.3.1 Dworshak Dam and Reservoir**

7180 The other physical, chemical and biological conditions in Dworshak Reservoir are not expected
7181 to change under the PA as compared to the No Action Alternative.

7182 **8.2.3.2 Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams and**
7183 **Reservoirs**

7184 The other physical, chemical and biological conditions in the lower Snake River Reservoirs are
7185 not expected to change under the PA as compared to the No Action Alternative.

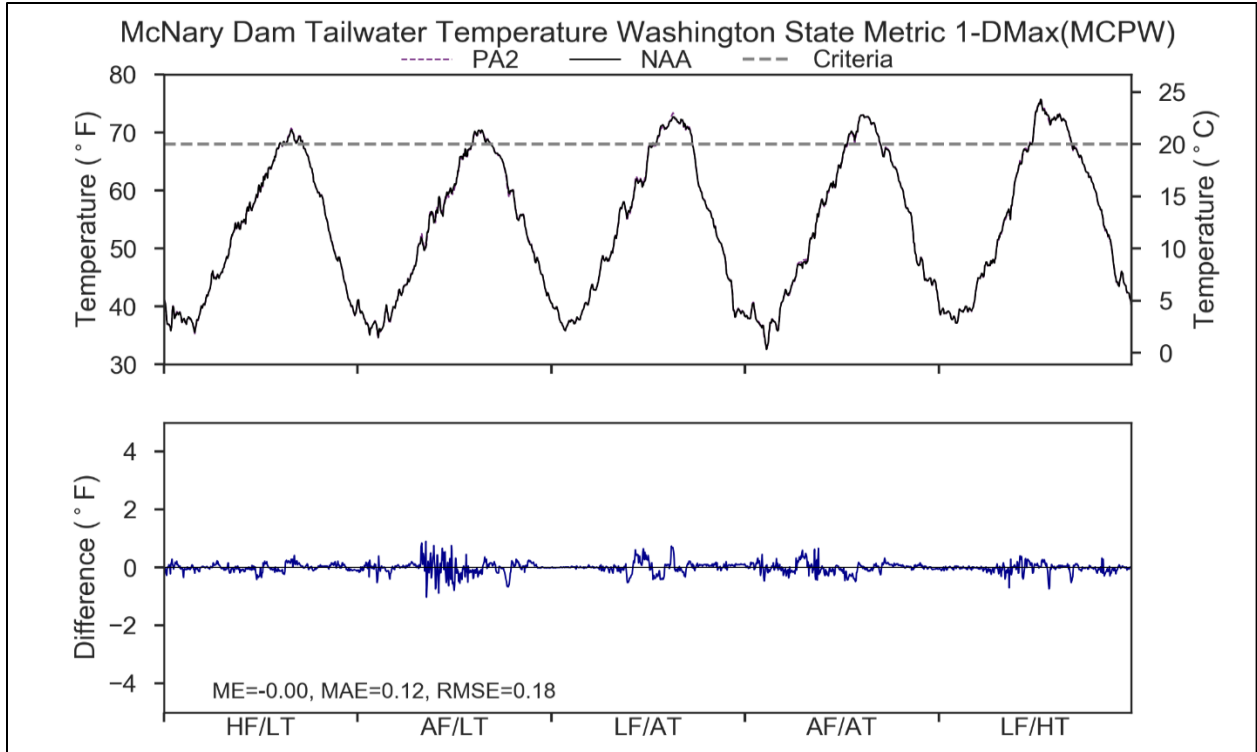
7186 **8.3 LOWER COLUMBIA RIVER**

7187 **8.3.1 Water Temperature**

7188 There are no specific structural or operational measures in the PA that are expected to
7189 influence water temperatures in the lower Columbia River. Details are provided below.

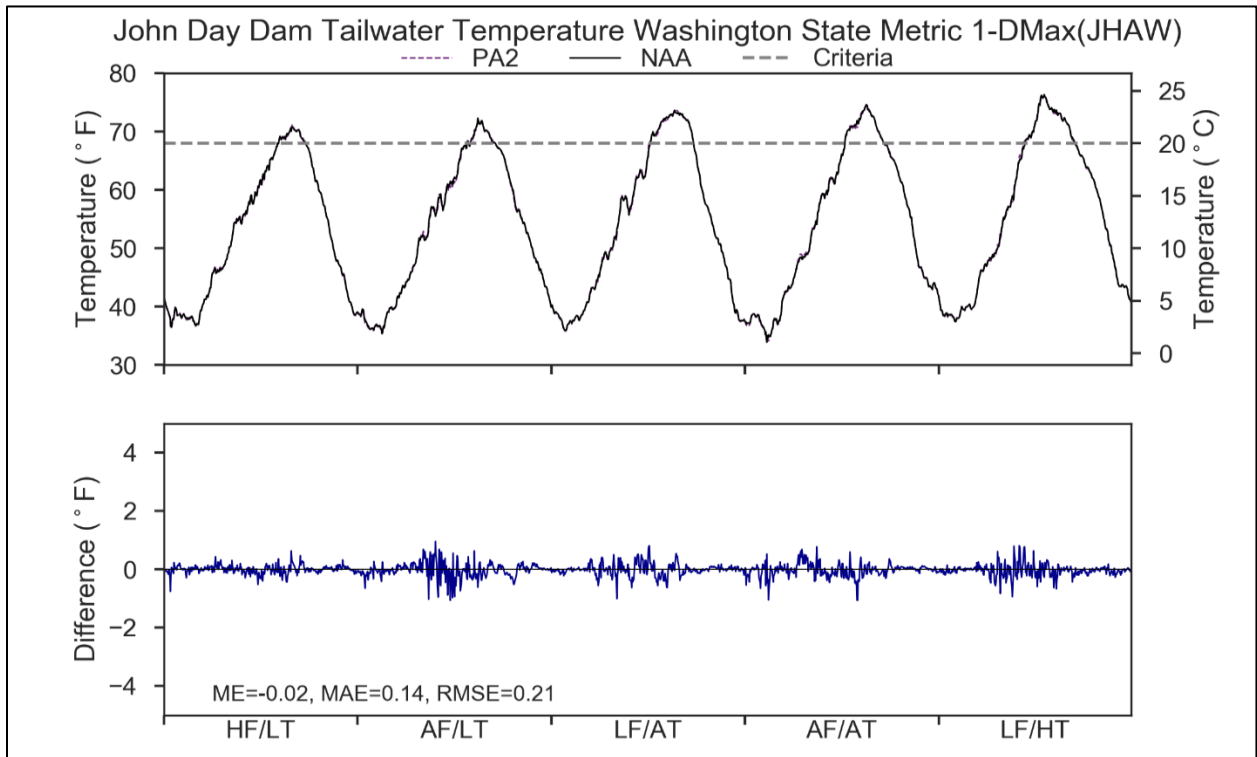
7190 **8.3.1.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

7191 The tailwater temperatures for the PA at McNary, John Day, The Dalles, and Bonneville Dams
7192 were modeled under a 5-year range of river and meteorological conditions, and compared to
7193 the modeled results for the No Action Alternative (Figure 8-33 through Figure 8-36). Just as with
7194 the No Action Alternative model results, the PA model results show that tailwater temperatures
7195 can exceed 68°F at all four dams during any of the years and conditions presented, and
7196 maximum water temperatures and the frequency of water temperature violations of state
7197 water quality standards would be higher during a year when river flows are lower than normal
7198 and summer ambient air temperatures are higher (as in LF/HT). The average frequency of water
7199 temperature violations of the state water quality standards would be nearly identical for the No
7200 Action Alternative and the PA for all four lower Columbia River dams (Figure 8-37). Generally,
7201 there differences in tailwater temperatures under the No Action Alternative and the PA are
7202 negligible.



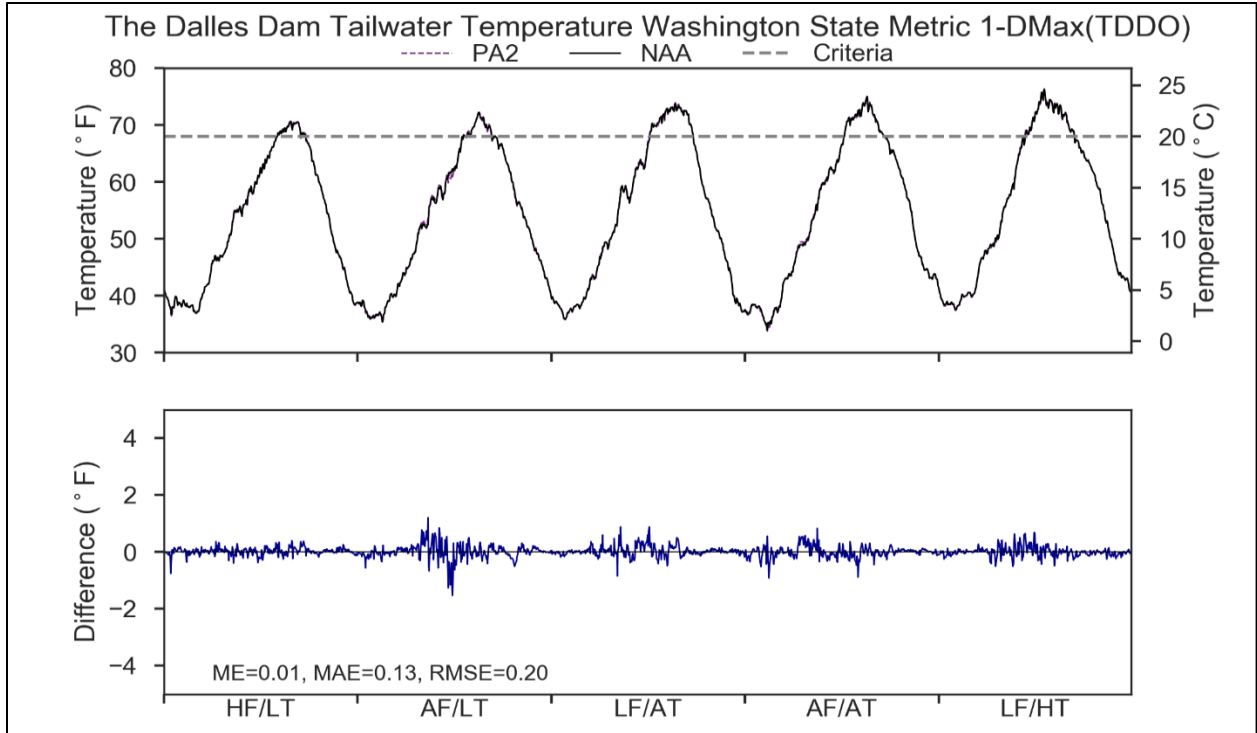
7203
 7204
 7205

Figure 8-33. Modeled Tailwater Temperature for the Preferred Alternative at McNary Dam Under a 5-year Range of River and Meteorological Conditions



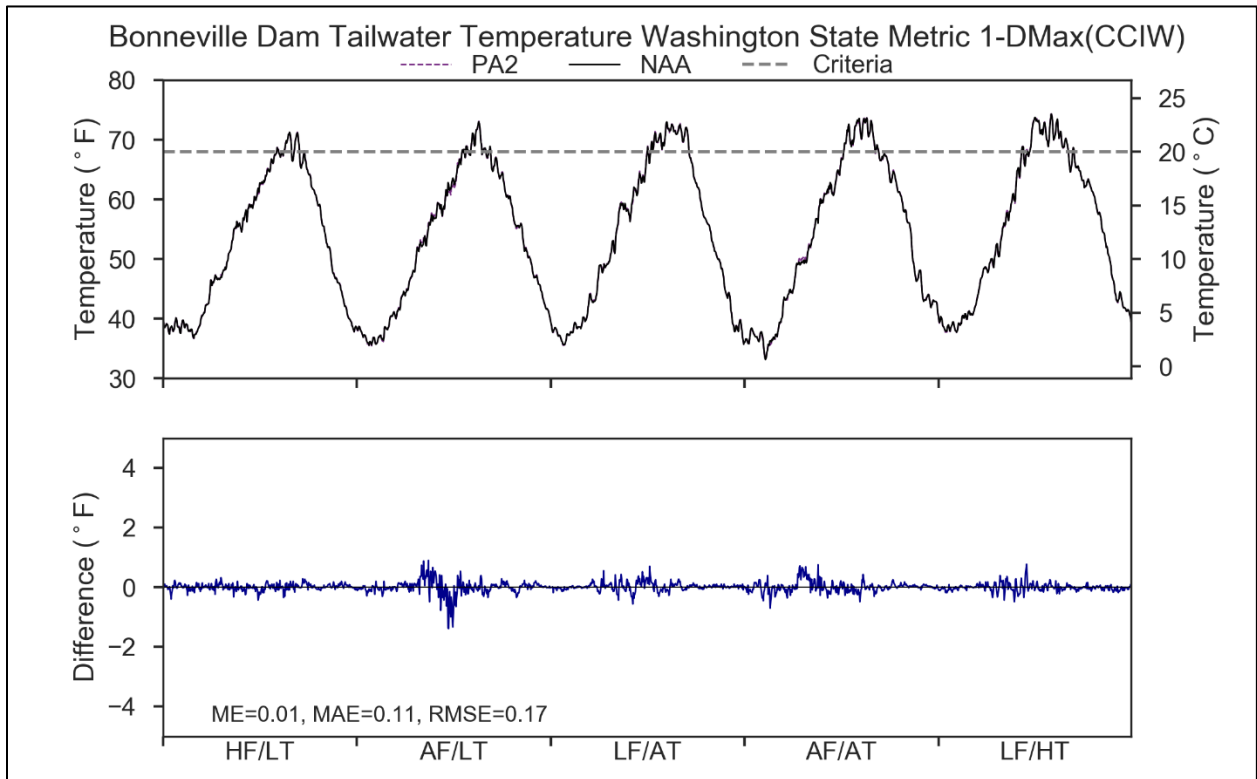
7206
 7207
 7208

Figure 8-34. Modeled Tailwater Temperature for the Preferred Alternative at John Day Dam Under a 5-year Range of River and Meteorological Conditions



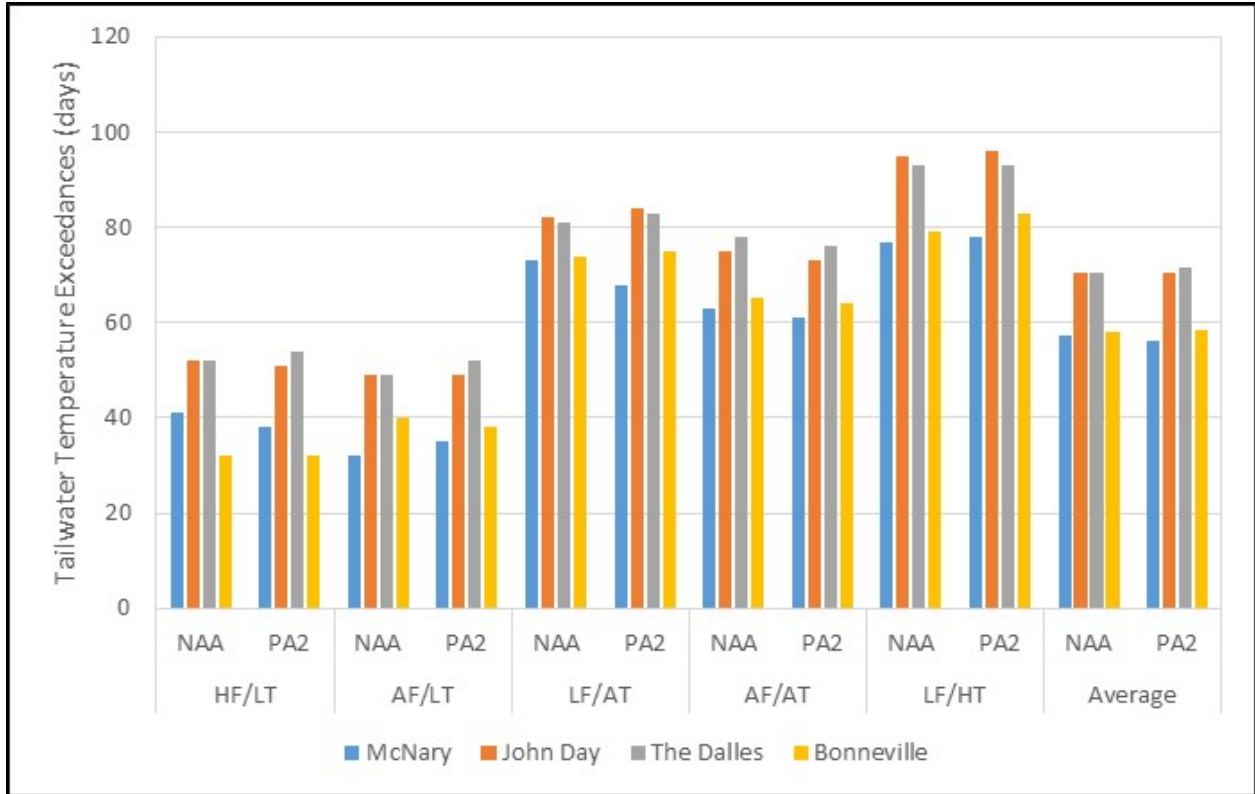
7209
 7210
 7211

Figure 8-35. Modeled Tailwater Temperature for the Preferred Alternative at The Dalles Dam Under a 5-year Range of River and Meteorological Conditions



7212
 7213
 7214

Figure 8-36. Modeled Tailwater Temperature for the Preferred Alternative at Bonneville Dam Under a 5-year Range of River and Meteorological Conditions



7215
 7216 **Figure 8-37. Frequency of Modeled Tailwater Temperature Violations of State Water Quality**
 7217 **Standards the Preferred Alternative and No Action Alternative at McNary, John Day, The**
 7218 **Dalles, and Bonneville Dams Under a 5-year Range of River and Meteorological Conditions**

7219 **8.3.2 Total Dissolved Gas**

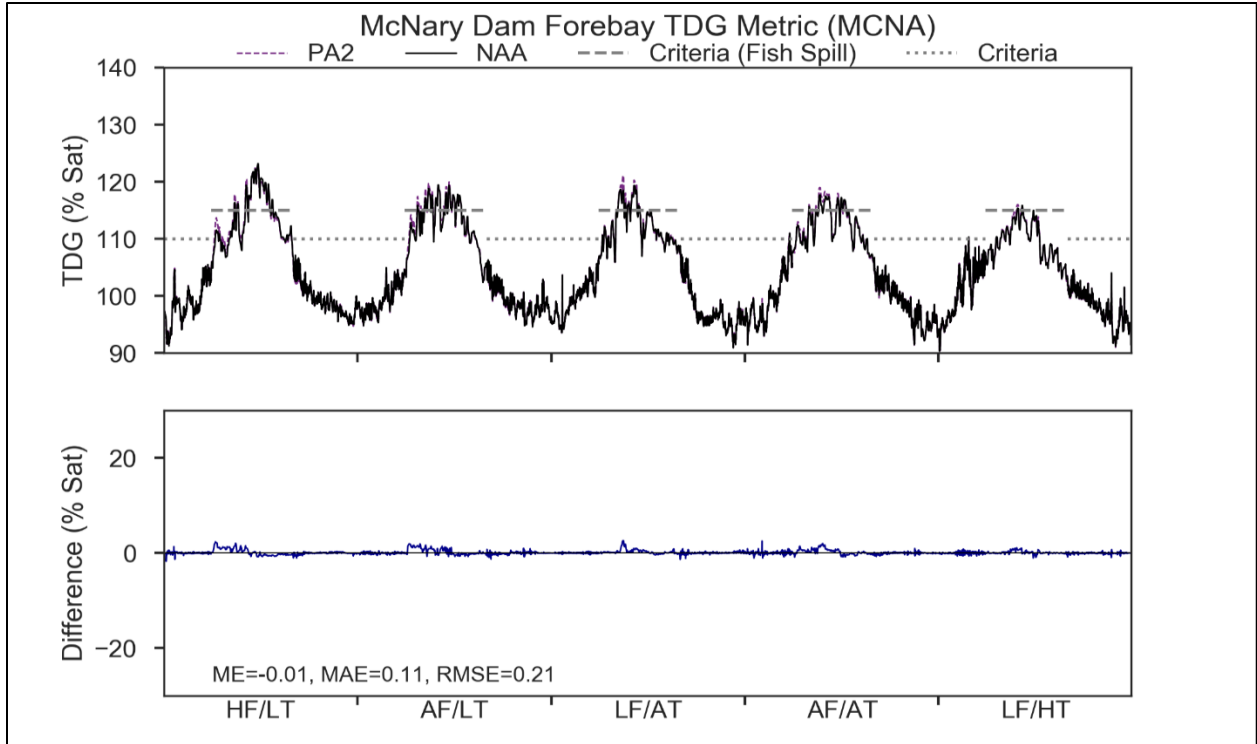
7220 The PA contains the *Juvenile Fish Passage Spill* measure, which is based on the results of the
 7221 spring 2019 Flexible Spill Test Operation and analyses of the four MO Alternatives. The *Juvenile*
 7222 *Fish Passage Spill* measure would be implemented during the spring juvenile salmonid
 7223 migration season at the lower Snake River and lower Columbia River Projects. In a 24-hr period,
 7224 the *Juvenile Fish Passage Spill* measure would involve 16 hours of spill operations up to the
 7225 125% TDG gas cap at most projects for juvenile outmigration. For the remaining 8 hours, the
 7226 projects would spill at a lower level (this level is referred to as performance standard spill).
 7227 These performance standard spill levels are slightly variable depending on the project, and may
 7228 be slightly higher or lower depending on river conditions and the opportunity to spill. This
 7229 operation would allow hydropower generation during times of peak demand, while still
 7230 providing for high spill for fish when it is expected to be most important (generally in the
 7231 evenings and very early morning hours). These operations would be implemented during the
 7232 spring juvenile migration, which at the lower Columbia River projects occurs April 10 through
 7233 June 16. When Flex spill ceases, the projects would transition to summer spill operations.

7234 Differences in forebay and tailwater TDG saturations and exceedances between the PA and the
 7235 No Action Alternative can be attributed to the *Juvenile Fish Passage Spill* measure. Details are
 7236 provided below.

7237 8.3.2.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs

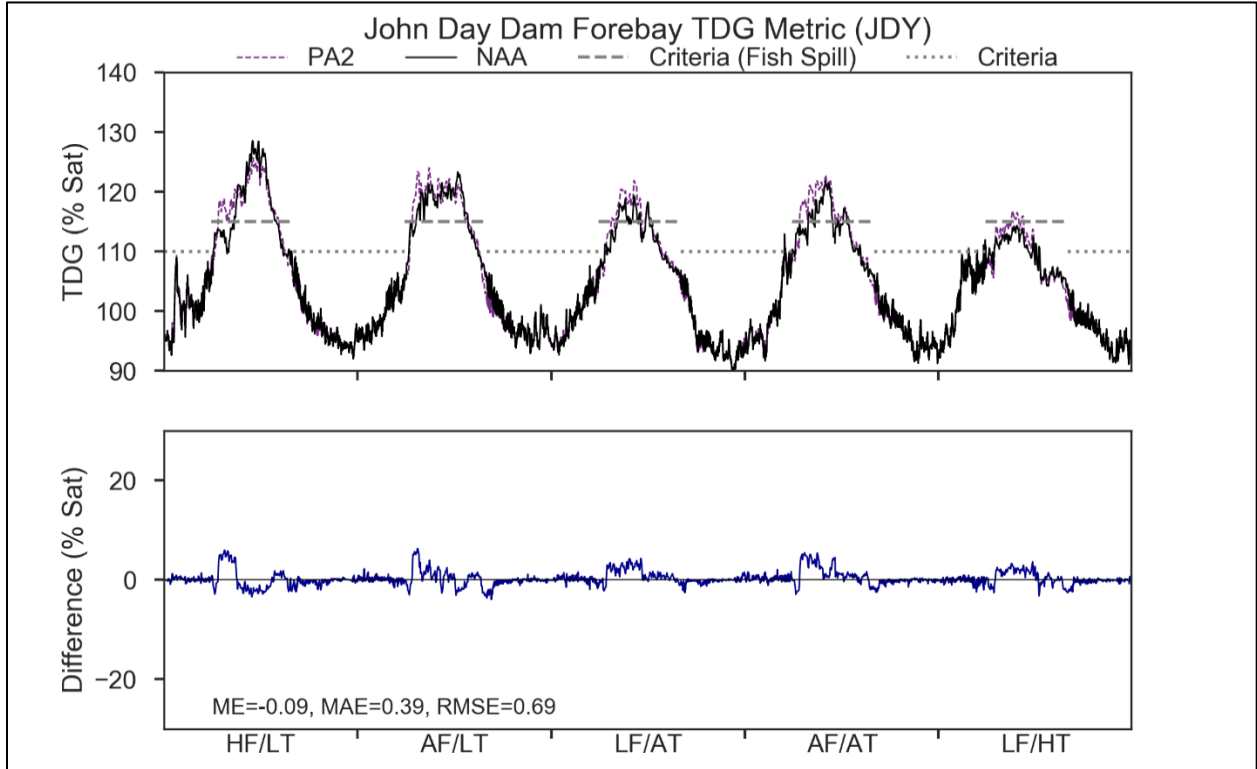
7238 Forebay TDG saturations under the PA at McNary, John Day, The Dalles, and Bonneville Dams
7239 were modeled under a 5-year range of river and meteorological conditions, and compared to
7240 the modeled results for the No Action Alternative (Figure 8-38 to Figure 8-41). The PA model
7241 results show that forebay TDG saturations can exceed 115 percent TDG at all four dams during
7242 all of the years and conditions presented. Maximum forebay TDG saturations would be higher
7243 during a year when river flows were higher than normal (as in 2011 [HF/LT]). Forebay TDG
7244 saturations would be similar under the PA and the No Action Alternative for McNary Dam
7245 during spill season. At John Day, The Dalles, and Bonneville, forebay TDG saturations would be
7246 similar under the PA as compared to the No Action Alternative, except for some periods in the
7247 early parts of fish spill season when TDG saturations under the PA would be higher than those
7248 for the No Action Alternative. The frequency of 110% TDG exceedances outside of current fish
7249 passage spill seasons would be similar under PA and the No Action Alternative (Figure 8-42). At
7250 all four dam forebays, the frequency of TDG going above 115% TDG would be greater under the
7251 PA than the No Action Alternative for all modeled river and meteorological conditions, though
7252 the impact is most apparent at John Day and The Dalles (Figure 8-43).

7253 Modeled tailwater TDG saturations for the PA at McNary, John Day, The Dalles, and Bonneville
7254 Dams can be found in Figure 8-44 through Figure 8-47. The PA model results show that
7255 tailwater TDG saturations would be greater than 120 percent TDG at all four dams during most
7256 of the years and conditions presented. Exceptions include LF/AT conditions at John Day and
7257 LF/HT conditions at McNary, John Day, and The Dalles. Maximum tailwater TDG saturations
7258 would be higher during a year when river flows were higher than normal and summer ambient
7259 air temperatures were lower (as in 2011). Tailwater TDG saturations in the PA would be
7260 generally similar to those for the No Action Alternative for all four dams during the spill season,
7261 though there are periods during fish spill season where PA TDG saturations would be higher or
7262 lower than for the No Action Alternative. Generally, the frequency of 110% TDG exceedances
7263 outside of current fish passage spill seasons would be similar under the PA and the No Action
7264 Alternative (Figure 8-48). During the current fish passage spill season, the frequency of TDG
7265 greater than 120% TDG at all four dams would be higher under PA than the No Action
7266 Alternative under most modeled river and meteorological conditions (Figure 8-49). Exceptions
7267 include AF/LT conditions at Bonneville and a few other conditions where 120% would not be
7268 exceeded under either alternative (LF/HT conditions at McNary, John Day, and The Dalles and
7269 LF/AT conditions at John Day). Due to the assumed higher amount of lack of market spill in the
7270 No Action Alternative, model results do not show a notable differences in TDG in the PA as
7271 compared to the No Action Alternative. TDG effects are negligible.



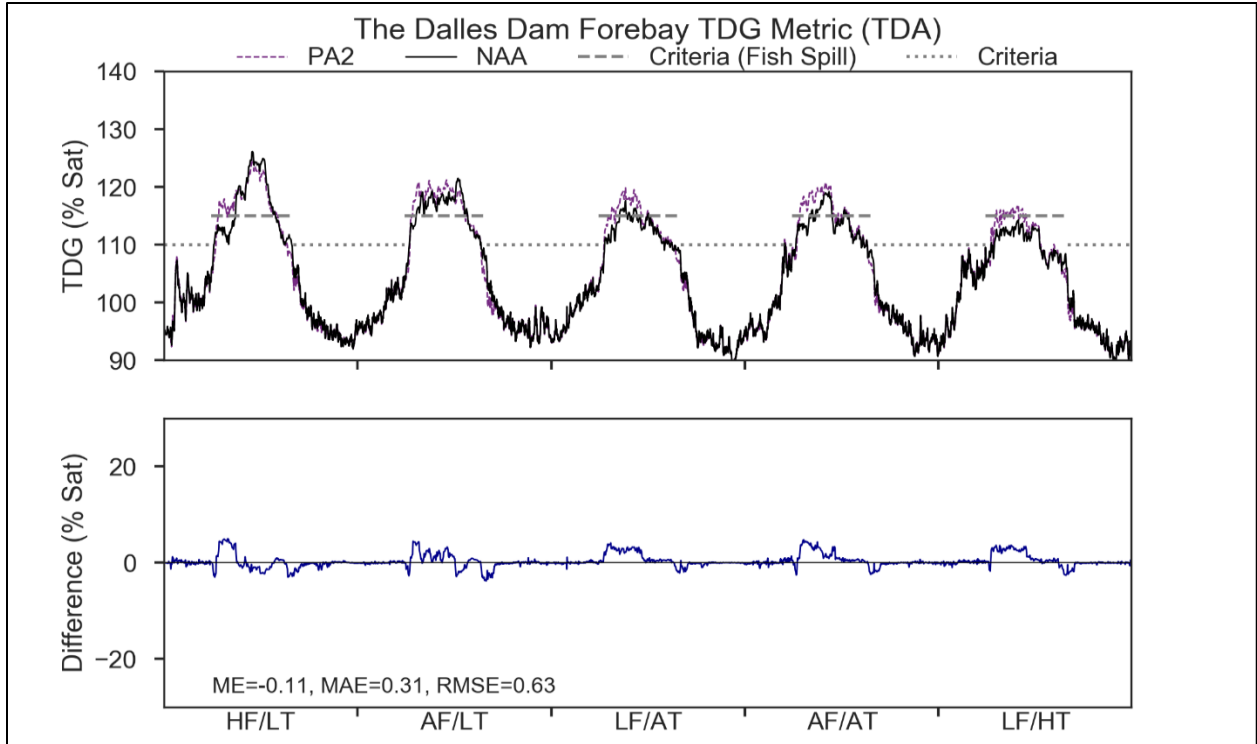
7272
 7273
 7274

Figure 8-38. Modeled Forebay Total Dissolved Gas for the Preferred Alternative at McNary Dam Under a 5-year Range of River and Meteorological Conditions



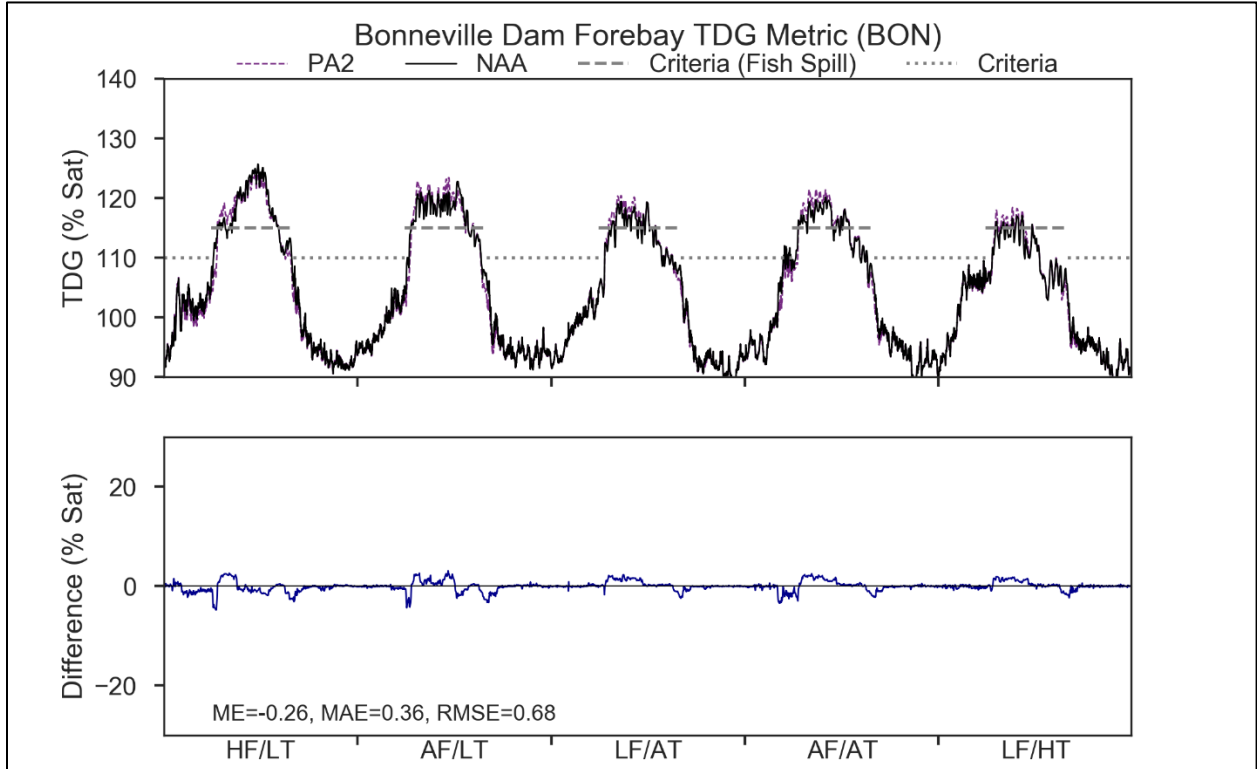
7275
 7276
 7277

Figure 8-39. Modeled Forebay Total Dissolved Gas for the Preferred Alternative at John Day Dam Under a 5-year Range of River and Meteorological Conditions



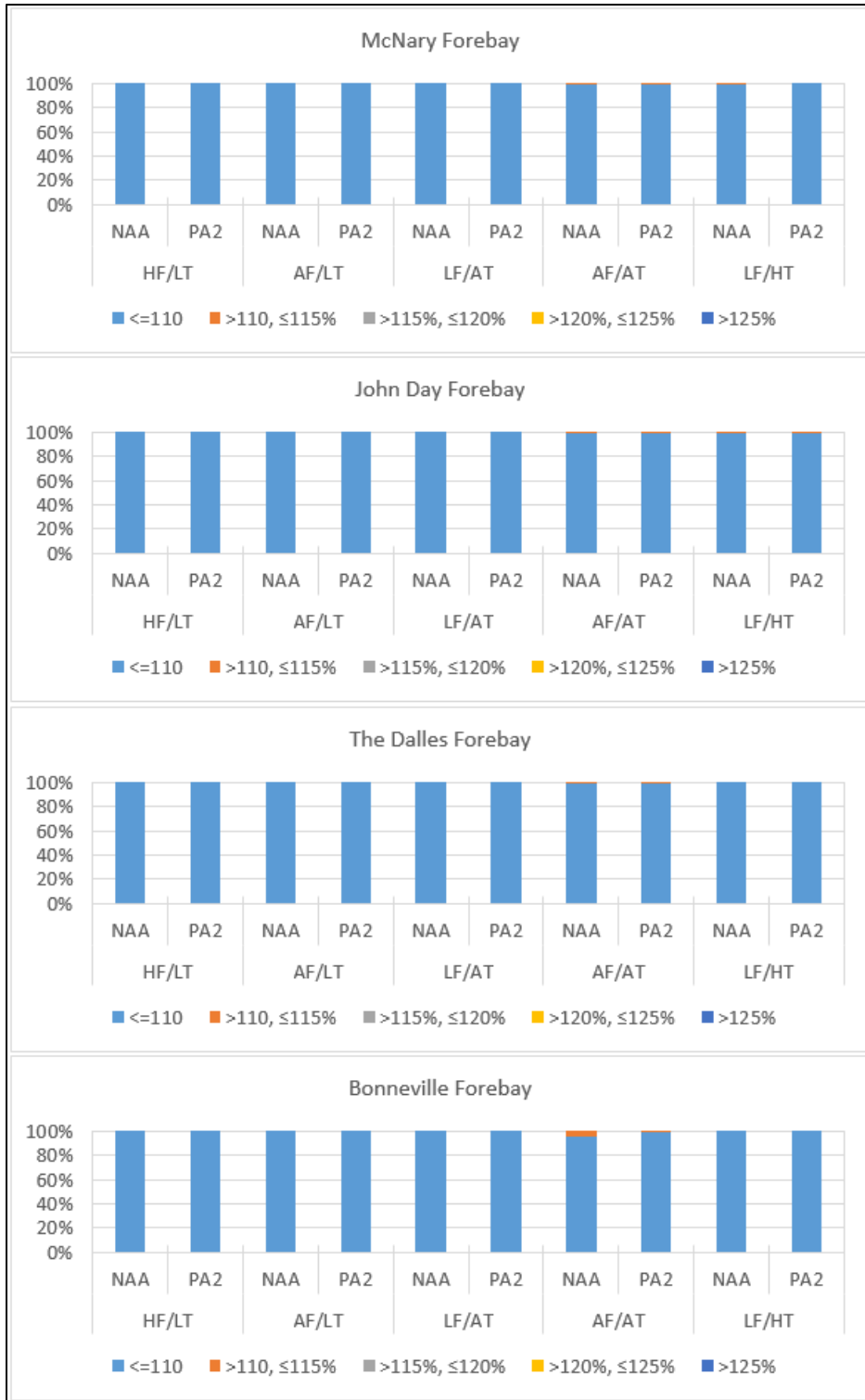
7278
 7279
 7280

Figure 8-40. Modeled Forebay Total Dissolved Gas for Preferred Alternative at The Dalles Dam Under a 5-year Range of River and Meteorological Conditions



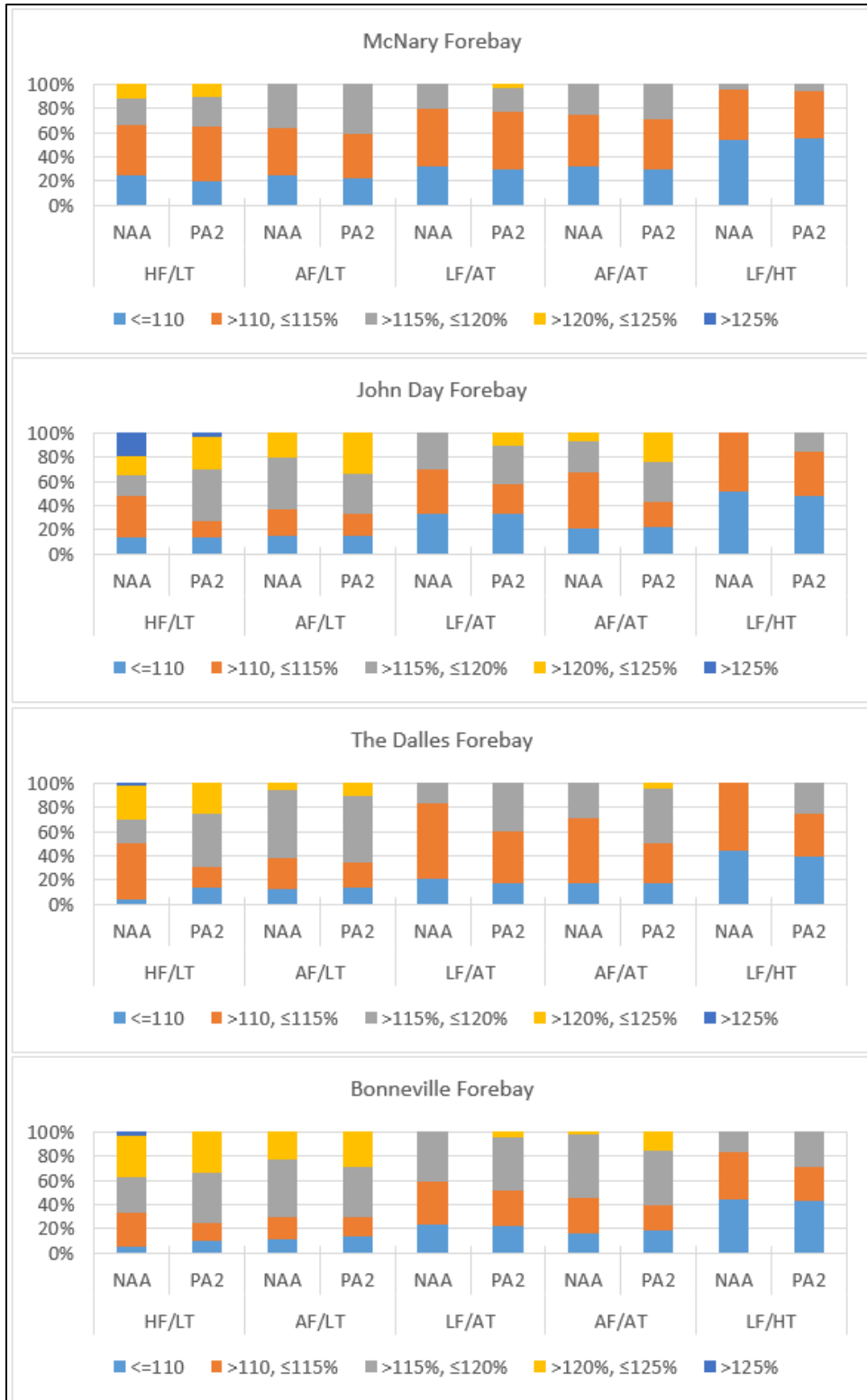
7281
 7282
 7283

Figure 8-41. Modeled Forebay Total Dissolved Gas for the Preferred Alternative at Bonneville Dam Under a 5-year Range of River and Meteorological Conditions



7284
 7285 **Figure 8-42. Frequency of Modeled Forebay Total Dissolved Gas Outside of Current Fish**
 7286 **Passage Spill Season for the Preferred Alternative and No Action Alternative at McNary, John**
 7287 **Day, The Dalles, and Bonneville Dams Under a 5-year Range of River and Meteorological**
 7288 **Conditions**

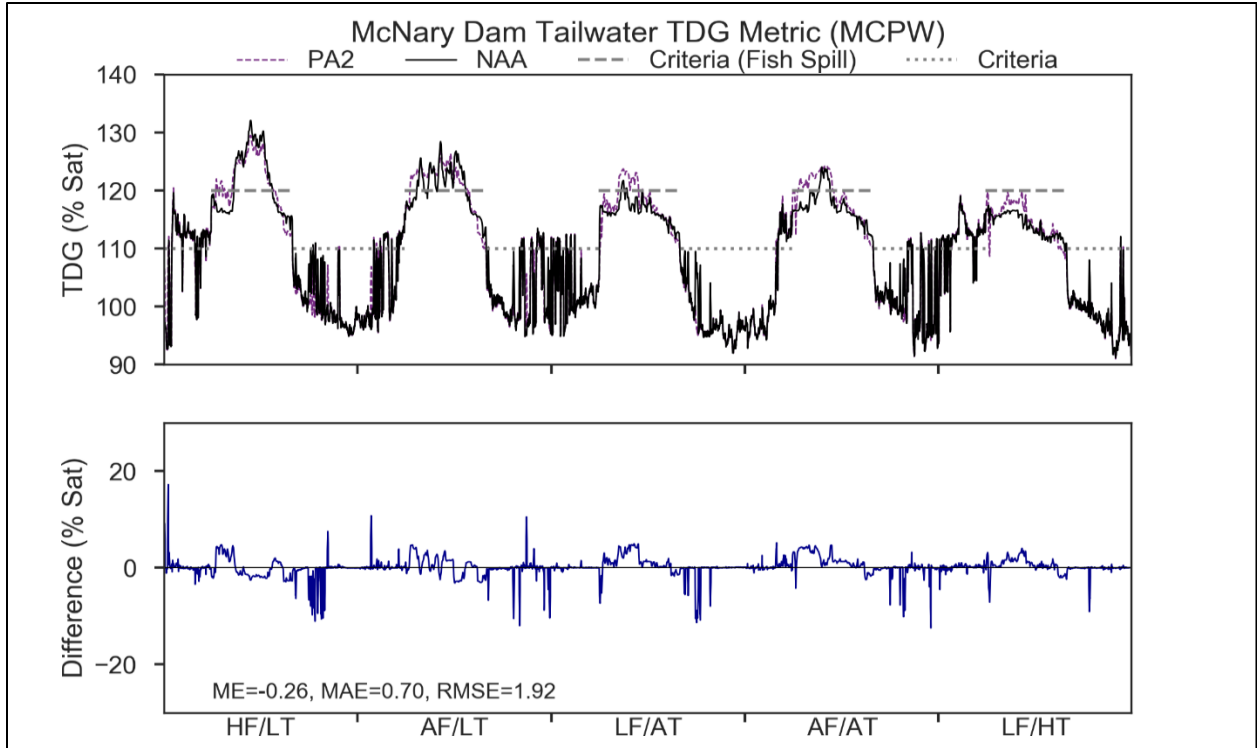
7289 Note: Current fish passage spill season is April 1 to August 31



7290
 7291
 7292
 7293
 7294

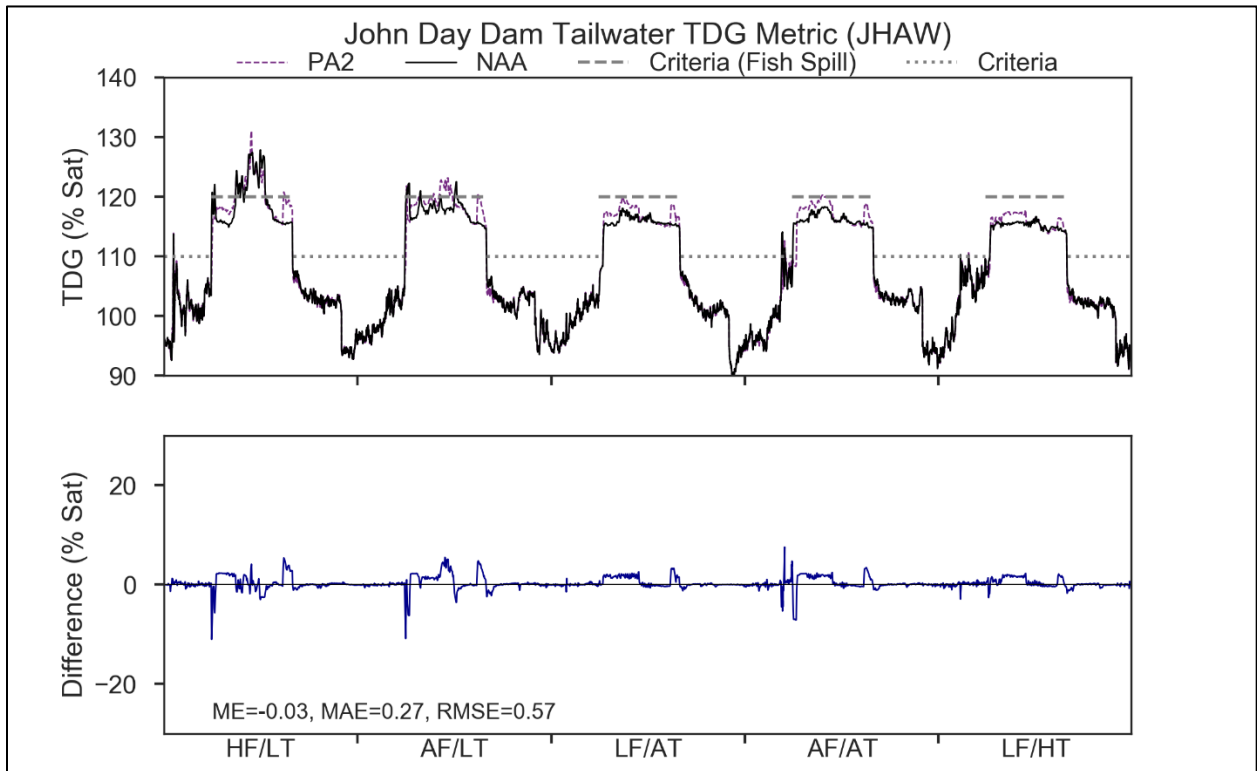
Figure 8-43. Frequency of Modeled Forebay Total Dissolved Gas During Current Fish Passage Spill Season for the Preferred Alternative and No Action Alternative at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-year Range of River and Meteorological Conditions

Note: Current fish passage spill season is April 1 to August 31



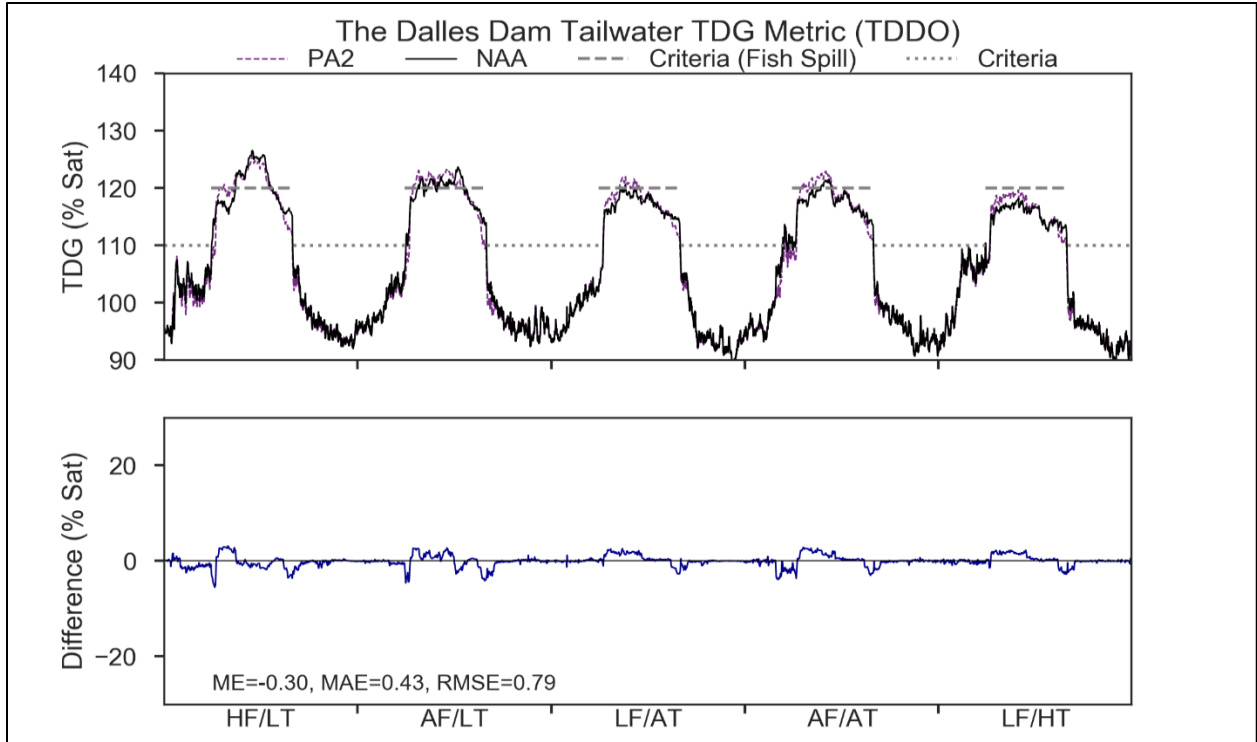
7295
 7296
 7297

Figure 8-44. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative at McNary Dam Under a 5-year Range of River and Meteorological Conditions



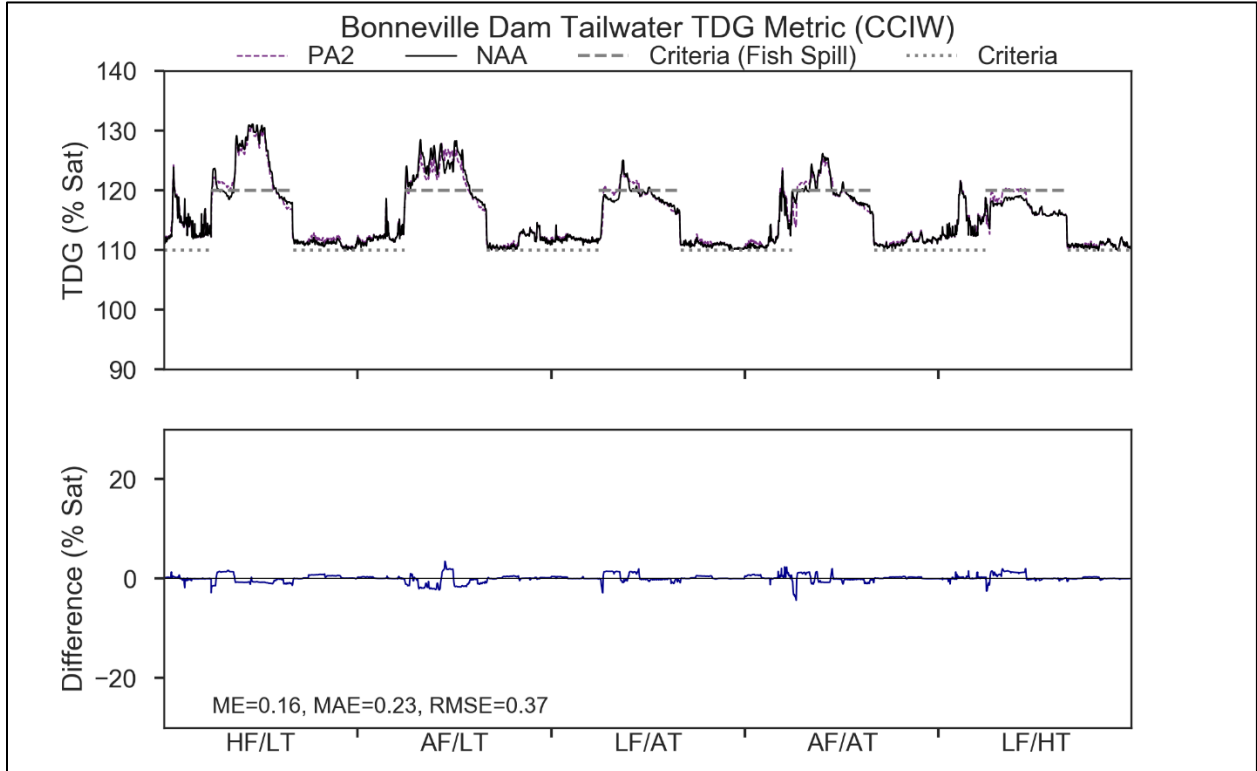
7298
 7299
 7300

Figure 8-45. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative at John Day Dam Under a 5-year Range of River and Meteorological Conditions



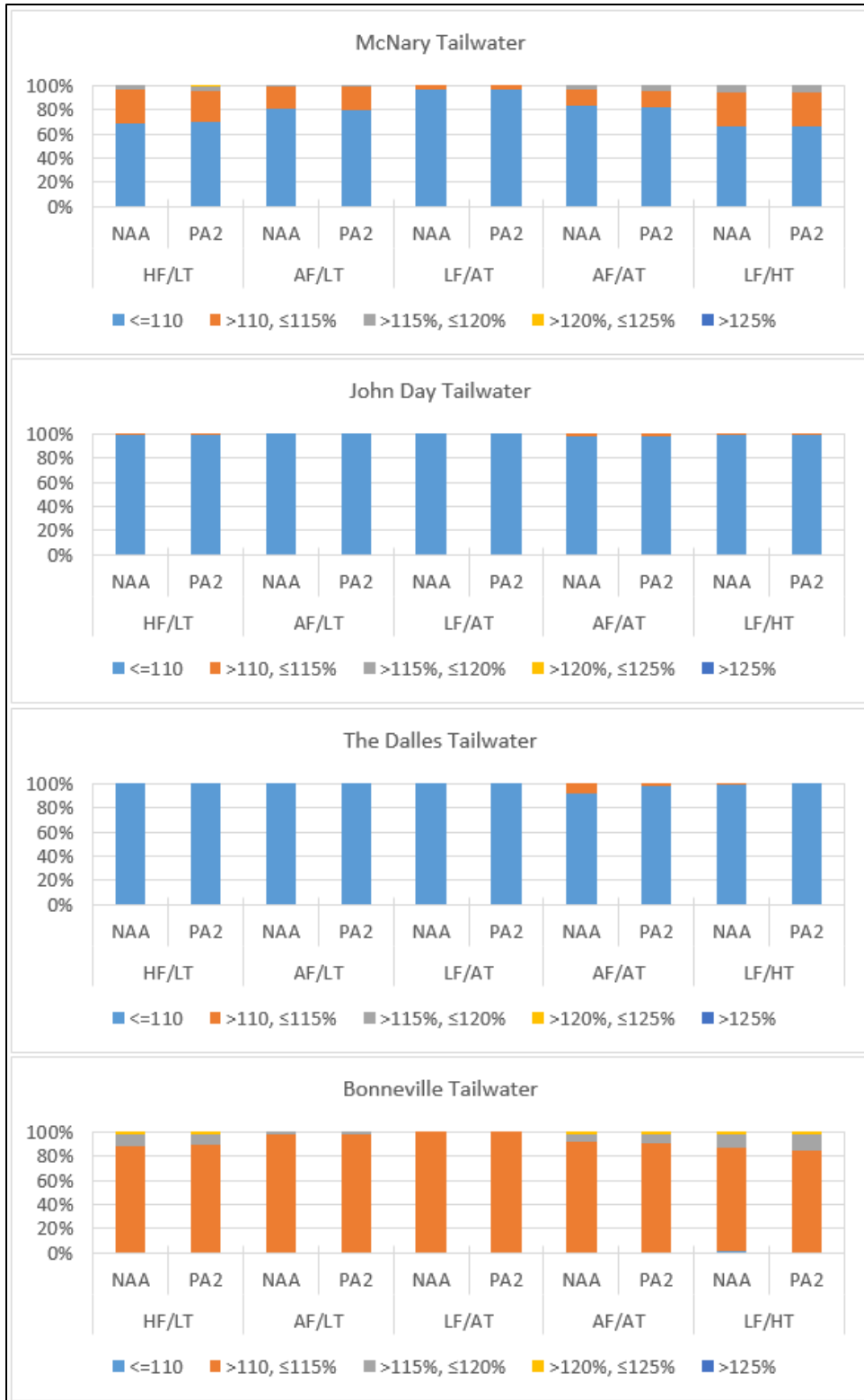
7301
 7302
 7303

Figure 8-46. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative at The Dalles Dam Under a 5-year Range of River and Meteorological Conditions



7304
 7305
 7306

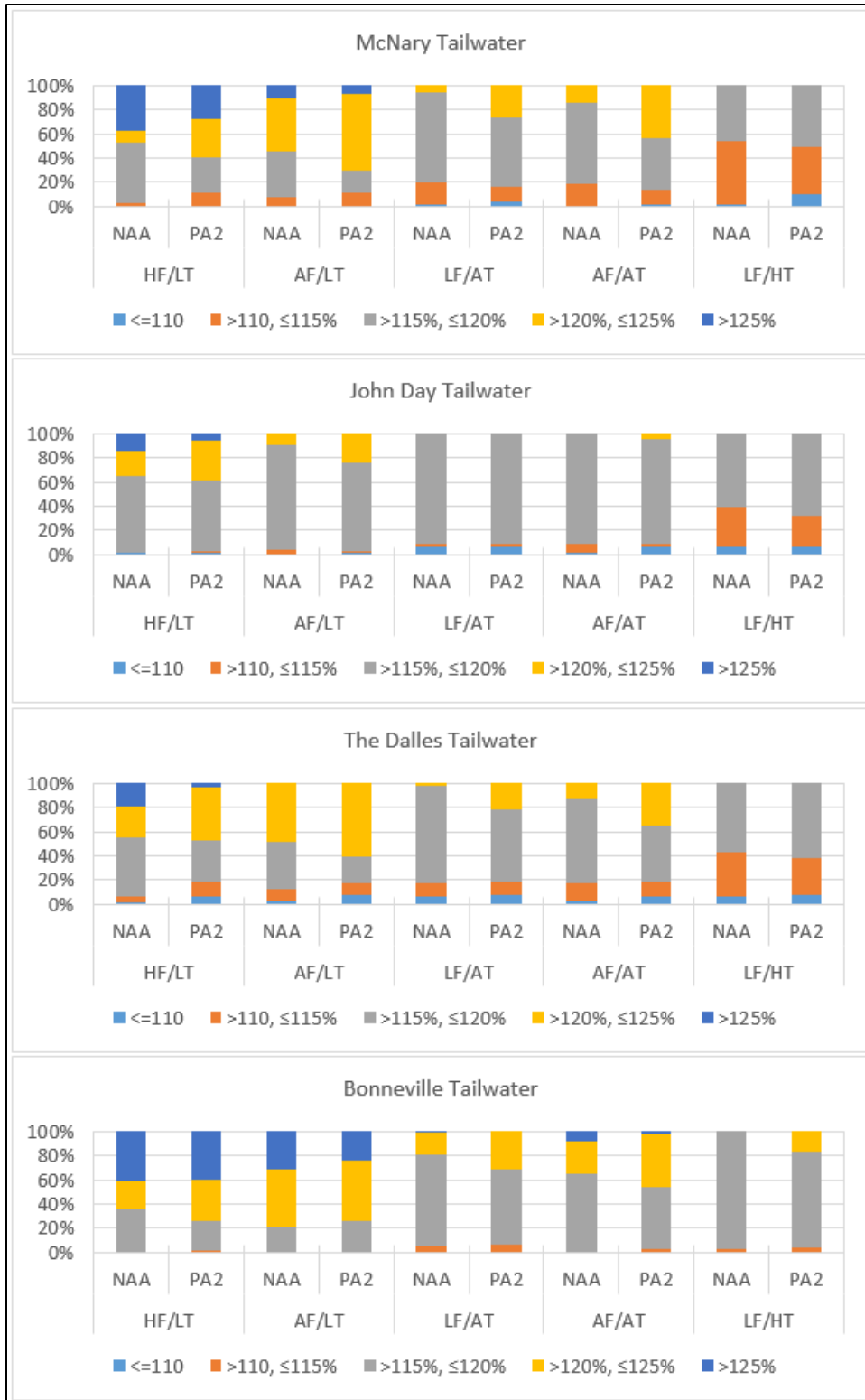
Figure 8-47. Modeled Tailwater Total Dissolved Gas for the Preferred Alternative at Bonneville Dam Under a 5-year Range of River and Meteorological Conditions



7307
 7308
 7309
 7310
 7311

Figure 8-48. Frequency of Modeled Tailwater Total Dissolved Gas Outside of Current Fish Passage Spill Season for the Preferred Alternative and No Action Alternative at McNary, John Day, and The Dalles Dams Under a 5-year Range of River and Meteorological Conditions

Note: Current fish passage spill season is April 1 to August 31



7312
 7313
 7314
 7315
 7316

Figure 8-49. Frequency of Modeled Forebay Total Dissolved Gas During Current Fish Passage Spill Season for the Preferred Alternative and No Action Alternative at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-year Range of River and Meteorological Conditions
 Note: Current fish passage spill season is April 1 to August 31

7317 **8.3.3 Other Physical, Chemical and Biological Processes**

7318 **8.3.3.1 McNary, John Day, The Dalles, and Bonneville Dams and Reservoirs**

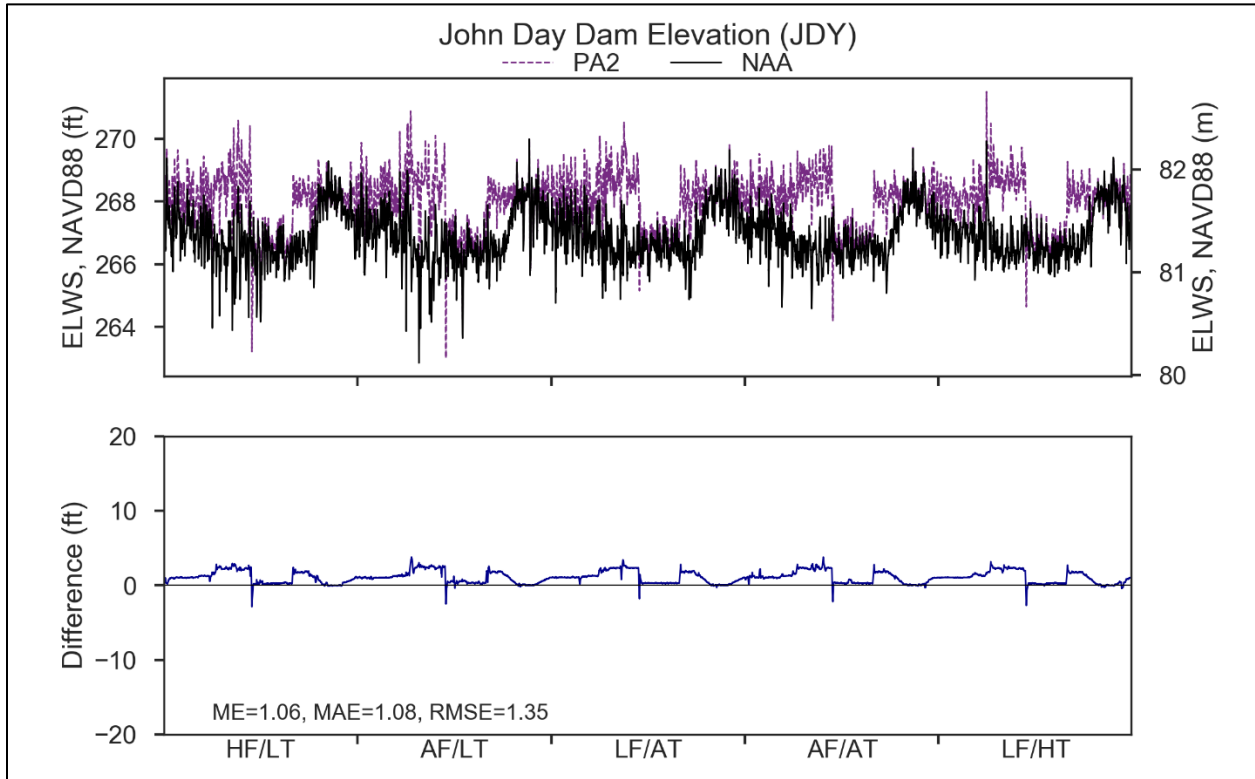
7319 The Preferred Alternative contains optimized versions of three operational measures from the
7320 multiple objective alternatives that would affect the John Day reservoir elevation:

- 7321 • *Predator Disruption Operations*: This measure would allow the Corps to manipulate the
7322 John Day reservoir elevation to decrease avian predation on ESA-listed juvenile salmon and
7323 steelhead in the lower Columbia River. The normal reservoir operating range of the John
7324 Day reservoir is up to elevation 266.5 feet (although it is authorized to operated up to 268
7325 feet). This measure would include operating between 264.5 - 266.5 feet during the period
7326 of April 10 - June 15; operations may be initiated earlier, prior to the start of nesting by
7327 Caspian Terns, to avoid take. The results of this action would be monitoring and
7328 communicated with the USFWS and NOAA Fisheries.
- 7329 • *Increased Forebay Range Flexibility*: This measure would provide operating flexibility during
7330 fish passage season (April 3 - August 31) by changing the operating elevation ranged
7331 restriction at John Day. The operating elevation range restriction at John Day would be MIP
7332 plus 2 feet (262.5 - 264.5 feet), except from April 1 - May 31 when the John Day forebay
7333 operating range would remain between elevations 263.5 and 265.5 feet. The operating
7334 range restrictions would end when spill is reduced or ends. Safety-related restrictions would
7335 continue, including but not limited to maintaining ramp rates for minimizing erosion and
7336 maintaining power grid reliability.
- 7337 • *John Day Full Pool*: This measure would remove current restrictions on seasonal pool
7338 elevations at John Day, allowing more operating flexibility for hourly and daily shaping of
7339 hydropower generation. This measure would allow John Day to use the full normal
7340 operating range (262.0 - 266.5 feet) outside of fish-passage season except as needed for
7341 flood risk management.

7342 These measures would generally lead to the John Day forebay elevation being higher for the PA
7343 than for the No Action Alternative, except from about June through August when the elevations
7344 for the PA and the No Action Alternative would be similar (Figure 8-50). Under the PA, the
7345 elevations would be lower from about June through August than the rest of the year
7346 presumably due to the operating range restriction described in the *Increased Forebay Range*
7347 *Flexibility* measure. No structural or operating measures are expected to impact the forebay
7348 elevations at McNary, The Dalles, and Bonneville; forebay elevations at these dams for both
7349 PA2 and the No Action Alternative would be similar.

7350 Raising and/or lowering the water level could lead to an increase in total suspended solids (TSS)
7351 and associated impacts (increased turbidity, decreased light attenuation, and/or increased
7352 concentrations of chemicals that may be associated with TSS like nutrients, metals, and
7353 organics). However, the impact is expected to be negligible in the large John Day Reservoir.

7354 Otherwise, the introduction of pollutants and excess nutrients from farming and industrial
7355 activities, as well as urban runoff, is expected to continue under the PA. As with the No Action
7356 Alternative, emerging contaminants such as pharmaceuticals and new pesticides will also likely
7357 become more prevalent. The lower Columbia River contains a variety of human-sourced
7358 compounds, including metals and organic contaminants. This condition is expected to remain
7359 generally unchanged, and it is expected that current water quality impairments would continue.



7360
7361 **Figure 8-50. Modeled Forebay Elevation for the Preferred Alternative at John Day Dam Under**
7362 **a 5-year Range of River and Meteorological Conditions**

7363 **8.4 SEDIMENT PROCESSES**

7364 **8.4.1 Sediment Sources**

7365 The PA includes a wide range of structural, fish passage, water management, hydropower and
7366 other measures. These proposed measures would have negligible effects on sediment sources
7367 or movement. The measures included in the PA are not expected to cause changes to land use
7368 within the CRS including upland recreation, flood management, agricultural, timber, or mining
7369 activities, and would not be expected to change population growth patterns in those areas.

7370 **8.4.2 Chemicals of Concern**

7371 No change is predicted to the list of sediment chemicals of concern, compared to the existing
7372 conditions and under the No Action Alternative. Throughout the basin, the contaminants of
7373 concern would remain. These include metals, polycyclic aromatic hydrocarbons (PAHs), volatile

7374 organic compounds (VOCs), pesticides and pesticide degradation products, PCBs, dioxins, and
7375 nutrients (ammonia).

7376 **8.5 CONCEPTUAL SITE MODEL**

7377 The conceptual site model for dredging under the preferred alternative is the same as the
7378 conceptual site model(s) for the existing conditions and under the No Action Alternative. Areas
7379 that are currently not dredged (such as Chief Joseph Reservoir) would not be dredged in the
7380 future, in spite of potential changes in sediment loading in the upper Columbia River Basin,
7381 since there are no navigational features maintained by dredging. Sediment management
7382 operations in the Snake and lower Columbia Rivers would remain as they currently are since
7383 sediment sources for those reaches are not affected. Where dredging is needed (such as at the
7384 confluence of the Snake and Clearwater Rivers), it is assumed that dredged materials would be
7385 of sufficient quality for either in-water or upland beneficial use, as habitat creation areas or as
7386 upland fill. Sediment characterization following the Sediment Evaluation Framework (RSET
7387 2018) or other applicable guidance would continue to be required for any new dredging or
7388 sediment related projects

7389 **8.5.1 Multiple Objective Alternative 4 Results – Water Temperature**

7390 In general, the PA would result in little to no change in water temperature conditions at Hungry
7391 Horse, Albeni Falls, Grand Coulee, and Chief Joseph dams and reservoirs, as compared to the
7392 No Action Alternative. Due to PA higher winter outflows elevations at Libby Dam, resulting from
7393 the deeper mid-April draft targets, Kootenai River water temperatures could be warmer in the
7394 winter as compared to the No Action Alternative. This could result in negligible to minor
7395 negative impacts to resident fish species.

7396 Negligible impacts to water temperature are expected at Dworshak Dam and Reservoir or in the
7397 lower Snake and Columbia Rivers under the PA.

7398 **8.5.2 Multiple Objective Alternative 4 Results – Total Dissolved Gas**

7399 There are no anticipated impacts to TDG expected downstream of Albeni Falls under PA.
7400 Negligible changes in TDG are expected downstream of Libby, Hungry Horse, Grand Coulee or
7401 Chief Joseph Dams.

7402 Under the PA, TDG would be higher in the lower Snake and Columbia River dams due to the
7403 *Juvenile Fish Passage Spill* measure, which sets tailwater TDG limits to 125 percent TDG with no
7404 forebay TDG limit. This results in moderate increases in TDG in the lower Snake River. Due to
7405 the assumed higher amount of lack of market spill in the No Action Alternative, model results
7406 do not show a notable differences in TDG in the PA as compared to the No Action Alternative in
7407 the lower Columbia River. TDG effects are negligible in this reach.

7408 **8.5.3 Multiple Objective Alternative 4 Results – Other Water Quality Impacts**

7409 In general, PA would result in negligible changes in other water quality parameters at all CRSO
7410 projects.

7411 **8.5.4 Multiple Objective Alternative 4 Results – Sediment Quality**

7412 Overall sediment distribution and quality within the entire system are expected to experience
7413 negligible impacts from the PA. The effects of the proposed changes on dredging requirements
7414 and the quality of dredged materials are expected to be negligible since existing transportation
7415 features (locks) are not changing and sediment sources are similarly un-impacted by the
7416 proposed measures.

7417

CHAPTER 9 - CONCLUSIONS

7418 The overall effects of the MOs and PA, as compared to the No Action for water temperature
 7419 have been summarized for water temperature and TDG (Table 9-1 and Table 9-2). The metrics
 7420 used (negligible, minor, moderate or major) in the summary tables describe the magnitude of
 7421 change relative to the No Action Alternative and do not signify if the change was a negative or
 7422 positive (improved or deteriorated water quality condition). The methodology used to
 7423 summarize these effects can be found in Section 2.6.

7424 **Table 9-1. Summary of Water Temperature Effects by EIS Alternative**

	MO1	MO2	MO3	MO4	PA
Libby	negligible	negligible	negligible	minor	negligible
Hungry Horse	negligible	negligible	negligible	negligible	negligible
Albeni Falls	negligible	negligible	negligible	minor	negligible
Grand Coulee	negligible	negligible	negligible	minor	negligible
Chief Joseph	negligible	negligible	negligible	minor	negligible
Dworshak	negligible	negligible	negligible	negligible	negligible
Lower Granite	major	negligible	major	negligible	negligible
Little Goose	moderate	negligible	major	negligible	negligible
Lower Monumental	moderate	negligible	major	negligible	negligible
Ice Harbor	negligible	negligible	major	negligible	negligible
McNary	negligible	negligible	minor	minor	negligible
John Day	negligible	negligible	minor	negligible	negligible
The Dalles	negligible	negligible	minor	negligible	negligible
Bonneville	negligible	negligible	negligible	negligible	negligible

7425

7426 Note: The level of effect is the magnitude of change relative to the No Action Alternative.

7427 **Table 9-2. Summary of Total Dissolved Gas Effects by EIS Alternative**

	MO1	MO2	MO3	MO4	PA
Libby	negligible	negligible	negligible	negligible	negligible
Hungry Horse	negligible	negligible	negligible	negligible	negligible
Albeni Falls	negligible	negligible	negligible	negligible	negligible
Grand Coulee	major	major	major	major	negligible
Chief Joseph	negligible	negligible	negligible	negligible	negligible
Dworshak	negligible	negligible	negligible	negligible	negligible
Lower Granite	negligible	minor	n/a	major	minor
Little Goose	negligible	negligible		major	major
Lower Monumental	negligible	minor		major	moderate
Ice Harbor	negligible	minor		moderate	minor
McNary	negligible	minor	minor	negligible	negligible
John Day	negligible	minor	minor	major	minor
The Dalles	negligible	moderate	negligible	moderate	negligible
Bonneville	negligible	negligible	negligible	negligible	negligible

7428 Note: The level of effect is the magnitude of change relative to the No Action Alternative.
7429

7430 Based on findings from the CRSO EIS water quality analysis, some broad conclusions regarding
7431 the operation and maintenance of CRSO projects can be made. These include:

7432 **9.1 UPPER COLUMBIA RIVER BASIN**

- 7433 • Water temperatures in Lake Roosevelt and below Grand Coulee Dam are influenced by the
7434 changes in operations including changes to storage timing (winter drafts for FRM in the
7435 *Winter System FRM Space* measure), reductions in reservoir volume due to the McNary
7436 Flow Target, by decreasing outflows for Lake Roosevelt Additional Water Supply, and by
7437 changes upstream that changes to inflows. Additionally, changes to spill levels and
7438 simplifying assumptions about outlet use and power plant operations influence modeled
7439 water temperatures and introduce some uncertainty.
- 7440 • Changes to operations (elevations and flows), reservoir temperatures, retention time, and
7441 potentially simplifying modeling assumptions resulted in changes to dissolved oxygen in the
7442 Spokane Arm of Lake Roosevelt. The results in MO2 and MO4 for LF/HT years predicted that
7443 a larger portion of the water column would have low dissolved oxygen.
- 7444 • Even though the major maintenance measure did not result in impacts to downstream
7445 water quality, it is anticipated that a reduction in power plant capacity could result in higher
7446 TDG during years with large water supplies requiring high discharges. Because the capacity
7447 to pass the water through the power plants would be reduced, additional spill would be
7448 required, increasing downstream TDG.

7449 **9.2 LOWER SNAKE RIVER BASIN**

- 7450 • Results suggest that it is critical to begin Dworshak water temperature management
7451 operations in early July to “get ahead” of warming in the lower Snake River. The proposed
7452 operational changes in the MOs either did not make a significant difference or resulted in
7453 higher temperatures, i.e., McNary Flow target and Modified Dworshak Summer Draft in the
7454 lower Snake River.
- 7455 • Reductions in spill operations on the lower Snake River during the late summer do not
7456 result in a reduction in water temperature.
- 7457 • Meeting TDG limits of 110 percent are typically not achievable due to minimum spill
7458 requirements, involuntary spill, and lack of market conditions.
- 7459 • Meeting TDG limits of 125 percent TDG are difficult to achieve throughout the juvenile
7460 downstream fish passage spill season in low flow years due to a lack of total river flow.
- 7461 • Dam breaching
- 7462 ○ Elevated river TDG due to dam spill operations will not occur. However, TDG above 110
7463 percent would still occur during breaching and is expected to be geographically localized
7464 and would occur much less frequently and for shorter durations under normative river
7465 conditions.
- 7466 ○ Water temperatures would be similar to what they were before the dams were built;
7467 daily maximums would exceed 68°F during the summer, daily fluctuations would be
7468 greater, and more rapid heating would occur in spring, followed by earlier cooling in the
7469 fall.
- 7470 • Re-suspension of sediments following dam breaching could result in:
- 7471 • Exposure of chemical contaminants that have been contained in reservoir
7472 sediment. Chemicals of concern include total DDT, dioxin, manganese, and un-
7473 ionized ammonia. DDT could potentially affect the biological system, and un-
7474 ionized ammonia concentrations may exceed EPA water quality criteria for the
7475 protection of aquatic life.
- 7476 • Low, and even anoxic, oxygen concentrations for up to several weeks during the
7477 breaching process, which would create harmful conditions for aquatic organisms.
- 7478 • Initial reduction of primary and secondary production while suspended solids
7479 concentrations and turbidity are elevated.
- 7480 • Damage to irrigation pumps and adverse effects to irrigated crops.
- 7481 • Phytoplankton and zooplankton would become minor components of the food web.
7482 Attached benthic algae and macroinvertebrates would dominate primary and
7483 secondary productivity after a new equilibrium is established.

7484 **9.3 LOWER COLUMBIA RIVER**

- 7485 • Results suggest that lower Columbia River water temperatures are not influenced by
7486 upstream structural and/or operational changes. This includes breaching of the lower Snake
7487 River dams.
- 7488 • Meeting TDG limits of 110 percent are typically not achievable due to minimum spill
7489 requirements, involuntary spill, and lack of market conditions.
- 7490 • Meeting TDG limits of 125 percent TDG are difficult to achieve throughout the juvenile
7491 downstream fish passage spill season in low flow years due to a lack of total river flow.

7492

CHAPTER 10 - REFERENCES

- 7493 Bass, R. E., A. I. Herson, and K. M. Bogdan. 2001. The NEPA Book: A Step-By-Step Guide on
7494 How to Comply With the National Environmental Policy Act.
- 7495 Christenson, D.J., R. L. Sund, and B. Marotz. 1996. "Hungry Horse Dam's Successful Selective
7496 Withdrawal System." *Hydro Review* 15.
- 7497 Corps (U.S. Army Corps of Engineers). 1993. 1992 Reservoir Drawdown Test – Lower Granite
7498 and Little Goose Dams. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla,
7499 Washington
- 7500 _____. 2002a. Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental
7501 Impact Statement. Appendix C, Water Quality. U.S. Army Corps of Engineers, Walla
7502 Walla District, Walla Walla, Washington.
- 7503 _____. 2002b. Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental
7504 Impact Statement. Appendix H, Fluvial Geomorphology. U.S. Army Corps of Engineers,
7505 Walla Walla District, Walla Walla, Washington.
- 7506 _____. 2014. Lower Snake River Programmatic Sediment Management Plan/Final
7507 Environmental Impact Statement. Walla Walla District. Walla Walla, Washington.
- 7508 EPA (U.S. Environmental Protection Agency). 2013. Aquatic Life Ambient Water Quality Criteria
7509 for Ammonia – Freshwater. EPA-822-R-13-001. U.S. Environmental Protection Agency,
7510 Office of Water, Office of Science and Technology, Washington, D.C.
- 7511 Fraley et. al. 1997. Mitigation, compensation, and future protection for fish populations
7512 affected by hydropower development in the Upper Columbia System, Montana. USA
7513 Regulated Rivers: Research and Management Vol 3, (3-18).
- 7514 Hanford Site, Department of Energy. 2018. Information on the River Corridor Project.
7515 <https://www.hanford.gov/>.
- 7516 High, B., C. A. Peery and D. H. Bennett. 2006. Temporary Staging of Columbia River Summer
7517 Steelhead in Coolwater Areas and Its Effect on Migration Rates. *Trans Amer Fish Soc.*
7518 135:519-528.
- 7519 IDEQ (Idaho Department of Environmental Quality). 2014. Integrated 303(d) Report.
7520 [http://www.deq.idaho.gov/water-quality/surface-water/monitoring-assessment/
7521 integrated-report.aspx](http://www.deq.idaho.gov/water-quality/surface-water/monitoring-assessment/integrated-report.aspx). _____. 2015. Idaho Nonpoint Source Management Plan.
7522 [http://www.deq.idaho.gov/media/60153107/idaho-nonpoint-source-management-
7523 plan.pdf](http://www.deq.idaho.gov/media/60153107/idaho-nonpoint-source-management-plan.pdf). [http://www.deq.idaho.gov/media/60153107/idaho-nonpoint-source-
7524 management-plan.pdf](http://www.deq.idaho.gov/media/60153107/idaho-nonpoint-source-management-plan.pdf)

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

- 7525 ISAB (Independent Scientific Advisory Board). 1997. Ecological impacts of the flow provisions
7526 of the Biological Opinion for endangered Snake River salmon on resident fishes in the
7527 Hungry Horse, and Libby systems in Montana, Idaho, and British Columbia. Independent
7528 Scientific Advisory Board. Report 97-3 for the Northwest Power Planning Council and
7529 National Marine Fisheries Service. Portland, OR.
- 7530 MacDonald, D. D., Sinclair, J. A., Crawford, M. A., Prencipe, H. J., Coady, M. R. 2012. *Evaluation*
7531 *and Interpretation of the Sediment Chemistry and Sediment Toxicity Data for the Upper*
7532 *Columbia River*. MacDonald Environmental Sciences Ltd.
- 7533 Meier, J. R., J. M. Lazorchak, M. Mills, P. Wernsing, and P. C. Baumann. "Monitoring Exposure of
7534 Brown Bullheads and Benthic Macroinvertebrates to Sediment Contaminants in the
7535 Ashtabula River Before, During, and After Remediation." *Environmental Toxicology*. 34(6).
- 7536 National Research Council. 2001. A Risk-Management Strategy for PCB-Contaminated
7537 Sediments. National Academy Press.
- 7538 _____. 2007. Sediment Dredging at Superfund Megsites: Assessing the Effectiveness. National
7539 Academy Press.
- 7540 Normandeau. 1999. Snake River Water Quality Appendices – Draft. Normandeau Associates,
7541 Inc., Bedford, New Hampshire, in conjunction with Washington State University and
7542 University of Idaho.
- 7543 Palmer, J. 2017. Cold Water Fish Refuges, EPA's Columbia River Cold Water Refuges Project. *The*
7544 *Water Report, Issue #164*.
- 7545 Peery, C. A., T. C. Bjornn, and L. C. Stuehrenberg, 2003. Water Temperatures and Passage of
7546 Adult Salmon and Steelhead in the Lower Snake River. Technical Report 2003-2.
7547 Prepared for U.S. Army Corps of Engineers, Walla Walla District, Walla Walla,
7548 Washington.
- 7549 Randle, T. J., and J. Bountry. 2017. Dam Removal Analysis Guidelines for Sediment. Prepared for
7550 Bureau of Reclamation, Technical Service Center, Denver, Colorado.
- 7551 Reclamation (U.S. Bureau of Reclamation). 2006. *Hungry Horse Selective Withdrawal System*
7552 *Evaluation 2000 - 2003, Hydraulic Laboratory Report HL-2006-06*. U.S. Department of
7553 Interior, Bureau of Reclamation, Technical Service Center, Hydraulic Investigations and
7554 Laboratory Group, Hungry Horse Project.
- 7555 Reidel, J.L.; Gable, C., Lawrence; J., Hebner, S. "Lake Roosevelt National Recreation Area,
7556 Washington Water Resources Scoping Report" 1997, National Park Service Technical
7557 Report NPS/NRWRD/NRTR-97/107.
- 7558 RSET (Northwest Regional Sediment Evaluation Team). 2018. Sediment Evaluation Framework
7559 for the Pacific Northwest. Prepared by the RSET Agencies. May 2018.

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

- 7560 Ryberg, Karen R. and Robert J. Gilliom. 2015. Trends in pesticide concentrations and use for
7561 major rivers of the United States. *Science of the Total Environment*, 538, pp. 431-
7562 444. Schenk, L.N., and Bragg, H.M., 2014, Assessment of suspended-sediment transport,
7563 bedload, and dissolved oxygen during a short-term drawdown of Fall Creek Lake,
7564 Oregon, winter 2012–13: U.S. Geological Survey Open-File Report 2014–1114,
7565 80p., <https://dx.doi.org/10.3133/ofr20141114>. ISSN 2331-1258 Schneider, M.L. and J.C.
7566 Carroll 1999. TDG exchange during spillway releases at Chief Joseph Dam, near-field
7567 study, June 6-10, 1999. Prepared for the Seattle District Corps of Engineers by the U.S.
7568 Army Waterways Experiment Station, Vicksburg, MS.
- 7569 Schneider, M. L. 2003. Total dissolved gas exchange at Libby Dam, Montana June-July 2002.
7570 Prepared for the Seattle District Corps of Engineers by the U.S. Army Engineer Research
7571 and Development Center, Vicksburg, MS.
- 7572 Schneider, M. L., Yates L. I., and K. L. Barko 2007. Total dissolved gas exchange at Albeni Falls
7573 Dam 2003. Prepared for the Seattle District Corps of Engineers by the U.S. Army
7574 Engineer Research and Development Center Coastal and Hydraulics Laboratory,
7575 Dallesport, WA.
- 7576 Schneider, M.L. 2012. Total dissolved gas exchange at Chief Joseph Dam: Post Spillway Flow
7577 Deflectors, April 28-May 1, 2009. Prepared for the Seattle District Corps of Engineers by
7578 the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS.
- 7579 U.S. Forest Service. 2017. Columbia River Gorge National Scenic Area Burned Area Emergency
7580 Response Summary – Eagle Creek Fire. October 10, 2017. [https://inciweb.nwcg.gov/
7581 photos/ORCGF/2017-09-03-1149-Eagle-Creek/related_files/pict20170919-180327-0.pdf](https://inciweb.nwcg.gov/photos/ORCGF/2017-09-03-1149-Eagle-Creek/related_files/pict20170919-180327-0.pdf).
- 7582 USGS (U.S. Geological Survey). 1960. Quality of Surface Waters of the United States, 1956. Parts
7583 9-14. Colorado River Basin to Pacific Slope Basins in Oregon and Lower Columbia River
7584 Basin. Geological Survey Water-Supply Paper 1453. Washington, D.C.: U.S. Government
7585 Printing Office.
- 7586 _____. 1961. Quality of Surface Waters of the United States, 1957. Parts 9-14. Colorado River
7587 Basin to Pacific Slope Basins in Oregon and Lower Columbia River Basin. Geological
7588 Survey Water-Supply Paper 1523. Washington, D.C.: U.S. Government Printing Office.
- 7589 _____. 1964. Quality of Surface Waters of the United States, 1958. Parts 9-14. Colorado River
7590 Basin to Pacific Slope Basins in Oregon and Lower Columbia River Basin. Geological
7591 Survey Water-Supply Paper 1574. Washington, D.C.: U.S. Government Printing Office.
- 7592 Washington Department of Ecology. 2018. Upper Columbia River Lake Roosevelt Site.
7593 <https://fortress.wa.gov/ecy/gsp/Sitepage.aspx?csid=12125#litigation>.
- 7594 Washington Office of Financial Management. 2018. 2018 Population Trends. [https://www.ofm.
7595 wa.gov/sites/default/files/public/dataresearch/pop/april1/ofm_april1_poptrends.pdf](https://www.ofm.wa.gov/sites/default/files/public/dataresearch/pop/april1/ofm_april1_poptrends.pdf).

Columbia River System Operations Environmental Impact Statement
Appendix D, Alternatives Evaluation for Water and Sediment Quality Impacts, Technical Appendix

- 7596 Williamson et al. 1998. Water quality in the Central Columbia Plateau, Washington and Idaho,
7597 1992-95: U.S. Geological Survey Circular 1144, 35 p.
- 7598 Weitkamp, D. E., and M. Katz. 1980. "A Review of Dissolved Gas Supersaturation Literature.
7599 *Transactions of the American Fisheries Society.*"109(6):659–702, November 1980.
- 7600 Weitkamp, D. E., Sullivan, R. D., Swant, T., and J. DosSantos. 2002. Gas bubble disease in
7601 resident fish of the Lower Clark Fork River. Report prepared for Avista Corporation by
7602 Parametrix, Inc.
- 7603 Willacker, J. J., C. A. Eagles-Smith, M. A. Lutz, M. T. Tate, J. M. Lepak, and J. T. Ackerman. 2016.
7604 "Reservoirs and Water Management Influence Fish Mercury Concentrations in the
7605 Western United States and Canada 2016." *Science of the Total Environmental* 568:739748.
- 7606 Yassien, H. and R.B. Ward. 2018. Nutrient transport for Koochanusa inflows and outflows: a 45-
7607 year comparison. HAY Engineering Services Ltd, Richmond, British Columbia Canada.



**Draft Columbia River System Operations
Environmental Impact Statement**

Annex A

**Lower Snake River Multiple Objective Alternative 3
Model Development Report**

Table of Contents

1		
2	CHAPTER 1 - Lower Snake River Multiple Objective Alternative 3 Model	1-1
3	1.1 Introduction	1-1
4	1.2 Selection.....	1-1
5	1.3 Lower Snake River Multiple objective Alternative 3 Model Development	1-2
6	1.3.1 Model Geometry.....	1-3
7	1.3.2 Model Flows.....	1-10
8	1.3.3 Water Temperature	1-13
9	1.3.4 Heat Flux and Model Parameterization Discussion	1-16
10	1.3.5 Evaluation of HEC-RAS parameterization	1-18
11	1.3.6 Model Sensitivity to Vertical Stratification	1-21
12	1.3.7 Model Sensitivity to parameters	1-22
13	1.3.8 Model Sensitivity to Daily Heat Fluxes.....	1-25
14	1.3.9 Comparison to Other Model Predictions.....	1-25
15	1.3.9.1 U.S. Environmental Protection Agency’s 2018 RBM10	1-26
16	1.3.9.2 2002 Feasibility Study	1-29
17	1.3.10 Model Results	1-29
18	1.3.10.1 Flow Comparison to No Action Alternative	1-29
19	1.3.10.2 Temperature Comparison to No Action Alternative	1-35
20	CHAPTER 2 - Model Conclusions	2-1
21	2.1 Model Assumptions and Uncertainty	2-1
22	2.1.1 Framework Uncertainty.....	2-1
23	2.1.2 Input Uncertainty.....	2-2
24	2.1.3 Parameter Uncertainty	2-2
25	2.1.4 Niche Uncertainty	2-3
26	2.2 Model Acceptability	2-5
27	CHAPTER 3 - References	3-1
28		
29		

30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55

List of Tables

Table 1-1. DSS File Paths for Each Flow and Stage Boundary..... 1-10
 Table 1-2. DSS File Paths for Each Temperature Boundary and Initial Conditions..... 1-14
 Table 1-3. Calibration Coefficients Used in the Lower Snake River No Action Alternative
 (HEC-RAS and W2) and MO3 (HEC-RAS) Models..... 1-17
 Table 1-4. Sensitivity to Increased Dispersion Coefficient 1-22
 Table 1-5. Sensitivity to Increased Roughness Coefficient..... 1-23
 Table 1-6. Sensitivity to Decreased Roughness Coefficient..... 1-23
 Table 1-7. Sensitivity to Increased Wind Coefficients 1-23
 Table 1-8. Sensitivity to Decreased Wind Coefficients 1-24
 Table 1-9. Sensitivity to Richardson wind coefficient..... 1-24
 Table 1-10. RBM10 Estimated Monthly Impact of Dam Impoundments on Snake River
 Temperatures (August; 2011–2016)..... 1-26
 Table 1-11. Lower Granite Tailrace, Comparison of RBM10 and HEC-RAS Predictions of
 Temperature without Lower Snake River Dams, 2011–2015 Weather and
 Hydrology, Monthly Average..... 1-27
 Table 1-12. Ice Harbor Tailrace, Comparison of RBM10 and HEC-RAS Predictions of
 Temperature without Lower Snake River Dams, 2011-2015 Weather and
 Hydrology, Monthly Average..... 1-28
 Table 1-13. 5-Year No Action Alternative versus Multiple Objective Alternative 3
 Statistical Comparisons for Flow (cms)..... 1-30
 Table 1-14. 5-Year No Action Alternative versus Multiple Objective Alternative 3
 Statistical Comparisons for Temperature (°C) 1-35
 Table 2-1. Root Mean Square Error (°C) by Month 2-4

List of Figures

Figure 1-1. Columbia River System Operations Multiple Objective 3 Model Schematic 1-2
 Figure 1-2. Lower Snake River Multiple Objective Alternative 3 Model Geometry 1-3
 Figure 1-3. Overlapping Clearwater Cross Section 7.8160 (top) and Cross Section 7.0348
 (below)..... 1-5
 Figure 1-4. Overlapping Cross Sections of the Snake River, Cross Section 147.85 (top) and
 Cross Section 140.40662 (bottom) 1-6
 Figure 1-5. Bridge Geometry and Upstream and Downstream Cross Sections at the
 Railroad Bridge (Clearwater River Mile Cross Section 0.591)..... 1-7
 Figure 1-6. Bridge Geometry and Upstream and Downstream Cross Sections at the
 Interstate Bridge (Snake River Mile Cross Section 138.671) 1-8
 Figure 1-7. Bridge Geometry and Upstream and Downstream Cross Sections at the
 Upper Snake Upper Bridge (Snake River Mile Cross Section 140.46) 1-9
 Figure 1-8. Lower Snake River Multiple Objective Alternative 3 Model Main Flow
 Boundaries 1-11
 Figure 1-9. ResSim (black) and HEC-RAS (red) Flows at Lower Granite Dam Bypass 1-11
 Figure 1-10. ResSim (black) and HEC-RAS (red) Flows at Little Goose Dam Bypass..... 1-12

72	Figure 1-11. ResSim (black) and HEC-RAS (red) Flows at Lower Monumental Dam Bypass	1-12
73	Figure 1-12. ResSim (black) and HEC-RAS (red) Flows at Ice Harbor Dam Bypass	1-13
74	Figure 1-13. Lower Snake River Multiple Objective Alternative 3 Model Main	
75	Temperature Boundaries.....	1-15
76	Figure 1-14. Lower Snake River Multiple Objective Alternative 3 Meteorological Stations	1-15
77	Figure 1-15. Hourly Temperature Comparison of HEC-RAS Existing Conditions	
78	Representation to Measurements at Lower Granite Dam Tailwater	1-19
79	Figure 1-16. Daily Average Temperature Comparison of HEC-RAS Existing Conditions	
80	Representation to Measurements at Lower Granite Dam Tailwater	1-19
81	Figure 1-17. Hourly Temperature Comparison of HEC-RAS Existing Conditions	
82	Representation to Measurements at Ice Harbor Dam Tailwater	1-20
83	Figure 1-18. Daily Average Temperature Comparison of HEC-RAS Existing Conditions	
84	Representation to Measurements at Ice Harbor Dam Tailwater	1-20
85	Figure 1-19. Comparison of One-dimensional Existing Conditions and Two-dimensional	
86	Existing Conditions at Ice Harbor Dam	1-21
87	Figure 1-20. Observed Temperature Profile at Ice Harbor Dam in mid-January and late	
88	June Compared to Multiple Objective Alternative 3 Predicted Temperature	1-22
89	Figure 1-21. Comparison of Hourly versus Daily Model Inputs to Daily Average	
90	Temperature Predictions	1-25
91	Figure 1-22. Ice Harbor tailrace, Comparison of 2015 Daily Average Temperature	
92	Prediction with No Lower Snake River Dams	1-28
93	Figure 1-23. Discharge Comparison at Dworshak Dam	1-30
94	Figure 1-24. Discharge Comparison at the Clearwater River at Orofino, Idaho.....	1-31
95	Figure 1-25. Discharge Comparison at the Snake River near Anatone, Idaho	1-31
96	Figure 1-26. Discharge Comparison at the Clearwater River near Peck, Idaho.....	1-32
97	Figure 1-27. Discharge Comparison at the Clearwater River near Spalding, Idaho	1-32
98	Figure 1-28. Discharge Comparison at Lower Granite Dam	1-33
99	Figure 1-29. Discharge Comparison at Little Goose Dam	1-33
100	Figure 1-30. Discharge Comparison at Lower Monumental Dam	1-34
101	Figure 1-31. Discharge Comparison at Ice Harbor Dam	1-34
102	Figure 1-32. Temperature Comparison at Dworshak Dam.....	1-36
103	Figure 1-33. Temperature Comparison at the Clearwater River at Orofino, Idaho	1-36
104	Figure 1-34. Temperature Comparison at the Snake River near Anatone, Idaho.....	1-37
105	Figure 1-35. Temperature Comparison at the Clearwater River near Peck, Idaho	1-37
106	Figure 1-36. Temperature Comparison at the Clearwater River near Spalding, Idaho.....	1-38
107	Figure 1-37. Temperature Comparison at Lower Granite Dam.....	1-38
108	Figure 1-38. Temperature Comparison at Little Goose Dam.....	1-39
109	Figure 1-39. Temperature Comparison at Lower Monumental Dam.....	1-39
110	Figure 1-40. Temperature Comparison at Ice Harbor Dam.....	1-40
111	Figure 2-1. Estimated Uncertainty of MO3 Predictions Compared to the No Action	
112	Alternative.	2-4
113		
114		

ACRONYMS AND ABBREVIATIONS

#OBS	number of observations
°C	degrees Celsius
°F	degrees Fahrenheit
AME	absolute mean error
ANA	Anatone, Idaho
ANQW	Anatone River station
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
CRSO	Columbia River System Operations
DENI	Dent Acres, Idaho, weather station
DWQI	North Fork Clearwater River at Ahsahka, Idaho, station
DWR	Dworshak Dam
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ft ² /s	square feet per second
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center River Analysis System
IHR	Ice Harbor Dam
LEGW	Legrow, Washington, station
LEWI	Lewiston, Idaho, station
LGS	Little Goose Dam
LMN	Lower Monumental Dam
LSR	Lower Snake River (model)
LWG	Lower Granite Dam
m	meters
m/s	meters per second
MAE	mean absolute error
MCN	McNary Dam
ME	mean error
mmHg	millimeters mercury
MO	Multiple Objective Alternative
MO3	Multiple Objective Alternative 3
ORFI	Clearwater River at Orofino, Idaho, station
PEK	Peck, Idaho
ResSim	reservoir simulation model (power/flood model)
RM	river mile
RBM10	River Basin Model-10
RMSE	root mean square error
SILW	Silcott Island, Washington, station
SPD	Spalding, Idaho
SWSolar W/m ²	short wave solar radiation

TMDL	total maximum daily load
W2	water quality model CE-QUAL-W2
WQ team	Columbia River System Operations water quality modeling team

117 **CHAPTER 1 - LOWER SNAKE RIVER MULTIPLE OBJECTIVE ALTERNATIVE 3 MODEL**

118 **1.1 INTRODUCTION**

119 The Lower Snake River (LSR) Multiple Objective Alternative 3 (MO3) model was developed to
120 evaluate water quality impacts from breaching of all four dams on the lower Snake River. Analysis
121 was performed using a 5-year period, spanning 2011 through 2015, to understand impacts under
122 a wide range of flow and meteorological conditions. MO3 has several notable measures (Chapter
123 2), the most significant of which is the removal of the lower Snake River dams, which would occur
124 over a 2-year period with Lower Granite and Little Goose Dams breached in the first year, Lower
125 Monumental and Ice Harbor Dams breached the second year. Unlike the other Multiple Objective
126 Alternatives (MOs), for MO3, the lower Snake River reach is represented by a one-dimensional
127 Hydrologic Engineering Center River Analysis System (HEC-RAS) model with dam breach
128 bathymetry. This geometry represents the channel at sediment movement equilibrium and is a
129 stable geometry. Other MOs used the two-dimensional CE-QUAL-W2 (W2) model that represents
130 the existing dam configuration.

131 **1.2 SELECTION**

132 Given the Columbia River System Operations (CRSO) project timeline, available resources, and
133 product quality, the CRSO water quality modeling team (WQ team) considered using either W2 or
134 HEC-RAS to represent temperature under the dam breach alternative. HEC-RAS is a depth-
135 averaged one-dimensional hydraulic model designed for free-flowing riverine conditions,
136 whereas W2 is designed primarily for stratified lakes and becomes unstable with a sloped water
137 surface and higher velocities. There are distinct advantages of both of these models.

138 The advantages of W2 are as follows:

- 139 • Use of calibrated parameterization identical to that of other CRSO models

140 The advantages of HEC-RAS are as follows:

- 141 • Stable hydraulics
- 142 • More precise cross-section and channel slope representation
- 143 • Bathymetry file for dam breach conditions already developed in HEC-RAS format

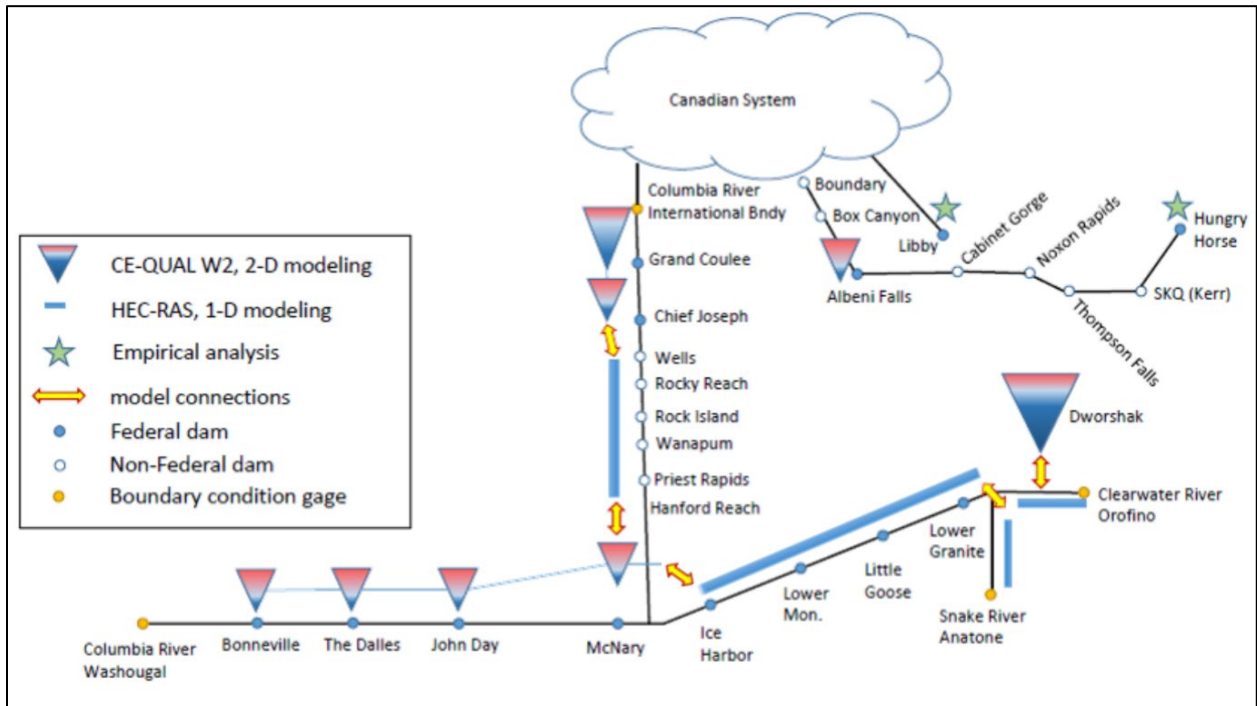
144 The water quality modeling team used past experiences and professional judgment to come to a
145 consensus decision and use HEC-RAS to represent the lower Snake River dam breach. Although
146 riverine models using W2 do exist, the amount of effort required to set up a stable model and
147 test a variety of parameter sets was not within the project constraints. There are several
148 instabilities that occur when developing a W2 riverine model, many of which involve unstable
149 water surface elevations due to having a sloped channel. Given this and past unsuccessful efforts
150 to set up a W2 riverine model on the Clearwater River due to stability issues over the observed
151 annual hydrograph, the WQ team chose to move forward by pursuing the development of a one-
152 dimensional model.

153 The WQ team used the following strategies to minimize the uncertainty introduced by not using
154 parameters that had been calibrated to an existing condition:

- 155 • When possible, use a similar parameterization to the calibrated W2 model or published
156 values.
- 157 • Utilize the same meteorology and solar radiation inputs as the calibrated W2 model.
- 158 • When the HEC-RAS heat balance representation needed different parameters than W2, utilize
159 the parameters from the calibrated Clearwater River HEC-RAS model.
- 160 • Use Edinger values for wind coefficients since the W2 calibration wind parameters represent
161 wind differently (Edinger, et. al. 1974; reported in Cole and Wells 2018).
- 162 • Perform a test of the parameterization utilizing the current hydraulics (with dams) and
163 comparing results to 2011 – 2015 measured water temperature.
- 164 • Perform a sensitivity analysis of the chosen parameterization to ensure that temperature
165 predictions are ideal.
- 166 • Compare the predictions of MO3 to other dam breach modeling efforts.

167 **1.3 LOWER SNAKE RIVER MULTIPLE OBJECTIVE ALTERNATIVE 3 MODEL DEVELOPMENT**

168 The LSR-MO3 model simulates water temperature using the newly developed HEC-RAS geometry
169 to represent dam breach. The software program HEC-RAS Version 5.0.3 and appropriate system
170 improvements and modifications were used for the MO3 model development. A depiction of the
171 full CRSO MO3 model is shown below in Figure 1-1; however, this report focuses solely on the
172 lower Snake River portion of the model development, which is shown in Figure 1-2.



173
174 **Figure 1-1. Columbia River System Operations Multiple Objective 3 Model Schematic**



175

176 **Figure 1-2. Lower Snake River Multiple Objective Alternative 3 Model Geometry**

177 Note: IHR = Ice Harbor, LMN = Lower Monumental, LGS = Little Goose, LWG = Lower Granite, ORFI = Clearwater
178 River at Orofino station, ANA = Anatone station on the Snake River.

179 **1.3.1 Model Geometry**

180 An in-depth sediment transport model was developed for the lower Snake River reach to
181 characterize sediment movement through the system from the breaching of the four lower
182 Snake River dams. A one-dimensional quasi-unsteady mobile bed model of the Clearwater
183 River, lower Snake River, and McNary Reservoir was employed using the HEC-RAS Version 5.0.6
184 software to inform on the scour, transport, and fate of materials stored in the lower Snake
185 River system. Once sediment equilibrium was achieved, the resulting channel was compared to
186 the 1934 river terrain and yielded similar characteristics. A channel geometry calibrated to the
187 1934 channel geometry was developed and provided for water quality analysis. Modifications
188 to the geometry include the addition of the dam structure remnants and configured flow
189 bypasses. The final channel geometry presented by the CRSO river mechanics team may be
190 different than the 1934 representation used in the water quality analysis. Additional refinement
191 of the sediment movement study and resulting channel geometry will not likely yield noticeable
192 differences in water temperature.

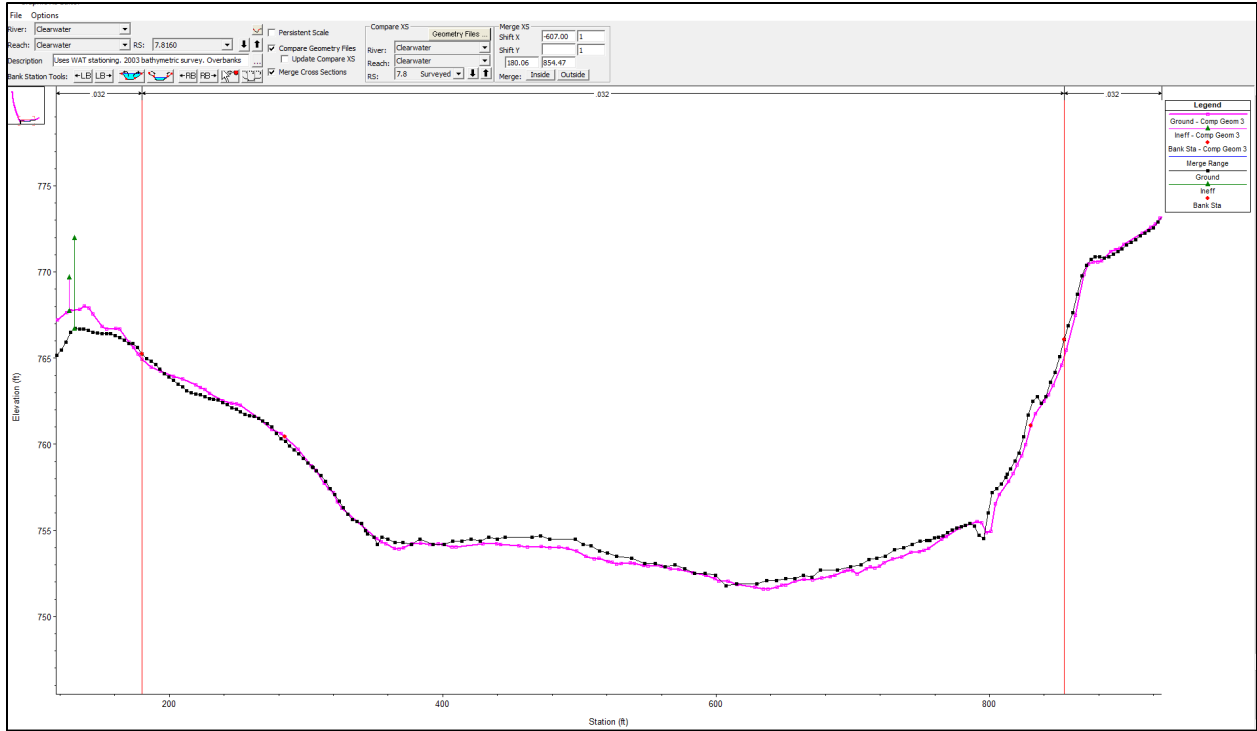
193 The geometry obtained from the CRSO river mechanics was updated with edits specific to the
194 Columbia River System Operations (CRSO) modeling so that impacts from MO3 could be directly
195 compared to the No Action Alternative (NAA). Geometry updates include the following:

- 196 1. The Snake and Clearwater River channels were extended further upstream to match the
197 CRSO model. The Orofino Creek reach was added and the North Fork Clearwater River was
198 extended to link with the upstream Dworshak W2 model. Cross sections from the CRSO

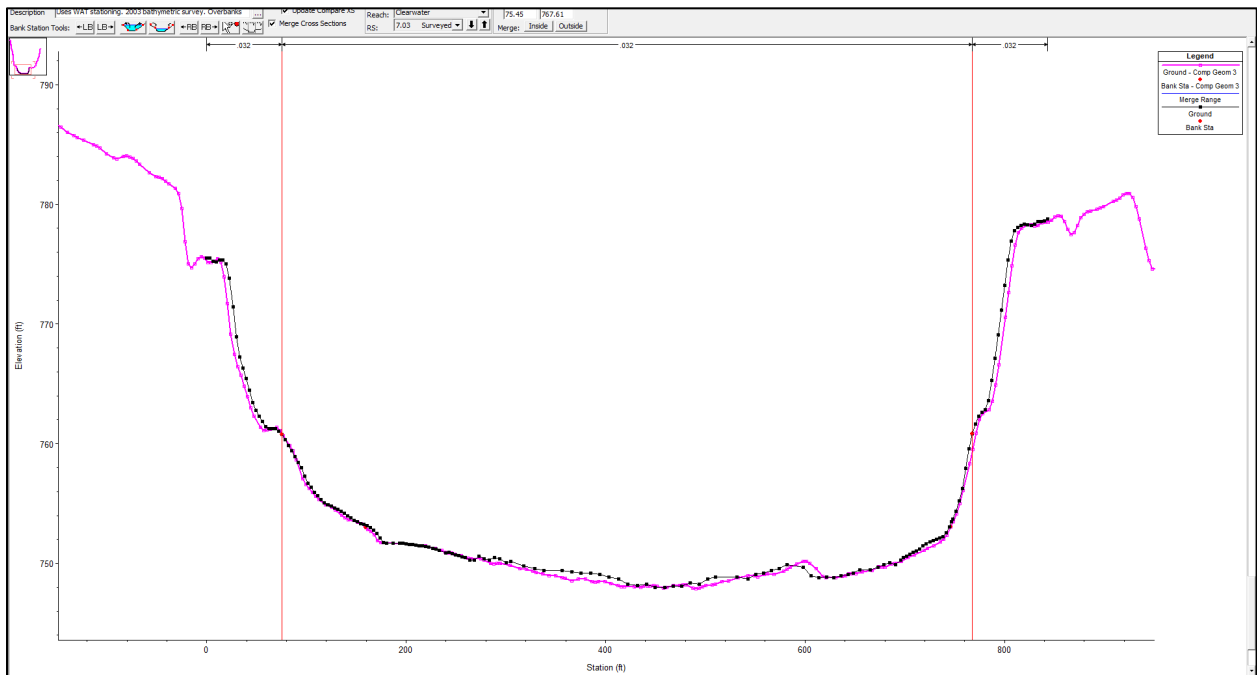
199 model were added as part of this extension. Channel slopes and downstream lengths were
200 verified during the updates. Cross sections along the Clearwater and Snake Rivers were
201 compared to identify major changes in channel geometries between the No Action and
202 MO3 models. Figure 1-3 shows two locations on the Clearwater River, cross sections 7.8160
203 and 7.0348. Similarly, Figure 1-4 shows the Snake River cross sections 147.85 and
204 140.40662. These cross sections are located at the upstream end of the 1934 geometry
205 where the cross sections transition to the CRSO existing condition geometry. The black line
206 represents the 1934 geometry with dam bypass and the pink line represents the CRSO No
207 Action Alternative geometry. Above the Snake and Clearwater Rivers confluence, all cross
208 sections were compared between geometry sets. In general, the Clearwater River reach
209 shows good agreement between datasets at most locations. However, the Snake River is
210 noticeably variable.

- 211 2. Bridges and bounding cross sections were copied over from the CRSO geometry and
212 corresponding reach lengths were adjusted. Downstream distances were adjusted based on
213 assigned river mile station.
- 214 3. Snake River bridges at river miles (RM) 136, 138, and 140 and Clearwater cross section
215 0.591 were imported into the 1934 geometry from the CRSO geometries. Bridge and pier
216 stationing were compared and shifted to best represent thalweg location within the
217 channel. Snake River cross section 138.7972 was copied as 138.633 to define an adjacent
218 cross section, as needed for bridge computation. Reach length distances and channel
219 elevations were adjusted base on channel slope to provide a smooth representation of the
220 channel. Figure 1-5 through Figure 1-7 compare bridge cross sections for the Clearwater and
221 Snake Rivers, respectively. It is important to note that cross section layout and distance
222 from the bridge varies between geometries. It should also be noted that the sediment study
223 did not include existing bridges and therefore does not consider bridge-related scour and
224 deposition potential in the MO3 1934 geometry.
- 225 4. Interpolated cross sections along Clearwater River were added to the MO3 1934 geometry
226 for stability. Interpolated cross sections were not necessary throughout the other reaches.

*Columbia River System Operations Environmental Impact Statement
Annex A, Lower Snake River Multiple Objective Alternative 3 Model Development Report*



227



228

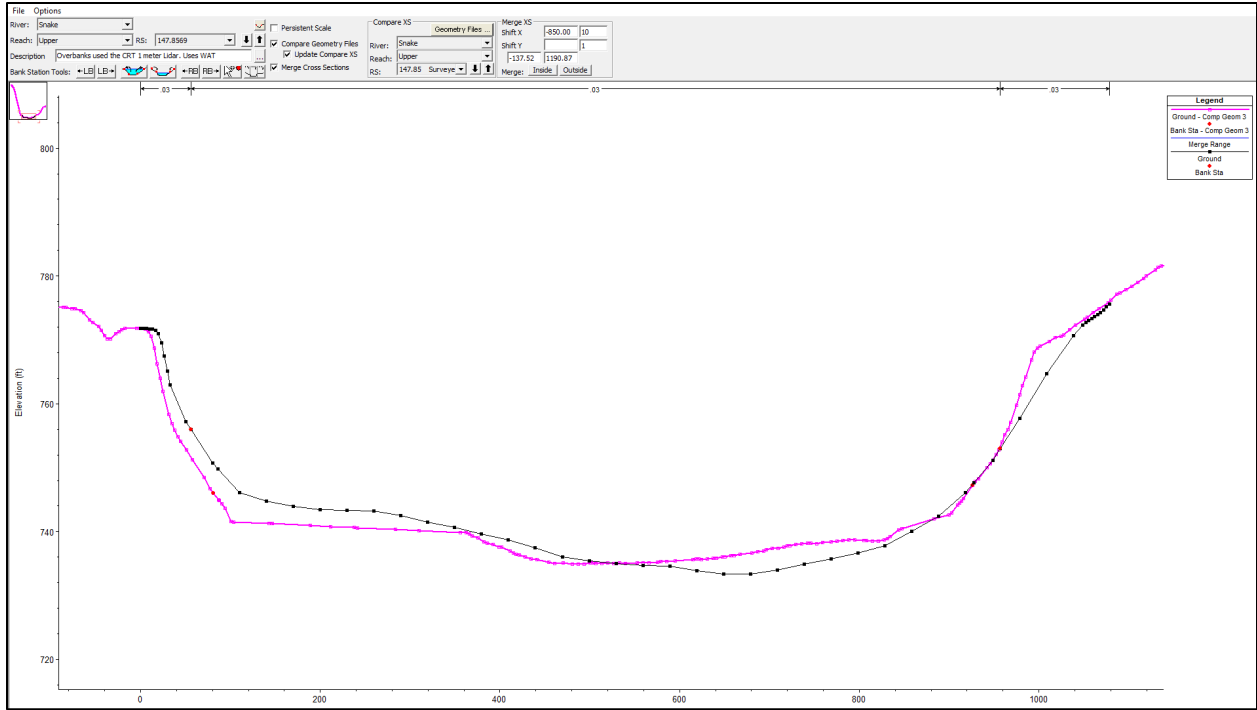
229 **Figure 1-3. Overlapping Clearwater Cross Section 7.8160 (top) and Cross Section 7.0348**

230 **(below)**

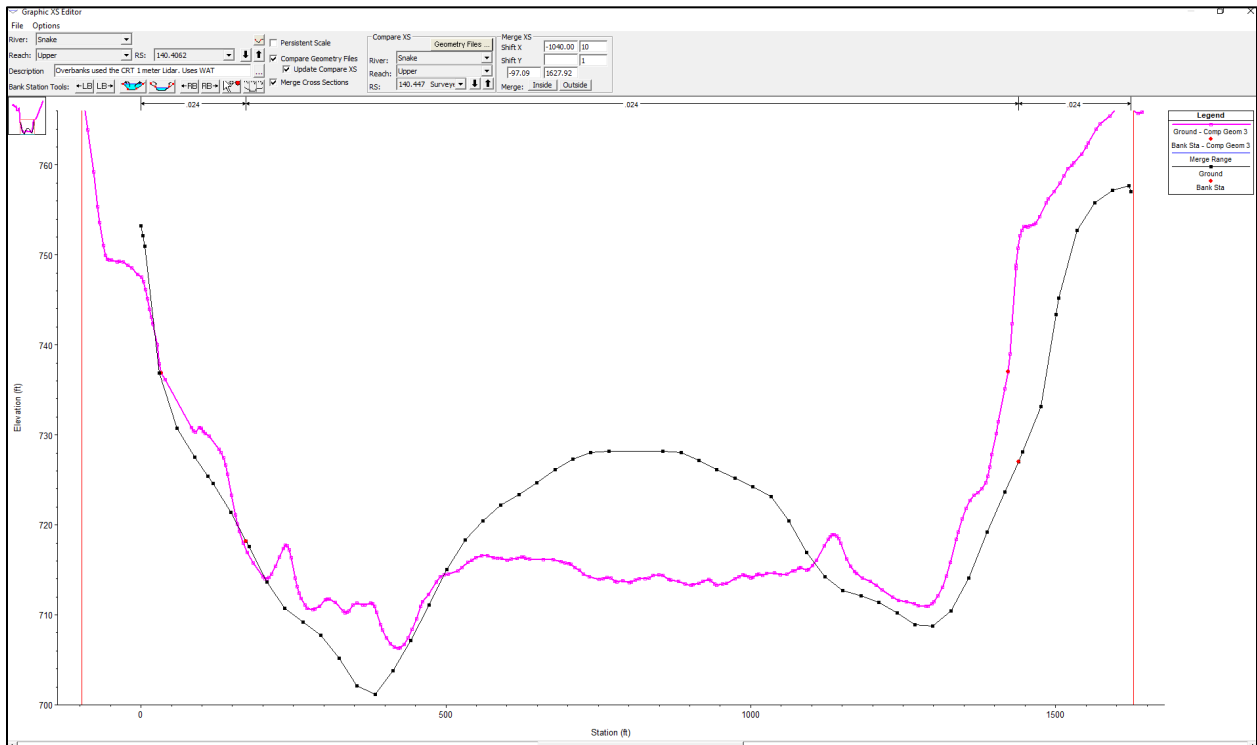
231 Note: MO3 1934 geometry is shown in black; CRSO No Action Alternative is shown in pink.

**Columbia River System Operations Environmental Impact Statement
Annex A, Lower Snake River Multiple Objective Alternative 3 Model Development Report**

232



233

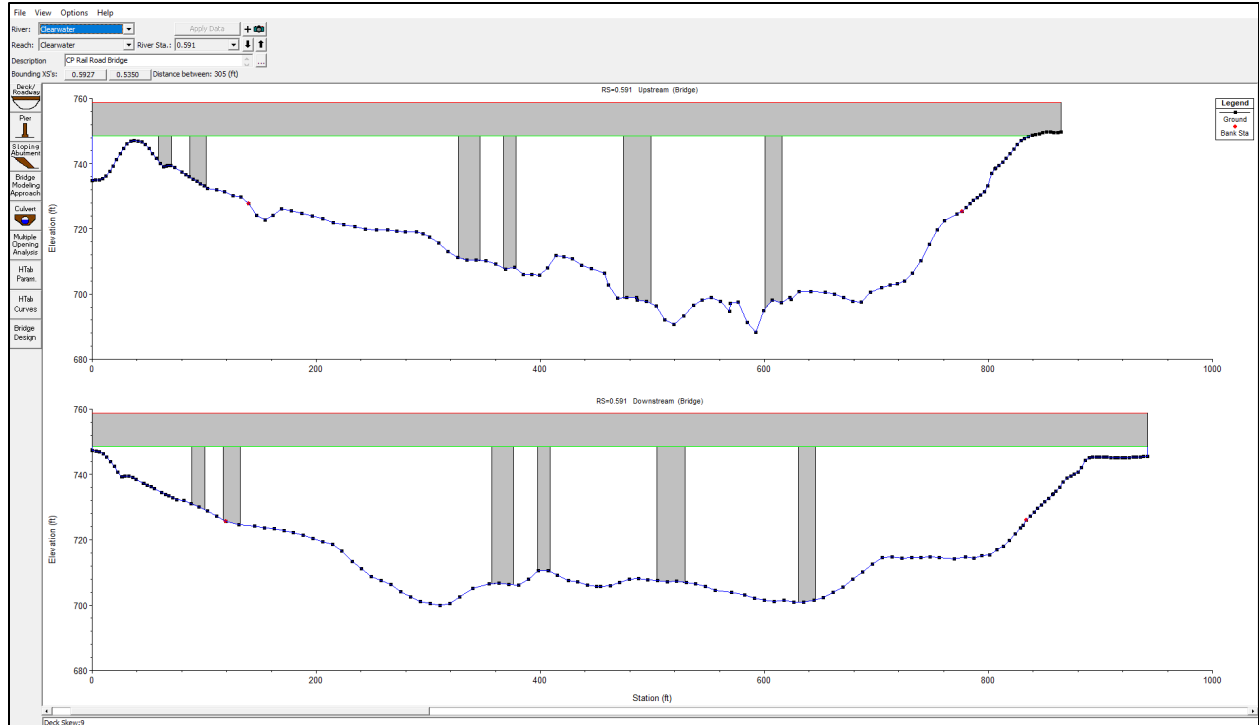


234 **Figure 1-4. Overlapping Cross Sections of the Snake River, Cross Section 147.85 (top) and**
 235 **Cross Section 140.40662 (bottom)**

236 Note: MO3 1934 geometry is shown in black; CRSO No Action Alternative is shown in pink.

*Columbia River System Operations Environmental Impact Statement
Annex A, Lower Snake River Multiple Objective Alternative 3 Model Development Report*

237



238

239

240

241

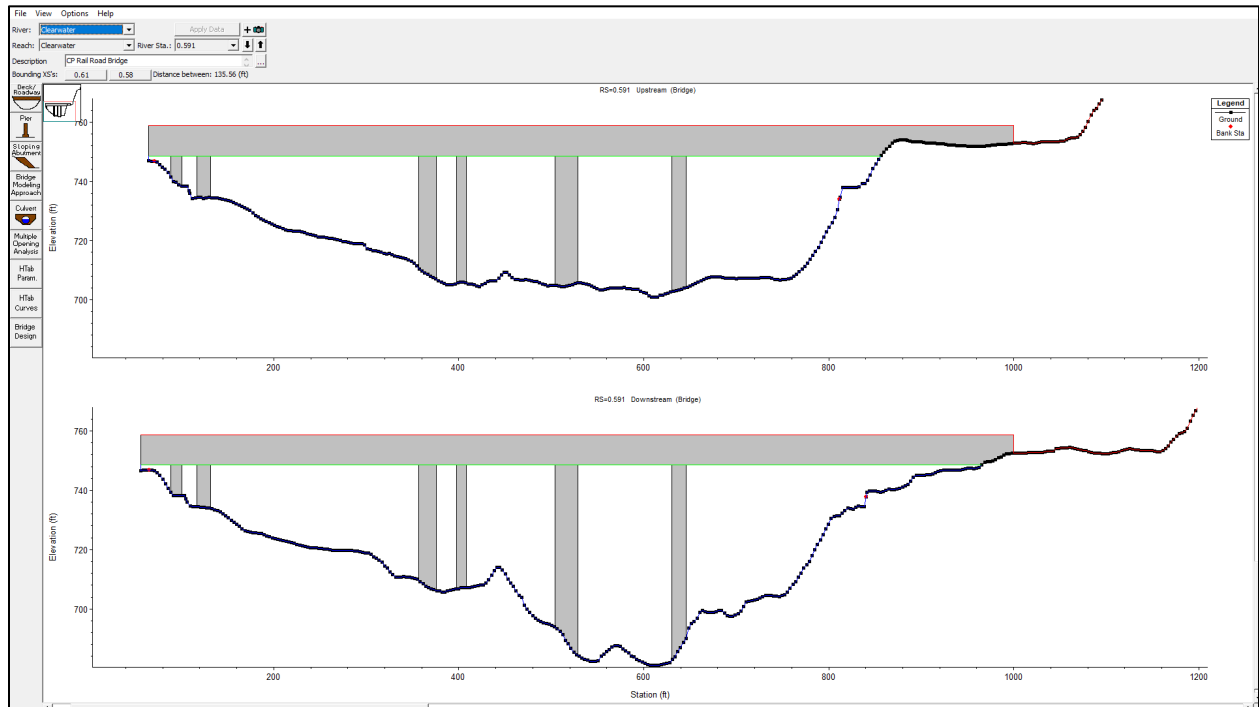
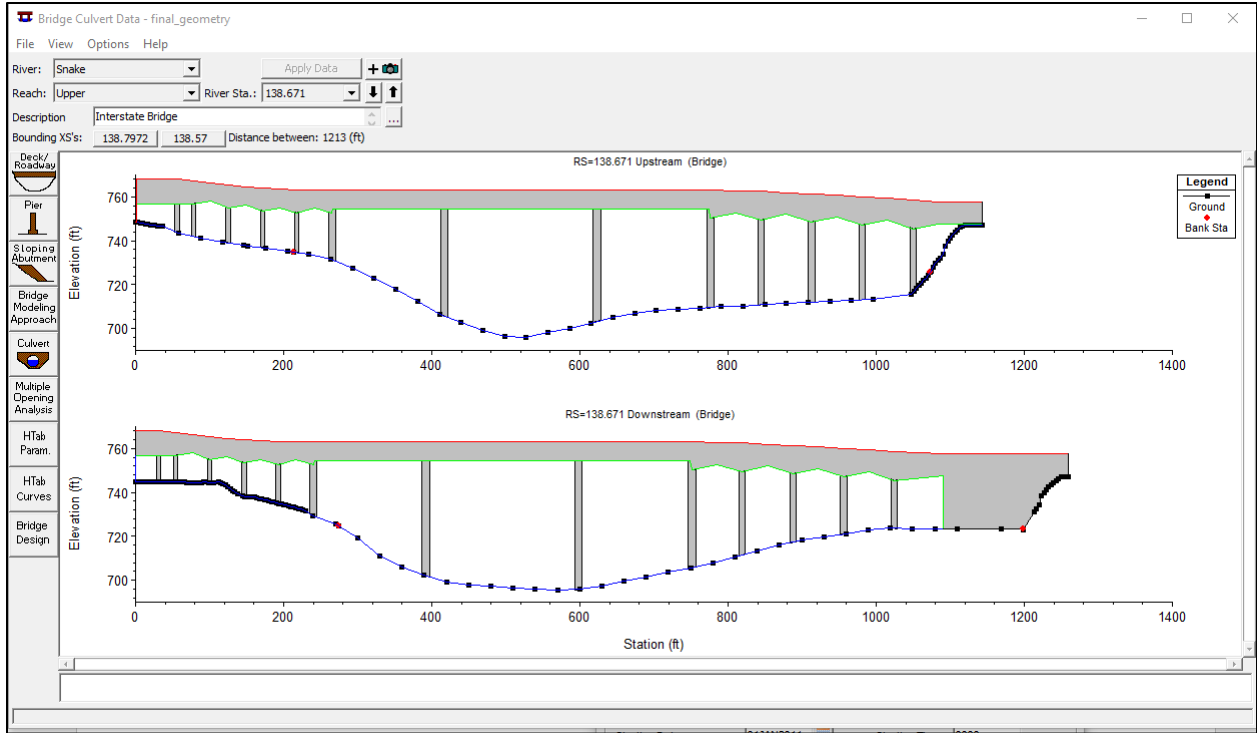


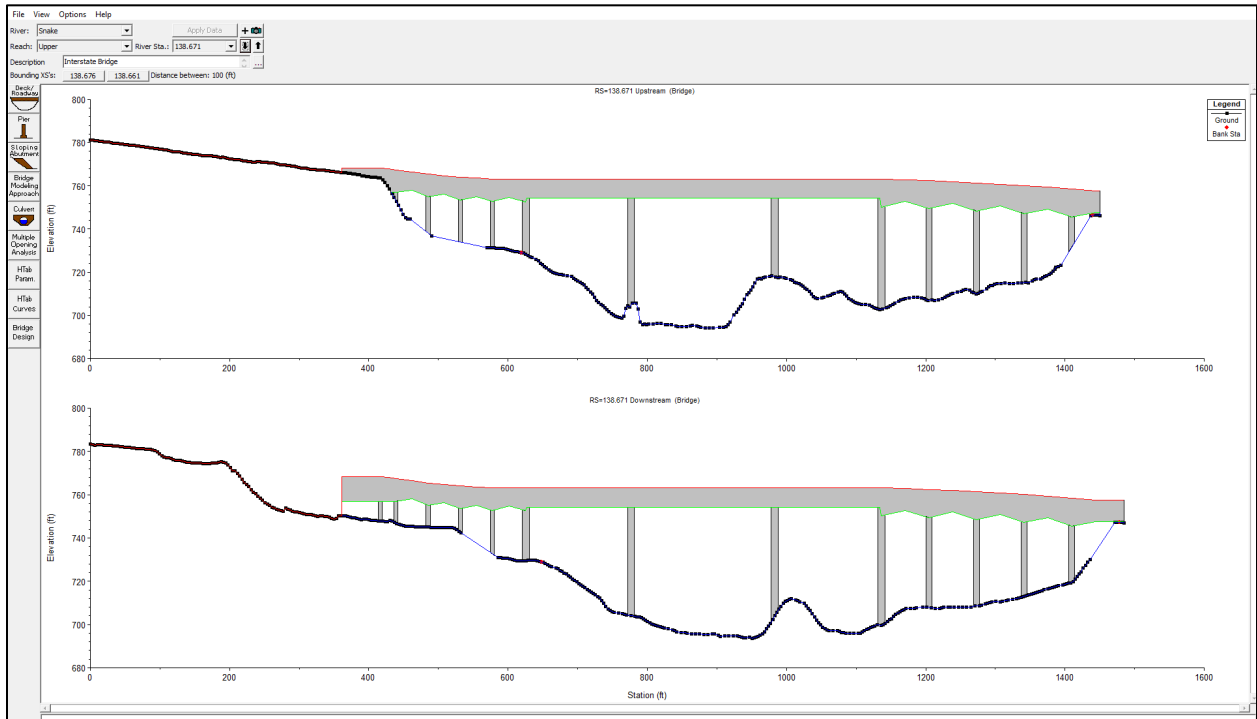
Figure 1-5. Bridge Geometry and Upstream and Downstream Cross Sections at the Railroad Bridge (Clearwater River Mile Cross Section 0.591)

Note: MO3 bridge is shown on the left and the CRSO No Action Alternative bridge is on the right.

*Columbia River System Operations Environmental Impact Statement
Annex A, Lower Snake River Multiple Objective Alternative 3 Model Development Report*



242



243

244

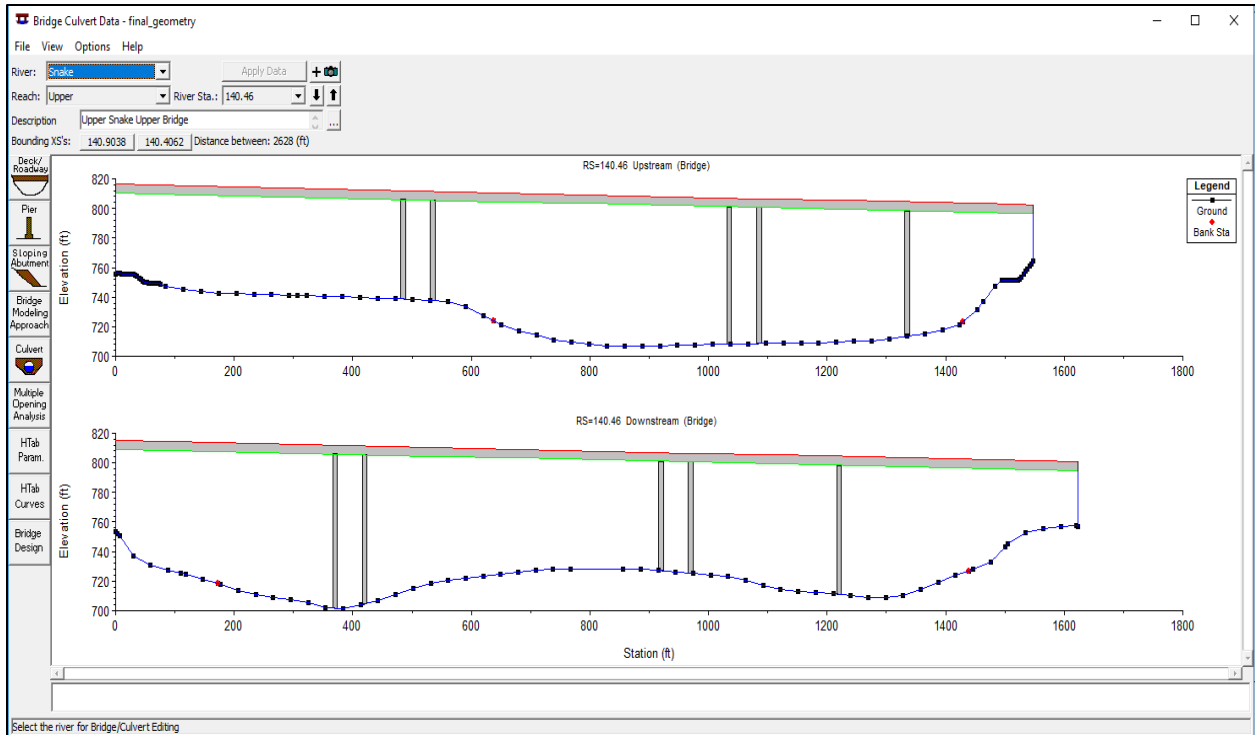
Figure 1-6. Bridge Geometry and Upstream and Downstream Cross Sections at the Interstate Bridge (Snake River Mile Cross Section 138.671)

245

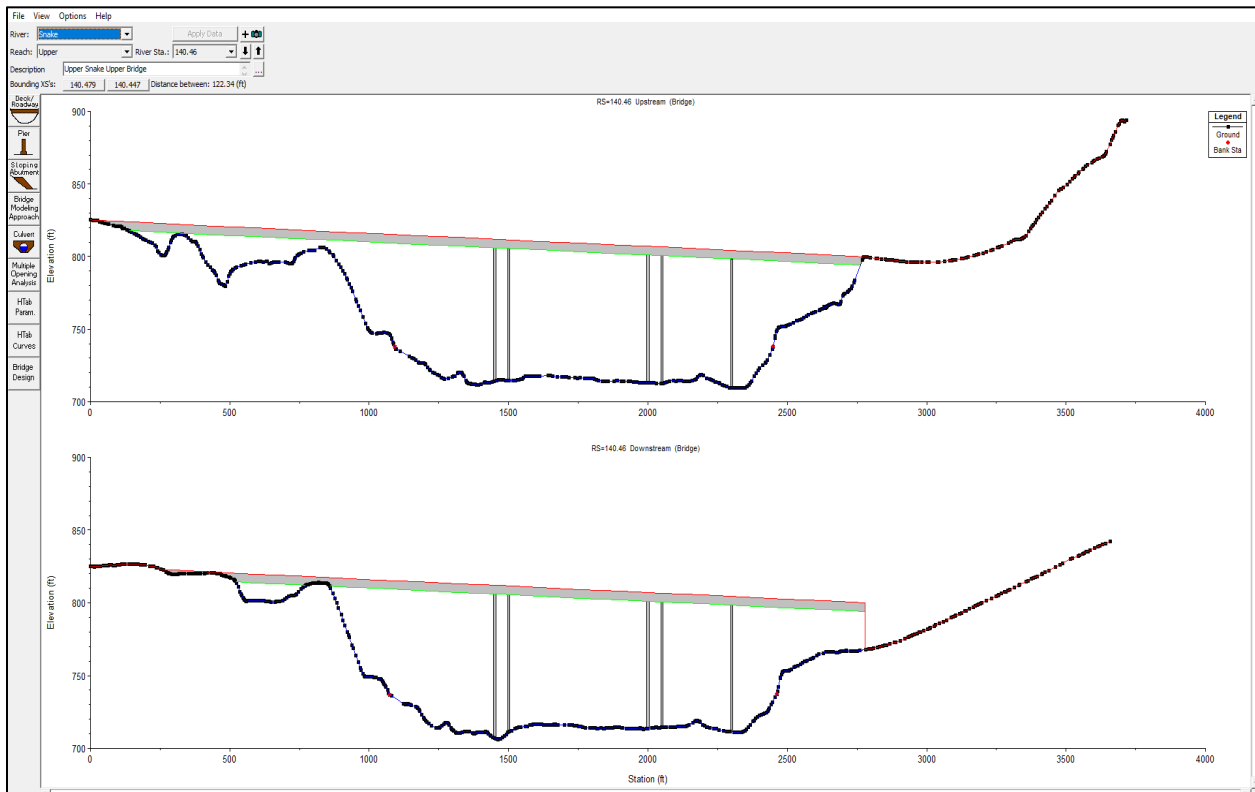
246

Note: MO3 bridge is shown on the left and the CRSO No Action Alternative bridge is on the right.

*Columbia River System Operations Environmental Impact Statement
Annex A, Lower Snake River Multiple Objective Alternative 3 Model Development Report*



247



248

249

Figure 1-7. Bridge Geometry and Upstream and Downstream Cross Sections at the Upper Snake Upper Bridge (Snake River Mile Cross Section 140.46)

250

251

Note: MO3 bridge is shown on the left and the CRSO No Action Alternative bridge is on the right.

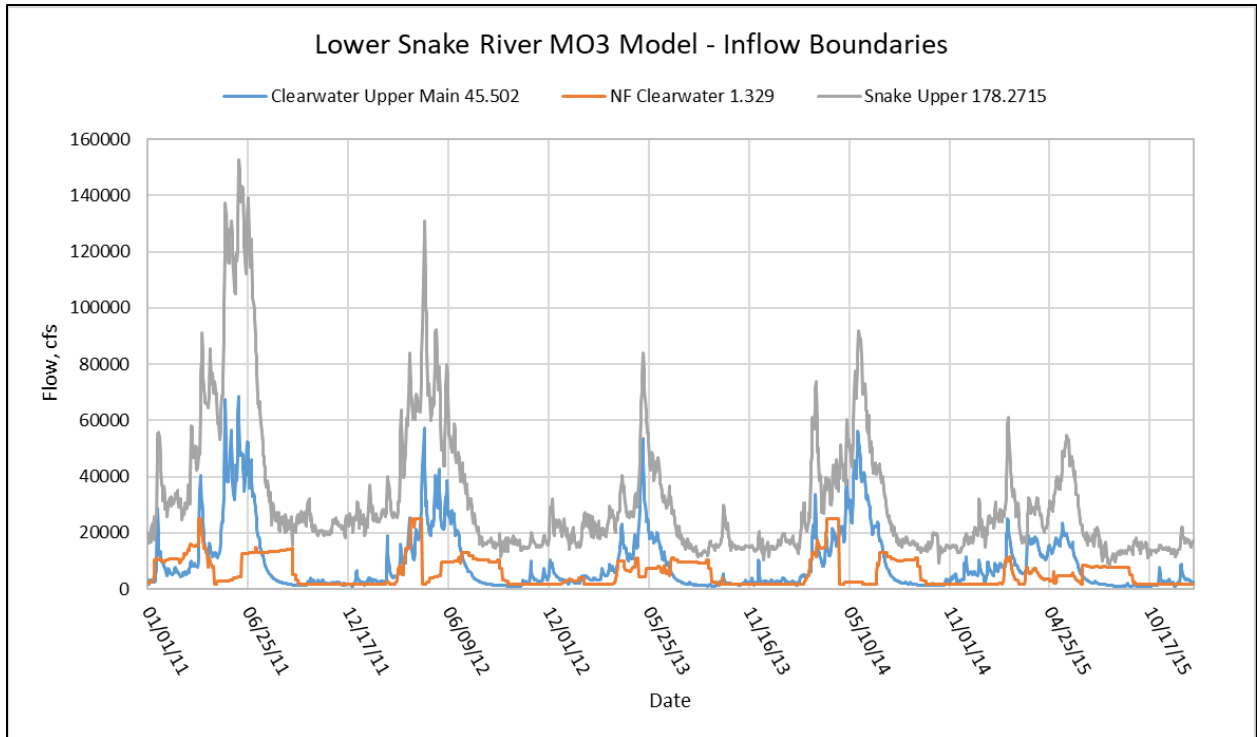
252 **1.3.2 Model Flows**

253 A DSS file for discharge time series was generated by the CRSO hydrology team using the HEC
254 reservoir simulation (ResSim) model for MO3, and data was extracted for locations in the model
255 system. The DSS was linked to a flow file identifying flow change locations and inflow
256 boundaries and is shown in Table 1-1; Figure 1-8 shows a plot of the major upstream flow
257 boundaries. Flow comparisons were made at each dam bypass location and indicated additional
258 flow balance was not needed. Figure 1-9 through Figure 1-12 show the modeled ResSim values
259 in black and the resulting HEC-RAS flows in red. Tributaries are not included in the model
260 between Lower Granite and Ice Harbor Dams.

261 **Table 1-1. DSS File Paths for Each Flow and Stage Boundary**

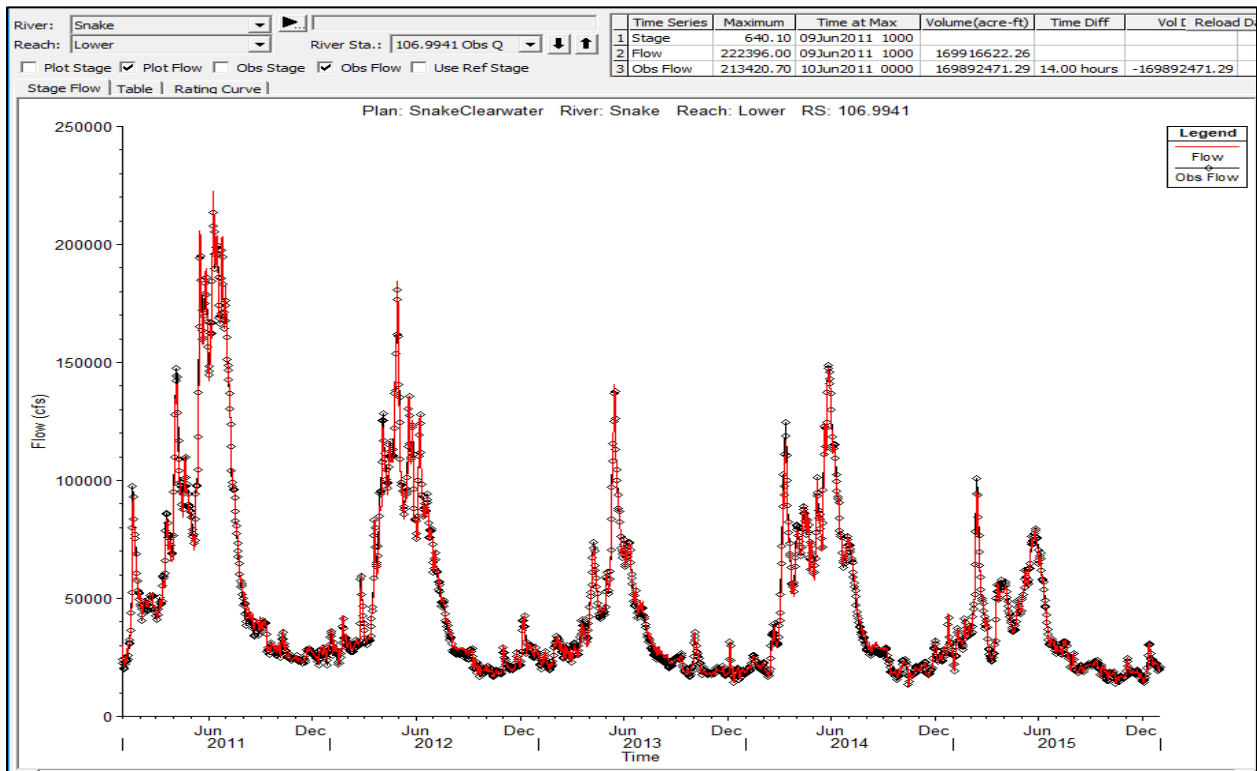
Flow	Station	Dam Location	Inflow Tributaries	DSS pathname
Major Inflows	1.329	NF Clearwater	(DWR) North Fork	//DWORSHAK-POOL/FLOW-OUT/01JAN2007/1DAY/FLOODMODEL1/
	1675	Orofino_Cr	Orofino (100 cfs)	Constant 100 cfs
	45.502	Clearwater	Upper Main	//OROFINO/FLOW/01JAN2007/1DAY/FLOODMODEL1/
	178.27	Snake	Upper	//SNAKE+GRANDE RONDE/FLOW/01JAN2007/1DAY/FLOODMODEL1/
Flow Balance	138.13–118.8	Snake	Lower	Constant 100 cfs (uniform lateral inflow)
Flow Checks	106.994	Snake	Lower	//LOWER GRANITE-POOL/FLOW-OUT/01JAN2007/1DAY/FLOODMODEL1/
	69.689	Snake	Lower	//LITTLE GOOSE-POOL/FLOW-OUT/01JAN2007/1DAY/FLOODMODEL1/
	41.384	Snake	Lower	//LOWER MONUMENTAL-POOL/FLOW-OUT/01JAN2007/1DAY/FLOODMODEL1/
	9.526	Snake	Lower	//ICE HARBOR-POOL/FLOW-OUT/01JAN2007/1DAY/FLOODMODEL1/

262 Note: cfs = cubic feet per second; DWR = Dworshak.



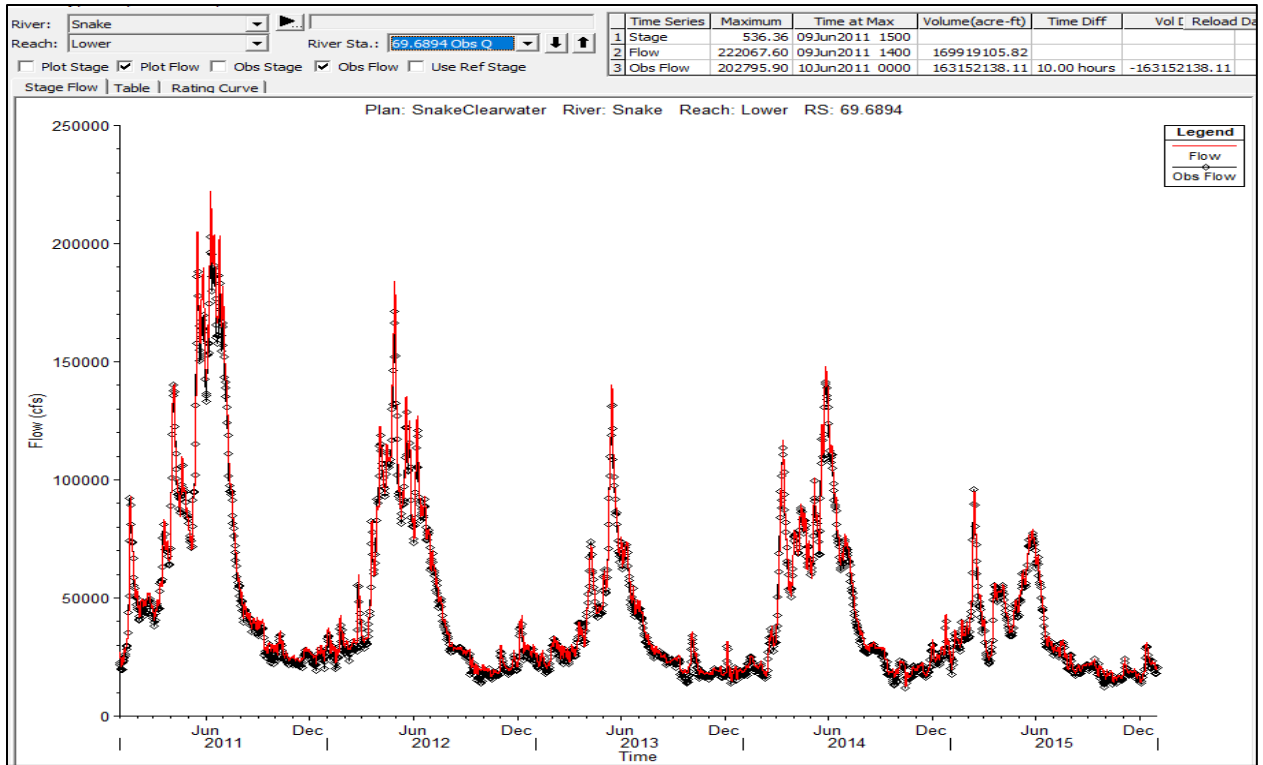
263
264

Figure 1-8. Lower Snake River Multiple Objective Alternative 3 Model Main Flow Boundaries



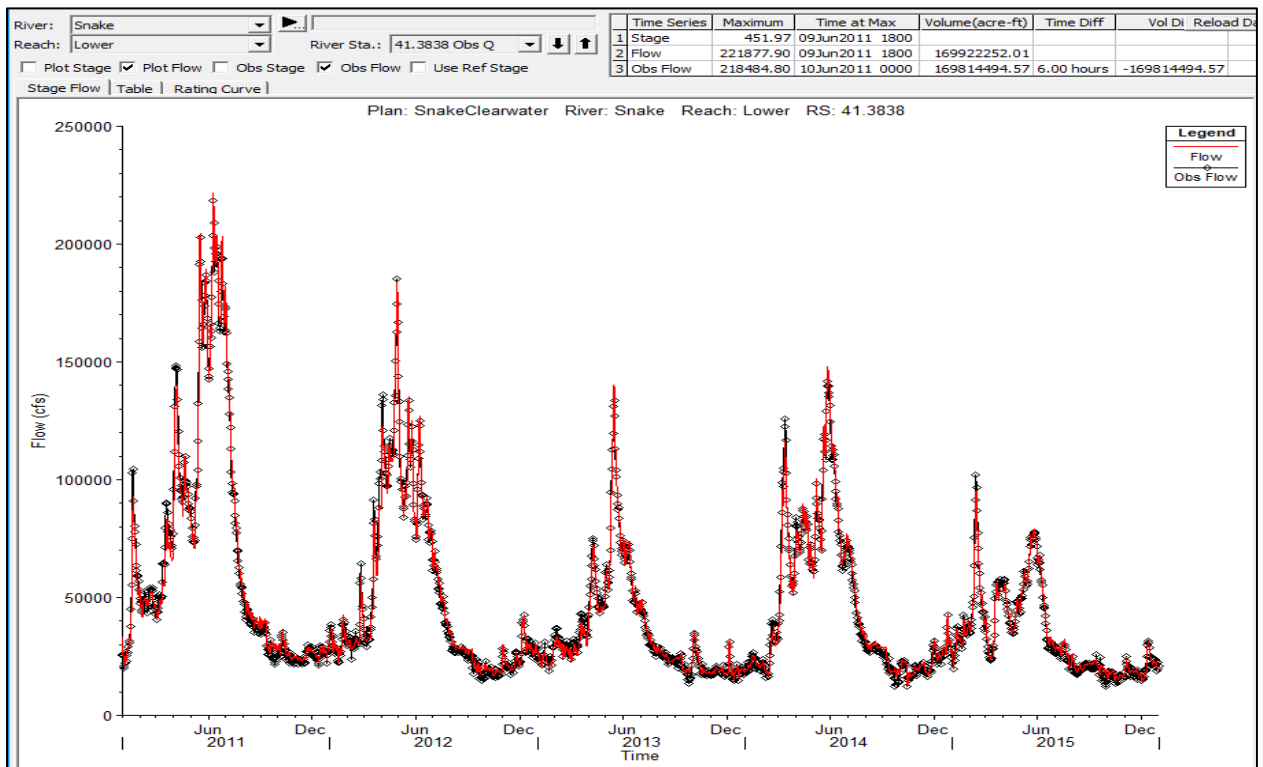
265
266

Figure 1-9. ResSim (black) and HEC-RAS (red) Flows at Lower Granite Dam Bypass



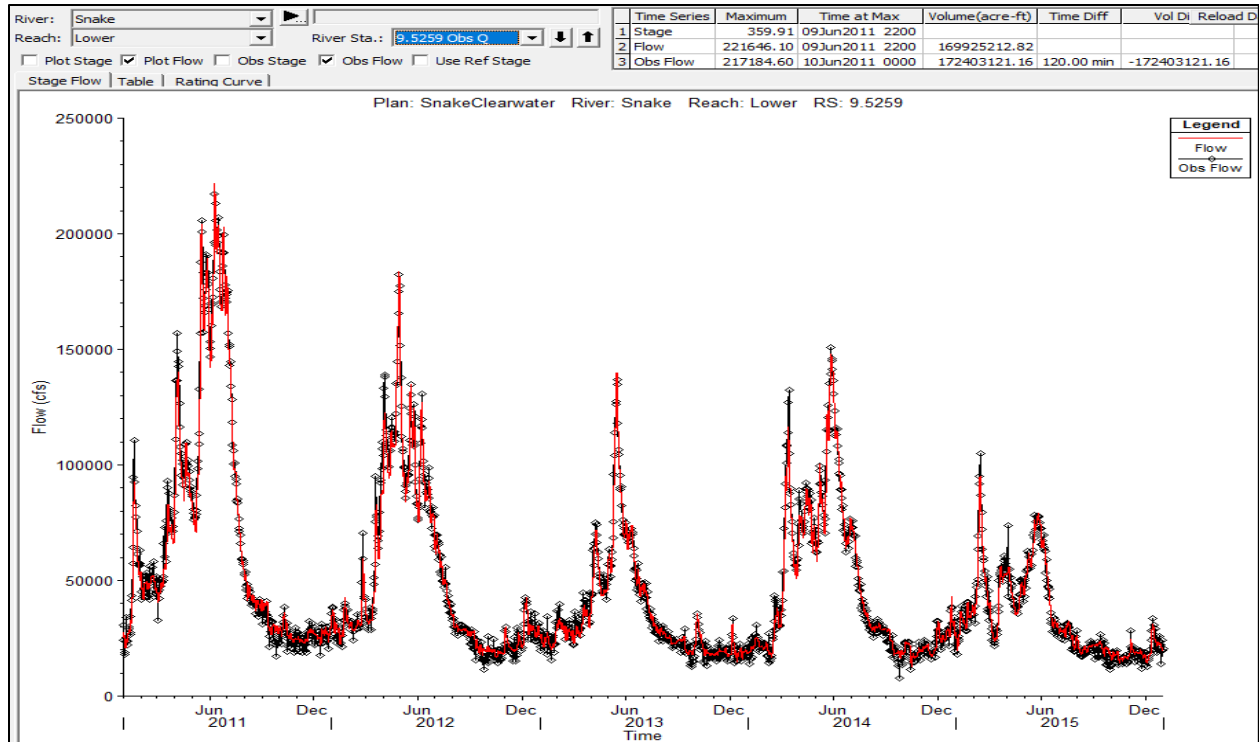
267
268

Figure 1-10. ResSim (black) and HEC-RAS (red) Flows at Little Goose Dam Bypass



269
270

Figure 1-11. ResSim (black) and HEC-RAS (red) Flows at Lower Monumental Dam Bypass



271
272 **Figure 1-12. ResSim (black) and HEC-RAS (red) Flows at Ice Harbor Dam Bypass**

273 **1.3.3 Water Temperature**

274 Upstream inflow temperatures and meteorological conditions are the biggest contributing
275 factors to temperature calibrations. Table 1-2 shows the DSS pathname used in the MO3 model
276 for temperature boundary and initial conditions; a plot is shown in Figure 1-13. During the
277 development of the HEC-RAS dam breach model, the following corrections were made to the
278 2011–2015 calibration of the Clearwater-Upper Snake HEC-RAS Model (called “Version 2”):

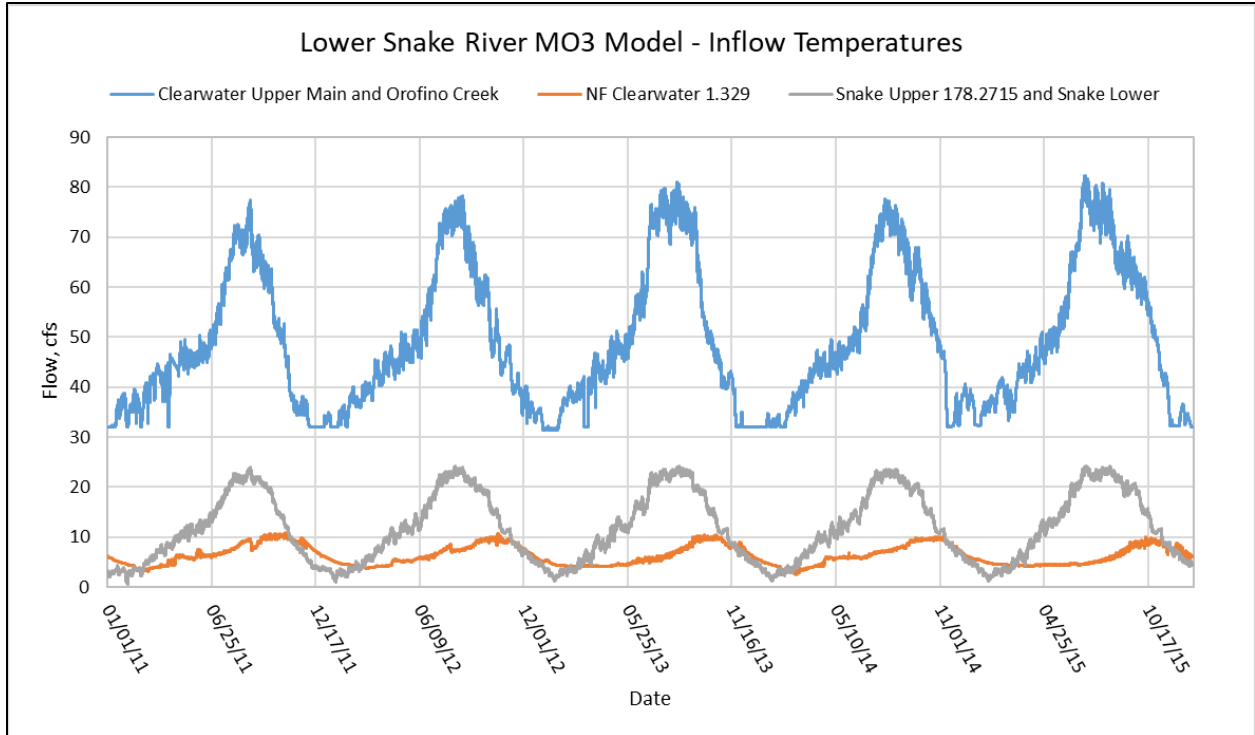
- 279 1. The Silcott Island, Washington (SILW), station data provided as DSS was 8 hours off when
280 compared to measured station data.
- 281 2. Station data representing the inputs from the W2 model was used. Using the W2 datasets
282 ensured calculated data for missing points was consistent between the No Action
283 Alternative and MO3 models.
- 284 3. A correction to the No Action Alternative inflow boundary temperatures was made. The
285 temperature at Orofino was incorrectly linked in the DSS file. This was updated in the CRSO
286 MO3 model; the same correction was made to the CRSO No Action Alternative run (called
287 v2) and results were compared.
- 288 4. Wind heights for all meteorological stations were set to non-standard height of 3 m.

289 Meteorology data was obtained from the W2 meteorological files as air temperature (degrees
290 Celsius [°C]), dew temperature (°C), atmospheric pressure (millimeters mercury [mmHg]), short
291 wave solar radiation (SWSolar W/m²), cloudiness (fraction), and wind speed (meters per second

292 [m/s]) and put into DSS format. This guaranteed that this MO3 model was consistent with the
293 No Action Alternative model in terms of meteorological data. Missing data was at most 1.0 day
294 and linearly interpolated. Data was linked to each dam as a separate meteorological station, as
295 pressure was calculated unique to each dam location. Figure 1-14 shows the geographic domain
296 for each meteorological station used for the LSR-MO3 model.

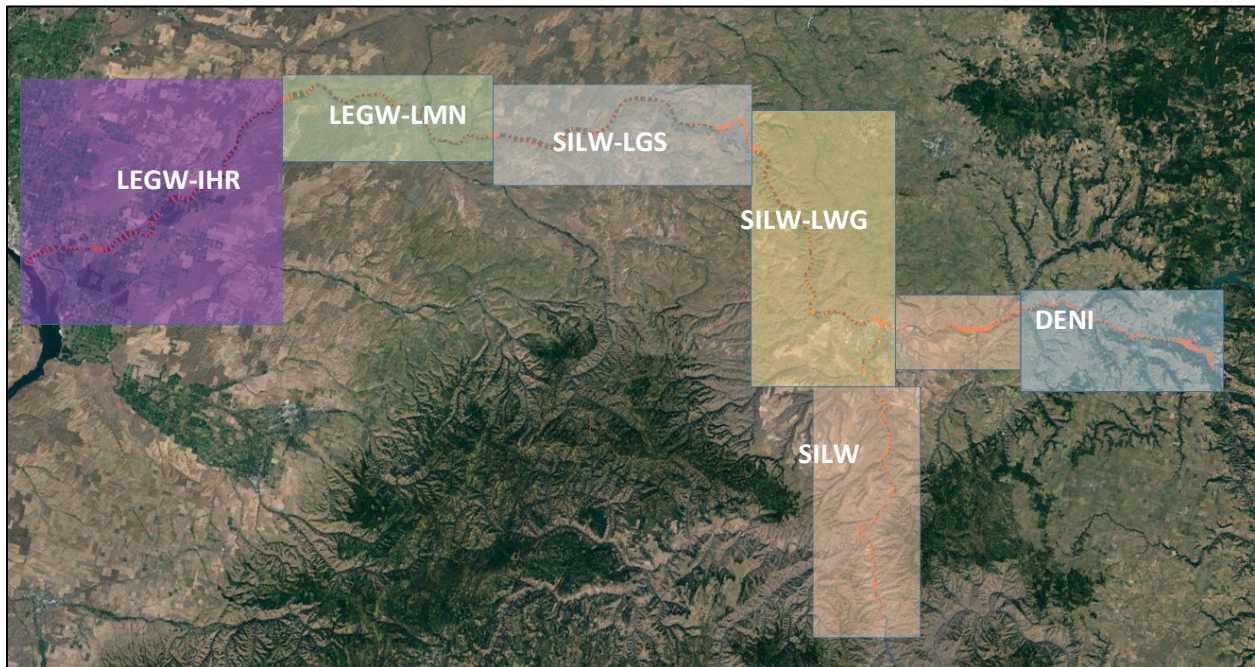
297 **Table 1-2. DSS File Paths for Each Temperature Boundary and Initial Conditions**

Temperature Boundary	Station	Location	Inflow Tributaries	DSS Pathname
Boundary Temperatures, Inflows	1.329	NF Clearwater	(DWR) North Fork	DWR_2011-2015_W2_Output.dss/DWR_DAM_W2_OUTPUT/TEMPERATURE/T/01DEC2010/1HOUR/TEMPERATURE/
	1675	Orofino_Cr	Orofino (100 cfs)	Orofino_water_temps.dss/USGS-ORFI/ORFI/T/01DEC2010/1HOUR/WATER_TEMP/
	45.502	Clearwater	Upper Main	Orofino_water_temps.dss/USGS-ORFI/ORFI/T/01DEC2010/1HOUR/WATER_TEMP/
	178.27	Snake	Upper	RAS_WQ.dss /GOES-REV/ANQW/TEMP-WATER/01SEP2010/1HOUR/MODIFIED/
	0.05	Snake	Lower	McNary Temps – not used
Boundary Temperatures, Uniform lateral flow	138.13 – 118.8	Snake	Lower	RAS_WQ.dss /GOES-REV/ANQW/TEMP-WATER/01SEP2010/1HOUR/MODIFIED/
Initial Conditions	45.502	Clearwater, Upper Main	1.5	Unchanged from NAA
	45.21	Clearwater, Middle	1.5	Unchanged from NAA
	40.658	Clearwater	1.5	Unchanged from NAA
	1.329	NF Clearwater	6	Unchanged from NAA
	1675	Orofino_Cr	1.5	Unchanged from NAA
	178.27	Snake	3	Unchanged from NAA
	138.329	Snake	3	Unchanged from NAA
Dispersion	Clearwater River: 10-500 ft ² /s, RAS calculated to be 500ft ² /s Snake River: 10-1000 ft ² /s, RAS calculated to be 1000ft ² /s Sensitivity was performed at 10-1000ft ² /s; RAS calculated to be 1000 ft ² /s			



298
 299
 300

Figure 1-13. Lower Snake River Multiple Objective Alternative 3 Model Main Temperature Boundaries



301
 302
 303
 304

Figure 1-14. Lower Snake River Multiple Objective Alternative 3 Meteorological Stations
 Note: LEGW = Legrow, Washington, station; SILW = Silcott Island, Washington, station; LGS = Little Goose; LWG = Lower Granite, LMN = Lower Monumental, DENI = Dent Acres, Idaho, station, IHR = Ice Harbor.

305 **1.3.4 Heat Flux and Model Parameterization Discussion**

306 Evaporation heat flux is typically the most uncertain part of the heat balance equation that a
307 model uses to predict water temperature. Calibration typically varies the coefficients (within
308 that heat balance equation) that relate measured wind speed to evaporation (i.e., heating and
309 cooling), so that a model can accurately predict water temperature. The WQ team was not
310 successful calibrating HEC-RAS under existing conditions on the lower Snake River (i.e., dams in
311 place). The root mean square error (RMSE) could not be minimized in HEC-RAS to a level
312 consistent with the W2 calibration: 0.65°C, at Ice Harbor (Corps, 2019). We hypothesize that
313 the one-dimensional model of the lower Snake River impoundments cannot be calibrated with
314 seasonally consistent coefficients (as in W2). A one-dimensional model does not account for
315 water temperature variation with depth, which leads to an oversimplified depiction of surface
316 water temperature. Three heat fluxes depend on the temperature of the water surface: back
317 radiation, evaporative heat loss, and surface heat conduction. Despite the mild and short-
318 duration stratification in these impoundments, there can be notable differences between the
319 surface and middle depth temperature in the lower Snake River. For example, in July 2015, at
320 Ice Harbor, there was a 2.5°C difference between the temperature at 0.5 m and 20 m with 36
321 hourly measurements exceeding a 5.0°C difference. The HEC-RAS model does not have an
322 option of changing the evaporation coefficient seasonally without code modification. W2 was
323 able to reproduce measurements within acceptable error using constant wind coefficients on
324 the lower Snake River. The WQ team hypothesizes that the one-dimensional model is not able
325 to accurately reproduce the heat budget in the existing lower Snake River (i.e., current
326 conditions) but could produce meaningful results under a dam breach bathymetry, with no
327 stratification.

328 Additionally, the W2 NAA models used wind sheltering coefficients of: Lower Granite = 1.2,
329 Little Goose = 0.9, Lower Monumental = 1.2, and Ice Harbor = 1.2. No adjustments were made
330 for wind speed in HEC-RAS to account for this because HEC-RAS does not explicitly model wind
331 sheltering.

332 Ultimately, the model parameter set chosen for HEC-RAS was based on the published values
333 (Edinger et. al. 1974; reported in Cole and Wells 2018), calibrated W2 modeling, HEC-RAS
334 modeling for an upstream reach, and default parameters (Table 1-3). The parameter set was
335 tested by running the model with an existing (i.e., with dams) bathymetry and comparing to
336 measurements. Generally, the HEC-RAS representation of the current system overpredicts mid-
337 summer temperatures and underpredicts winter temperatures but is believed to corroborate
338 the HEC-RAS heat balance routines and the parameter set for a one-dimensional representation
339 of a dam breach bathymetry.

340 **Table 1-3. Calibration Coefficients Used in the Lower Snake River No Action Alternative (HEC-**
341 **RAS and W2) and MO3 (HEC-RAS) Models**

Category	(Met Station)	Units	HEC-RAS Default	NAA	MO3
Initial Temperature		°C	–	0.1–6.2 ^{3/}	0.1–6.2
Dispersion Coefficients – Upper Limit		ft ² /s	–	500 (CLWR) ^{3/} 1,000 (SNK) ^{3/}	500 (CLWR) 1,000 (SNK)
Dispersion Coefficients – Lower Limit		ft ² /s	–	100 ^{3/}	100
Meteorological Coefficients					
Atmospheric Pressure – DENI		mmHg	–	DWQI ^{3/}	DWQI
Atmospheric Pressure – SILW		mmHg	–	LWG Trendline ^{3/}	LWG Trendline
Dust Coefficient	DENI	–	0.06	– ^{2,3/}	– ^{2/}
	SILW	–	0.06	– ^{2,3/}	– ^{2/}
Wind – a coefficient	DENI	–	1	1 ^{3/}	1
	SILW	–	1	1	1
	SILW-LWG	–	1	9.0 (W2) ^{4/}	9.2
	SILW-LGS	–	1	9.0 (W2)	9.2
	LEGW-LMN	–	1	9.0 (W2)	9.2
	LEGW-IHR	–	1	9.0 (W2)	9.2
Wind – b coefficient	DENI	–	1	0.3 ^{3/}	0.3
	SILW	–	1	0.5	0.5
	SILW-LWG	–	1	0.4 (W2)	0.46
	SILW-LGS	–	1	0.4(W2)	0.46
	LEGW-LMN	–	1	0.4 (W2)	0.46
	LEGW-IHR	–	1	0.4 (W2)	0.46
Wind – c coefficient	DENI	–	1	1	1
	SILW	–	1	0.5	0.5
	SILW-LWG	–	1	1.9 (W2)	2
	SILW-LGS	–	1	1.9 (W2)	2
	LEGW-LMN	–	1	1.9 (W2)	2
	LEGW-IHR	–	1	1.9 (W2)	2
Richardson # Used	DENI	–	False	True	True
	SILW	–	False	True	True
	SILW-LWG	–	False	–	True
	SILW-LGS	–	False	–	True
	LEGW-LMN	–	False	–	True
	LEGW-IHR	–	False	–	True
Kh/Kw (Diffusivity ratio)	DENI	–	1	0.9 ^{3/}	0.9
	SILW	–	1	1	1
	SILW-LWG	–	1	–	1
	SILW-LGS	–	1	–	1
	LEGW-LMN	–	1	–	1
	LEGW-IHR	–	1	–	1

Category	(Met Station)	Units	HEC-RAS Default	NAA	MO3
Anemometer (Wind gage) Height (m)	DENI	m	2	3	3
	SILW	m	2	3	3
	SILW-LWG	m	2	3 (W2)	3
	SILW-LGS	m	2	3 (W2)	3
	LEGW-LMN	m	2	3 (W2)	3
	LEGW-IHR	m	2	3 (W2)	3

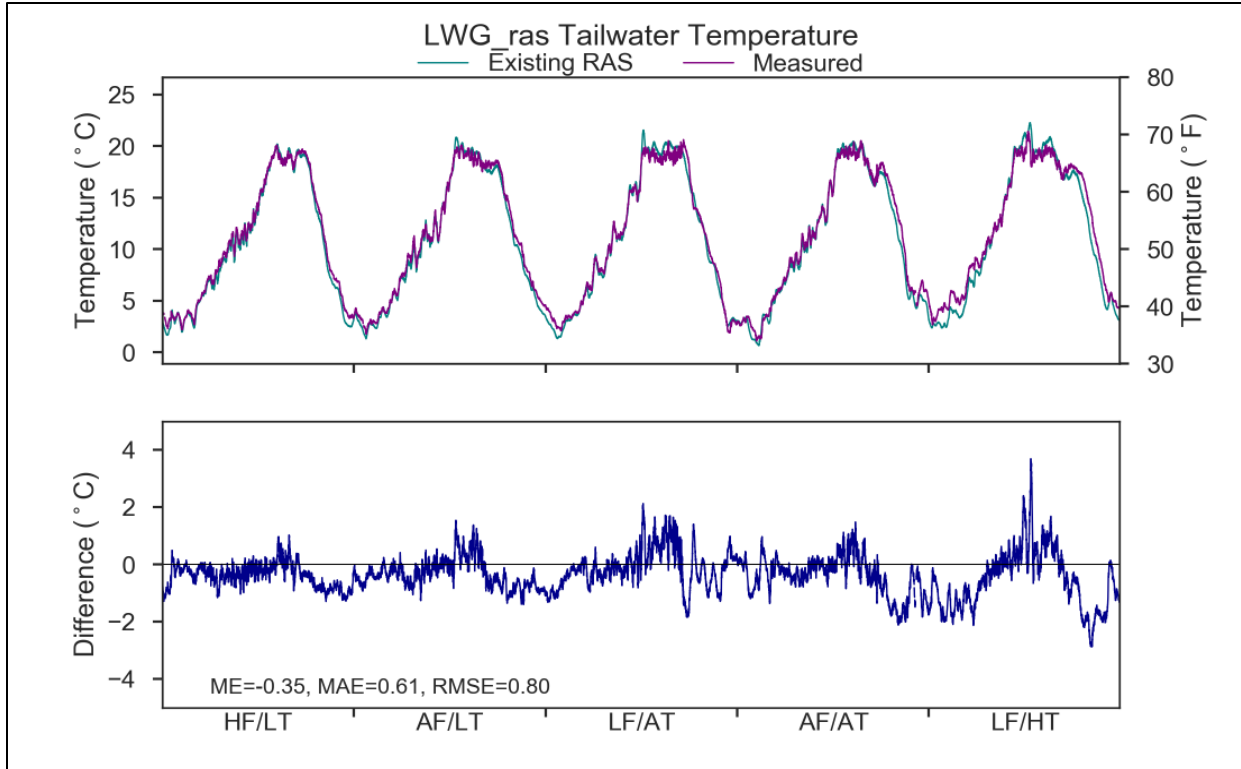
342 Note: CLWR = Clearwater River; DWQI = Ahsahka, Idaho, station; m = meter; SNK = Snake River.
 343 2/ Solar radiation is read in from W2 No Action Alternative model input. Dust coefficient is not needed in this case.
 344 3/ This value was updated after the original No Action Alternative due to an error in upstream boundary
 345 temperatures discovered during the MO3 modeling. No Action Alternative Version 2 is used for comparison to
 346 MO3 but differs from the documented calibration.
 347 4/ W2 indicates a parameter from the W2 NAA.

348 **1.3.5 Evaluation of HEC-RAS parameterization**

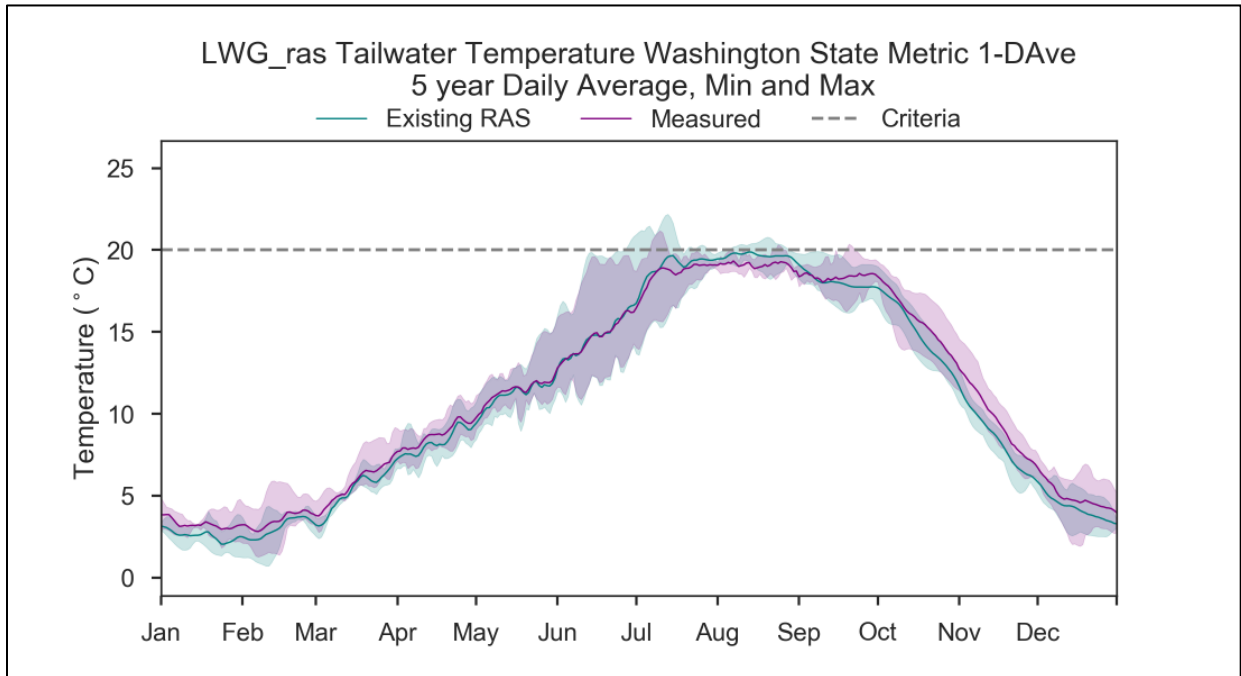
349 The WQ team tested the parameterization of the HEC-RAS LSR-MO3 model (above) under
 350 existing bathymetry/hydraulics (i.e., with dams) with 2011–2015 observed weather and
 351 hydrology. This test provides the WQ team with an additional level of confidence that this
 352 model can be directly applied to the MO3 model.

353 The one-dimensional, existing conditions model was set up using the same geometry as used in
 354 the USACE’s Columbia River Basin modeling schematic and was updated to include all of the
 355 existing conditions for 2011–2015 at all boundary conditions. All figures are available from the
 356 WQ team¹, but only results at Lower Granite and Ice Harbor will be presented in this report. As
 357 shown in Figure 1-15 through Figure 1-18, the Lower Granite model, the uppermost reservoir
 358 on the lower Snake, underpredicts water temperature consistently throughout the year except
 359 during the summer, at which time the temperature is overpredicted. These differences are
 360 even more pronounced at Ice Harbor. The WQ team believes these results corroborate the
 361 HEC-RAS heat balance routines and the parameter set for a one-dimensional representation of
 362 dam breach of the lower Snake River.

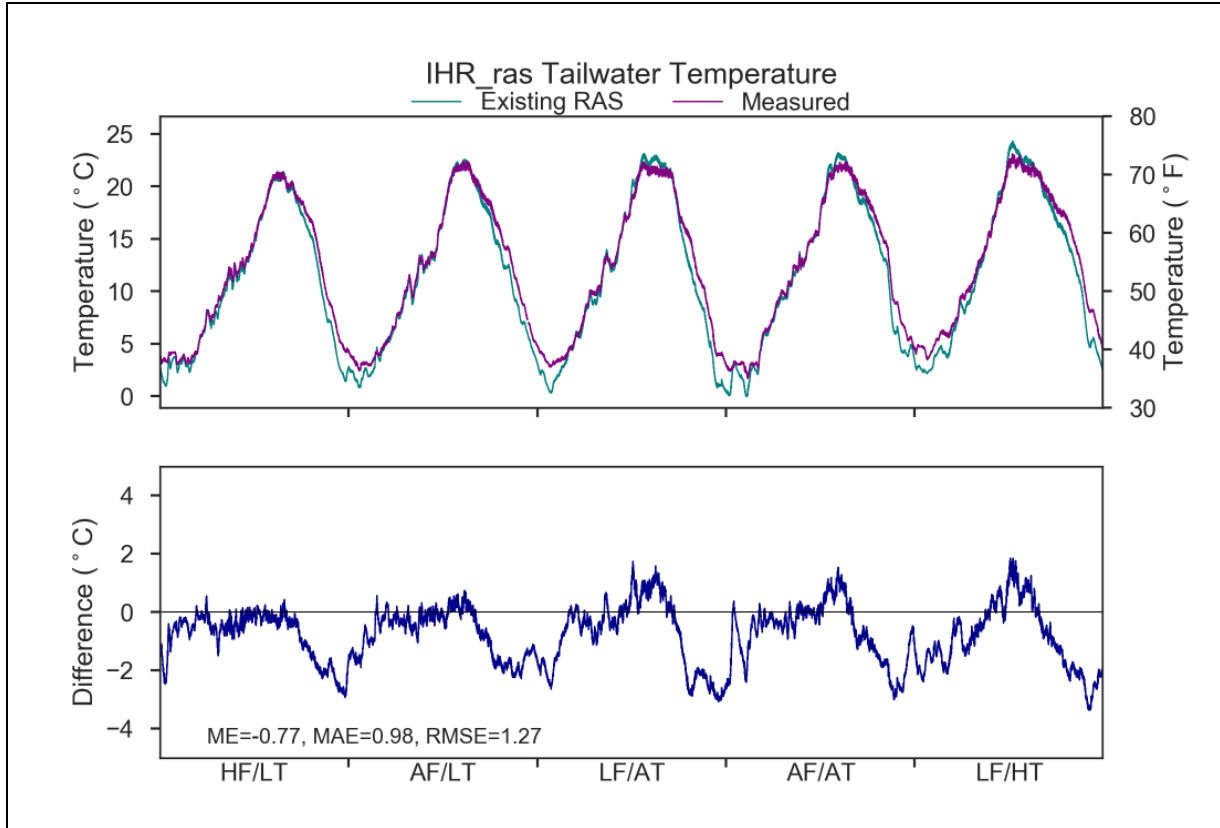
¹ \\nww-netapp1.nww.ds.usace.army.mil\Common\Planning Programs and Project Management\CRSO-EIS\Water Quality\Models\zzz_Sensitivity\LSR_CLW_Existing_RAS_v2\post_processing



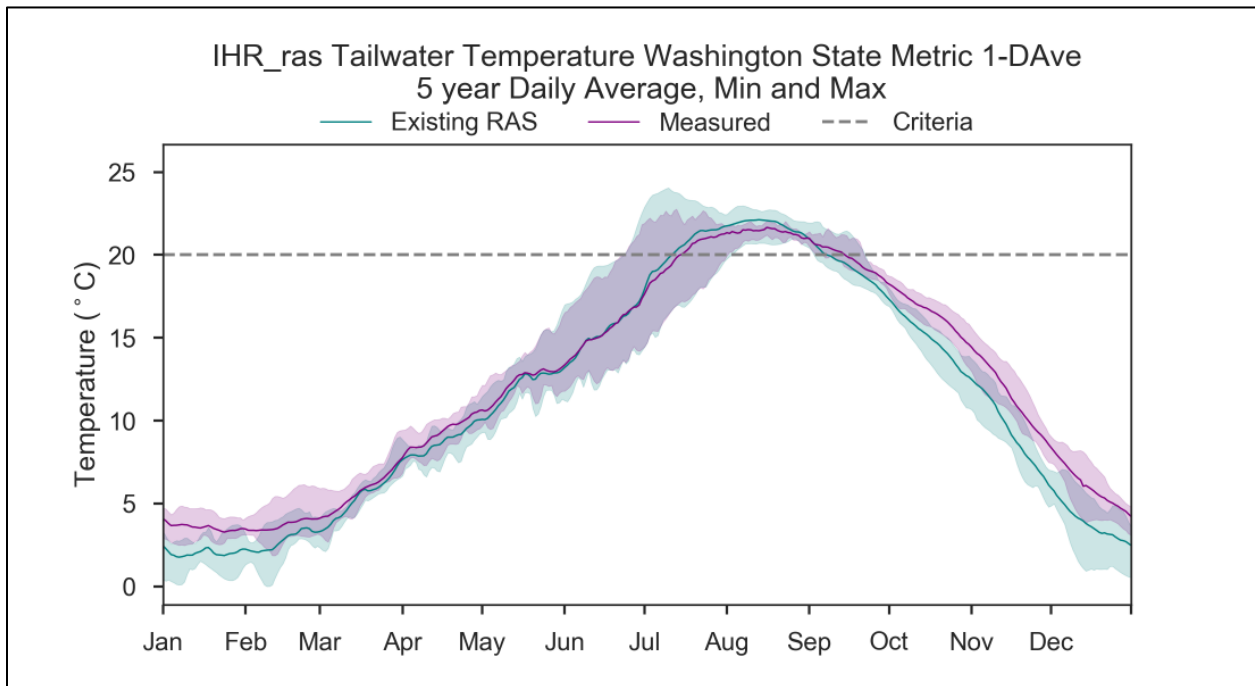
363
 364 **Figure 1-15. Hourly Temperature Comparison of HEC-RAS Existing Conditions Representation**
 365 **to Measurements at Lower Granite Dam Tailwater**



366
 367 **Figure 1-16. Daily Average Temperature Comparison of HEC-RAS Existing Conditions**
 368 **Representation to Measurements at Lower Granite Dam Tailwater**



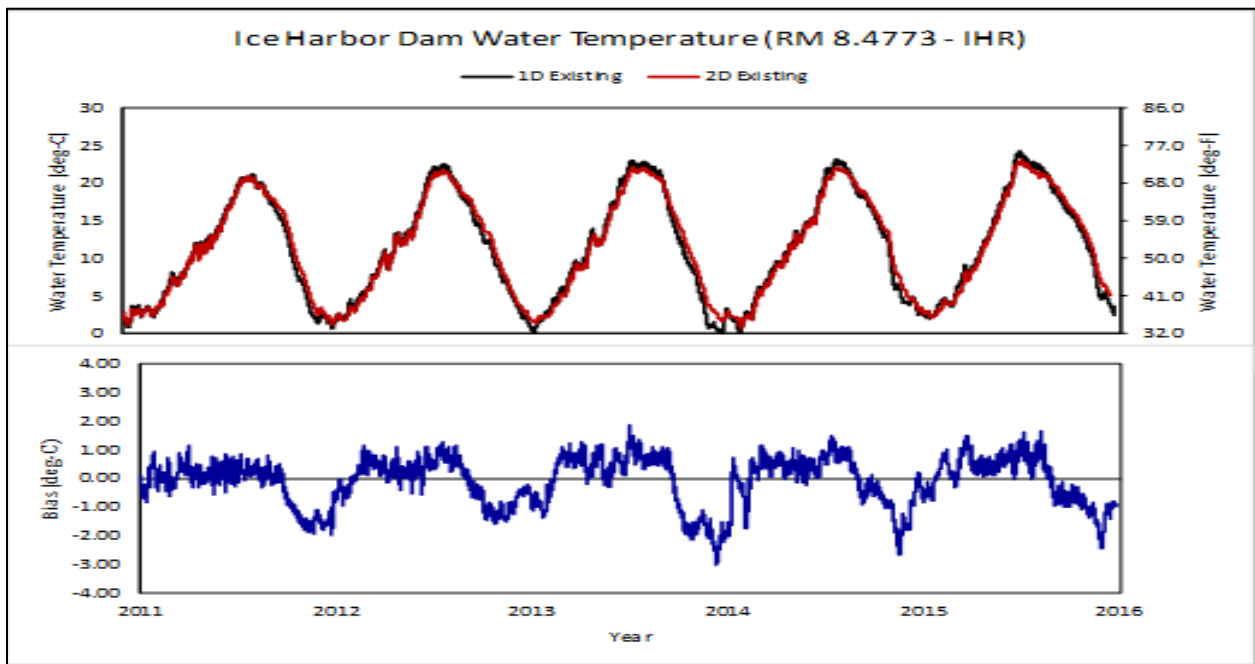
369
 370 **Figure 1-17. Hourly Temperature Comparison of HEC-RAS Existing Conditions Representation**
 371 **to Measurements at Ice Harbor Dam Tailwater**



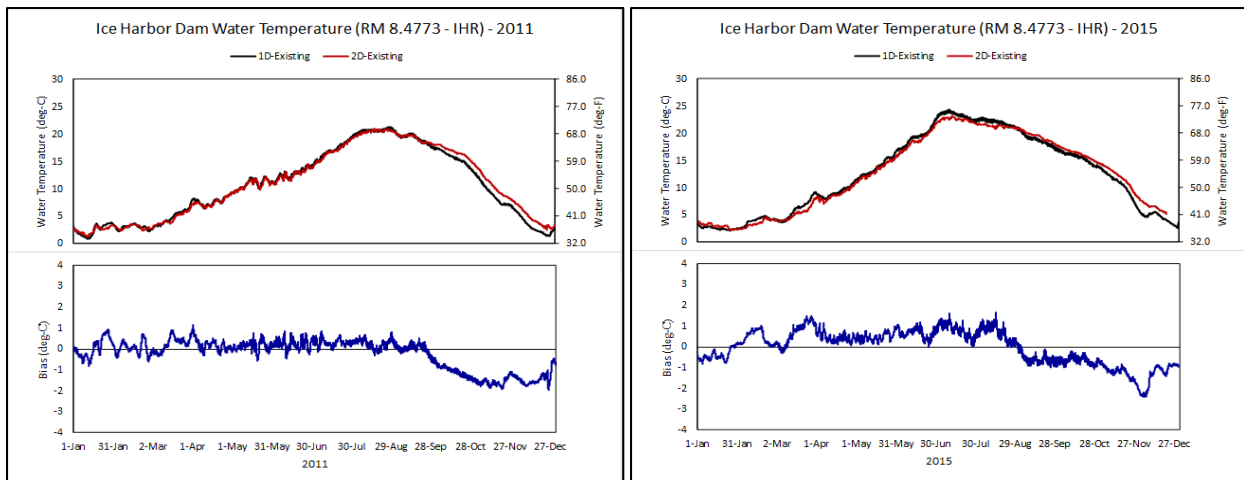
372
 373 **Figure 1-18. Daily Average Temperature Comparison of HEC-RAS Existing Conditions**
 374 **Representation to Measurements at Ice Harbor Dam Tailwater**

375 **1.3.6 Model Sensitivity to Vertical Stratification**

376 The largest assumption made is that the use of the one-dimensional model will produce similar
 377 results as the two-dimensional model under the same conditions, which may not necessarily be
 378 valid in every month/season. The one-dimensional existing conditions simulation produces
 379 temperatures that are slightly warmer in the winter and early spring and cooler in summer and
 380 fall as compared to the W2 two-dimensional model. A comparison of temperatures at Ice
 381 Harbor is shown in Figure 1-19. Figure 1-20 shows the comparison of the MO3 predicted
 382 temperature at IHR compared to the actual observed temperature profile. Since W2 is a 2D
 383 model and the water can be released from different outlets to optimize the desired
 384 temperature, one can see from the image that the depth averaged value may skew the results
 385 in either direction depending on surface temperatures and dam operations.



386

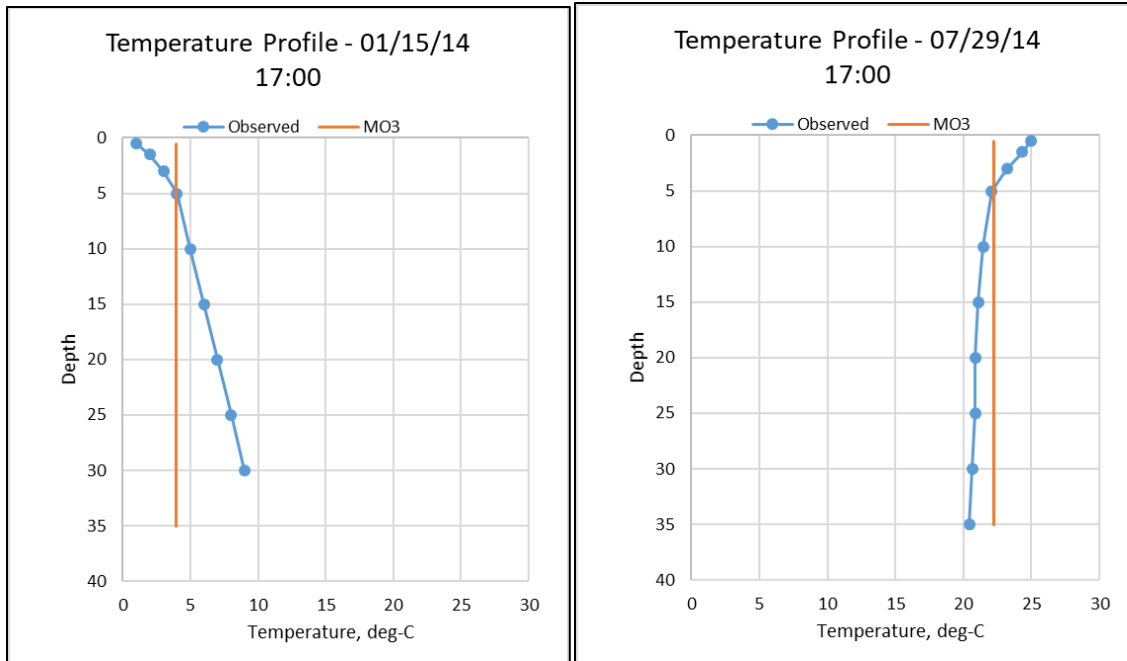


387

388

389

Figure 1-19. Comparison of One-dimensional Existing Conditions and Two-dimensional Existing Conditions at Ice Harbor Dam



390
391 **Figure 1-20. Observed Temperature Profile at Ice Harbor Dam in mid-January and late June**
392 **Compared to Multiple Objective Alternative 3 Predicted Temperature**

393 **1.3.7 Model Sensitivity to parameters**

394 For the sensitivity model, the 2014 No Action Alternative flow and weather conditions were
395 chosen to represent a base condition with parameters and model setup described above with
396 dam breach bathymetry (Table 1-4 through Table 1-9). A single parameter was changed by a
397 specified amount and the change in error statistics from the base condition is reported. The
398 focus was on the lower Snake River, since there was not a typical calibration performed.

399 **Table 1-4. Sensitivity to Increased Dispersion Coefficient**

Parameter:	Initial Value:	Tested Value:			
Dispersion	10–500 ft ² /s	1,000 ft ² /s			
		(°C)			
STATION	#OBS	ME	AME	RMSE	
(ANQW 166.656)	8,737	0.000	0.005	0.007	
Spalding (SPDI 11.745)	8,737	-2.193	2.205	4.842	
Lewiston (LEWI 3.944)	8,737	-2.164	2.175	4.776	
LWG Tailwater (106.28)	8,737	-0.765	0.771	1.748	
LGS Tailwater (68.84)	8,737	-0.648	0.654	1.474	
LMN Tailwater (39.78)	8,737	-0.571	0.593	1.299	
IHR Tailwater (5.722)	8,737	-0.494	0.502	1.117	

400 Note: #OBS = number of observations; AME = absolute mean error; ME = mean error; RMSE = root mean square
401 error.

402 **Table 1-5. Sensitivity to Increased Roughness Coefficient**

Parameter:	Initial Value:	Tested Value:			
Manning's N	Range	All N values increased by 0.0079			
		(°C)			
STATION		#OBS	ME	AME	RMSE
(ANQW 166.656)		8,737	0.007	0.031	0.040
Spalding (SPDI 11.745)		8,737	0.059	0.105	0.389
Lewiston (LEWI 3.944)		8,737	0.076	0.127	0.390
LWG Tailwater (106.28)		8,737	0.029	0.145	0.200
LGS Tailwater (68.84)		8,737	0.027	0.184	0.242
LMN Tailwater (39.78)		8,737	0.025	0.210	0.270
IHR Tailwater (5.722)		8,737	0.025	0.234	0.299

403 Note: Change in roughness value was based on guidance for roughness uncertainty as described in EM 1110-2-
404 1619, Risk-Based Analysis for Flood Damage Reduction Studies (U.S. Army Corps of Engineers [Corps] 1996).

405 **Table 1-6. Sensitivity to Decreased Roughness Coefficient**

Parameter:	Initial Value:	Tested Value:			
Manning's N	Range	All N values decreased by 0.0079			
		(°C)			
STATION		#OBS	ME	AME	RMSE
(ANQW 166.656)		8,737	0.000	0.000	0.000
Spalding (SPDI 11.745)		8,737	-0.044	0.087	0.217
Lewiston (LEWI 3.944)		8,737	-0.070	0.121	0.256
LWG Tailwater (106.28)		8,737	-0.018	0.036	0.072
LGS Tailwater (68.84)		8,737	-0.015	0.030	0.058
LMN Tailwater (39.78)		8,737	-0.014	0.027	0.049
IHR Tailwater (5.722)		8,737	-0.012	0.023	0.040

406 Note: Change in roughness value was based on guidance for roughness uncertainty as described in EM 1110-2-
407 1619, Risk-Based Analysis for Flood Damage Reduction Studies (Corps 1996)

408 **Table 1-7. Sensitivity to Increased Wind Coefficients**

Parameter:	Initial Value:	Tested Value:
a	9.2	92
b	0.46	4.6
c	2.0	3.0
Kh/Kw	1.0	1.5

STATION	(°C)			
	#OBS	ME	AME	RMSE
(ANQW 166.656)	8,737	0.000	0.000	0.000
Spalding (SPDI 11.745)	8,737	0.000	0.000	0.000
Lewiston (LEWI 3.944)	8,737	0.000	0.000	0.000
LWG Tailwater (106.28)	8,737	-0.438	1.604	2.093
LGS Tailwater (68.84)	8,737	-0.378	1.719	2.163
LMN Tailwater (39.78)	8,737	-0.243	1.803	2.265
IHR Tailwater (5.722)	8,737	-0.262	1.759	2.241

409 **Table 1-8. Sensitivity to Decreased Wind Coefficients**

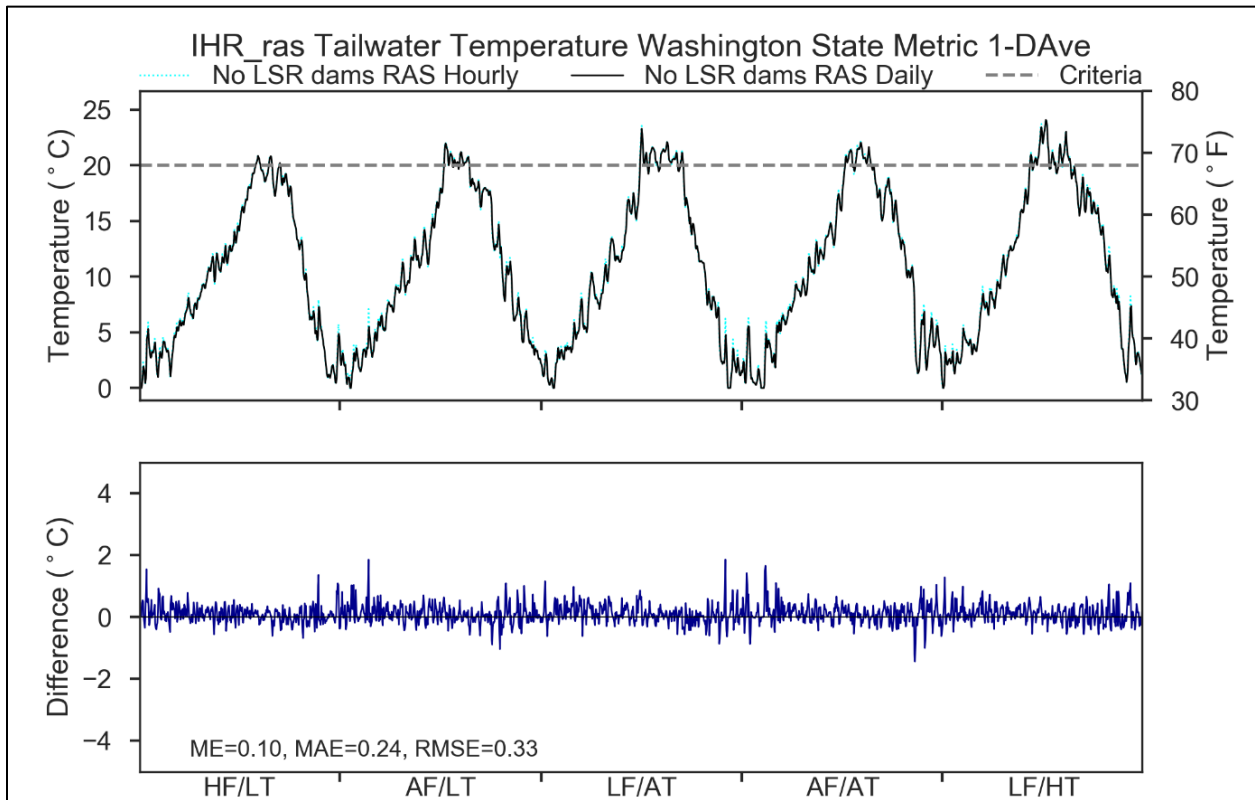
Parameter:	Initial Value:	Tested Value:		
a	9.2	0.92		
b	0.46	0.046		
c	2.0	1.0		
Kh/Kw	1.0	0.5		
STATION	(°C)			
	#OBS	ME	AME	RMSE
(ANQW 166.656)	8,737	0.000	0.000	0.000
Spalding (SPDI 11.745)	8,737	0.000	0.000	0.000
Lewiston (LEWI 3.944)	8,737	0.000	0.000	0.000
LWG Tailwater (106.28)	8,737	0.180	0.266	0.393
LGS Tailwater (68.84)	8,737	0.361	0.514	0.743
LMN Tailwater (39.78)	8,737	0.445	0.666	0.954
IHR Tailwater (5.722)	8,737	0.556	0.849	1.200

410 **Table 1-9. Sensitivity to Richardson wind coefficient**

Parameter:	Initial Value:	Tested Value:		
Richardson # Used	True	False		
STATION	(°C)			
	#OBS	ME	AME	RMSE
(ANQW 166.656)	8,737	0.000	0.000	0.000
Spalding (SPDI 11.745)	8,737	0.000	0.000	0.000
Lewiston (LEWI 3.944)	8,737	0.000	0.000	0.000
LWG Tailwater (106.28)	8,737	0.000	0.000	0.000
LGS Tailwater (68.84)	8,737	0.000	0.000	0.000
LMN Tailwater (39.78)	8,737	0.000	0.000	0.000
IHR Tailwater (5.722)	8,737	0.000	0.000	0.000

411 **1.3.8 Model Sensitivity to Daily Heat Fluxes**

412 During the evaluation of the model and comparison to River Basin Model 10 (RBM10) the WQ
413 team felt it was necessary to evaluate the sensitivity of predicted temperature to daily average
414 heat fluxes. HEC-RAS and W2 both calculate the heat balance using hourly data while RBM10
415 uses daily average data. This test was accomplished by daily averaging the solar radiation and
416 weather inputs into the HEC-RAS model and comparing to the hourly input dam breach model
417 run. There was an expected change in the daily ranges of temperatures but there was also an
418 effect on the daily average predicted temperatures. The largest effect was observed at Ice
419 Harbor. Daily averaging caused an overall average of 0.10°C warming of the model results with
420 an RMSE of 0.33°C (Figure 1-21).



421
422 **Figure 1-21. Comparison of Hourly versus Daily Model Inputs to Daily Average Temperature**
423 **Predictions**

424 **1.3.9 Comparison to Other Model Predictions**

425 The U.S. Environmental Protection Agency (EPA) is also developing a temperature model of the
426 Columbia River system that will be used in the total maximum daily load (TMDL) and
427 investigates the impact of dams on temperature. The EIS water quality model and the EPA
428 model overlap geographically and temporally, so they are compared directly below. The Lower
429 Snake River Juvenile Salmon Migration Feasibility Report/EIS (Corps 2002) documents historical
430 temperature analysis and three distinct temperature modeling efforts that predict

431 temperatures without dams. These modeling efforts are not directly comparable to the EIS
432 effort because they use a different hydrology and flow, but are qualitatively discussed below.

433 **1.3.9.1 U.S. Environmental Protection Agency’s 2018 RBM10**

434 The RBM10 model is a one-dimensional mathematical model of the thermal energy budget of
435 the mainstem Columbia and Snake Rivers (Tetra Tech 2018). It simulates daily average water
436 temperature under conditions of gradually varied flow. The 2018 RBM10 model simulates
437 temperatures from 1970 through 2016. The Columbia River is represented from the U.S.-
438 Canada border to the mouth; the Snake River from Anatone to its mouth; and the Clearwater
439 River from Orofino to its mouth. The terms of the heat exchange are similar to W2 and HEC-
440 RAS. The model was calibrated by seasonally and spatially varying one evaporation heat flux
441 parameter to minimize error with tailrace temperature gages.

442 The EPA evaluated sources of temperature impairments on the Columbia and Snake Rivers
443 using the 2018 RBM10 model (EPA 2018). To evaluate the dams within the model domain, EPA
444 developed a “free-flowing” scenario in which the channel velocity, depth, and width is
445 calculated as if the dams did not impound the river based on current, measured channel
446 geometry. Other than the hydraulics, the free-flowing scenario uses the same 1970–2016
447 hydrology, weather, and temperature boundary conditions as the calibrated RBM10 model. The
448 free-flowing scenario includes the temperature and flow inputs from 1970–2016 from
449 Dworshak Dam, because it is outside of the model domain.

450 **Table 1-10. RBM10 Estimated Monthly Impact of Dam Impoundments on Snake River**
451 **Temperatures (August; 2011–2016)**

Location	RBM10 Free Flowing		Cumulative Impact	
	°C	°F	°C	°F
LWG	18.7	65.6	0.8	1.4
LGS	19.1	66.3	1.2	2.2
LMN	19.1	66.4	1.5	2.7
IHR	19.7	67.5	1.7	3.1

452 Note: °F = degrees Fahrenheit; °C = degrees Celsius

453 Source: EPA 2018

454 There are differences between EPA’s free-flowing scenario and the MO3 results that make it
455 difficult to interpret a direct comparison of reported results:

- 456 • MO3 uses a daily maximum temperature as its primary metric while free-flowing uses a
457 daily average temperature.
- 458 • MO3 summarizes results based a 5-year weather period (2011–2015) while free-flowing
459 summarizes results from 6 years (2011–2016).

- 460 • MO3 uses a simulated flow and temperature from Dworshak representing operations based
461 on the No Action Alternative with slight modifications, while free-flowing uses observed
462 flows and temperatures from Dworshak Dam.
- 463 • MO3 computes a change in temperature from No Action Alternative temperatures that are
464 estimated using the W2 calibrated model. Free-flowing computes a change in temperature
465 from the calibrated RBM10 model. Neither of the scenarios are compared directly to
466 observed historic data.

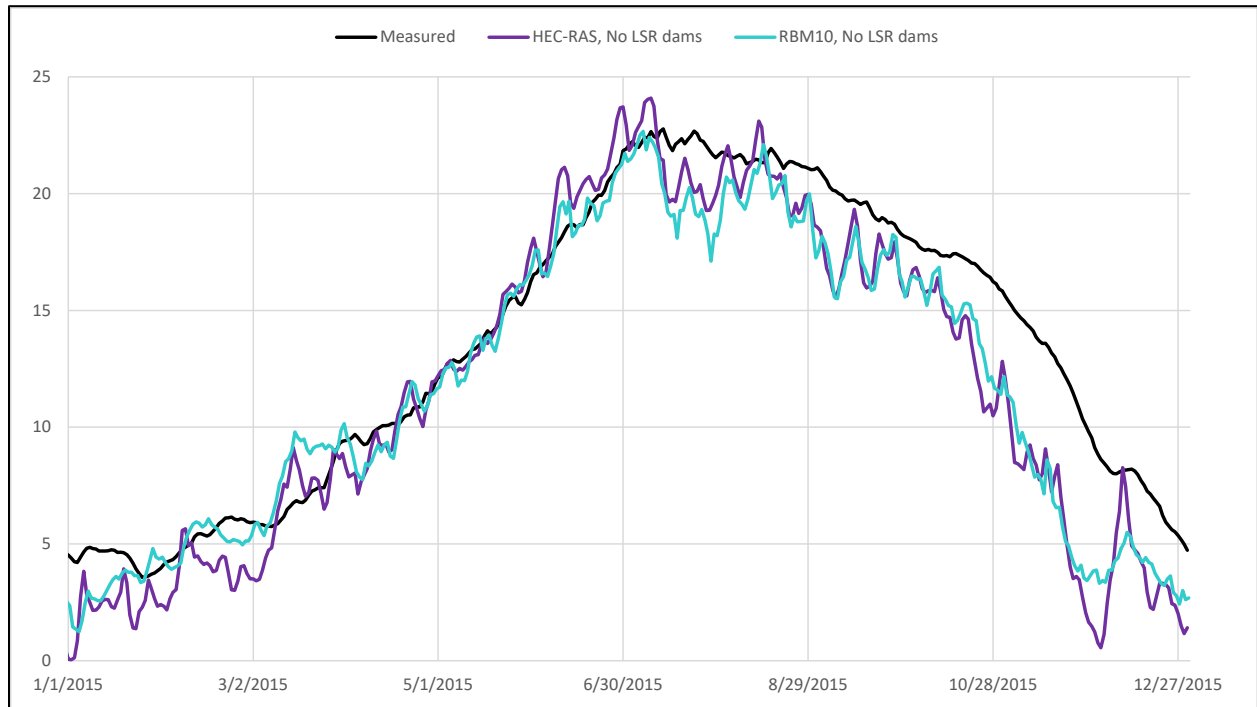
467 In order to more directly compare HEC-RAS to RBM10, an additional scenario was run in HEC-
468 RAS meant to be as similar as feasible to free-flowing. This “no lower Snake River dams”
469 scenario used the 1934 bathymetry but 2011–2015 measured flows and temperature inputs at
470 Dworshak and other boundaries. The temperature results were summarized as daily averages,
471 in degrees Celsius by month at Lower Granite and Ice Harbor (Table 1-11 and Table 1-12). The
472 “predicted impact” for each model is based on the same measured temperatures. The RBM10
473 results are reported from 2011–2015 (Figure 1-22).

474 **Table 1-11. Lower Granite Tailrace, Comparison of RBM10 and HEC-RAS Predictions of**
475 **Temperature without Lower Snake River Dams, 2011–2015 Weather and Hydrology, Monthly**
476 **Average**

Month	Measured (°C)	No LSR Dams, RBM10 (°C)	RBM10 Predicted Impact of No LSR Dams (°C)	No LSR Dams, RAS (°C)	HEC-RAS Predicted Impact of No LSR Dams (°C)	No LSR Dam HEC-RAS - RBM10 (°C)
1	3.3	3.0	-0.3	2.5	-0.7	-0.5
2	3.5	3.8	0.3	3.2	-0.3	-0.6
3	5.7	6.3	0.6	5.6	-0.1	-0.7
4	8.7	8.3	-0.4	8.3	-0.4	0.0
5	11.4	11.3	-0.1	11.2	-0.2	-0.1
6	14.6	14.6	0.0	14.7	0.1	0.1
7	18.6	18.2	-0.3	18.5	0.0	0.3
8	19.1	18.8	-0.3	19.0	-0.1	0.2
9	18.4	18.0	-0.4	18.0	-0.4	0.0
10	15.8	13.8	-2.0	13.7	-2.1	-0.1
11	9.6	7.3	-2.4	7.6	-2.0	0.3
12	4.9	4.3	-0.6	4.3	-0.7	0.0

477 **Table 1-12. Ice Harbor Tailrace, Comparison of RBM10 and HEC-RAS Predictions of**
478 **Temperature without Lower Snake River Dams, 2011-2015 Weather and Hydrology, Monthly**
479 **Average**

Month	Measured (°C)	No LSR Ddams, RBM10 (°C)	RBM10 predicted impact of no LSR dams (°C)	No LSR dams, RAS (°C)	HEC-RAS predicted impact of no LSR dams (°C)	No LSR dam HEC-RAS - RBM10 (°C)
1	3.6	2.7	-0.9	2.1	-1.5	-0.6
2	3.7	3.9	0.2	3.2	-0.5	-0.7
3	5.7	6.8	1.1	6.1	0.4	-0.7
4	9.3	8.9	-0.4	8.8	-0.4	0.0
5	12.3	12.0	-0.3	12.0	-0.3	0.0
6	15.3	15.3	-0.1	15.6	0.3	0.4
7	20.0	19.2	-0.8	20.0	0.0	0.8
8	21.4	19.9	-1.5	20.4	-1.0	0.5
9	19.8	17.8	-1.9	17.9	-1.9	0.0
10	16.6	13.2	-3.4	13.1	-3.5	-0.1
11	11.5	6.6	-5.0	6.5	-5.0	0.0
12	6.0	3.7	-2.3	3.2	-2.9	-0.5



480 **Figure 1-22. Ice Harbor tailrace, Comparison of 2015 Daily Average Temperature Prediction**
481 **with No Lower Snake River Dams**
482

483 **1.3.9.2 2002 Feasibility Study**

484 The 2002 Feasibility Study (Corps 2002) documents three different modeling efforts that
485 estimate the impact of the lower Snake River dams: 1999 RBM10, WQRSS, and MASS1. The
486 1999 RBM10 results were quantified. Based on Table 4-4 in that report, near Ice Harbor Dam, a
487 dam breach would reduce the number of days exceeding 20°C (68°F) from 62 days to 42 days
488 per year based on averaging results from 1994, 1995, and 1997. The focus of the WQRSS model
489 was biological productivity and temperature was mainly considered in context of productivity.
490 MASS1 results of the dam breach were presented graphically. MASS1 predicted more
491 temperature variability after a dam breach than existing conditions. Based on Figures 4-8 and 4-
492 11 in the 2002 Feasibility Study, the MASS1 analysis near Ice Harbor Dam after a dam breach
493 predicts a water temperature increase during July and August with more days exceeding 20°C
494 and more rapid cooling during September. However, due to the uncertainties in the simulation
495 model, the authors of the MASS1 study concluded that the results showed only small
496 differences between the current and without dam river temperature regimes.

497 **1.3.10 Model Results**

498 The following section serves to present the results of the LSR-MO3 model and compares those
499 results to the results from the No Action Alternative (Version 2). This ensures that we are
500 comparing models with the same upstream boundary temperatures.

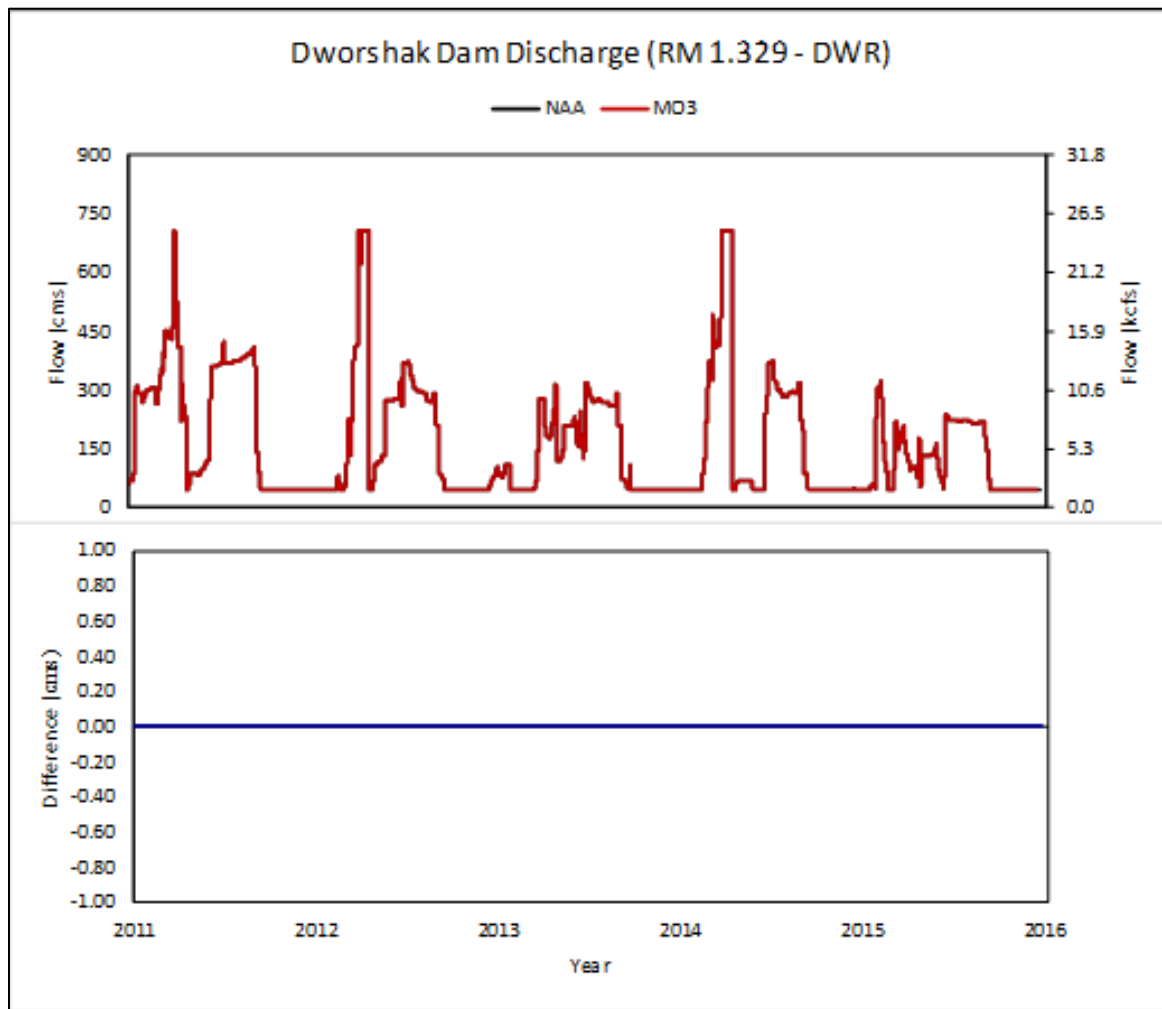
501 **1.3.10.1 Flow Comparison to No Action Alternative**

502 The upstream flows out of Dworshak and at Orofino remained unchanged as can be seen in
503 Figure 1-23 and Figure 1-24. The upstream flow from Anatone, Idaho, did change slightly due to
504 operational changes in MO3. This is shown in Figure 1-25. There are also very small changes
505 seen on the Clearwater River at Peck and Spalding, Idaho, (Figure 1-26 and Figure 1-27), but the
506 reason for this is uncertain. It could be due to the effects of dam breaching where water is
507 moving through the system faster, or it could simply be due to the slightly different geometries
508 used for the model since MO3 used the geometry from the sediment model. Flow changes,
509 shown in Table 1-13, provide an overview of the model comparison between the No Action
510 Alternative and MO3. Statistics are calculated using (No Action Alternative – MO3), so a positive
511 number means the No Action Alternative prediction was higher than that of MO3. From Lower
512 Granite and below, the major differences in flow can be attributed to a temporal shift forward
513 in the timing of flow from the No Action Alternative (with dams) to MO3 (dams breached).

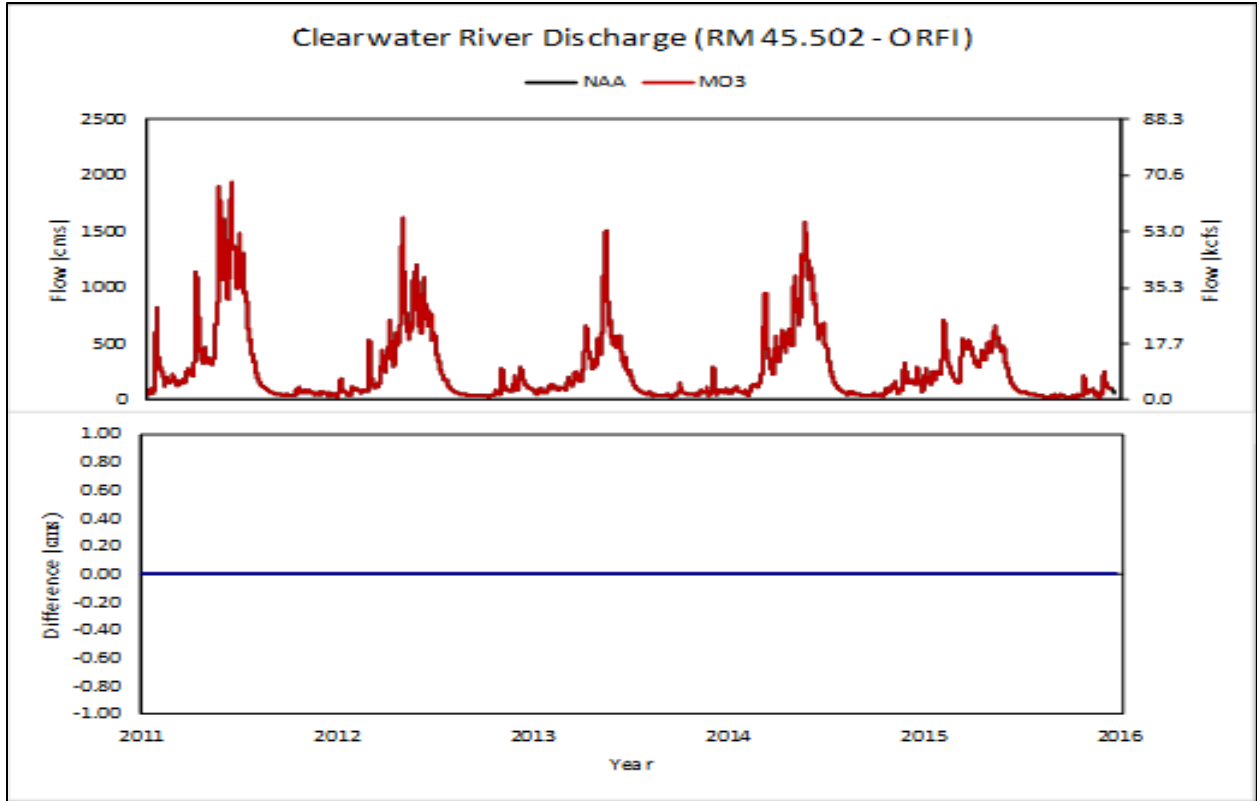
514 **Table 1-13. 5-Year No Action Alternative versus Multiple Objective Alternative 3 Statistical**
515 **Comparisons for Flow (cms)**

	Average Flow		Min Flow		Max Flow		(NAA - MO3) Statistics		
	NAA	MO3	NAA	MO3	NAA	MO3	ME	MAE	RMSE
DWR	166.18	166.18	45.31	45.31	707.92	707.92	0.00	0.00	0.00
ORFI	259.91	259.91	25.49	25.49	1945.37	1945.37	0.00	0.00	0.00
PEK	428.93	428.93	73.83	73.81	2067.86	2068.74	-0.07	0.30	0.53
SPD	428.93	428.93	74.00	74.01	2060.55	2060.58	-0.02	0.09	0.24
ANA	897.47	897.47	239.65	239.59	4318.38	4318.41	-0.01	0.39	1.04
LWG	1328.95	1329.19	378.66	360.49	6043.37	6297.38	29.16	103.59	182.89
LGS	1276.22	1329.21	336.81	362.52	5742.37	6287.98	-23.14	126.43	193.35
LMN	1328.31	1329.24	343.17	364.09	6186.76	6282.73	96.83	142.57	248.00
IHR	1348.51	1329.26	216.98	365.56	6149.75	6275.89	94.48	162.87	259.64

516 Note: ANA = Anatone; MAE = mean absolute error; ME = mean error; RMSE = root mean square error; PEK = Peck;
517 SPD = Spalding.



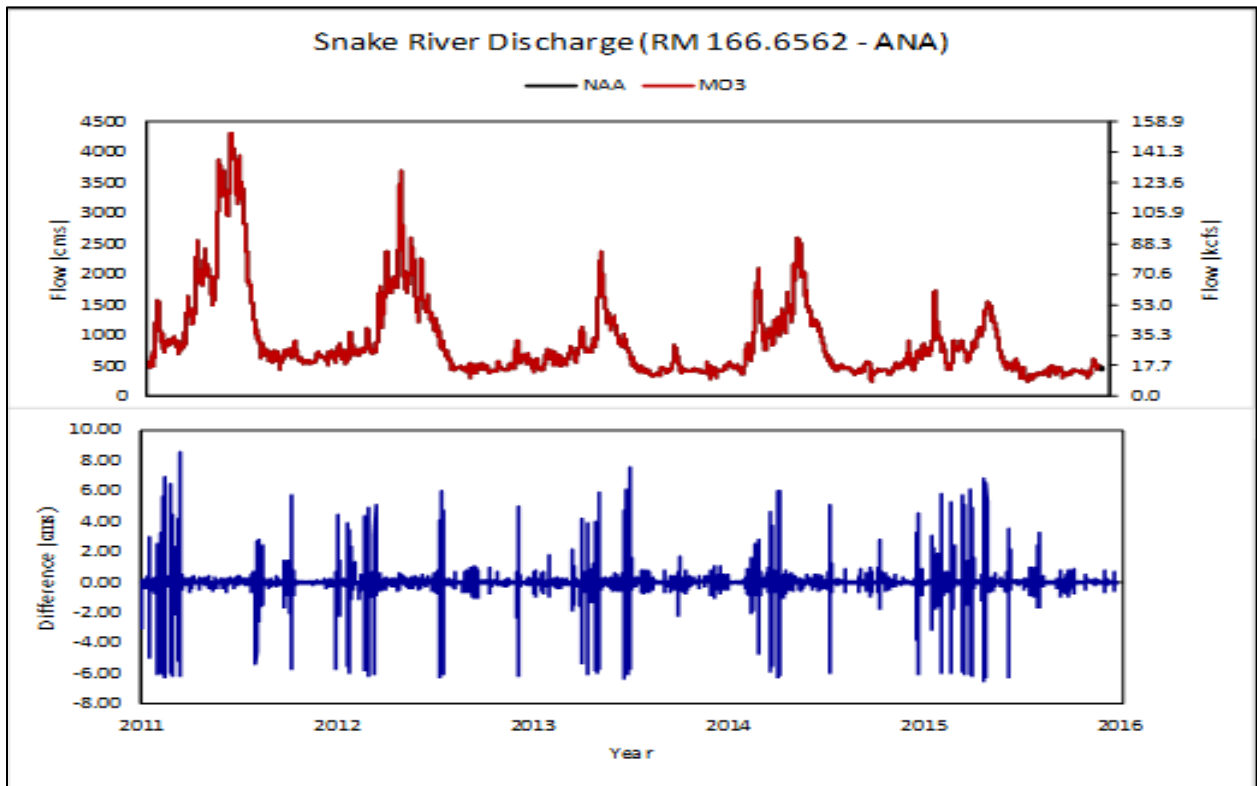
518 **Figure 1-23. Discharge Comparison at Dworshak Dam**
519



520

521

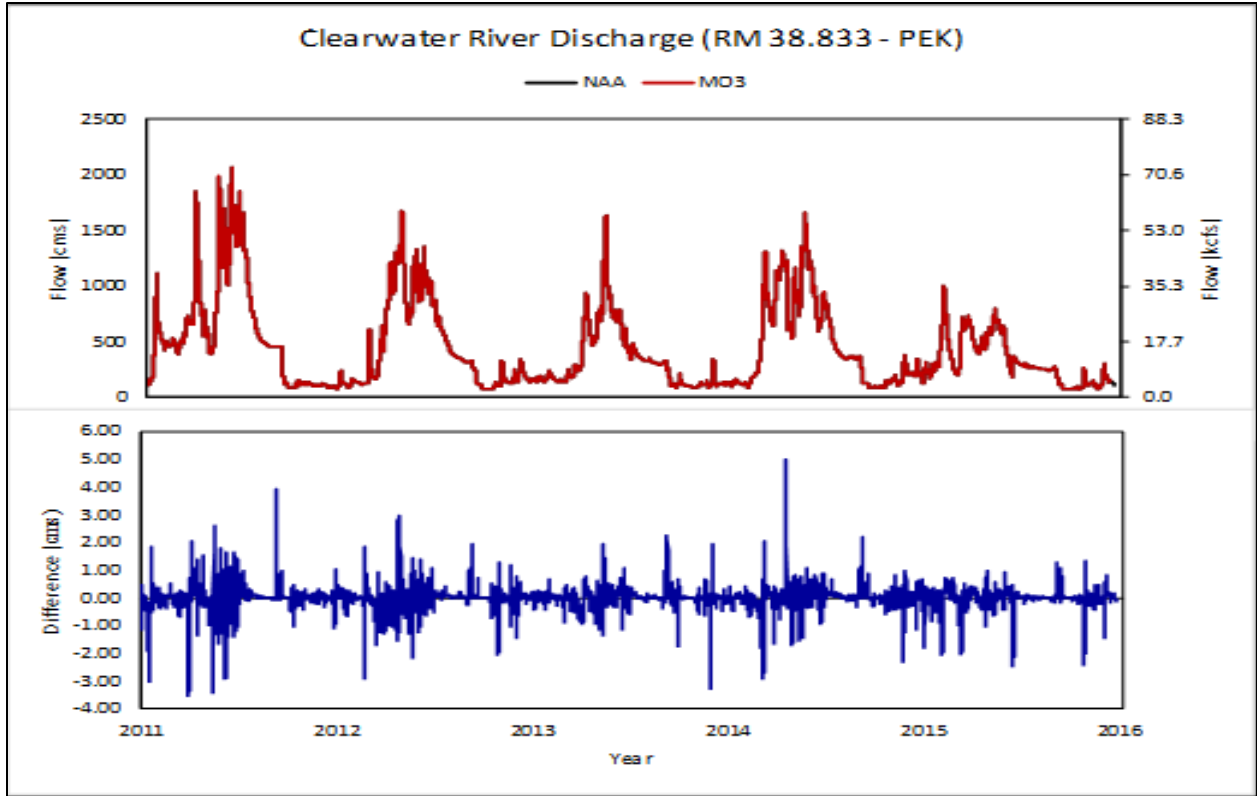
Figure 1-24. Discharge Comparison at the Clearwater River at Orofino, Idaho



522

523

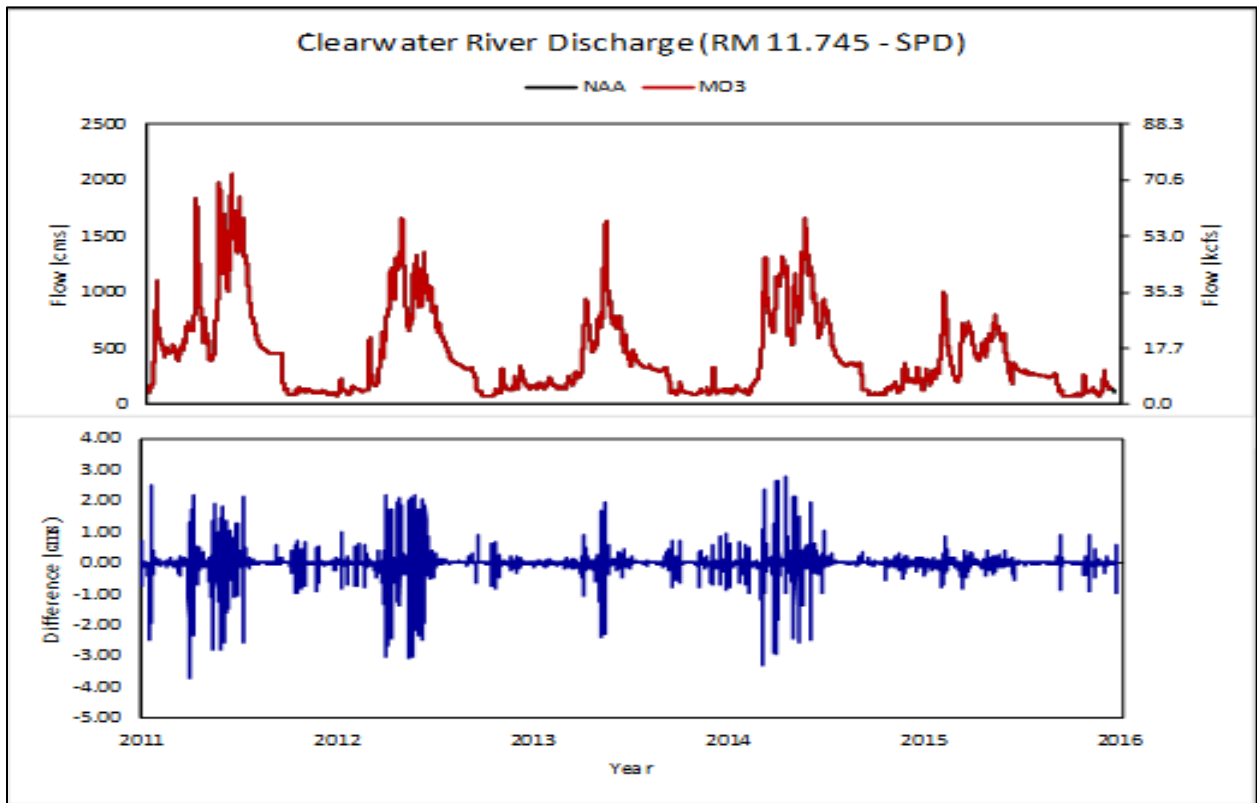
Figure 1-25. Discharge Comparison at the Snake River near Anatone, Idaho



524

525

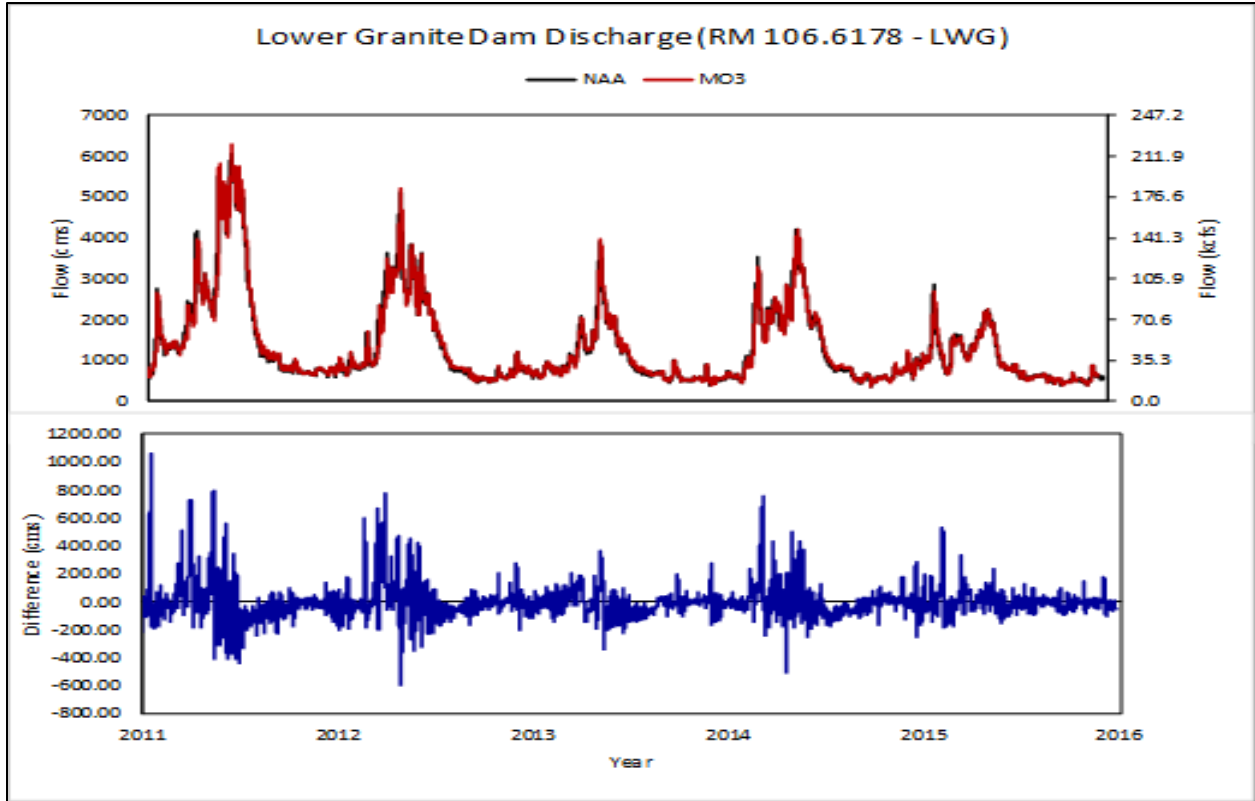
Figure 1-26. Discharge Comparison at the Clearwater River near Peck, Idaho



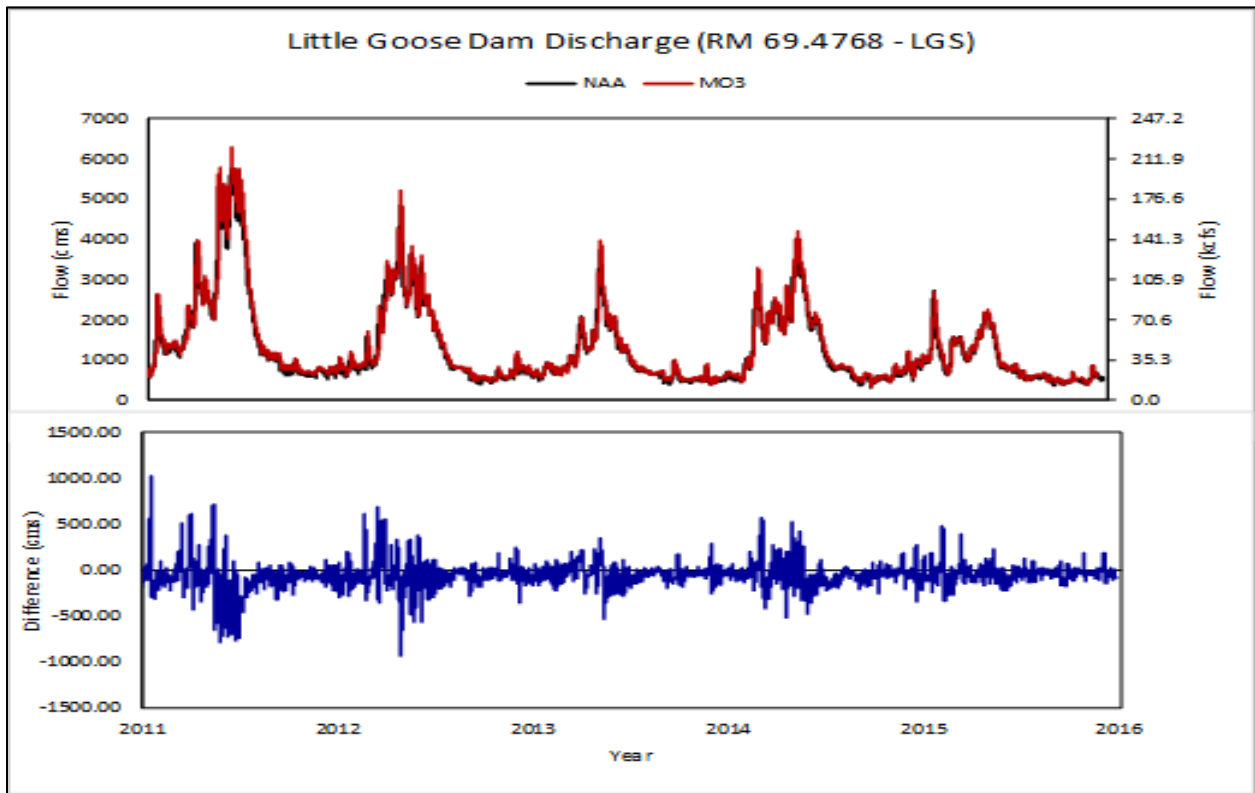
526

527

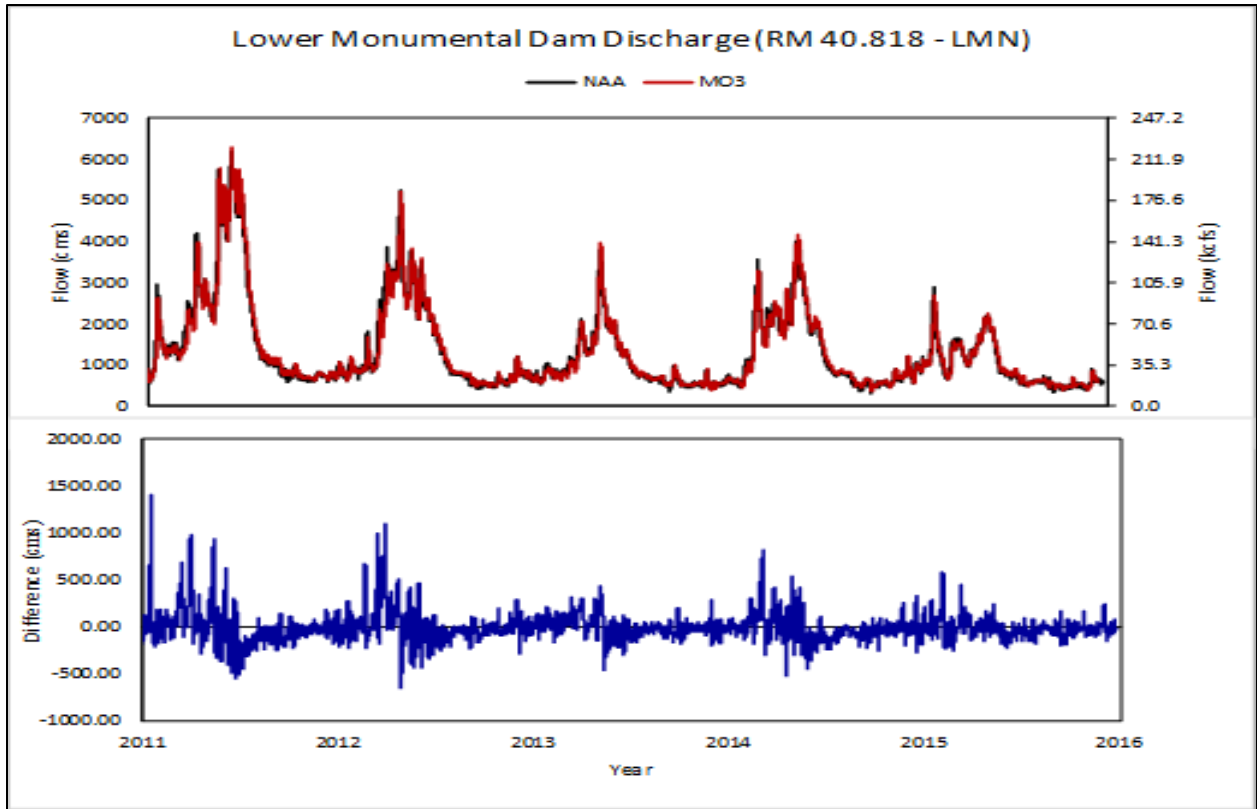
Figure 1-27. Discharge Comparison at the Clearwater River near Spalding, Idaho



528
529 **Figure 1-28. Discharge Comparison at Lower Granite Dam**

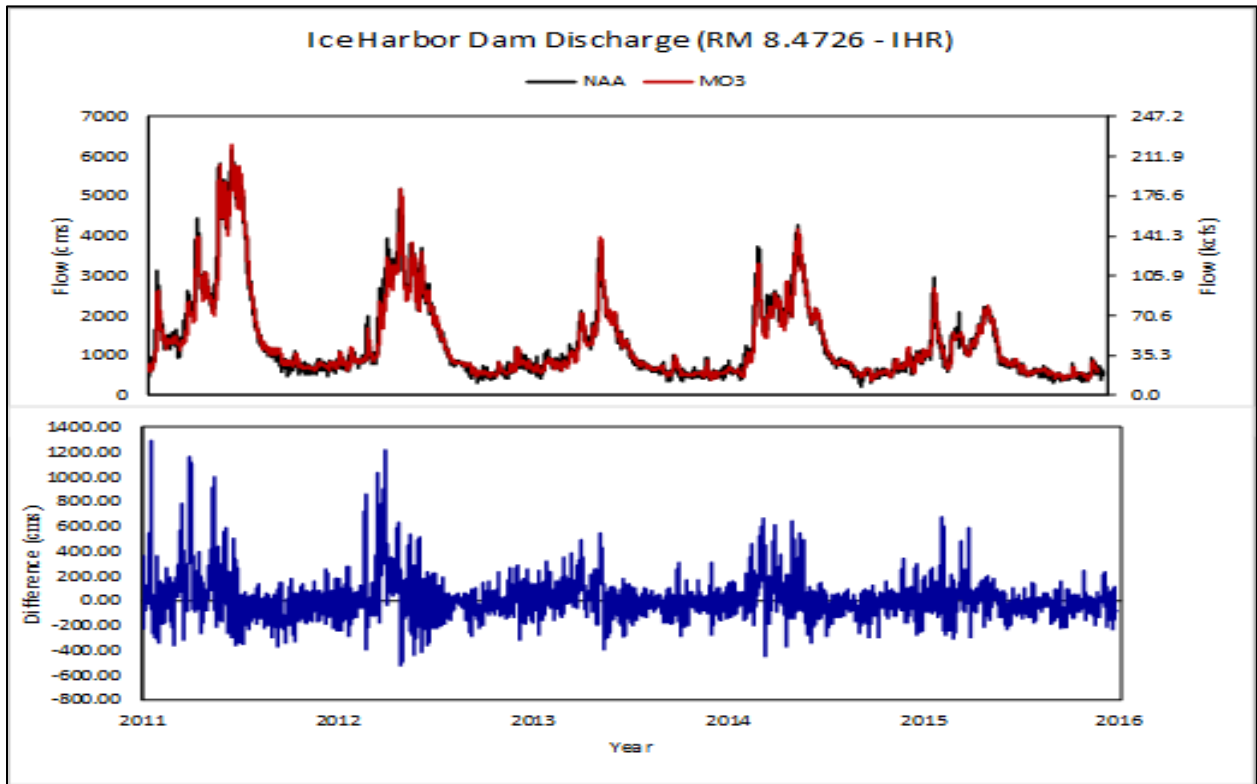


530
531 **Figure 1-29. Discharge Comparison at Little Goose Dam**



532

533 Figure 1-30. Discharge Comparison at Lower Monumental Dam



534

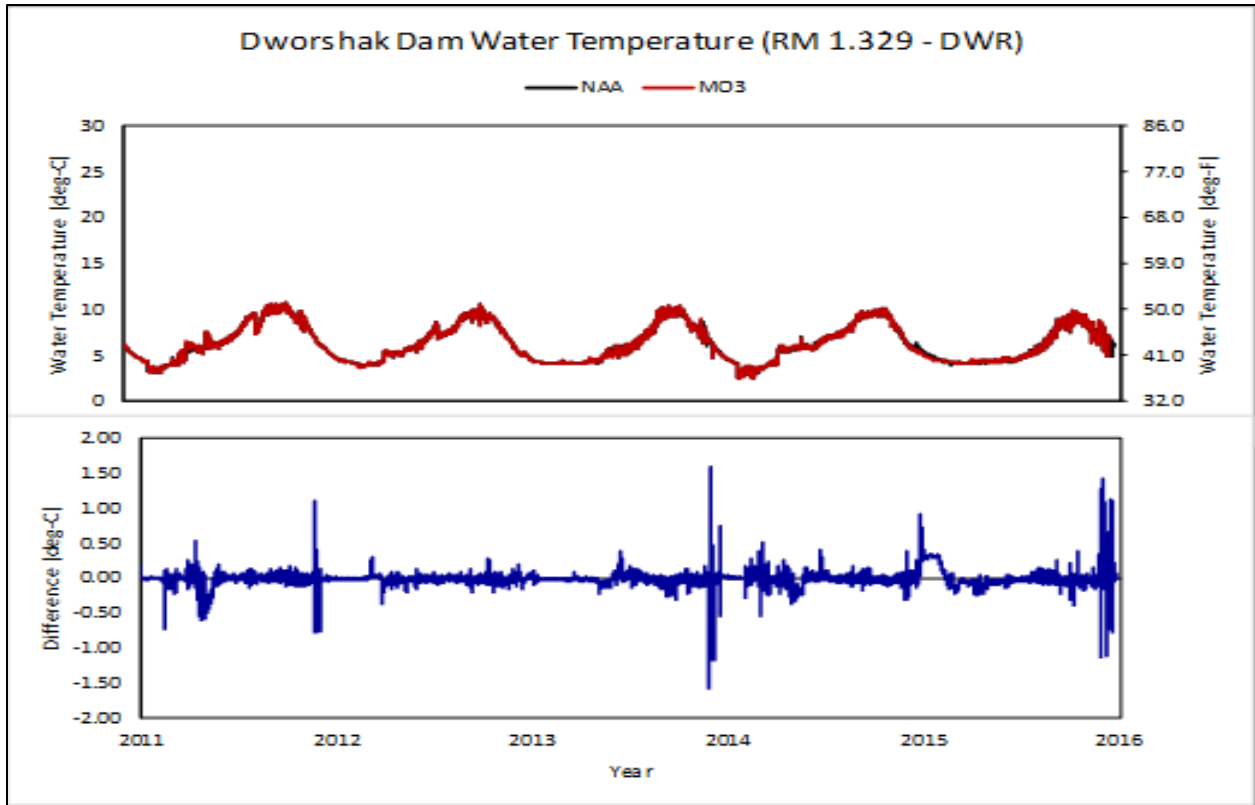
535 Figure 1-31. Discharge Comparison at Ice Harbor Dam

536 **1.3.10.2 Temperature Comparison to No Action Alternative**

537 The upstream boundary temperatures appear to be slightly different as can be seen in
538 Figure 1-32 through Figure 1-34. This phenomenon is likely due to changes in the hydraulic
539 calculation between the No Action Alternative and MO3 in the lower Snake River, which can
540 cause slight changes in the hydraulic calculation upstream (e.g., timestep, dispersion, and cell
541 size). The results shown are at the end of the most upstream reach. The effects seen at Peck
542 and Spalding, Idaho, (Figure 1-35 and Figure 1-36) are uncertain as well. The predictions are
543 different due to both flow differences (Figure 1-23 through Figure 1-31) and possibly the dam
544 breaching. Figure 1-37 through Figure 1-40 show the largest differences due to the dam
545 breaching. MO3 temperatures are cooler by approximately 0.2°C at the lower Snake River dam
546 sites. Table 1-14 gives an overview of the model comparison between the No Action Alternative
547 and MO3 (No Action Alternative-MO3).

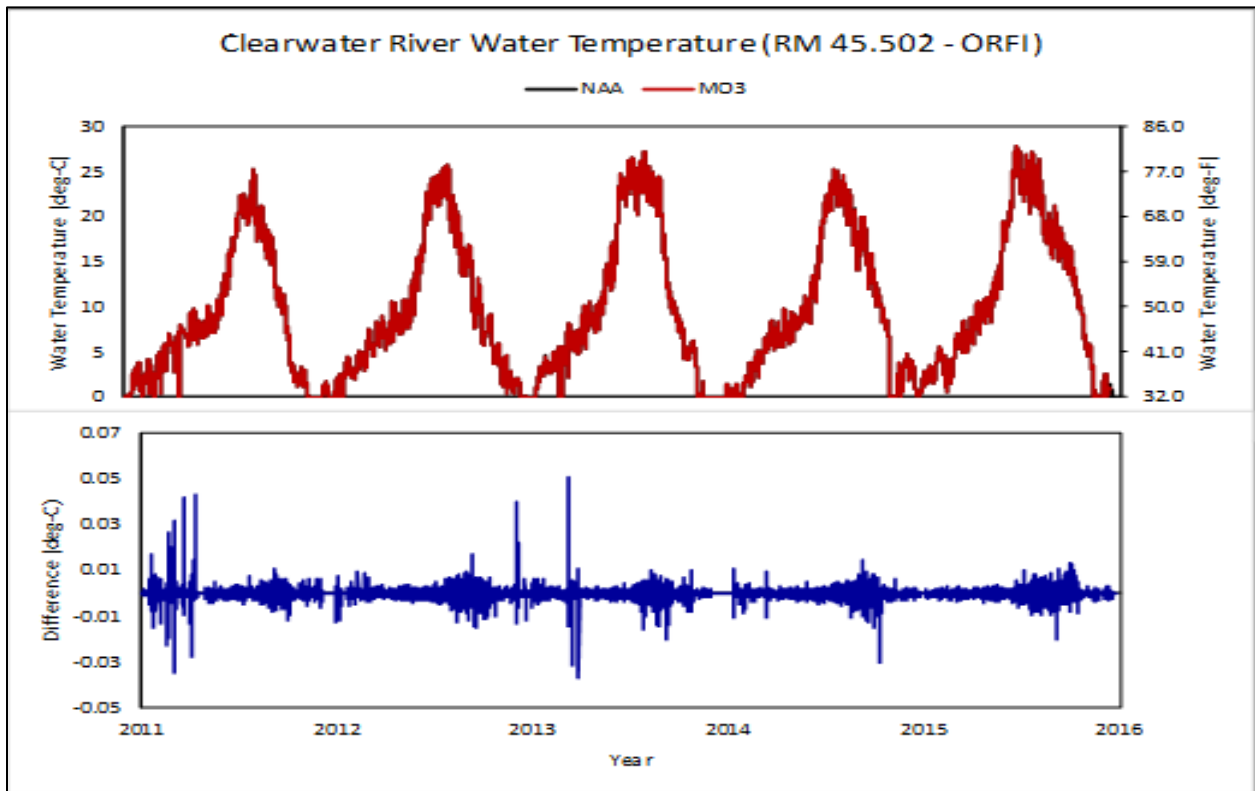
548 **Table 1-14. 5-Year No Action Alternative versus Multiple Objective Alternative 3 Statistical**
549 **Comparisons for Temperature (°C)**

	Average Temperature		Min Temperature		Max Temperature		(NAA - MO3) Statistics		
	NAA	MO3	NAA	MO3	NAA	MO3	ME	MAE	RMSE
DWR	6.33	6.33	2.56	2.48	10.80	10.82	-0.01	0.03	0.07
ORFI	9.50	9.50	-0.35	-0.35	27.91	27.91	0.00	0.00	0.00
PEK	7.21	7.19	0.61	0.62	17.77	17.56	-0.01	0.04	0.06
SPD	7.58	7.58	0.08	0.07	19.63	19.63	-0.01	0.02	0.05
ANA	11.89	11.89	0.57	0.57	24.92	24.92	0.00	0.00	0.00
LWG	11.10	10.57	0.36	0.38	21.95	22.17	-0.22	0.78	0.95
LGS	11.10	10.62	0.36	0.00	21.95	23.71	-0.16	0.92	1.14
LMN	11.30	10.67	0.49	0.00	22.48	24.11	-0.20	0.98	1.21
IHR	11.50	10.77	0.94	0.00	23.17	24.52	-0.25	1.03	1.31



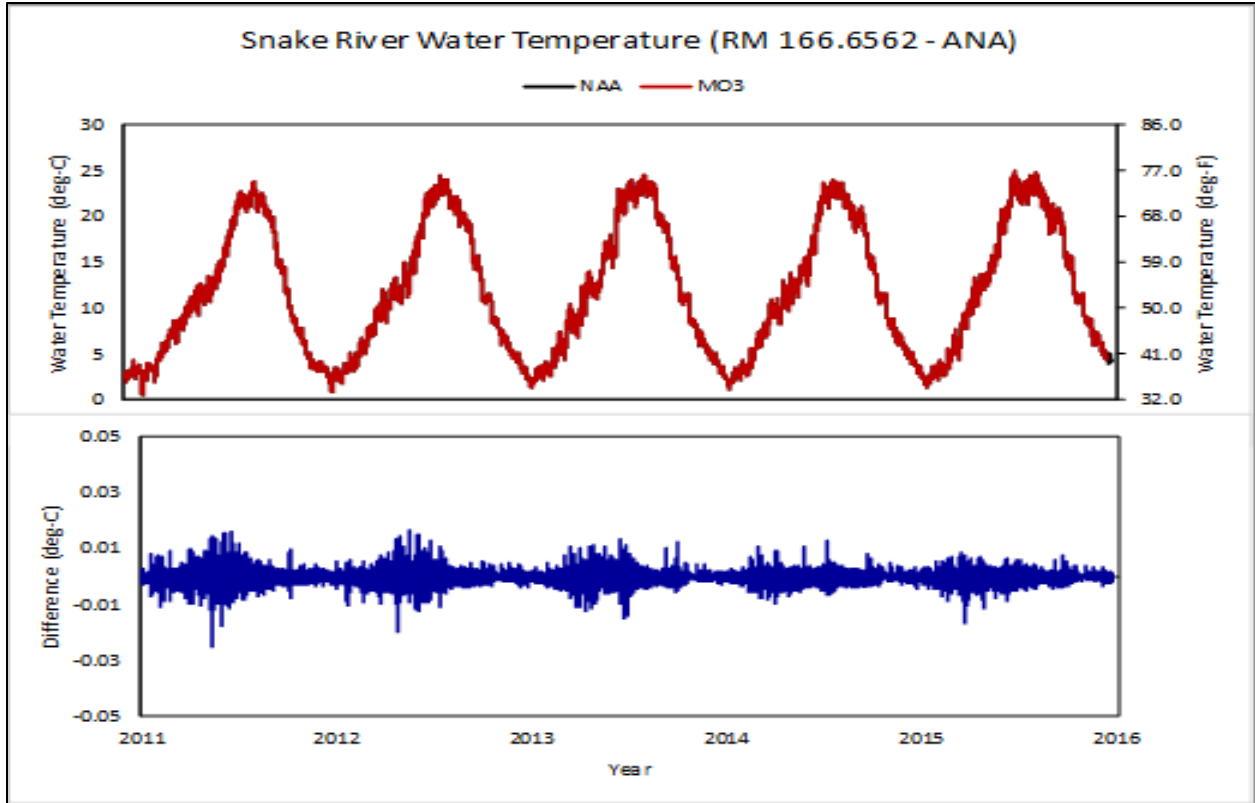
550

551 **Figure 1-32. Temperature Comparison at Dworshak Dam**



552

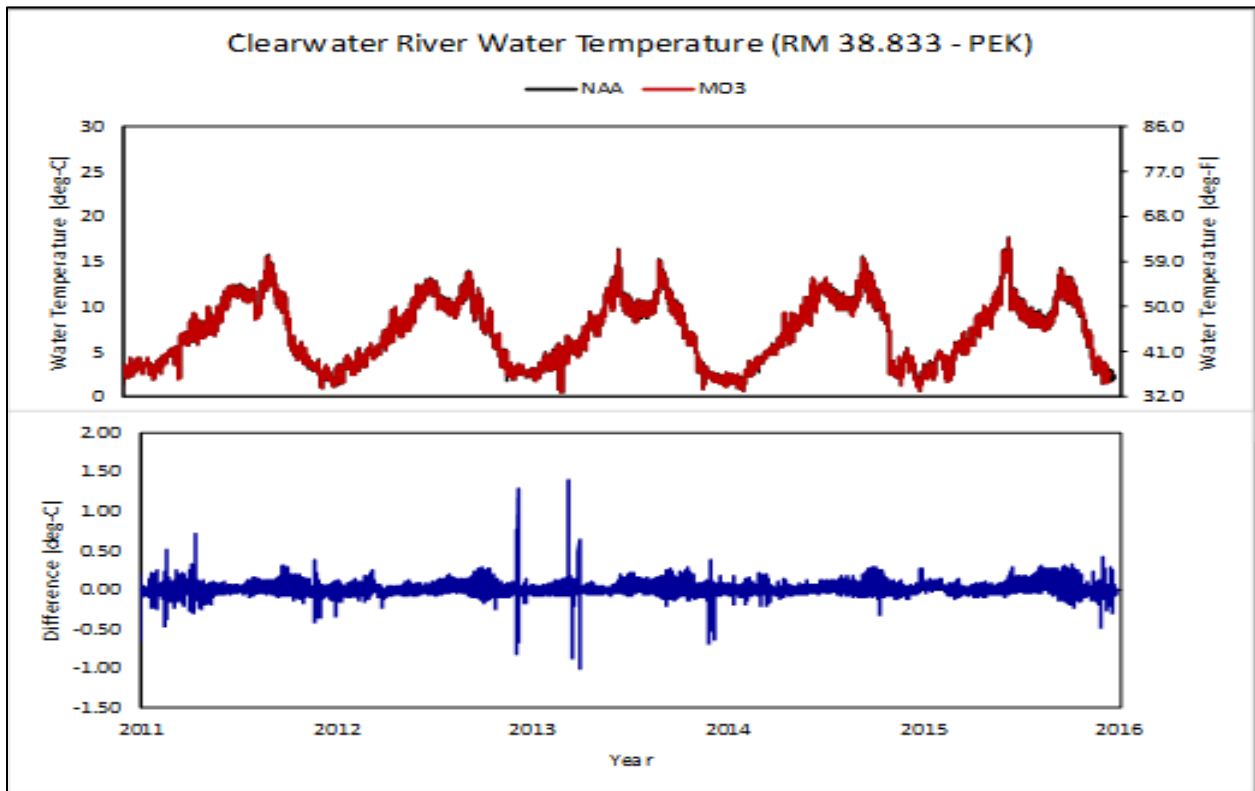
553 **Figure 1-33. Temperature Comparison at the Clearwater River at Orofino, Idaho**



554

555

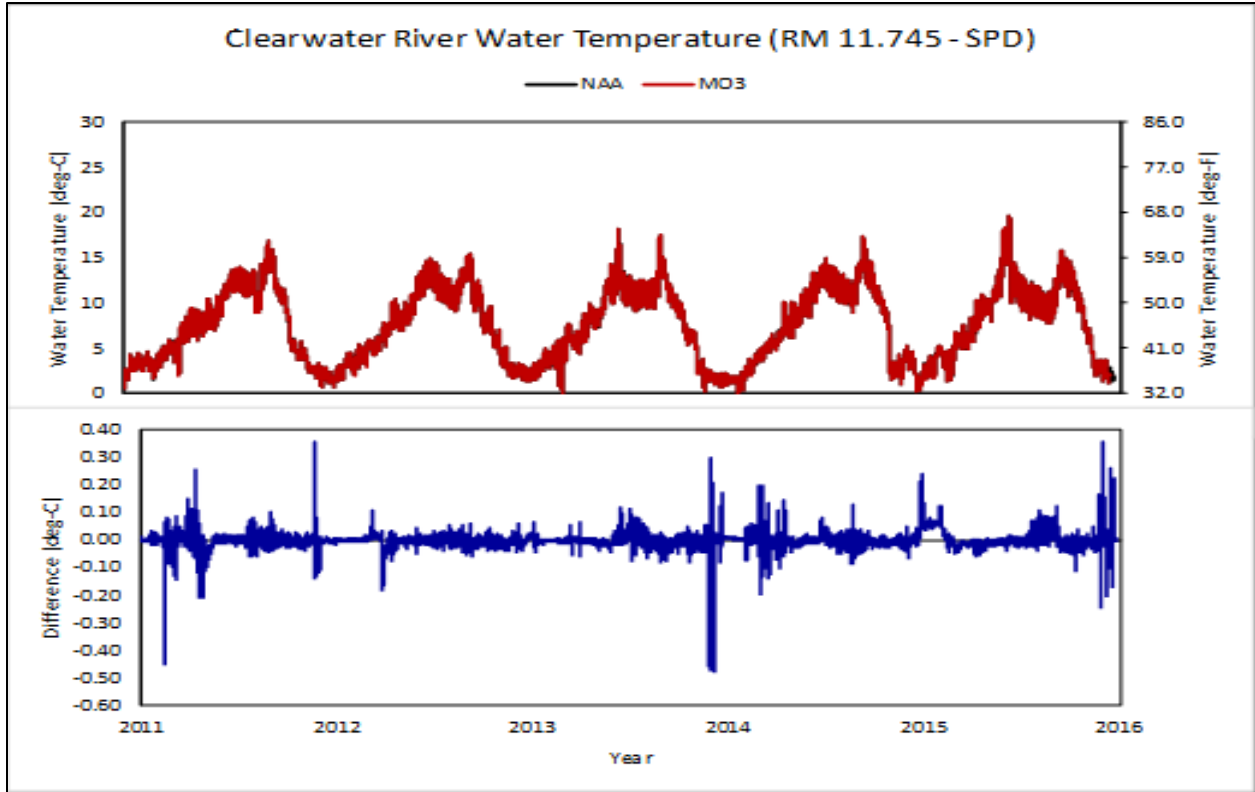
Figure 1-34. Temperature Comparison at the Snake River near Anatone, Idaho



556

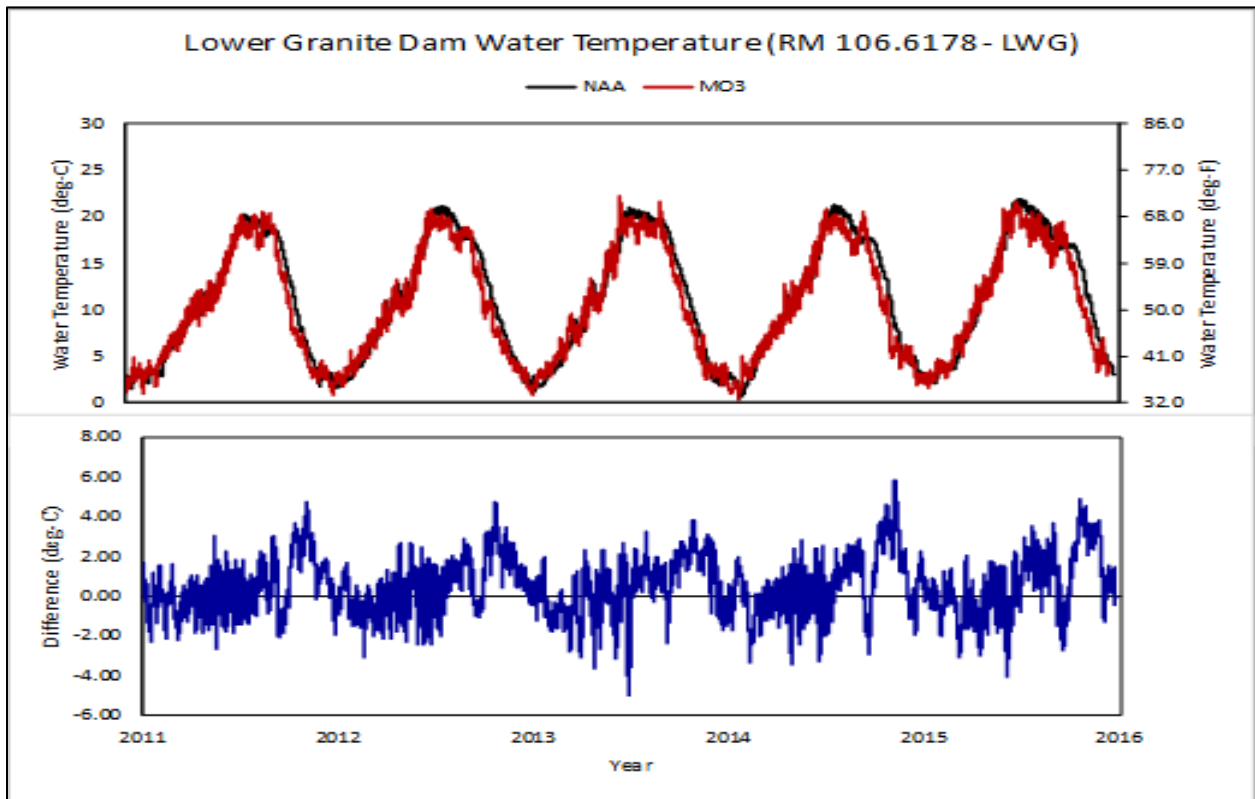
557

Figure 1-35. Temperature Comparison at the Clearwater River near Peck, Idaho



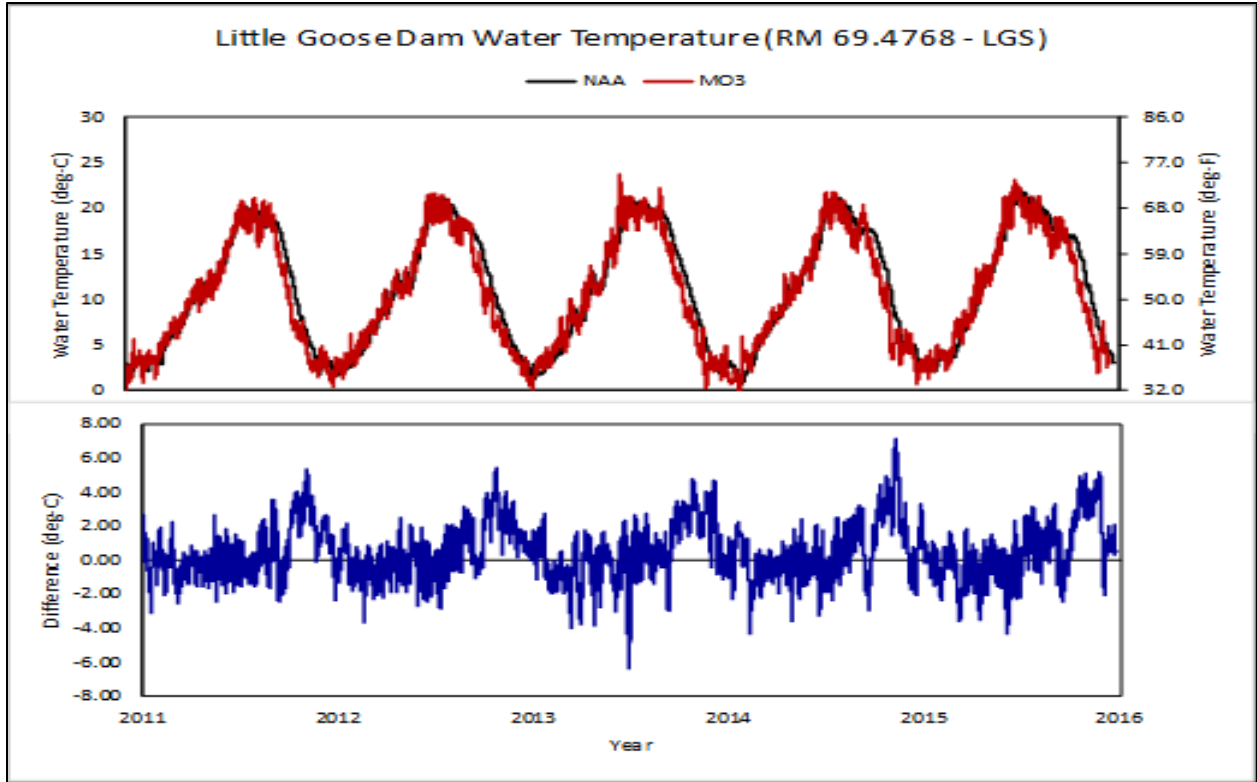
558
559

Figure 1-36. Temperature Comparison at the Clearwater River near Spalding, Idaho



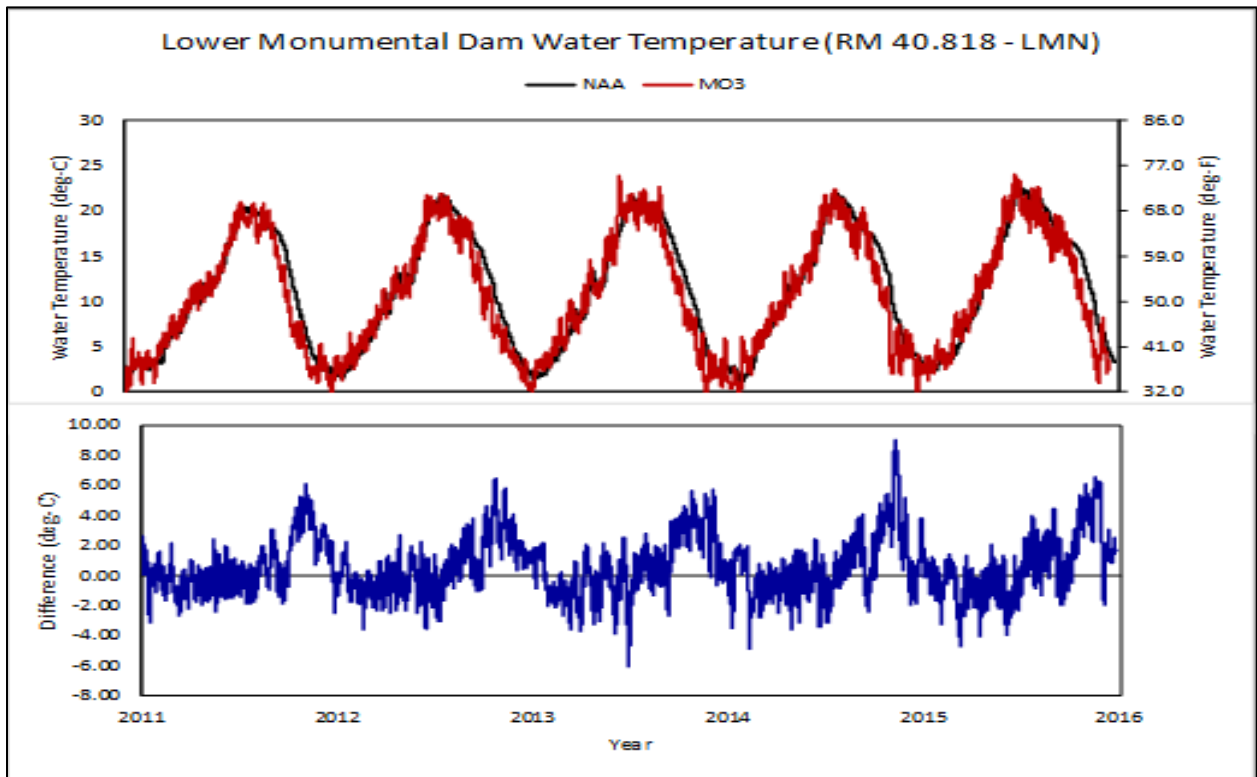
560
561

Figure 1-37. Temperature Comparison at Lower Granite Dam



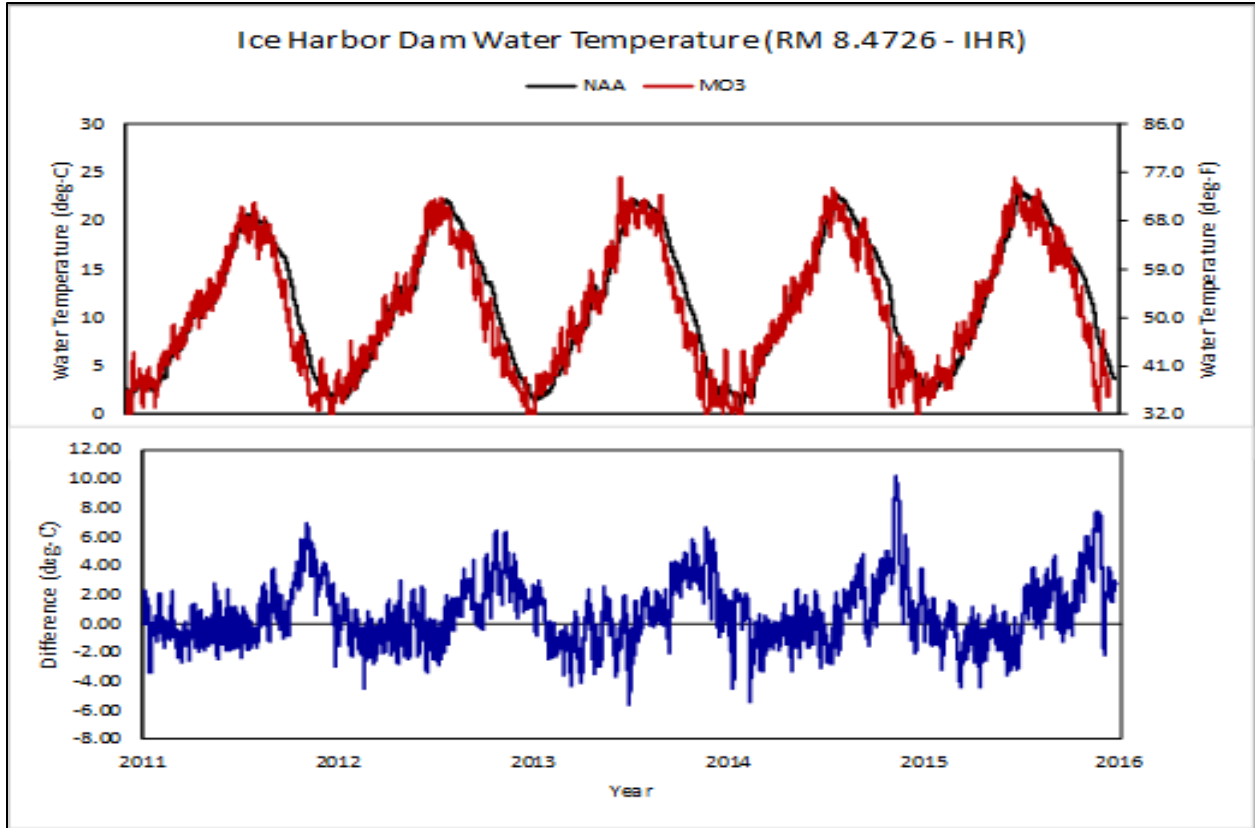
562
563

Figure 1-38. Temperature Comparison at Little Goose Dam



564
565

Figure 1-39. Temperature Comparison at Lower Monumental Dam



566
567

Figure 1-40. Temperature Comparison at Ice Harbor Dam

568

CHAPTER 2 - MODEL CONCLUSIONS

569 The LSR-MO3 model was developed to model the water quality effects (water temperature)
570 from breaching of the lower Snake River dams. Unless explicitly stated above, all coefficients,
571 parameters, and computation equations, 2011 initial conditions, and modeling methodology
572 were identical to the calibrated W2 system model and the No Action Alternative.

573 2.1 MODEL ASSUMPTIONS AND UNCERTAINTY

574 MO3 temperature predictions have the greatest uncertainty in the EIS water quality modeling
575 analysis because of the major change in the hydraulics of the system. Uncertainty analysis of
576 mechanistic model predictions is an emerging field and a quantified assessment was beyond
577 the constraints of the EIS due to model run times and needed development of an approach.
578 Uncertainty was reduced and evaluated to the extent practicable.

579 Several assumptions were made for the LSR-MO3 model development. All flow boundaries and
580 downstream stage at McNary Reservoir were set based on MO3 flow conditions from the CRSO
581 reservoir operations team. Any flow deviations from the No Action Alternative will have an
582 impact on the model results. All upstream temperature boundary conditions were set identical
583 to those used in the No Action Alternative (v2).

584 Types of model uncertainty can be separated into four broad categories (after EPA 2009):

- 585 • Framework uncertainty, resulting from incomplete knowledge about factors that control
586 the behavior of the system being modeled; limitations in spatial or temporal resolution; and
587 simplifications of the system
- 588 • Input uncertainty, resulting from data measurement errors and inconsistencies between
589 measured values and those used by the model (e.g., in their level of aggregation/averaging)
- 590 • Parameter uncertainty, resulting from a non-unique calibration and simplified physical
591 processes
- 592 • Niche uncertainty, resulting from the use of a model outside the system for which it was
593 originally developed and/or developing a larger model from several existing models with
594 different spatial or temporal scales.

595 2.1.1 Framework Uncertainty

596 Mathematical models offer a simplified representation of physical processes. The model
597 framework for the CRSO is composed of W2 and HEC-RAS, both of which are well known and
598 widely used models with a relatively long history. The models are appropriate choices to
599 evaluate the impacts of operations on water temperature. The model framework operates at
600 high spatial and temporal resolutions which capture the appropriate processes. The model
601 framework's longitudinal resolutions vary from 1.5 to 4,185 m and the temporal resolution is
602 less than 1 hour. W2, a two-dimensional, laterally averaged model is used to represent the
603 reservoirs, so stratification and longitudinal differences can be calculated. For the rivers, HEC-

604 RAS assumes that the lateral and depth variations are much less important than the
605 longitudinal variations. The simplifications of the heat budget and inputs to the model are
606 widely tested and generally accepted. The WQ team believes very little uncertainty is
607 introduced into the EIS analysis through the development of the basic model framework.

608 **2.1.2 Input Uncertainty**

609 Boundary conditions are used in the model framework to represent external sources and forces
610 (i.e., tributaries and meteorology, respectively). Typically, boundary conditions are altered to
611 test different water quality scenarios, so uncertainty is introduced not only in the current
612 representation of boundary conditions but also in the scenarios. The uncertainty due to flow
613 and temperature boundary conditions by using measurements at an hourly resolution for the
614 calibration of the model at gage locations at the geographic boundaries of the model. For
615 scenarios, daily flow inputs were derived from a rule-based operations model: ResSim. The WQ
616 team confirmed that measured flow inputs and model-derived routing produced similar
617 temperature results as using daily ResSim flows for each project and reach. Hourly solar
618 radiation inputs were derived using W2 formulas rather than measured inputs. It was the
619 professional judgment of the WQ team that this approach reduces uncertainty associated with
620 a sparse and less reliable solar radiation monitoring network. Weather inputs were based on
621 readily available and reliable data streams from stations within the basin (e.g., USBR AgriMet
622 and airports). The WQ team believes very little uncertainty is introduced into the EIS analysis
623 through the development of model inputs that represent current conditions or changes to
624 operations of the current dams. However, the bathymetry and resulting hydraulics of the dam
625 breach scenario are important factors in the temperature prediction. The WQ team did not
626 evaluate the uncertainty of the dam breach bathymetry and the impact on uncertainty of the
627 temperature prediction.

628 **2.1.3 Parameter Uncertainty**

629 Model parameters are semi-empirical in that they are determined not through site-specific field
630 or laboratory measurements but through literature review and goodness-of-fit between model
631 output and field measurements. For example, the wind sheltering coefficient in W2 is a
632 parameter that adjusts the wind speed, which was measured at a given location (not the
633 reservoir itself) (e.g., an airport). Parameters are adjusted, but constrained to the range of
634 typical literature values, to minimize the error between the measured water temperature and
635 the model estimates of the current system. The inherent assumption in most modeling similar
636 to this effort is that parameter uncertainty has been minimized when an acceptable calibration
637 has been achieved. Parameter uncertainty can be quantified; however, the WQ team does not
638 know of any cases where the impact of parameter uncertainty on allocations has been
639 quantified for a model of this complexity. The iterative process of adjusting parameters to
640 calibrate the model inherently considers the sensitivity of the model to the parameters. The
641 typical parameter estimation process of minimizing error was not possible on the lower Snake
642 River, one-dimensional model, HEC-RAS. To minimize the uncertainty due to the derivation of
643 M03 parameters of the lower Snake River, the WQ team conducted the following analysis:

644 review of literature values, sensitivity analysis, comparison to similar modeling efforts, and
645 corroboration with measurements. The WQ team believes that further decrease in model
646 parameter uncertainty for MO3 results could result in an increase to model niche uncertainty.

647 **2.1.4 Niche Uncertainty**

648 The appropriateness of the model the setting of the CRSO was discussed in Section 2.4.1.1,
649 above. An important part of niche uncertainty is whether the parameters used to represent the
650 current condition are also representative of a different condition. A dam breach would result in
651 an extreme change in hydraulics. The heat exchange occurs at the water surface, so changes to
652 the channel width will impact every aspect of the heat balance. The depth of the water also
653 impacts how heat fluxes result in temperature changes. Lastly, the travel time of a parcel of
654 water changes, so the overall exposure to heat fluxes changes. Therefore, application of
655 parameters from an existing condition to altered hydraulics are an important source of model
656 niche uncertainty. The decision not to incorporate seasonally variable wind coefficients was
657 intended to reduce model niche uncertainty. Since W2 was able to represent current conditions
658 with constant wind coefficients, the WQ team believes that seasonally variable could take on
659 surrogate roles in the heat balance to account for the one-dimensional simplification. In other
660 words, a more complex parameterization may result in an “overcalibrated” model that leads to
661 greater model niche uncertainty.

662 The pattern and magnitude of the mean daily MO3 results with estimated uncertainty bounds
663 are compared to the No Action Alternative with uncertainty bounds. The RMSE between the
664 system model and hourly observed measurements was calculated for the following results:

- 665 • W2 system model results at the Ice Harbor Dam tailwater (used in the No Action
666 Alternative)
- 667 • HEC-RAS system model results at the Clearwater River at Spalding, Idaho (used in the No
668 Action Alternative), used to estimate the uncertainty of HEC-RAS representation of a
669 riverine site.
- 670 • HEC-RAS existing condition (one-dimensional representation of the system model) at the Ice
671 Harbor tailwater (described above, Figure 1-17).

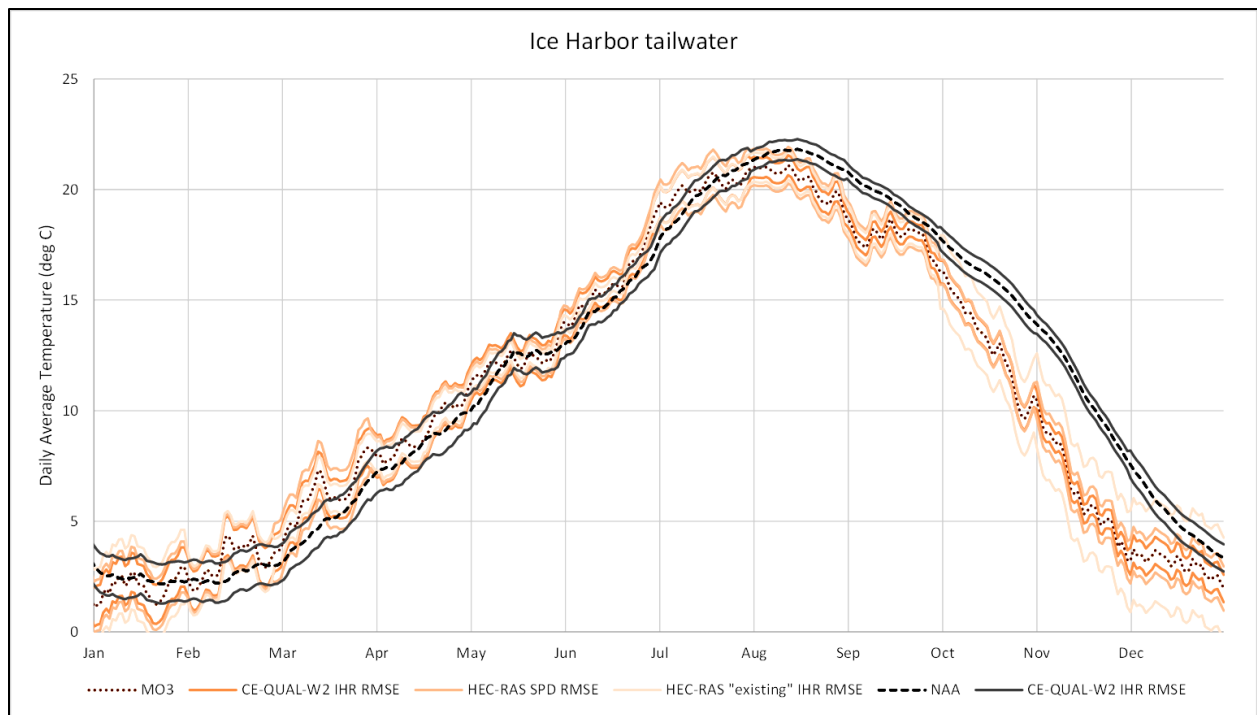
672 These three RMSE values were used as estimates of the MO3 uncertainty and were applied to
673 model results. No Action Alternative temperature predictions are more certain than MO3
674 because there are fewer changes to the model from the calibrated conditions. Therefore, No
675 Action Alternative uncertainty was estimated using W2 at Ice Harbor.

676 RMSE is a close approximation of the standard deviation, which is a typical measure used to
677 quantify the amount of variation or dispersion of a set of values. A true uncertainty analysis is
678 beyond the scope of this analysis. Using RMSE is a conservative estimate of uncertainty which,
679 at best, accounts for model framework uncertainty and model input uncertainty. The actual
680 uncertainty is greater than reported here because this estimate does not include model

681 parameter or model niche uncertainty. This analysis does not include variability in weather or
682 hydrology beyond the 2011–2015 period (Table 2-1 and Figure 2-1).

683 **Table 2-1. Root Mean Square Error (°C) by Month**

Month	W2 Calibration IHR	HEC-RAS Calibration SPD	HEC-RAS "Existing" IHR
January	0.88	1.15	1.68
February	0.88	0.99	1.11
March	0.84	1.32	0.62
April	0.95	0.87	0.68
May	0.79	0.61	0.44
June	0.59	0.76	0.31
July	0.70	1.02	0.71
August	0.45	0.83	0.66
September	0.35	0.81	0.66
October	0.52	0.57	1.66
November	0.42	0.85	2.14
December	0.62	1.00	2.30



684
685 **Figure 2-1. Estimated Uncertainty of MO3 Predictions Compared to the No Action Alternative.**

686 When the estimates of the 5-year daily means plus/minus the RMSE overlap, there is a low
687 confidence that MO3 will result in different temperatures than the No Action Alternative. Based
688 on overlapping uncertainty bounds, we observe the following:

- 689 • At no time is the predicted MO3 temperature warmer than the No Action Alternative and
690 the bounds of uncertainty, except for five scattered days between February and June.
- 691 • MO3 is predicted to be cooler than the No Action Alternative (outside the bounds of
692 uncertainty) for the following periods: August 16 to September 19 and October 9 to
693 December 7 (except scattered two-day periods).
- 694 • The predictions of MO3 and the No Action Alternative, including uncertainty, overlap for
695 most of the year: December 8 to August 16. There is still a possible temperature impact of
696 dam breach during that period but it is not predicted to be greater than the uncertainty of
697 the analysis.

698 **2.2 MODEL ACCEPTABILITY**

699 Based on results presented in this report and the calibration reports, the CRSO WQ modeling
700 team concluded that this model is sufficient to use for water temperature predictions under
701 MO3. This model predicts the expected water temperature response expected from dam
702 breaching based on well-documented thermal effects of reservoirs.

703

CHAPTER 3 - REFERENCES

704 Corps (U.S. Army Corps of Engineers). 1996. Engineering and Design Manual for Risk-Based
705 Analysis for Flood Damage Reduction Studies EM 1110-2-1619.

706 _____. 2002. Final Lower Snake River Juvenile Salmon Migration Feasibility
707 Report/Environmental Impact Statement, Appendix C, Water Quality. Walla Walla
708 District. Walla Walla, WA.

709 _____. 2019. Columbia River System Operations Environmental Impact Statement. Portland
710 Division. Portland, OR.

711 Edinger, J.E., Brady, D.K., and Geyer, J.C. 1974. "Heat Exchange and Transport in the Environ-
712 ment", Rpt. No. 14, EPRI Publication No. 74-049-00-34, prepared for Electric Power
713 Research Institute, Cooling Water Discharge Research Project RP-49), Palo Alto, CA.

714 EPA (U.S. Environmental Protection Agency). 2009. Guidance on the Development, Evaluation,
715 and Application of Regulatory Environmental Models. EPA/100/K-09/003.

716 _____. 2018. Assessment of Impacts to Columbia and Snake River Temperatures using the
717 RBM10 Model. Draft Report, December 2018.

718 Cole, T.M., and Wells, S. A. (2018) "CE-QUAL-W2: A two-dimensional, laterally averaged,
719 hydrodynamic and water quality model, version 4.1," Department of Civil and
720 Environmental Engineering, Portland State University, Portland, OR.

721 Tetra Tech. 2018. Update of the RBM10 Temperature Model of the Columbia and Snake Rivers.
722 Prepared for U.S. Environmental Protection Agency, Region 10. Seattle, WA.



Draft Columbia River System Operations Environmental Impact Statement

Annex B

Water Quality Methods for Fish Survival Modeling

EXECUTIVE SUMMARY

PURPOSE OF TECHNICAL APPENDIX

This technical appendix documents the analysis and post-processing of Columbia River System water quality modeling results (Appendix X) for the Columbia River System Operations (CRSO) Multiple Objective Alternatives (MO) (including the No Action Alternative). Methods described include: (1) development of a water temperature mapping tool that allows 5 years of water quality modeling results to be re-sequenced to the 80-year period of record (POR) and (2) estimation of daily average total dissolved gas (TDG) at each CRSO dam during the POR. Both efforts were compiled under each MO with POR operational data from the Hydrology and Hydraulics (H & H) Technical Team and delivered as data products to the Fish Technical Team. This appendix has been prepared as documentation for multiple ongoing efforts by the co-lead agencies including, but not limited to, the CRSO Environmental Impact Statement.

ORGANIZATION OF THIS APPENDIX

This appendix consists of two parts:

- 1) Development and implementation of the water temperature mapping tool.
- 2) Methods used to estimate TDG under each alternative in the CRSO study.

Table of Contents

CHAPTER 1 - Introduction	1-1
CHAPTER 2 - Water Temperature Mapping	2-1
2.1 Overview	2-1
2.1.1 Development of Water Temperature Regression Models	2-1
2.1.2 Estimation of Monthly Bonneville Dam Water Temperature	2-7
2.1.3 Synthesizing a Historical Period Water Temperature Dataset	2-7
CHAPTER 3 - Total Dissolved Gas Estimations.....	3-1
3.1 Methods.....	3-1
3.1.1 Spill Patterns	3-6
3.1.2 Alternative-Specific Details	3-8
CHAPTER 4 - References	4-1

List of Tables

Table 1-1. Strengths and Weaknesses of Different Approaches to Analyzing the Multiple Objective Alternatives in the 1928–2008 Period of Record	1
Table 1-2. Project Acronyms and Groupings	2
Table 2-1. Multiple Linear Regression Coefficients Predicting Monthly Water Temperature at Bonneville Dam	2-4
Table 3-1. Data Variables Used to Compute Tailwater and Downstream Forebay Total Dissolved Gas at Selected Dams within the CRSO Water Quality Model Domain	3-1
Table 3-2. Rules Specifying Spill Patterns Used for Lower Monumental Dam in Odd-numbered Years for Multiple Objective Alternative 1	3-8
Table 3-3. Rules Specifying Spill Patterns used for Lower Monumental Dam in Even-numbered Years for Multiple Objective Alternative 1	3-8

List of Figures

Figure 2-1. Monthly Water Temperature Regression Model Fit Statistics.....	2-5
Figure 2-2. Time-series Representation of Measured and Modeled Water Temperature of the Columbia River at Bonneville Dam.....	2-6
Figure 2-3. Scatter-plot Representation of Measured and Modeled Water Temperature of the Columbia River at Bonneville Dam for each Month	2-6
Figure 2-4. Monthly Box Plots of Estimated Columbia River Water Temperature at Bonneville Dam for Two Timeframes: the Model Development Period (1975–2017) and the EXT Period (2011–2015).....	2-7
Figure 2-5. Colorized Table of Percentiles for the Water Quality Modeling EXT Period (2011-2015), Where Percentiles were Calculated Based on the Regression Period of 1975–2017	2-8

Figure 2-6. Colorized Table of Water Temperature Percentiles for the Columbia River System Operations Period of Record (1928–2008)	2-9
Figure 2-7. Mapped Water temperature Data Comparison to Measurements Downstream of Ice Harbor Dam on the Snake River.....	2-10
Figure 2-8. Mapped Water Temperature Data Comparison to Measurements Downstream of The Dalles Dam on the Columbia River	2-10
Figure 2-9. Fit Statistics of Mapped Data Compared to Observations (2008–2017) for the Entire Year and Spring for Each Project in the CRSO Model Domain.....	2-11
Figure 3-1. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas below Lower Granite Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in Little Goose Dam	3-2
Figure 3-2. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas below Little Goose Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in Lower Monumental Dam.....	3-3
Figure 3-3. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas below Lower Monumental Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in Ice Harbor Dam.....	3-3
Figure 3-4. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas below Ice Harbor Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in McNary Dam	3-4
Figure 3-5. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas below McNary Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in John Day Dam	3-4
Figure 3-6. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas below John Day Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in The Dalles Dam	3-5
Figure 3-7. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas below The Dalles Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in Bonneville Dam.....	3-5
Figure 3-8. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas below Bonneville Dam and Total Dissolved Gas at Warrendale (Dwnstrm Forebay)	3-6

Acronyms and Abbreviations

Bonneville	Bonneville Power Administration
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
CRSO	Columbia River System Operations
EIS	environmental impact statement
EXT	extended timeframe for water quality modeling (2011–2015)
H & H	hydrology and hydraulics
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center River Analysis System
kcms	thousand cubic feet per second
MO	Multiple Objective Alternative
NOAA	National Oceanic and Atmospheric Administration
POR	period of record (for this study, 1928–2007)
RBM10	one-dimensional water temperature model of Columbia/Snake R
ResSim	Reservoir Simulator (U.S. Army Corps of Engineers software)
TDG	total dissolved gas
USGS	U.S. Geological Survey
WSE	water surface elevation

CHAPTER 1 - INTRODUCTION

Water quality modeling is a time- and data-intensive procedure. Recent data (2011–2015) have been used to calibrate water quality models (temperature and total dissolved gas [TDG]) of the Columbia River. As part of the Columbia River System Operations (CRSO) study, historical flows were simulated during a historical 80-year (1928–2008) period of record (POR). In order to run fish models under multiple alternatives that rely on this 80-year period, a method of generating longer-term data sets for water temperature and TDG was needed. The lack of observed meteorological and water quality data available in the 80-year POR made developing water quality models (CE-QUAL-W2, Hydrologic Engineering Center River Analysis System [HEC-RAS], RBM10) complicated and time intensive for the CRSO project due dates (Table 1-1). The 2011–2015 period (referred to as EXT) captured a wide range of flow, weather, and water quality conditions for assessing potential operational/structural changes within each MO. This allowed a wider array of water quality data to be mapped back to the 80-year POR.

Table 1-1. Strengths and Weaknesses of Different Approaches to Analyzing the Multiple Objective Alternatives in the 1928–2008 Period of Record

	CE-QUAL-W2 + HEC-RAS	Statistical “Mapping” Approach	RBM10
Temporal Resolution	Sub-daily	Daily	Daily
Spatial Resolution	2D: vertical (depth) and longitudinal (downstream)	2D: vertical (depth) and longitudinal (downstream)	1D: Longitudinal (downstream)
Calibration Data Timeframe	2011–2015; limited quality data availability prior to 2008	Data available 1972–2018	Data available 1970-2016
TDG estimates	Physically/empirically based equations	Physically/empirically based equations	None
Development Effort/Time	High	Low	High
Run-Time	Days	Hours	Days

This technical appendix has been prepared as documentation for multiple ongoing efforts by the co-lead agencies including, but not limited to, the CRSO Environmental Impact Statement (EIS). Effects of the MOs on river mechanics (e.g., sediment transport), groundwater, power, and fish passage, etc., all of which may generally fall under the H & H umbrella, are covered in separate appendices. Projects may occasionally be referred to using an acronym instead of the full name (e.g., LWG instead of Lower Granite) in tables, or as a group (e.g., lower Snake projects instead of Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) in tables or the text. Table 1-2 may be used as a guide to these acronyms and groupings.

Table 1-2. Project Acronyms and Groupings

Acronym	Common Name	Project Group
BON	Bonneville	Lower Columbia
TDA	The Dalles	
JDA	John Day	
MCN	McNary	
IHR	Ice Harbor	Lower Snake
LMN	Lower Monumental	
LGS	Little Goose	
LWG	Lower Granite	
DWR	Dworshak	Dworshak
PRD	Priest Rapids	Middle Columbia
WAN	Wanapum	
RIS	Rock Island	
RRH	Rocky Reach	
WEL	Wells	
CHJ	Chief Joseph	
GCL	Grand Coulee	
HGH	Hungry Horse	Hungry Horse
LIB	Libby	Libby

1 **CHAPTER 2 - WATER TEMPERATURE MAPPING**

2 **2.1 OVERVIEW**

3 The goal of this effort is to represent water temperature in the forebay (multiple depths) and
4 tailwater at each project in the CRSO domain in the POR. Generally, this was done as follows:

- 5 • Step 1. Develop monthly water temperature regression models at Bonneville Dam in the
6 1972–2018 period.
- 7 • Step 2. Use regression models to estimate monthly Bonneville Dam water temperature in
8 POR and EXT periods.
- 9 • Step 3. Calculate percentiles for model development period (1972–2018; including EXT) and
10 POR period.
- 11 • Step 4. Find closest percentile for each month in EXT that matches to POR percentiles and
12 assign System Model temperature results in the forebay (surface, mid, bottom depths) and
13 tailwater for each month in POR.

14 The regression models allow a comparison of historical monthly water temperatures based on
15 monthly flow and regional air temperature. This methodology assumes that the average
16 residence time in this portion of the Columbia system is about one month.

17 **2.1.1 Development of Water Temperature Regression Models**

18 A series of regression models estimating monthly Columbia River water temperature at
19 Bonneville Dam as a function of monthly air temperature and streamflow were developed to
20 predict water temperature in a historical period (1928–2008 POR) in which minimal water
21 temperature data at Bonneville Dam is available.

22 The best regression fits as determined by the statistical program R (R Core Team 2018)
23 depended on the following data from U.S. Army Corps of Engineers (Corps) Dataquery 2.0
24 (Corps 2018a) (some sourced from U.S. Geological Survey [USGS 2018]):

- 25 • BON-ScrollCase.Temp-Water.Inst.~1Day.0.CBT-RAW, (Daily water temperature at Bonneville
26 Dam)
- 27 • IHR.Flow-Out.Ave.~1Day.1Day.CBT-REV [*IHR*], (Ice Harbor outflow, in cubic feet per second
28 [cfs])
- 29 • PRD.Flow-Out.Ave.~1Day.1Day.CBT-REV [*PDT*], (Priest Rapids outflow, in cfs)
- 30 • BON.Flow-Out.Ave.~1Day.1Day.CBT-REV [*BON_Flow.Out*], (Bonneville outflow, in cfs)

31 Additionally, monthly mean northwest region air temperature data (°F) [named *nwt*] was
32 retrieved from the National Oceanic and Atmospheric Administration (NOAA) National Center
33 for Environmental Information data portal (NOAA 2017). Regression models were developed

34 with BON-scrollcase data 1975–2017. Years with more than 3 months of missing data were
35 removed from the dataset. This led to removal of years 1981–1985 and 1992.

36 Data was transformed as follows:

- 37 • BON_Flow data was inverted: e.g., $BON_Flow.Out.Inv=1/BON_Flow.Out$
- 38 • The ratio of IHR/PDT was used to represent the ratio of Snake River to Columbia River flows
39 upstream of McNary Dam (named IHR_PDT_Ratio): $IHR_PDT_Ratio=IHR/PDT$
- 40 • Inverse flow, flow ratio, and air temperature data (*nwt*) were lagged by 1 and 2 months
41 yielding the following variables (BON_Flow.Out.Inv.L1, BON_Flow.Out.Inv.L2,
42 IHR_PDT_Ratio.L1, IHR_PDT_Ratio.L2, nwt.L1, and nwt.L2)

43 Regression models were developed for each month using the $lm()$ and $stepAIC()$ methods in the
44 statistical software R version 3.3.2 (R Core Team 2018). Table 2-1 shows the model coefficients
45 for each monthly model (empty cells indicate that the term was determined not significant in
46 predicting water temperature in that month). The form of each monthly model equation is as
47 follows:

$$\begin{aligned} 48 \quad BON_{WT} = & \text{(Intercept)} + \\ 49 \quad & c1*BON_Flow.Out.Inv + c2*BON_Flow.Out.Inv.L1 + c3*BON_Flow.Out.Inv.L2 + \\ 50 \quad & c4*IHR_PDT_Ratio + c5*IHR_PDT_Ratio.L1 + c6*IHR_PDT_Ratio.L2 + \\ 51 \quad & c7*nwt + c8*nwt.L1 + c9*nwt.L2 \end{aligned}$$

52 Most monthly regression models depended on the air temperature from the previous 2 months
53 (NWT.L1, NWT.L2). Only January and February equations resulted in a (negative) dependence
54 on air temperature with the current month. These months also had some of the highest error
55 associated with the fit statistics.

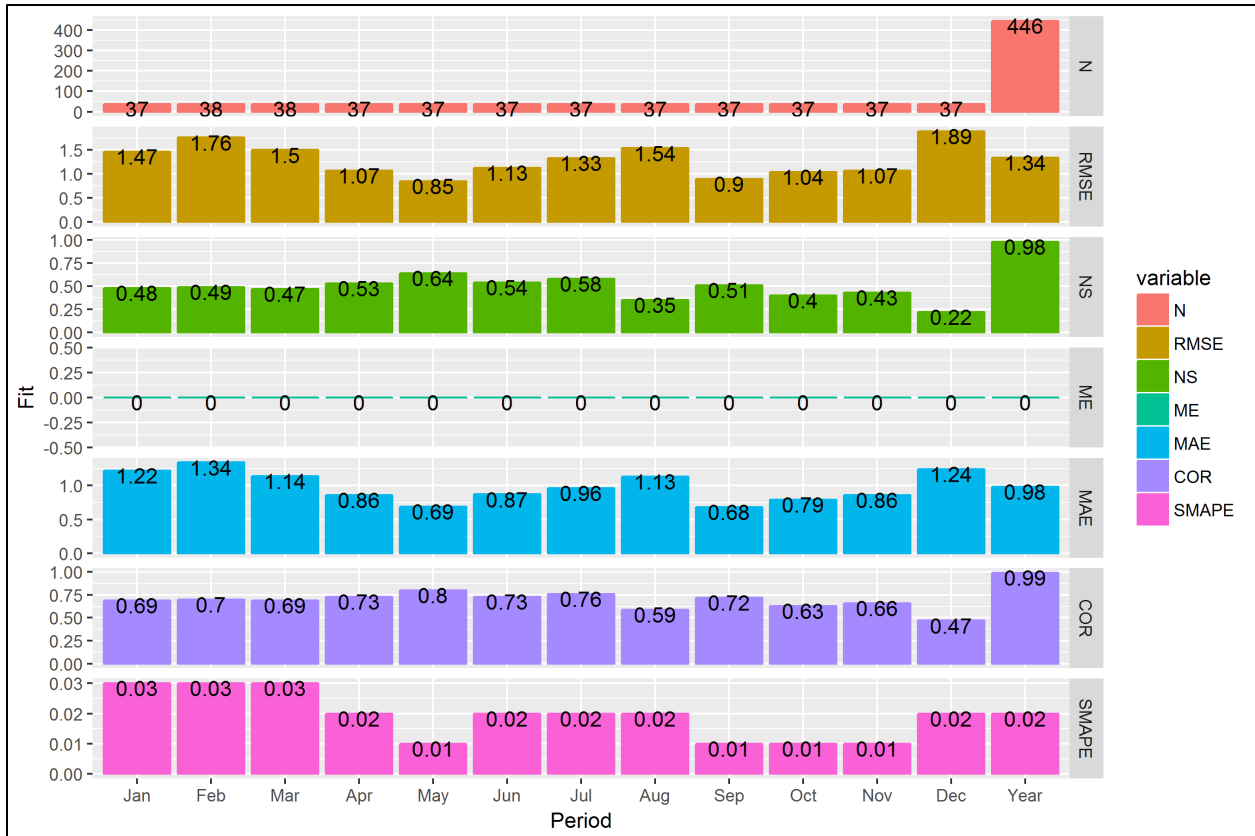
56 While regression equations for most months depended on flow variables, winter (Dec-Feb) and
57 late summer (Jul-Sep) had fewer dependencies, and instead, depended primarily on air
58 temperature. Qualitatively, higher magnitude of flow (BON_Flow.Out.Inv variables) model
59 coefficients (c1, c2, c3) can be associated with a greater dependence to Bonneville flow. In
60 other words, larger positive or negative values in c1, c2, and c3 indicate a greater dependence
61 on Bonneville flow in those months' equations. For example, August water temperature
62 increases as August flow increases ($c1 \sim 6.4E5$), and as July flow decreases ($c2 \sim -4.2E5$).
63 However, the lowest magnitude of these August BON_Flow.Out.Inv coefficients is associated
64 with August (c1), so water temperature in August is more dependent on August flow increases,
65 than July flow decreases. Another example, September, has a relatively minor dependence on
66 flow increases in August (relatively small magnitude c2), but significant coefficient values
67 related to air temperature (c7, c8, and c9). Coefficients of Snake to Columbia River flow
68 variables (c4, c5, c6) were important in most months except for March, Jul, Aug, Sep, and Dec.
69 Negative values associated with these coefficients indicate that water temperatures increase as

70 Snake River flow decreases in comparison to the Columbia River. Future developments of these
71 regression equations could work toward standardizing coefficients across data type, so that
72 relative dependencies between flow and air temperature could be assessed better across
73 months and data types.

74 **Table 2-1. Multiple Linear Regression Coefficients Predicting Monthly Water Temperature at Bonneville Dam**

Month	(Intercept)	c1 BON_Flow. Out.Inv	c2 BON_Flow. Out.Inv.L1	c3 BON_Flow. Out.Inv.L2	c4 IHR_PDT_R atio	c5 IHR_PDT_R atio.L1	c6 IHR_PDT_R atio.L2	c7 nwt	c8 nwt.L1	c9 nwt.L2
Jan	1.24E+01			7.74E+05		-1.11E+01	2.60E+01	2.88E-01	3.41E-01	
Feb	2.69E+01				-4.97E+00			1.53E-01	3.22E-01	
Mar	3.50E+01	8.14E+05	-1.11E+06	6.21E+05					1.97E-01	
Apr	3.22E+01		6.97E+05	-9.05E+05		2.96E+00	-5.64E+00	2.71E-01	1.81E-01	
May	2.80E+01		5.14E+05	-3.59E+05		2.94E+00	-3.44E+00	2.21E-01	2.40E-01	1.36E-01
Jun	3.60E+01	1.11E+06		-3.66E+05	2.65E+00			1.80E-01	2.04E-01	
Jul	3.94E+01		4.91E+05					2.05E-01	2.12E-01	
Aug	4.08E+01	6.40E+05	-4.22E+05					4.24E-01		
Sep	4.24E+01		1.74E+05					2.44E-01	2.73E-01	-1.13E-01
Oct	2.16E+01	-5.50E+05	3.49E+05		6.83E+00			4.13E-01	3.60E-01	
Nov	2.21E+01	8.62E+05	-4.77E+05		-9.96E+00	1.51E+01		2.66E-01	3.72E-01	
Dec	2.62E+01							3.08E-01	2.73E-01	

75



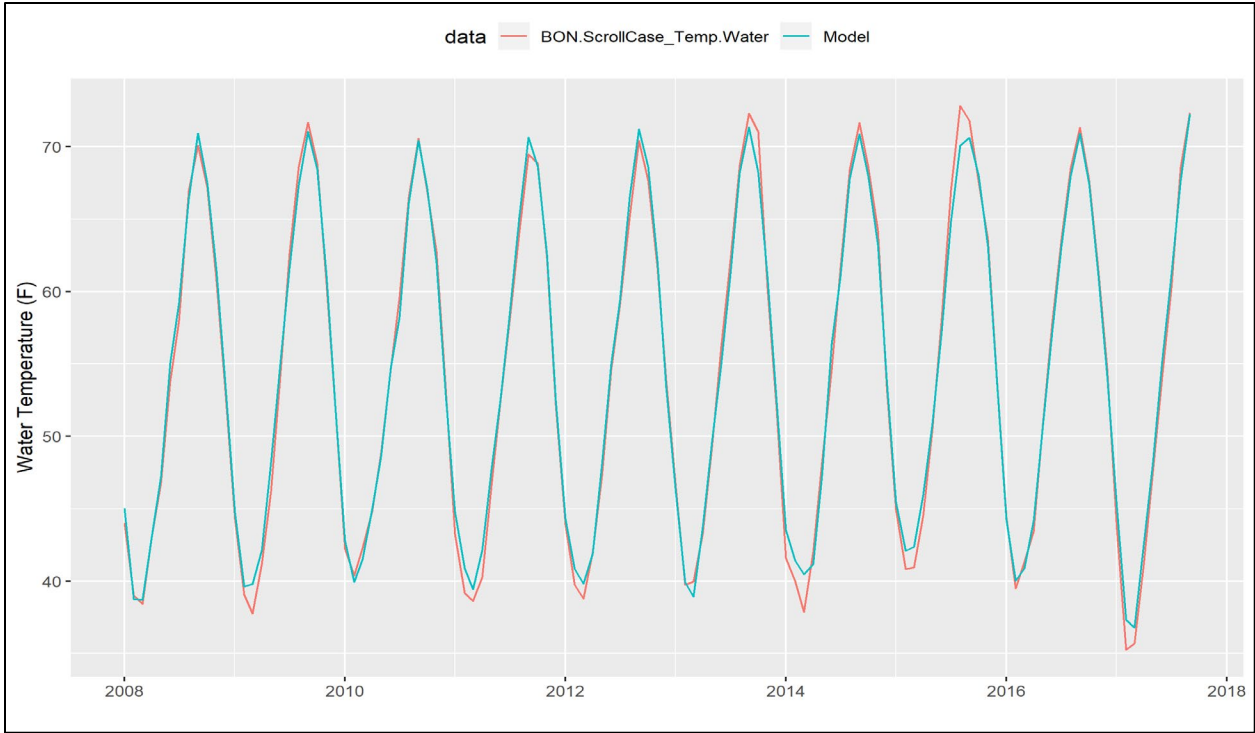
76

77 **Figure 2-1. Monthly Water Temperature Regression Model Fit Statistics**

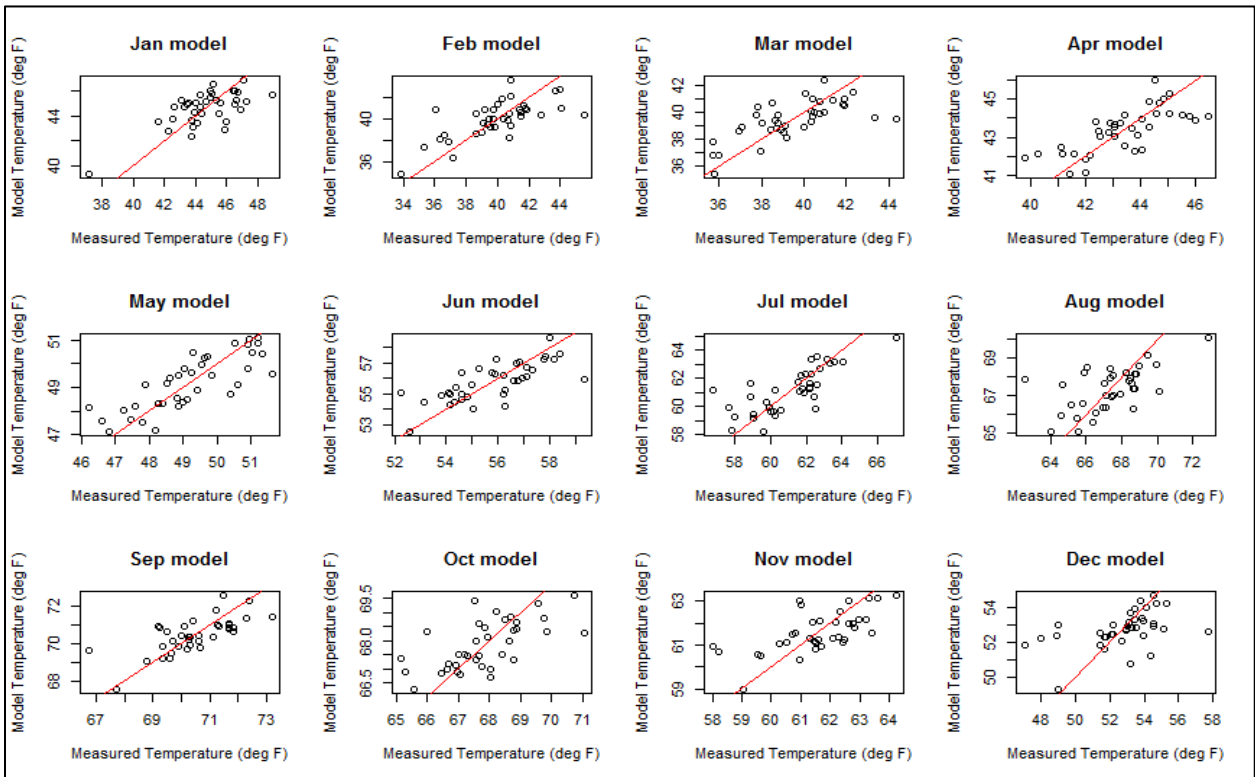
78 Note: N = number of observations, RMSE = root mean squared error, NS = Nash-Sutcliffe error, ME = mean error
79 (°F), MAE = mean absolute error (°F), COR = Pearson correlation coefficient, SMAPE = standard mean absolute
80 percent error.

81 Monthly model fits were calculated and tabulated in Figure 2-1. Monthly fits are generally less
82 than 1.34°F (0.74°C) MAE. Monthly model results were then re-assembled to the model
83 development date range (1975–2017), where an overall MAE value was 0.98 shown in
84 Figure 2-1 in the “Year” column.

85 A time-series comparison of the model and measured data is shown in Figure 2-2. While the
86 extremes in the summer and winter months are not as close of a model fit as spring and fall,
87 the overall trend is a fairly close fit. Scatter plots of each monthly model are shown in
88 Figure 2-3.



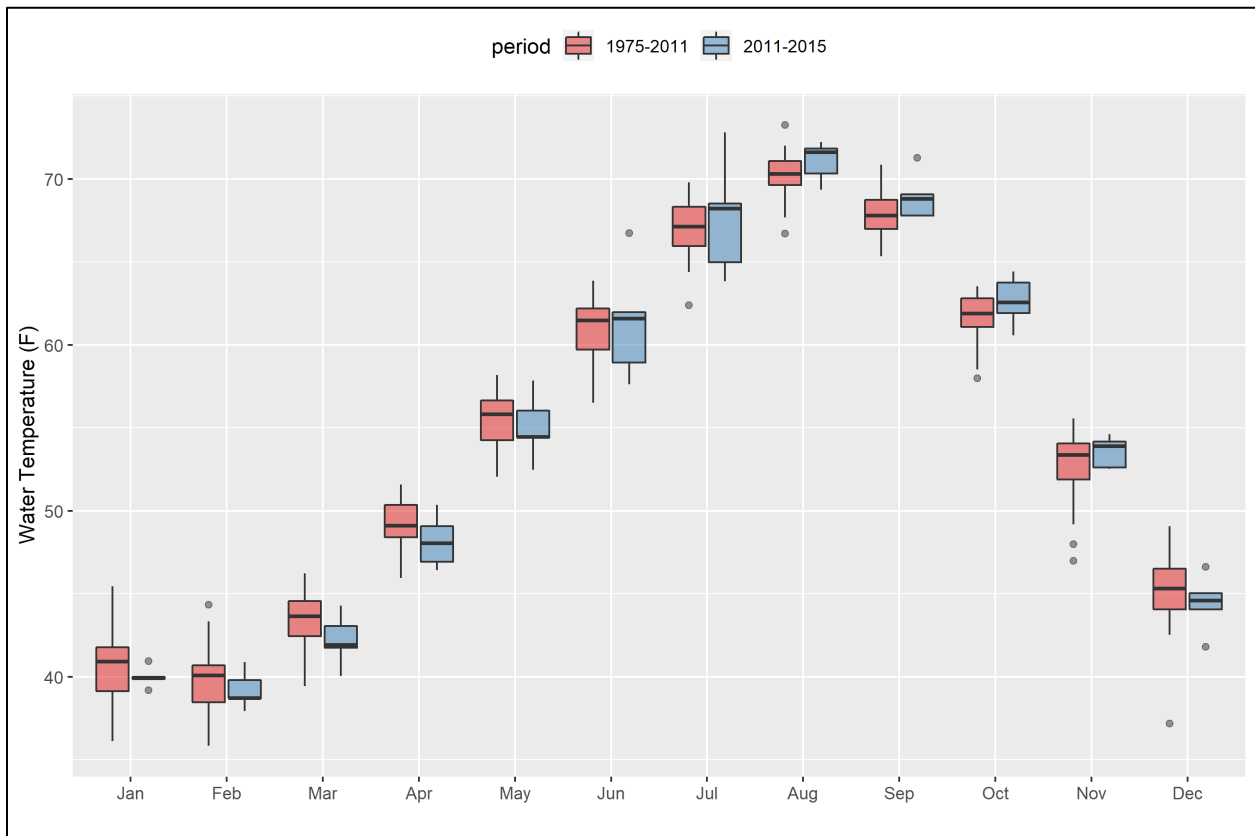
89
 90 **Figure 2-2. Time-series Representation of Measured and Modeled Water Temperature of the**
 91 **Columbia River at Bonneville Dam**



92
 93 **Figure 2-3. Scatter-plot Representation of Measured and Modeled Water Temperature of the**
 94 **Columbia River at Bonneville Dam for each Month**

95 **2.1.2 Estimation of Monthly Bonneville Dam Water Temperature**

96 Prior to applying the regression models to the EXT and POR timeframe for the temperature
97 mapping, the monthly temperature distribution was examined in the model development
98 period (1975–2017) and the two periods in which the percentile mapping occurs (from EXT to
99 POR) (Figure 2-4). The 2011–2015 EXT period is generally within the distribution of the 1928–
100 2008 POR, but shows a smaller variation among years compared to the POR, which could be
101 explained by the fewer number of years in the EXT period. Caution is advised in applying this
102 model over long periods to infer climatic signals, as it is empirically based on the 1975–2017
103 timeframe, which assumes the environmental conditions in that period are stationary and do
104 not change over time. This is likely an inaccurate assumption when applied to multi-decadal
105 timeframes. However, for the purposes of the CRSO EIS, these regression equations provide a
106 snapshot in time and a reference condition with which to compare the alternatives.



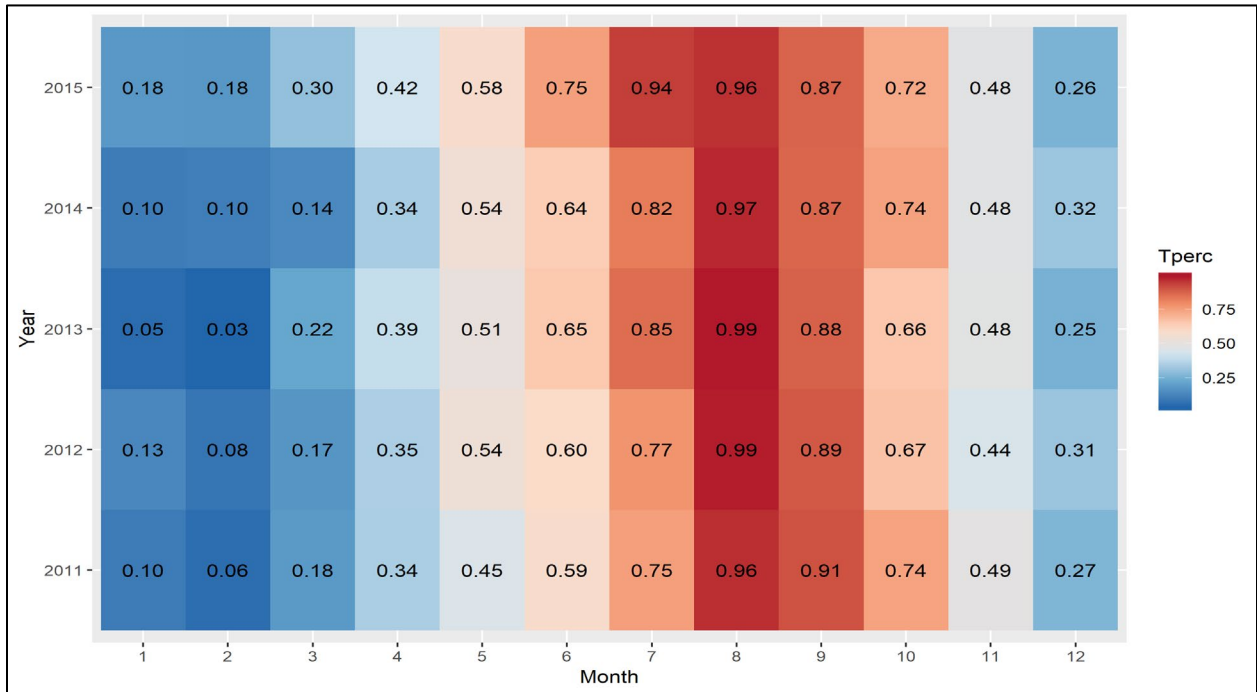
107
108 **Figure 2-4. Monthly Box Plots of Estimated Columbia River Water Temperature at Bonneville**
109 **Dam for Two Timeframes: the Model Development Period (1975–2017) and the EXT Period**
110 **(2011–2015)**

111 Note: Boxes indicate the inner quartile range (25th and 75th percentiles).

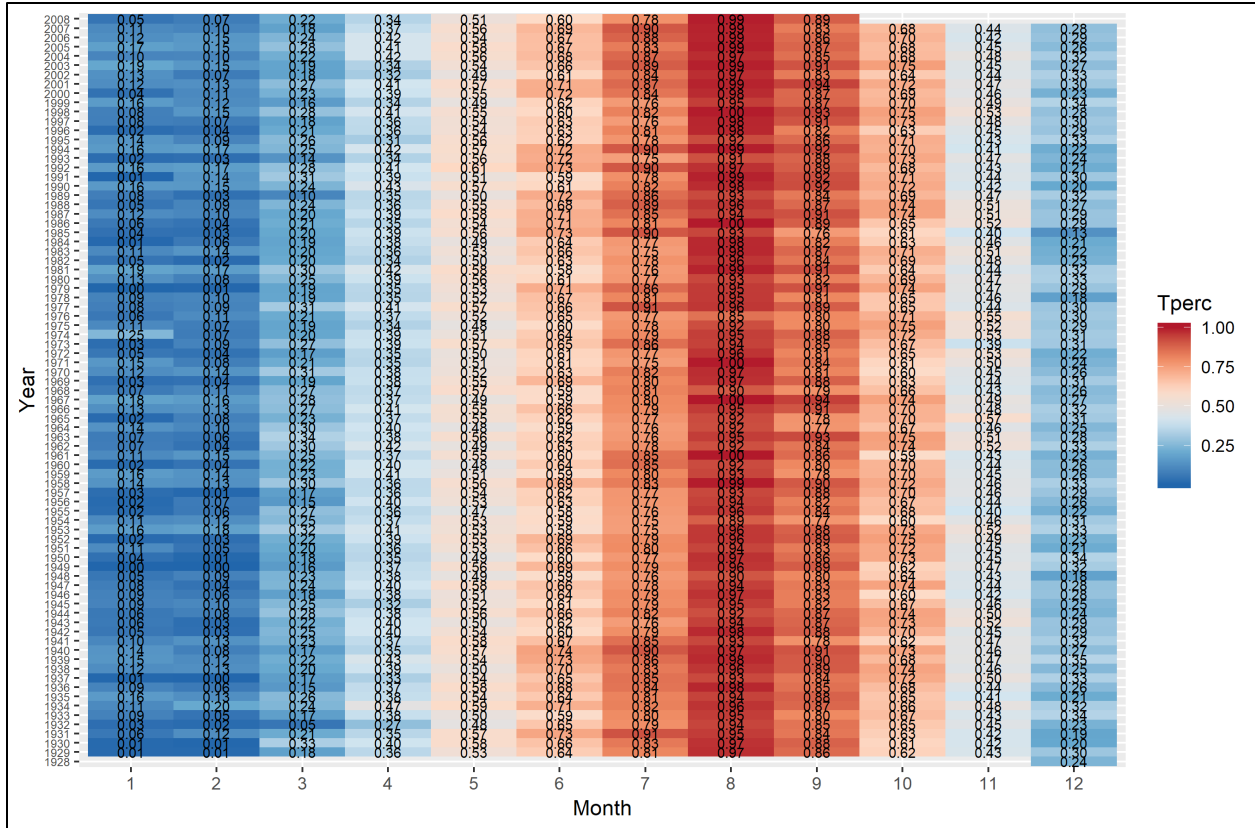
112 **2.1.3 Synthesizing a Historical Period Water Temperature Dataset**

113 Following the development of the monthly water temperature regression models, the
114 percentiles for each month in the present regression model development period (1975–2017)

115 and POR (1928–2008) periods were calculated (Figure 2-5 and Figure 2-6). Percentiles for the
 116 EXT water quality modeling period (2011–2015) were extracted from the regression period in
 117 Figure 2-5. Next, the percentile in each month of the historical period was used to find the
 118 closest-fitting percentile in the water quality modeling period. For example, the percentile for
 119 June 1928 (0.56) was matched to the closest absolute difference in percentile from all of the
 120 June percentiles in the water quality modeling period (0.55 in June 2013). This process was
 121 repeated for each month in the historical period.



122
 123 **Figure 2-5. Colorized Table of Percentiles for the Water Quality Modeling EXT Period (2011-**
 124 **2015), Where Percentiles were Calculated Based on the Regression Period of 1975–2017**



125
126 **Figure 2-6. Colorized Table of Water Temperature Percentiles for the Columbia River System**
127 **Operations Period of Record (1928–2008)**

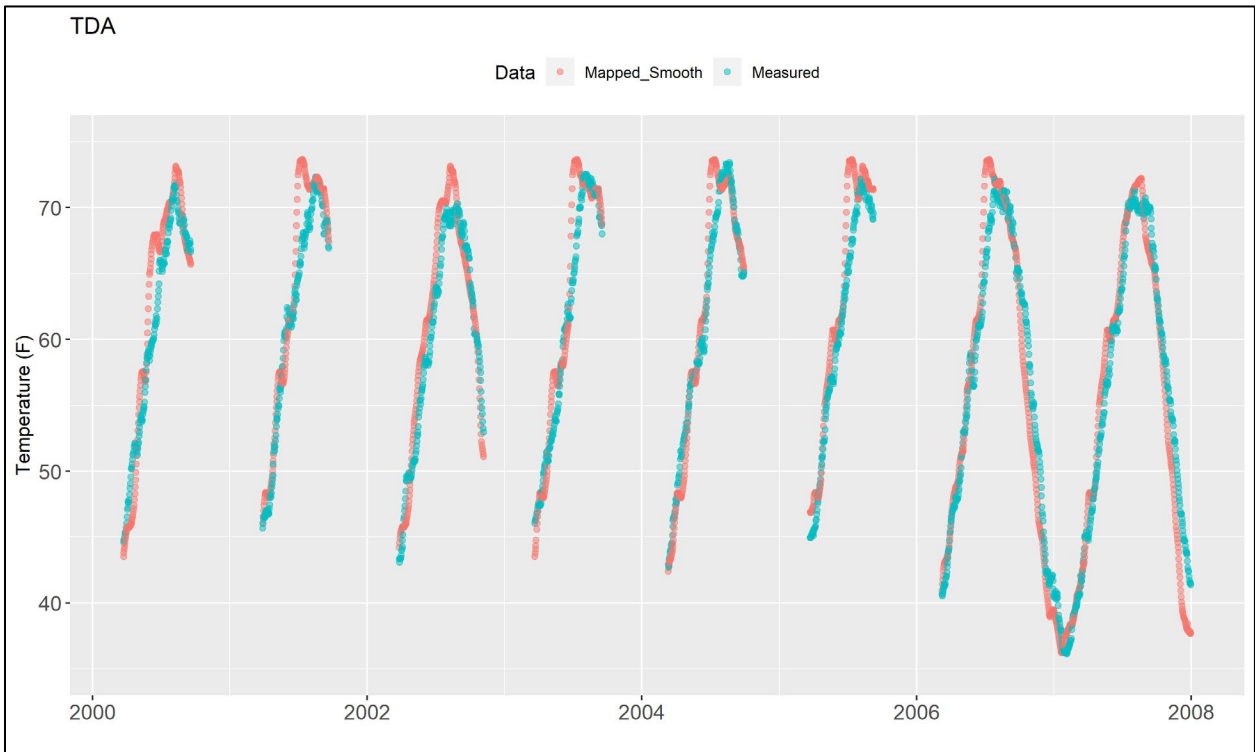
128 **2.1.3.1 Mapped Water Temperature Validation**

129 The mapped data was compared to observations and is shown for Ice Harbor Dam on the Snake
130 River and The Dalles Dam on the Columbia River in Figure 2-7 and Figure 2-8, respectively.
131 Mapped data fits with observations were best on the Snake River and decreased in goodness-
132 of-fit moving downstream in the lower Columbia. Fit statistics were tabulated for each project
133 over the entire year and the spring months (April–June) in Figure 2-9. The mean error (bias) is
134 generally less than 1°F over the entire year, and less than 2°F during the spring. A count of the
135 number of times in which a year was picked for a given month is shown in Figure 2-8.



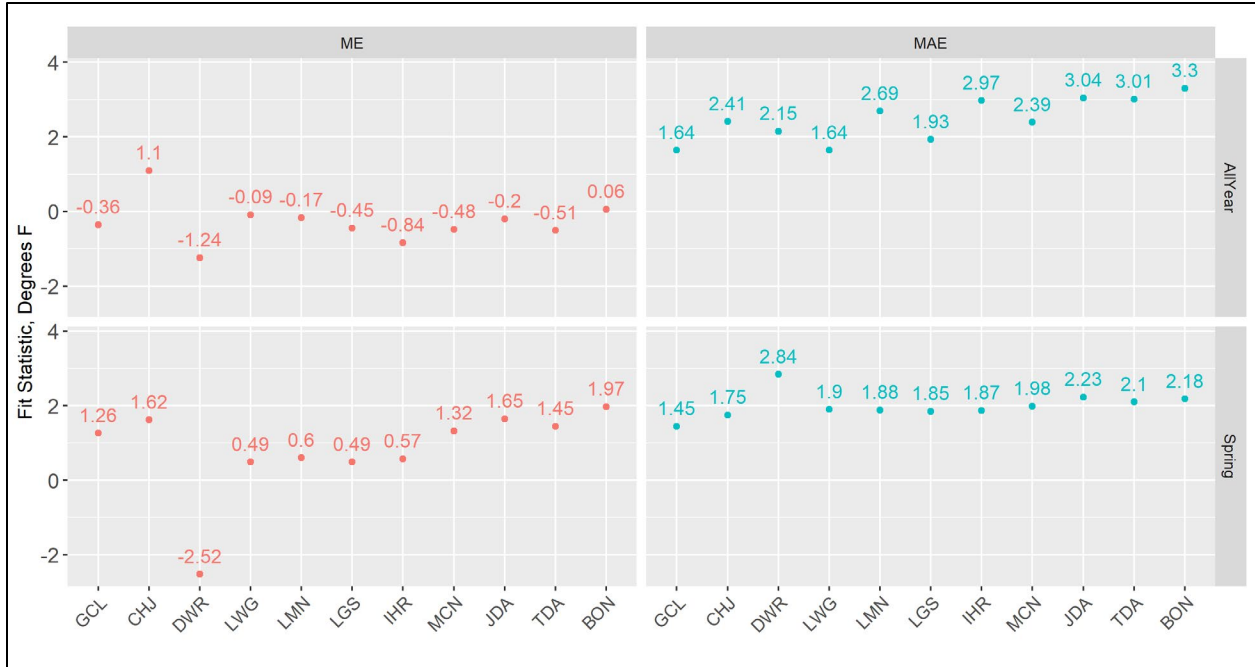
136
137
138

Figure 2-7. Mapped Water temperature Data Comparison to Measurements Downstream of Ice Harbor Dam on the Snake River



139
140
141

Figure 2-8. Mapped Water Temperature Data Comparison to Measurements Downstream of The Dalles Dam on the Columbia River



142
 143 **Figure 2-9. Fit Statistics of Mapped Data Compared to Observations (2008–2017) for the**
 144 **Entire Year and Spring for Each Project in the CRSO Model Domain**
 145 Note: ME = mean error, MAE = mean absolute error, AllYear = entire year, Spring = April to June.

146

CHAPTER 3 - TOTAL DISSOLVED GAS ESTIMATIONS

147 3.1 METHODS

148 TDG was estimated under each MO at Grand Coulee, Chief Joseph, Dworshak, Lower Granite,
149 Lower Monumental, Little Goose, Ice Harbor, McNary, John Day, The Dalles, and Bonneville
150 Dams for the 1928–2008 period using the equations and parameters within the CE-QUAL-W2
151 models and those calibrated for SYSTDG-Lite (Corps 2018b). These equations calculate
152 downstream tailwater and forebay TDG below each dam based on the variables shown in
153 Table 3-1.

154 **Table 3-1. Data Variables Used to Compute Tailwater and Downstream Forebay Total**
155 **Dissolved Gas at Selected Dams within the CRSO Water Quality Model Domain**

Predictor Variables	Source	Averaging Timestep	Used for Tailwater TDG	Used for Downstream Forebay TDG
Spill Flow, Power Flow	H & H operation modeling	Daily	X	
Tailwater Elevation	H & H operation modeling	Daily	X	
Total Flow	H & H operation modeling	Daily		X
Forebay Elevation	H & H operation modeling	Daily		X
Barometric Pressure	Long-term observations	Monthly	X	X
Wind Speed, Degassing Rate	Long-term observations	Monthly		X
Spill Pattern	Long-term observations	Monthly	X	
Tailwater Temperature, Downstream Forebay Temperature	Water quality simulation and mapped to POR	Daily		X
Upstream TDG	SYS-TDG-Lite estimates	Daily	X	X

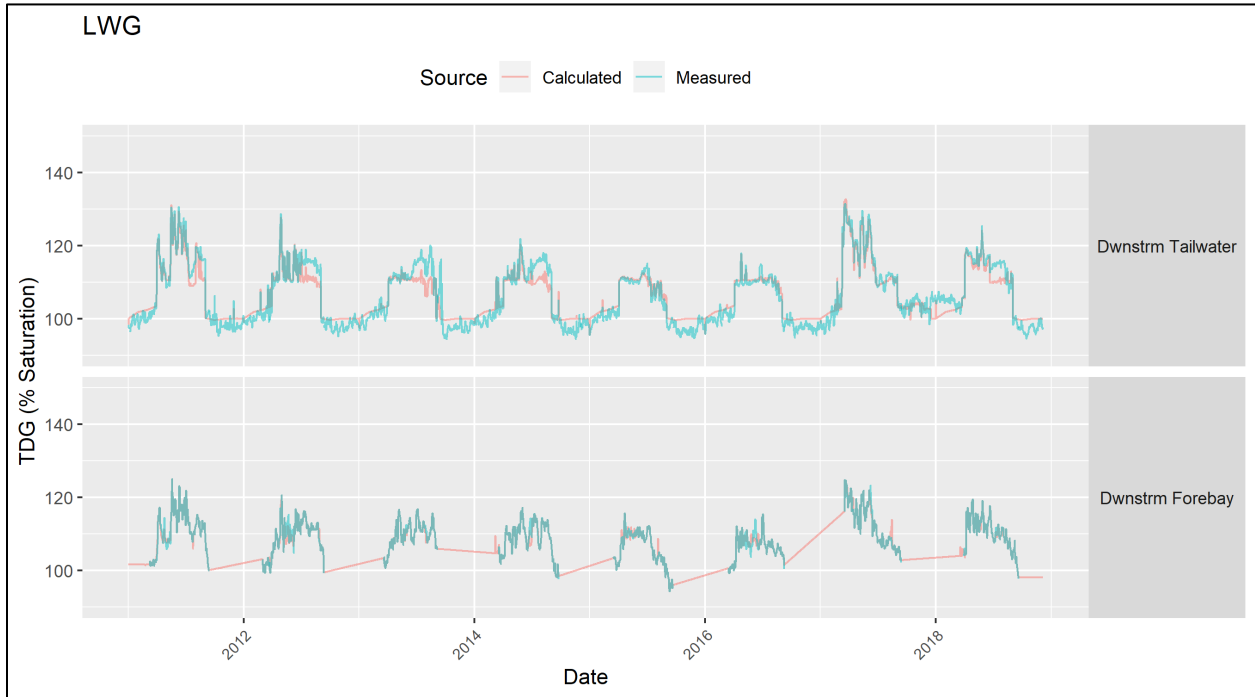
156 Tailwater TDG was based on the upstream forebay TDG (estimated from long-term monthly
157 average observations at Dworshak and Grand Coulee), total spill, total flow, forebay elevation,
158 tailwater elevation, and long-term monthly average barometric pressure. Downstream forebay
159 TDG was primarily based on a monthly average degassing rate for each reservoir and is used to
160 calculate the downstream forebay TDG, which is then used to calculate tailwater TDG at the
161 next dam downstream (Corps 2019). The upstream TDG in Grand Coulee, Dworshak, and Lower
162 Granite forebays was assumed to be the long-term historical monthly average forebay TDG.
163 TDG through the middle Columbia dams between Chief Joseph and McNary was not altered,
164 but simply passed downstream from Chief Joseph to McNary. For degassing within the McNary
165 Reservoir, the upstream TDG was assumed as follows:

166
$$TDG_{MCN_usMix} = \frac{TDG_{HNF} * Q_{HNF} + TDG_{IHR} * Q_{IHR}}{Q_{HNF} + Q_{IHR}}$$

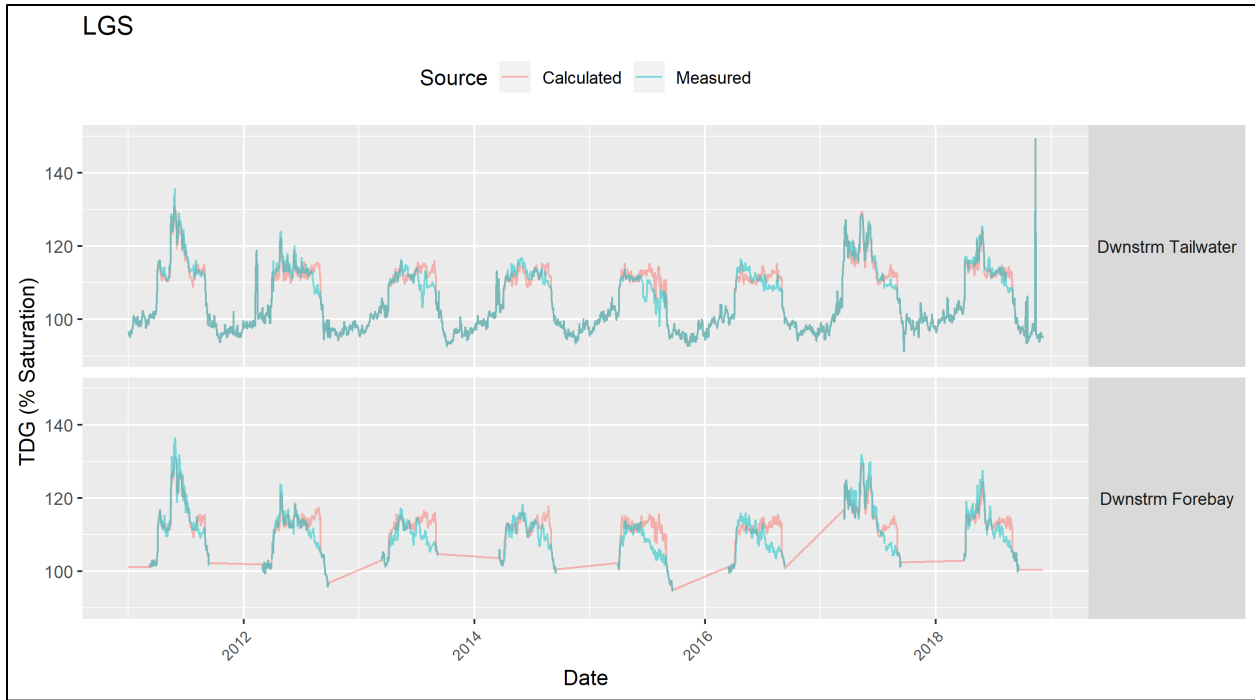
167 where Q_{IHR} = total flow from Ice Harbor (from H & H modeling), Q_{PRD} = total flow from Priest
168 Rapids Dam (from H & H modeling), TDG_{HNF} = long-term monthly average TDG at the Hanford
169 Reach, TDG_{IHR} = Ice Harbor Dam tailwater TDG (from SYSTDG methods), TDG_{MCN_usMix} =

170 mixed total dissolved gas upstream of the McNary Reservoir. Only total flow, water
171 temperature, and TDG from the Hanford Reach was used in the McNary Reservoir. Following
172 some comparisons of forebay TDG to historical observations in 2011–2018 (Figure 3-1–
173 Figure 3-8), wind speed was multiplied by 2.5 in the McNary and John Day Reservoirs and by 3
174 in The Dalles Reservoir to better estimate the degassing occurring in each of those reservoirs.

175 The following figures were used to check the TDG estimates against measurements at each
176 project in the lower Snake and lower Columbia Rivers for the No Action Alternative.

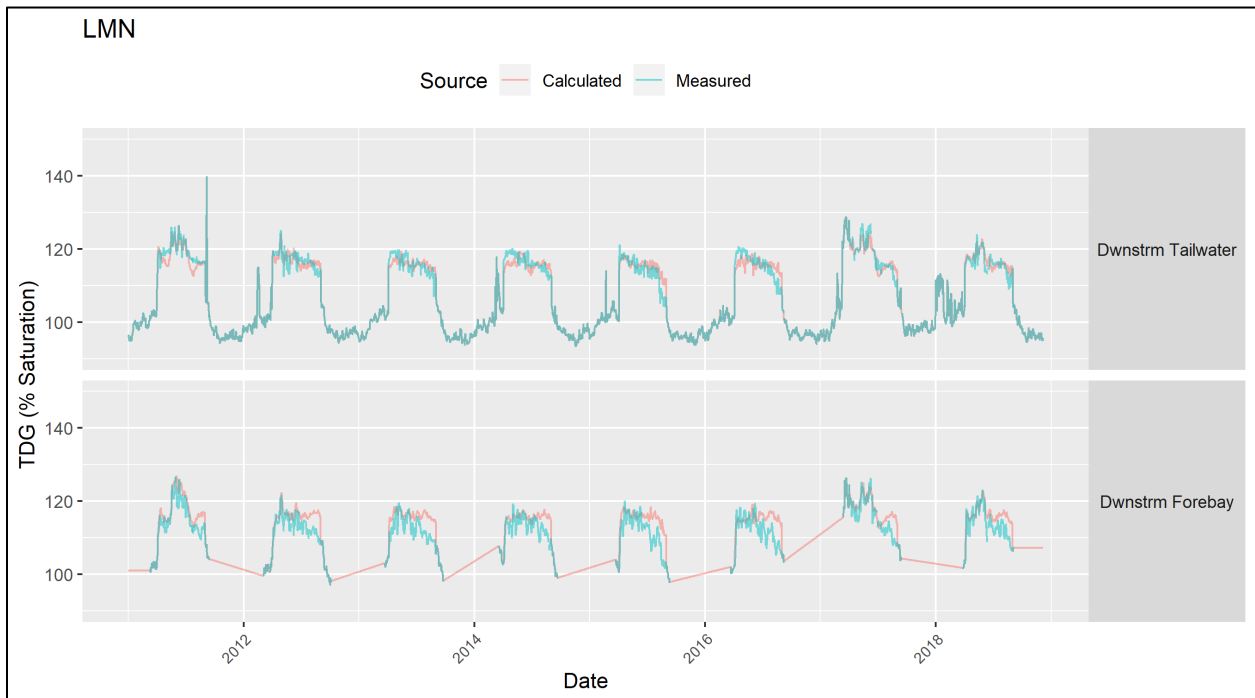


177
178 **Figure 3-1. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas**
179 **below Lower Granite Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas**
180 **in Little Goose Dam**



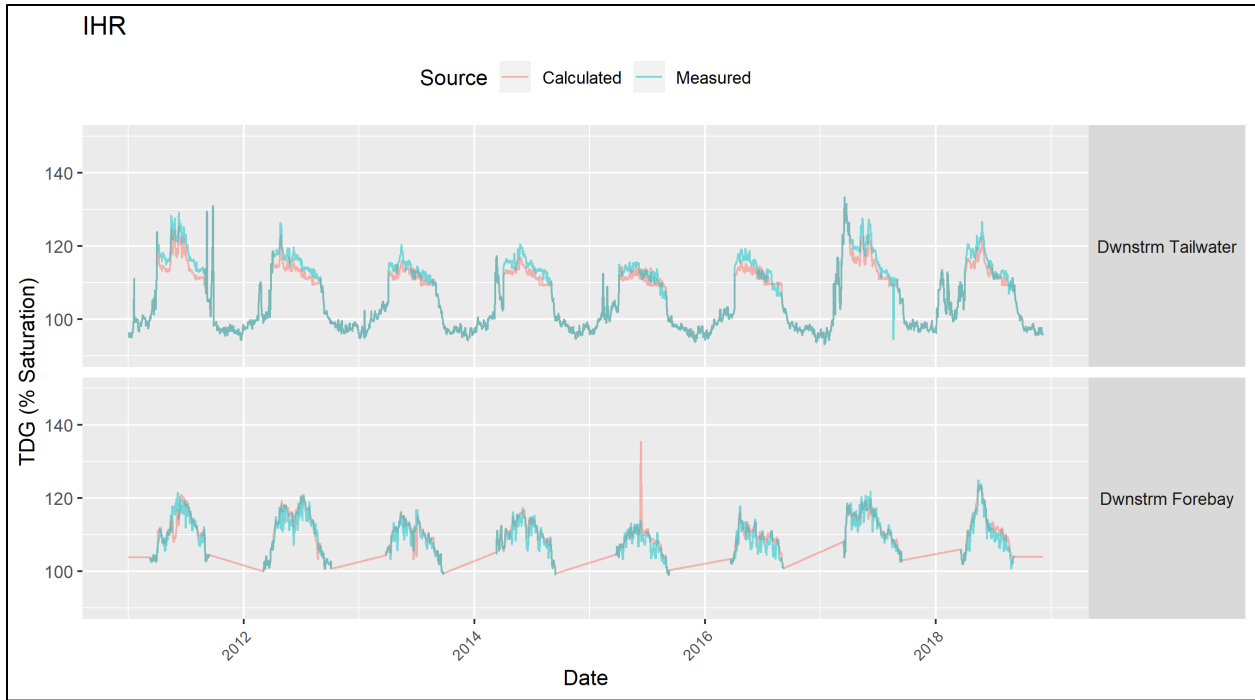
181
182
183
184

Figure 3-2. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas below Little Goose Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in Lower Monumental Dam



185
186
187
188

Figure 3-3. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas below Lower Monumental Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in Ice Harbor Dam



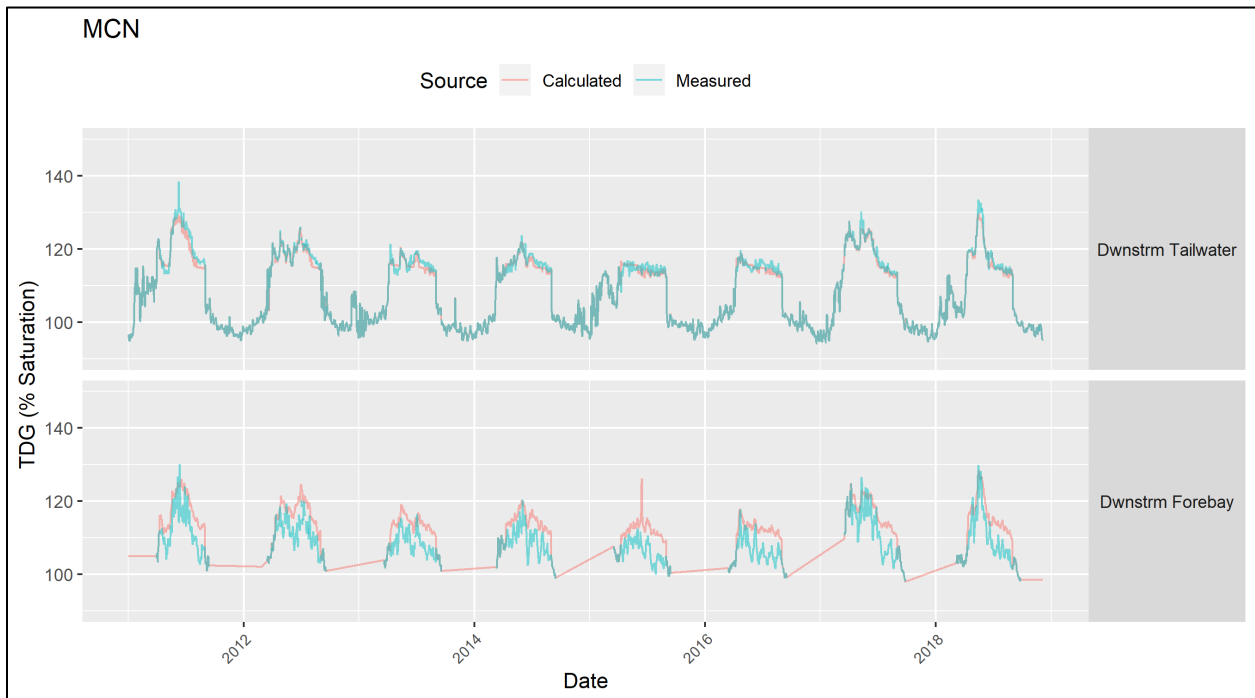
189

190

191

192

Figure 3-4. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas below Ice Harbor Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in McNary Dam



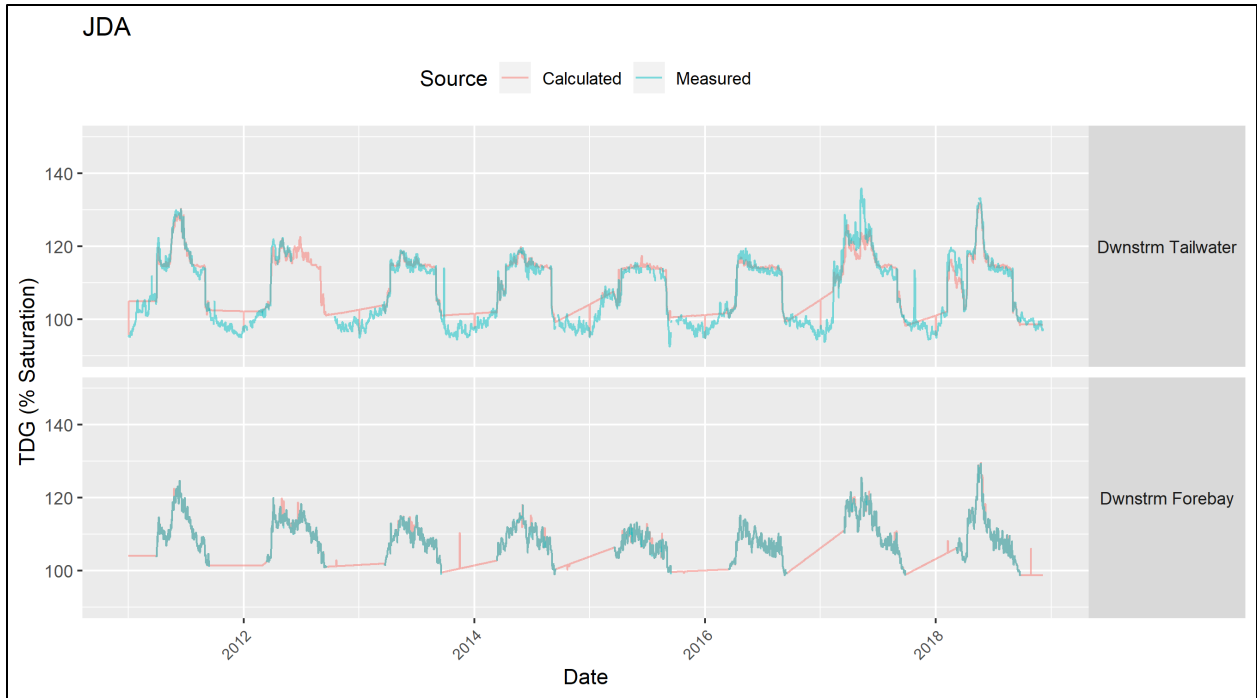
193

194

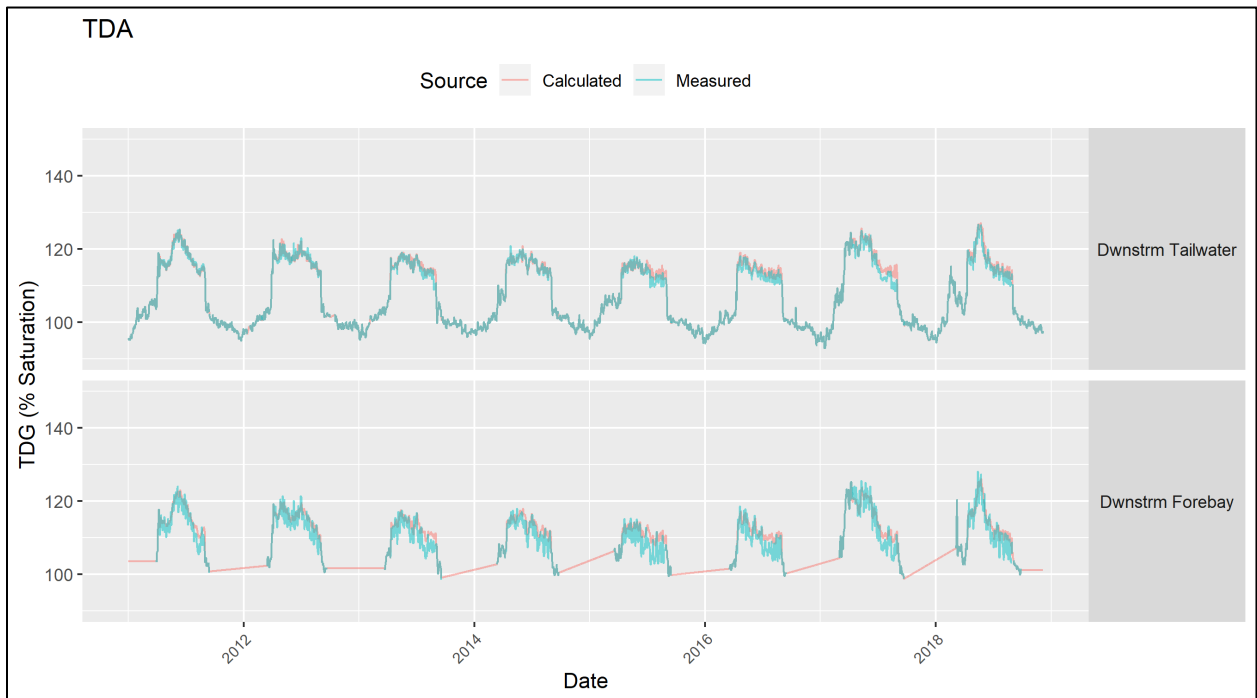
195

196

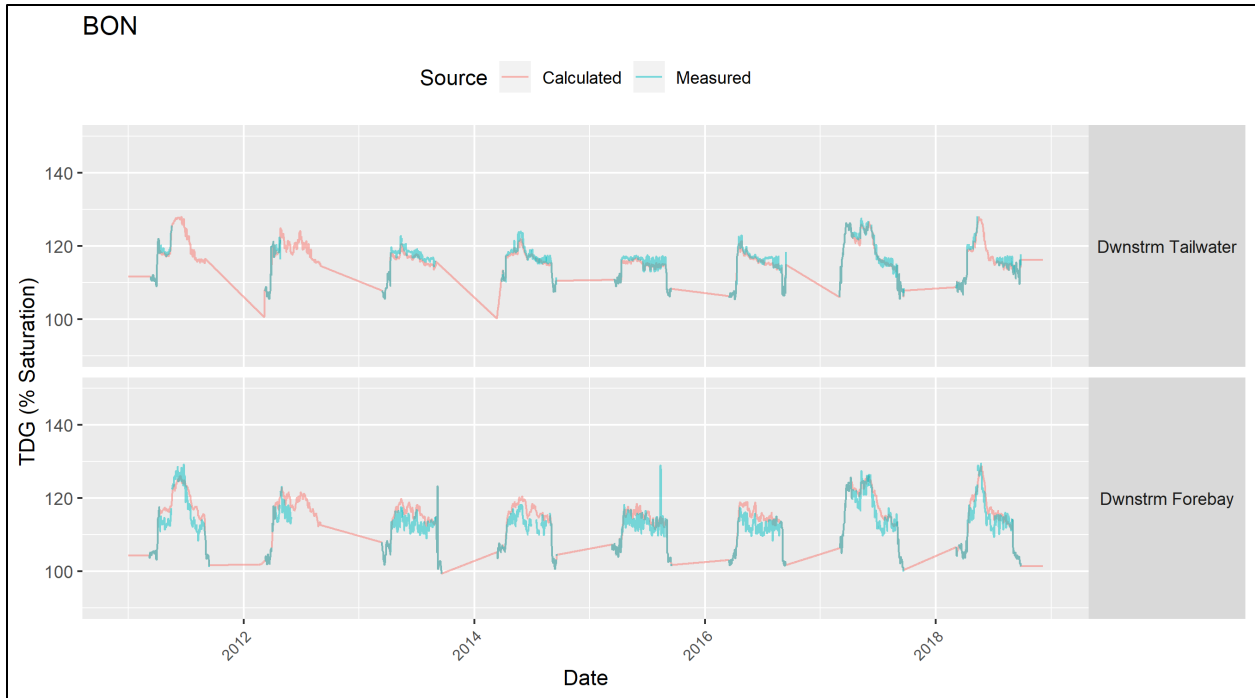
Figure 3-5. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas below McNary Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in John Day Dam



197
198 **Figure 3-6. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas**
199 **below John Day Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in**
200 **The Dalles Dam**



201
202 **Figure 3-7. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas**
203 **below The Dalles Dam and Downstream Forebay (Dwnstrm Forebay) Total Dissolved Gas in**
204 **Bonneville Dam**



205
206 **Figure 3-8. Observed and Calculated Tailwater (Dwnstrm Tailwater) Total Dissolved Gas**
207 **below Bonneville Dam and Total Dissolved Gas at Warrendale (Dwnstrm Forebay)**

208 **3.1.1 Spill Patterns**

209 Spill patterns were used to estimate the distribution of flow among the various spillbays
210 throughout the year with varying amounts of total spill flow. Spill pattern changes can lead to
211 changes in TDG as measured at the gage below the dam. SYSTDG-Lite is a model developed for
212 real-time management of the Columbia-Snake River dissolved gas concentrations (Corps
213 2018b). The equations from SYSTDG-Lite were used in the CRSO project to estimate TDG
214 downstream of each project. The following logic was used to assign spill patterns to each
215 project when calculating tailwater TDG in the specific month of interest.

216 Lower Granite Dam:

- 217 • If the number of the month is [1,2,3,9,10,11,12], use “No RSW” patterns
- 218 • If the number of the month is [4,5,6], use “Spring Spill Patterns with RSW”
- 219 • If the number of the month is [7,8]:
 - 220 ○ At total flow \geq 30 thousand cubic feet per second (kcfs), use “Summer Spill Patterns with
 - 221 RSW”
 - 222 ○ At total flow $<$ 30 kcfs, use “Spill Patterns with No RSW”

223 Little Goose Dam:

- 224 • If the number of the month is [1,2,3,9,10,11,12], use “Spill Patterns with No ASW”

- 225 • If the number of the month is [4, 5, 6]:
- 226 ○ At total flow \leq 85 kcfs, use “Spill Patterns with ASW-Hi”
- 227 ○ At total flow $>$ 85 kcfs, use “Spill Patterns with ASW-Lo”
- 228 • If the number of the month is [7, 8]:
- 229 ○ At total flow \geq 35 kcfs, use “30% Spill Patterns with ASW in High Crest”
- 230 ○ At total flow $<$ 35 kcfs, use “30% Spill Patterns with No ASW”
- 231 Lower Monumental Dam_uniform:
- 232 • If the number of the month is [1,2,3,9,10,11,12], use “Spill Patterns with No RSW”
- 233 • If the number of the month is [4, 5, 6, 7, 8]: use “Uniform Spill Patterns with RSW”
- 234 Lower Monumental Dam_bulk:
- 235 • If the number of the month is [1,2,3,9,10,11,12], use “Spill Patterns with No RSW”
- 236 • If the number of the month is [4, 5, 6, 7, 8]: use “Bulk Spill Patterns with RSW”
- 237 Ice Harbor Dam:
- 238 • If the number of the month is [1,2,3,9,10,11,12], use “Spill Patterns with No RSW”
- 239 • If the number of the month is [4, 5, 6], use “Spill Patterns with RSW”
- 240 • If the number of the month is [7, 8]:
- 241 ○ At total flow \geq 30 kcfs, use “Spill Patterns with RSW”
- 242 ○ At total flow $<$ 30 kcfs, use “Spill Patterns with No RSW”
- 243 McNary Dam:
- 244 • If the number of the month is [0,1,2,3,6,7,8,9,10,11,12], use “No TSWs” patterns
- 245 • If the number of the month is [4,5], use “With TSWs” patterns
- 246 John Day Dam:
- 247 • If the number of the month is [0,1,2,3,9,10,11,12], use “No TSWs” patterns
- 248 • If the number of the month is [4,5,6,7,8], use “With TSWs” patterns
- 249 The Dalles Dam:
- 250 • Always use “Juvenile Fish Passage at 40% of Total Project Outflow”

251 Bonneville Dam:

- 252 • Always use the one published spill pattern

253 Chief Joseph Dam:

- 254 • Always use “Center First” spill pattern.

255 Grand Coulee Dam:

- 256 • Drum gate and outlet tube, always use a uniform pattern

257 **3.1.2 Alternative-Specific Details**

258 Some exceptions to the general rules described for the No Action Alternative are as follows:

- 259 • **Multiple Objective Alternative 1:** Two year types were used: Test and Base (see further
260 description in the Spill Analysis [Appendix X], Section 3.3.2, Multiple Objective Alternative 1
261 Spill Operations and Plots). The two year types only affected Lower Monumental Dam,
262 where the spill pattern changed depending on Table 3-2 and Table 3-3.

263 **Table 3-2. Rules Specifying Spill Patterns Used for Lower Monumental Dam in Odd-numbered**
264 **Years for Multiple Objective Alternative 1**

Date	Filename	Flowmin (kcfs)	Flowmax (kcfs)
January 1	LMN_spill_pattern_noSWeirOp.csv	0	9999
April 3	LMN_spill_pattern_bulk.csv	0	65
April 3	LMN_spill_pattern_bulk.csv	65	9999
May 12	LMN_spill_pattern_bulk.csv	0	65
May 12	LMN_spill_pattern_uniform.csv	65	9999
June 21	LMN_spill_pattern_bulk.csv	0	30
June 21	LMN_spill_pattern_uniform.csv	30	9999
September 1	LMN_spill_pattern_noSWeirOp.csv	0	9999

265 **Table 3-3. Rules Specifying Spill Patterns used for Lower Monumental Dam in Even-numbered**
266 **Years for Multiple Objective Alternative 1**

Date	Filename	Flowmin	Flowmax
April 3	LMN_spill_pattern_bulk.csv	0	65
April 3	LMN_spill_pattern_uniform.csv	65	9999
May 12	LMN_spill_pattern_bulk.csv	0	65
May 12	LMN_spill_pattern_bulk.csv	65	9999

*Columbia River System Operations Environmental Impact Statement
Appendix B, Water Quality Methods and Tools*

Date	Filename	Flowmin	Flowmax
June 21	LMN_spill_pattern_bulk.csv	0	30
June 21	LMN_spill_pattern_uniform.csv	30	9999
September 1	LMN_spill_pattern_noSWeirOp.csv	0	9999

- 267 • **Multiple Objective Alternative 2:** This measure specifies unprecedented low spill flow
268 values, in which very limited observations exist to calibrate the SYSTDG-Lite equation
269 parameters. TDG was estimated to be 110 percent when spill flow was at or below the
270 threshold of 50 kcfs at McNary and John Day.
- 271 • **Multiple Objective Alternative 3:** TDG at the lower Snake River projects was assumed to be
272 100 percent due to dam breaches at Lower Granite, Little Goose, Lower Monumental, and
273 Ice Harbor.
- 274 • **Multiple Objective Alternative 4:** Spill patterns that began in April were extended to also
275 include March.

276

CHAPTER 4 - REFERENCES

- 277 Corps (U.S. Army Corps of Engineers) 2018a. Dataquery 2.0, Query Timeseries from Corps
278 Northwestern Division. Accessed April 16, 2018, [http://www.nwd-wc.usace.army.mil/
279 dd/common/dataquery/www/](http://www.nwd-wc.usace.army.mil/dd/common/dataquery/www/).
- 280 _____. 2018b. SYSTDG-Lite parameter estimation, 2011 to 2018. Unpublished technical
281 summary, U.S. Army Corps of Engineers Northwestern Division.
- 282 _____. 2019. Monthly spill total dissolved gas tables documentation, February 4, 2019.
283 Unpublished technical summary, U. S. Army Corps of Engineers Northwestern Division.
- 284 NOAA (National Oceanic and Atmospheric Administration). 2017. NOAA National Centers for
285 Environmental Information, Climate at a Glance: U.S. Time Series, Minimum
286 Temperature. Published October 2017. Accessed October 12, 2017, [http://www.ncdc.
287 noaa.gov/cag/](http://www.ncdc.noaa.gov/cag/)
- 288 R Core Team. 2018. R: A Language and Environment for Statistical Computing. R Foundation for
289 Statistical Computing, Vienna, Austria. <https://www.R-project.org/>
- 290 USGS (U.S. Geological Survey). 2018. National Water Information System: Web Interface.
291 Accessed April 16, 2018, <https://waterdata.usgs.gov/nwis>.



**Draft Columbia River System Operations
Environmental Impact Statement**

Annex C

**Lower Snake River Multiple Objective Alternative 3
Dissolved Oxygen Analysis Report**

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29

Table of Contents

CHAPTER 1 - Lower Snake River Multiple Objective Alternative 3 Dissolved Oxygen Analysis..... 1-1

 1.1 Introduction 1-1

 1.2 Analysis 1-1

 1.2.1 Method 1..... 1-1

 1.2.2 Method 2..... 1-3

 1.3 Conclusion..... 1-10

CHAPTER 2 - References 2-1

List of Figures

Figure 1-1. Time Series Plot of Sediment Flux into Lower Monumental Dam Based on Estimated Suspended Sediment Concentrations 2011 Flows 1-2

Figure 1-2. Habitat (DO concentration) Analysis of the Lower Monumental Reservoir 1-5

Figure 1-3. Range in the Number of Days in which the Volume-weighted Average Dissolved Oxygen Concentration was Below a Given Threshold (Below_DO_Threshold)..... 1-6

Figure 1-4. Lower Monumental Reservoir Habitat (DO) Analysis at Differing Sediment Oxygen Demand Levels (0.1, 0.5, 1.0, and 2.0 g/m²/d)..... 1-8

Figure 1-5. Estimates of Volume Weighted DO Concentrations at the Lower Monumental Dam Headwater Segment (DO-2 [top]) and Forebay Segment (DO-28 [bottom]) 1-9

List of Tables

Table 1-1. Lower Snake River Sediment Data..... 1-7

Table 1-2. Number of Days when the Volume-Weighted Average Dissolved Oxygen Concentration in Lower Monumental Reservoir is Estimated to be Below Selected Criteria..... 1-10

30

Acronyms and Abbreviations

Corps	U.S. Army Corps of Engineers
W2	CE-QUAL-W2
CIN	concentration input
CRSO	Columbia River System Operations
DO	dissolved oxygen
FTU	Formazin Turbidity Units
g/cm ³	grams per cubic centimeter
g/m ² /d	grams per square meter per day
H & H	hydrology and hydraulics
HABTATC	Habitat analysis card in W2
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center River Analysis System
mg/L	milligrams per liter
MO	Multiple Objective Alternative
N ₂	nitrogen
RM	River Mile
SOD	sediment oxygen demand
SSC	suspended solid concentration
TURB	turbidity

31

32 **CHAPTER 1 - LOWER SNAKE RIVER MULTIPLE OBJECTIVE ALTERNATIVE 3**
33 **DISSOLVED OXYGEN ANALYSIS**

34 **1.1 INTRODUCTION**

35 Multiple Objective Alternative 3 (MO3) calls for the drawdown and breaching of the four lower
36 Snake River dams in a 2-year period. In the first year, Lower Granite and Little Goose Dams
37 would be breached, while in the second year Lower Monumental and Ice Harbor Dams would
38 be breached. This analysis focuses on the first year of dam breaching, when it is anticipated that
39 dissolved oxygen (DO) concentrations could be most compromised since few tributaries exist
40 connected to the Lower Monumental Reservoir to counteract the oxygen demand that would
41 be created from the high amounts of suspended sediment released from upstream. Under the
42 second year of breaching, when Lower Monumental and Ice Harbor Dams are breached,
43 significant sediment would be deposited in McNary Reservoir; however, the Columbia River
44 should help to dilute anoxic water flowing downstream from the lower Snake River, lessening
45 the effects in McNary Reservoir.

46 **1.2 ANALYSIS**

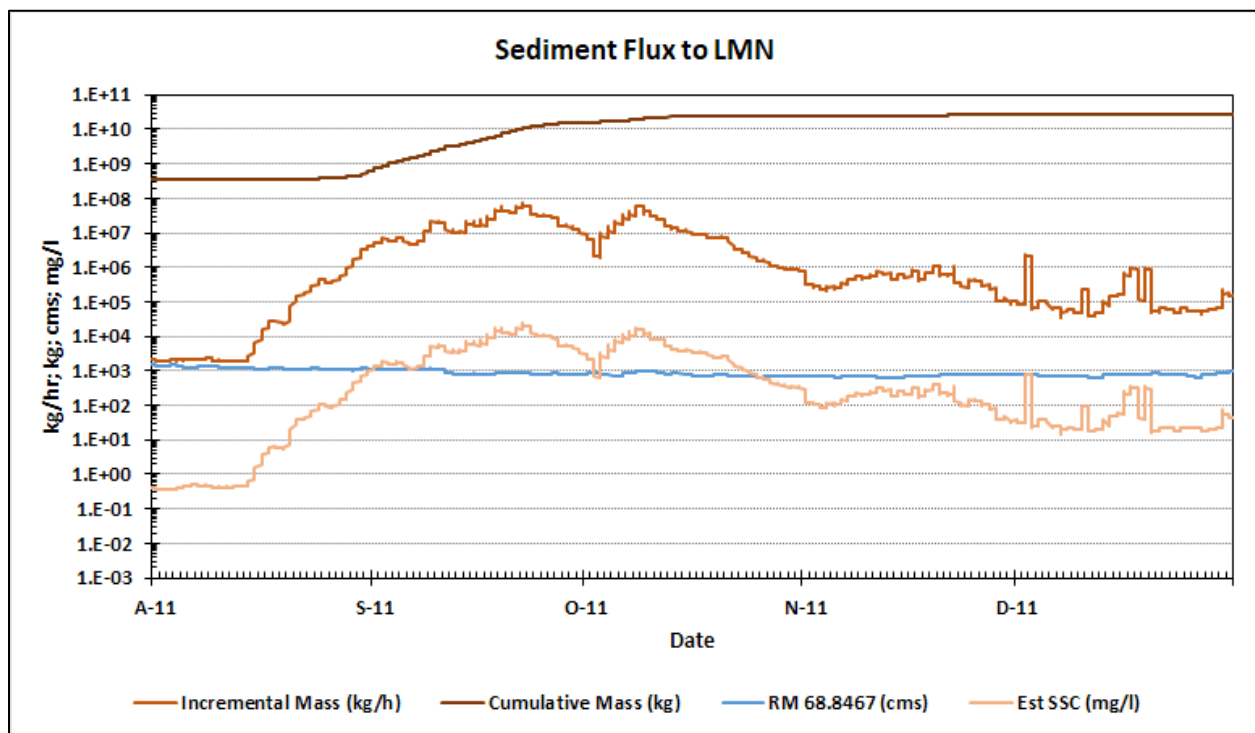
47 To estimate the short-term effects of reservoir drawdown and breaching on DO concentrations,
48 a simplistic modeling approach that focused on Lower Monumental Reservoir was pursued
49 using two methods. The first method was developed using correlations of measured data from
50 Fall Creek Lake, Oregon (USGS, 2019). The second method was based on the mobilization of
51 anoxic pore water and the biochemical oxidation of organic matter associated with deposited
52 and re-mobilized/re-suspended sediments during reservoir drawdown and dam breach. This
53 method assumed sediment oxygen demand (SOD) rates of 0.1, 0.5, 1.0, and 2.0 grams per
54 square meter per day (g/m²/d). These analysis methods are described in further detail below.

55 **1.2.1 Method 1**

56 Using the Lower Monumental CE-QUAL-W2 (W2) model, a method was developed to create an
57 “informed” time series concentration input file (CIN). The W2 model, as constructed, does not
58 model the intricate aspects of DO in the reservoir/system. Instead, the CRSO modeling focus
59 included water temperature and total dissolved gas (nitrogen [N₂] and DO) related to flow/spill
60 rates, reaeration, and meteorological conditions. The CIN file includes DO concentration. A
61 “baseline” CIN representing 100 percent DO saturation was developed using water
62 temperature, and stage from the MO3 S-CW_RAS output at River Mile (RM) 68.8467 (Little
63 Goose Dam), and Little Goose Dam dew point temperature from the lower Snake
64 meteorological input. Initial DO concentrations (100 percent saturation) were then adjusted
65 based on estimated sediment concentrations during the simultaneous drawdown and
66 breaching of Lower Granite and Little Goose Dams.

67 Estimation of movement of stored sediments upstream of Lower Monumental Dam during the
68 drawdown and breach was performed by the H & H River Mechanics team. Estimated
69 suspended sediment concentration (SSC) time series data at the Little Goose site (immediately

70 upstream of Lower Monumental) during drawdown and breach, for a “moderate hydrology”
 71 scenario, was obtained and attributed to 2011 No Action Alternative flows. Estimated elevated
 72 SSC concentrations occur in two distinct pulses related to mobilized sediments during the
 73 drawdown period and during the breaching of dam embankments in the evaluated construction
 74 plan where drawdown occurs August 1 to September 20 and breach occurs October 2 to 9.
 75 Estimated peak SSC concentrations are as high as 24,300 milligrams per liter (mg/L) with
 76 concentrations greater than 5,000 mg/L for 26 days. Assuming a bulk density of 1.5 grams per
 77 cubic meter (g/cm^3), the estimated SSC concentrations, and 2011 flows in the lower Snake
 78 River, approximately 22 million cubic yards of sediment would enter the Lower Monumental
 79 Reservoir in the first 3 months following Lower Granite and Little Goose Dam breachings,
 80 representing approximately 20 percent of all sediments stored upstream from 1934 through
 81 2010 (Figure 1-1).



82
 83 **Figure 1-1. Time Series Plot of Sediment Flux into Lower Monumental Dam Based on**
 84 **Estimated Suspended Sediment Concentrations 2011 Flows**

85 Note: Data is from Little Goose dam site (Hydrologic Engineering Center River Analysis System [HEC-RAS]), and
 86 assumes bulk density of $1.5 \text{ g}/\text{cm}^3$ during drawdown and breach of Lower Granite and Little Goose Dams.

87 Measured data (SSC, DO) downstream of a dam breach is not abundantly available, but data
 88 collected during drawdowns of Fall Creek Lake, OR (2012-13) and ensuing years included SSC,
 89 turbidity, and DO. That raw data was obtained from the USGS gauge, Fall Creek Lake, Oregon
 90 (USGS Gage 14151000, Fall Creek Blw Winberry Creek, Near Fall Creek, OR [USGS, 2019]).
 91 Measured data was then used to develop statistical relationships. A limited dataset of
 92 coincident turbidity (TURB) and SSC data (2017) yielded a linear relationship of $\text{TURB} =$
 93 0.4964SSC ($R^2=0.78$). Coincident DO and TURB data (2012 - 2018) suggested decreasing DO with

94 increasing TURB, although the linear relationship was weak ($DO = -0.0025TURB + 12.03$, $R^2 =$
95 0.05) (DO range: 0.7 to 13.9 mg/l; Turbidity range: 0.1 to 3000 [3000 FTU was maximum
96 possible recorded by the equipment]). An altered LMN CIN file was developed by estimating a
97 time series of TURB from SSC data, then adjusting (reducing) 100% saturation CIN DO time
98 series based on the DO/TURB relationship.

99 The W2 model of LMN was then run with the altered CIN. An additional W2 feature (HABTATC)
100 was employed to aid in quantification of LMN volume meeting selected DO criteria. Model
101 results indicated 80% or greater of whole reservoir volume with DO concentration less than or
102 equal to 2.5 mg/l for about 4 days during the initial SSC pulse, and about 3 days during the
103 secondary SSC pulse. 100% of whole reservoir volume with DO less than 2.5 mg/l occurred for
104 less than 1 day. Using the 5 mg/l DO criterion, during the initial SSC pulse, 80% or greater of the
105 whole reservoir volume had DO concentrations of 5 mg/l or less for about 11 days with about 3
106 days of 100% reservoir volume less than 5 mg/l. During the secondary SSC pulse, 80% or greater
107 of the whole reservoir volume had DO concentrations of 5 mg/l or less for about 6 days, with 4
108 days of 100% reservoir volume less than 5 mg/l. From a spatial perspective, the headwater
109 segment in the LMN model maintained DO concentrations of 2.5 mg/l or less for about 18 days
110 during the initial SSC pulse, and 7 days during the secondary SSC pulse. The segment of the
111 LMN model including the forebay maintained DO concentrations of 2.5 mg/l or less for about
112 10 days during the initial SSC pulse, and about 7 days during the secondary SSC pulse.

113 **1.2.2 Method 2**

114 A second methodology was developed also based on the assumptions of the mobilization of
115 anoxic pore water and the biochemical oxidation of organic matter associated with deposited
116 (and remobilized/resuspended) sediments during water level drawdown and dam breach.
117 Based on river mechanics modeling and the anticipated release of high concentrations of
118 suspended sediment during drawdown and dam breaching, and estimating sediment is mostly
119 composed of silt/clay [83%], the organic material bound to this sediment is assumed to be high.
120 Based on these factors, combined with observations from other systems, the following
121 assumptions were made:

- 122 1) Assume an SOD of the stored sediments ($0.5 \text{ g/m}^2/\text{d}$),
- 123 2) Assume a wet bulk density of the stored sediment (1.5 g/cm^3),
- 124 3) Assume if $SSC > 10 \text{ mg/l}$, 83% of SSC is silt/clay,
- 125 4) Assume 5% of silt/clay fraction is volatile solids/anoxic pore water immediately affecting
126 DO.

127 These conservative parameter estimates were informed using the literature and are cited
128 below.

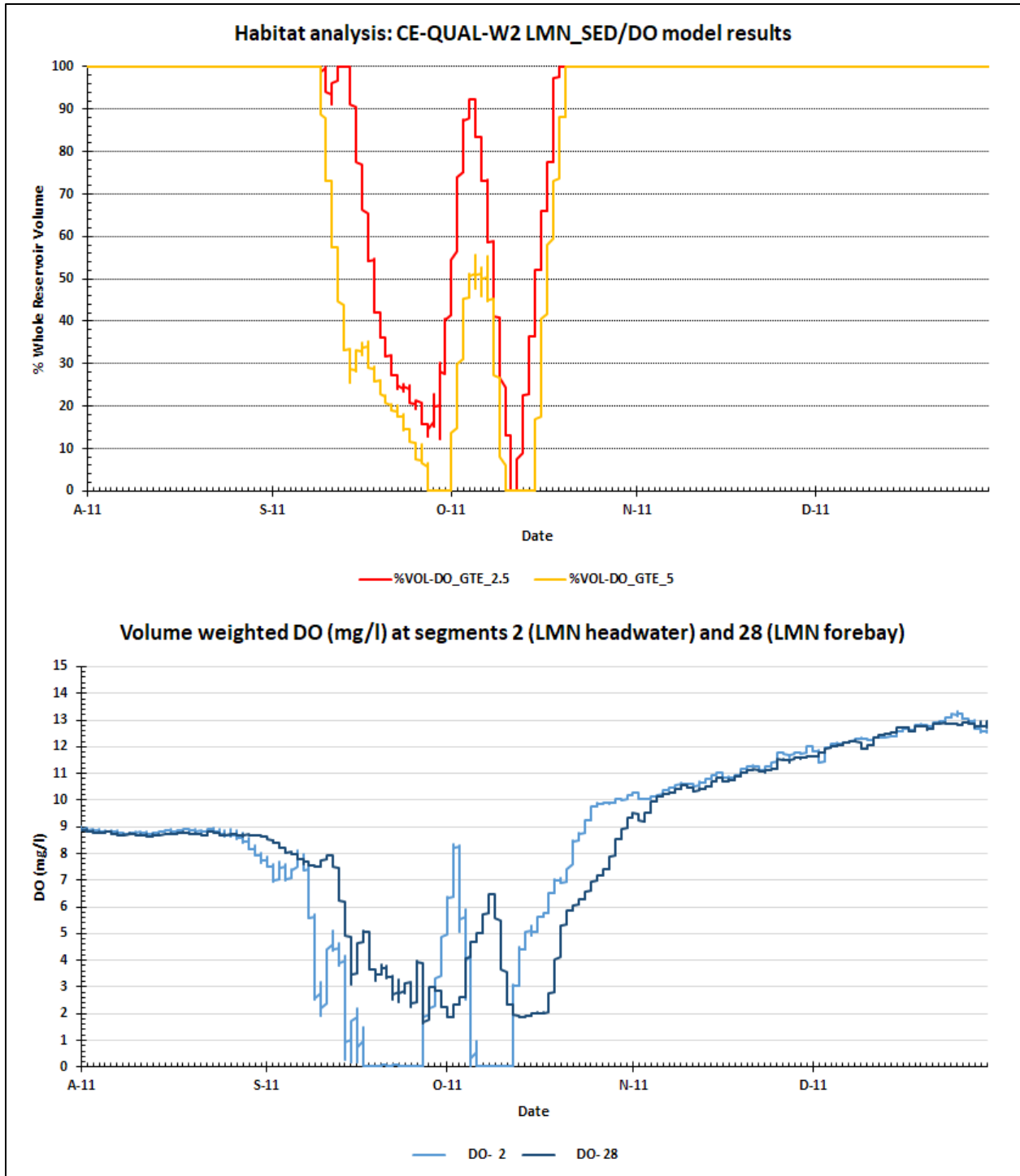
129 Using this methodology, informing a CIN where DO at 100% saturation is reduced based on the
130 above assumptions, resulted in DO concentration effects in LMN during the drawdown and
131 breach very similar to the first method. Model results indicated 80% or greater of whole
132 reservoir volume with DO concentration less than or equal to 2.5 mg/l for about 4 days during
133 the initial SSC pulse, and 3 days during the secondary SSC pulse. 100% of whole reservoir

134 volume with DO less than 2.5 mg/l occurred for about 1 day. Using the 5 mg/l DO criterion,
135 during the initial SSC pulse, 80% or greater of the whole reservoir volume had DO
136 concentrations of 5 mg/l or less for about 11 days with about 3 days of 100% reservoir volume
137 less than 5 mg/l. During the secondary SSC pulse, 80% or greater of the whole reservoir volume
138 had DO concentrations of 5 mg/l or less for about 7 days, with 5 days of 100% reservoir volume
139 less than 5 mg/l. From a spatial perspective, the headwater segment in the LMN model
140 maintained DO concentrations of 2.5 mg/l or less for about 19 days during the initial SCC pulse,
141 and about 7 days during the secondary SSC pulse. The segment of the LMN model including the
142 forebay maintained DO concentrations of 2.5 mg/L or less for about 10 days during the initial
143 SCC pulse, and about 7 days during the secondary SSC pulse (Figure 1-2).

144 A comparison of volume-weighted results from these two approaches is summarized for two
145 model segments/locations, at the head of reservoir and forebay in Lower Monumental
146 Reservoir (Figure 1-3).

147 SOD determinations were completed for several sediment cores collected from the Lower
148 Snake River system in 1997 (Normandeau Associates 1999) and are shown in Table 1-1.
149 Observations made in 1997 correspond reasonably well with sediment composition
150 assumptions made by the H & H river mechanics team (83 percent silt/clay) and the assumed 5
151 percent organic matter component of sediments. Measured 1997 SOD levels were all higher
152 (0.8 to 2.2 g/m²/d) than the estimated 0.5 g/m²/d.

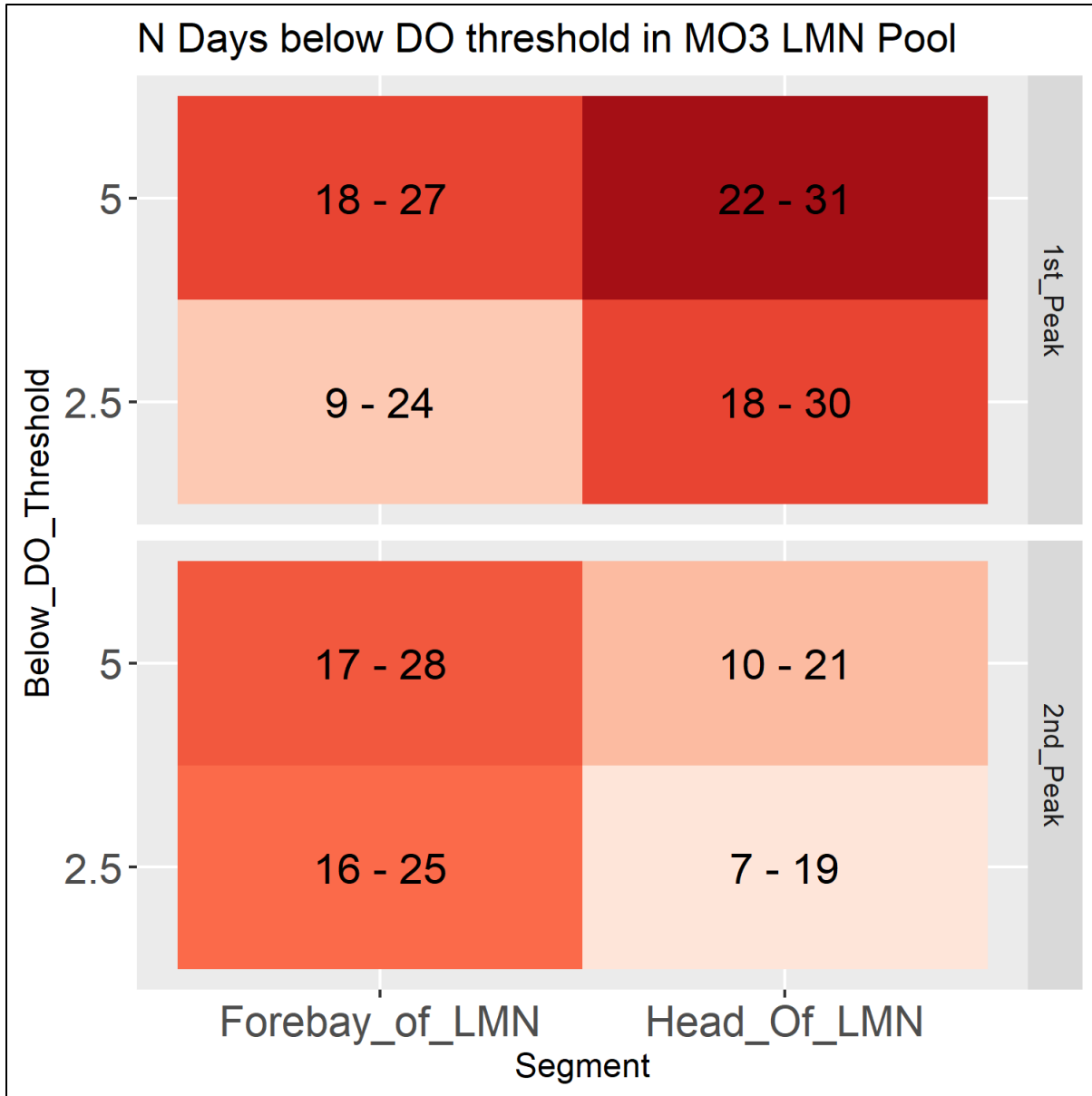
153 To encompass a more complete range of potential DO effects within Lower Monumental
154 Reservoir following upstream dam drawdown and breach, the second method was used to
155 generate CIN files for Lower Monumental at SOD levels of 0.1, 0.5, 1.0, and 2.0 g/m²/d.
156 Although a range of DO concentrations are provided based on a range of SOD levels, SOD, as
157 measured in the lower Snake River in 1997 showed levels in the 1.0 to 2.0 g/m²/d range. That
158 said, the DO effects associated with the 0.5 g/m²/d estimates are likely optimistic, at best,
159 given that 1997 SOD levels were all higher (0.8 to 2.2 g/m²/d). Figure 1-4 indicates significantly
160 diminished volumes of habitable reservoir space of greater duration with increased SOD levels.
161 Similarly, Figure 1-5 shows that with increasing SOD levels, volume weighted DO concentrations
162 in the headwater and forebay segments of Lower Monumental diminish more rapidly, and low
163 concentrations are maintained longer, during and after the drawdown and breach.



164
 165
 166
 167
 168
 169
 170

Figure 1-2. Habitat (DO concentration) Analysis of the Lower Monumental Reservoir

Note: Figures show data during/after drawdown and breach of Lower Granite and Little Goose assuming SOD of 0.5 g/m²/d of the mobilized sediment. Top figure shows percentage of whole reservoir volume greater than or equal to the two selected DO criteria (2.5 [red] and 5 [yellow] mg/L in the period following drawdown and breach. The bottom figure shows volume weighted DO concentrations at the Lower Monumental headwater segment (DO- 2 [light blue]) and the Lower Monumental forebay segment (DO-28 [dark blue]) following drawdown and breach.

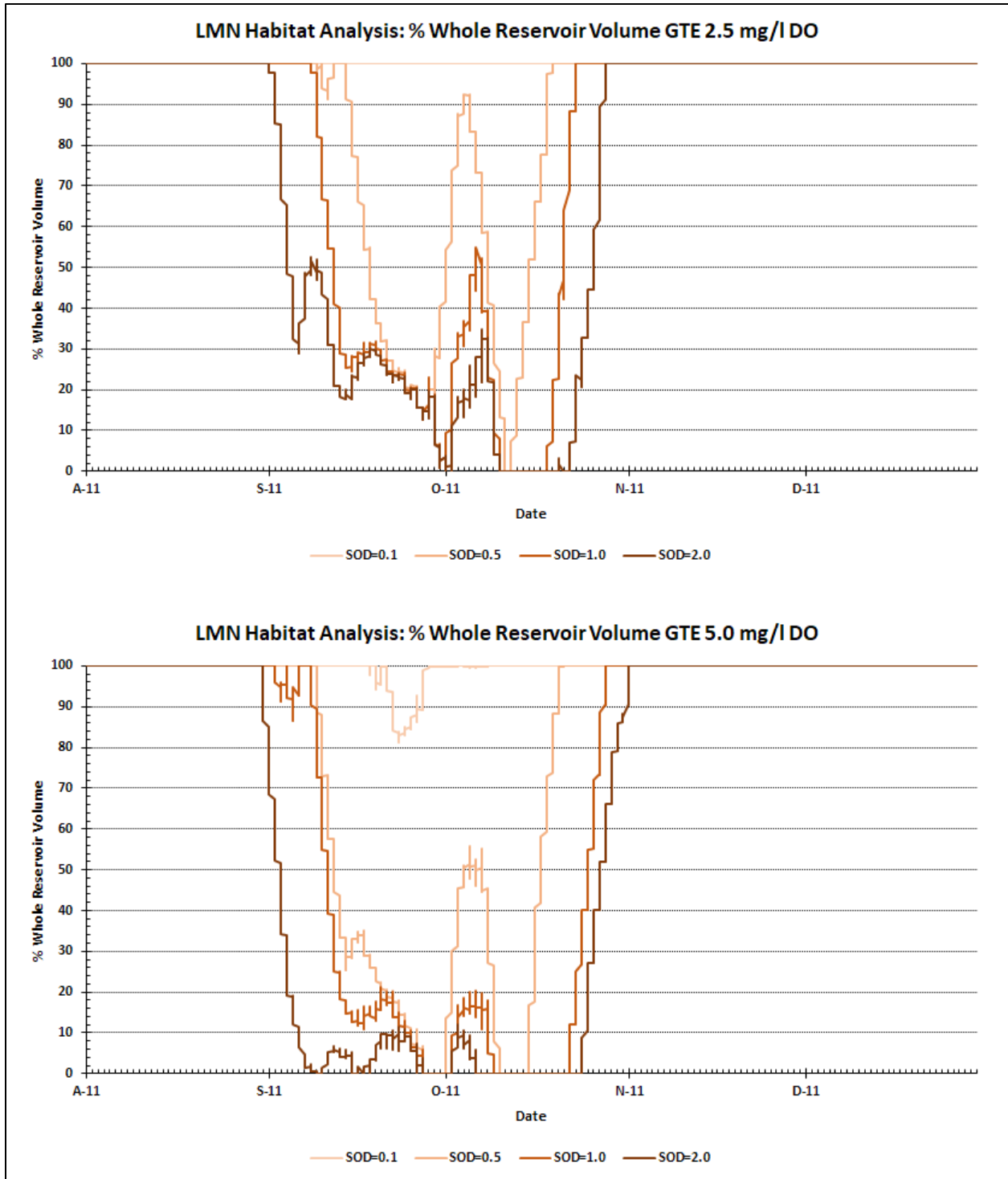


171
 172 **Figure 1-3. Range in the Number of Days in which the Volume-weighted Average Dissolved**
 173 **Oxygen Concentration was Below a Given Threshold (Below_DO_Threshold)**
 174 Note: Data is from during the two peaks in suspended sediment derived from a hypothetical dam breach at two
 175 model segments/locations: at the head of reservoir (Head_Of_LMN) and forebay (Forebay_of_LMN) in Lower
 176 Monumental Reservoir

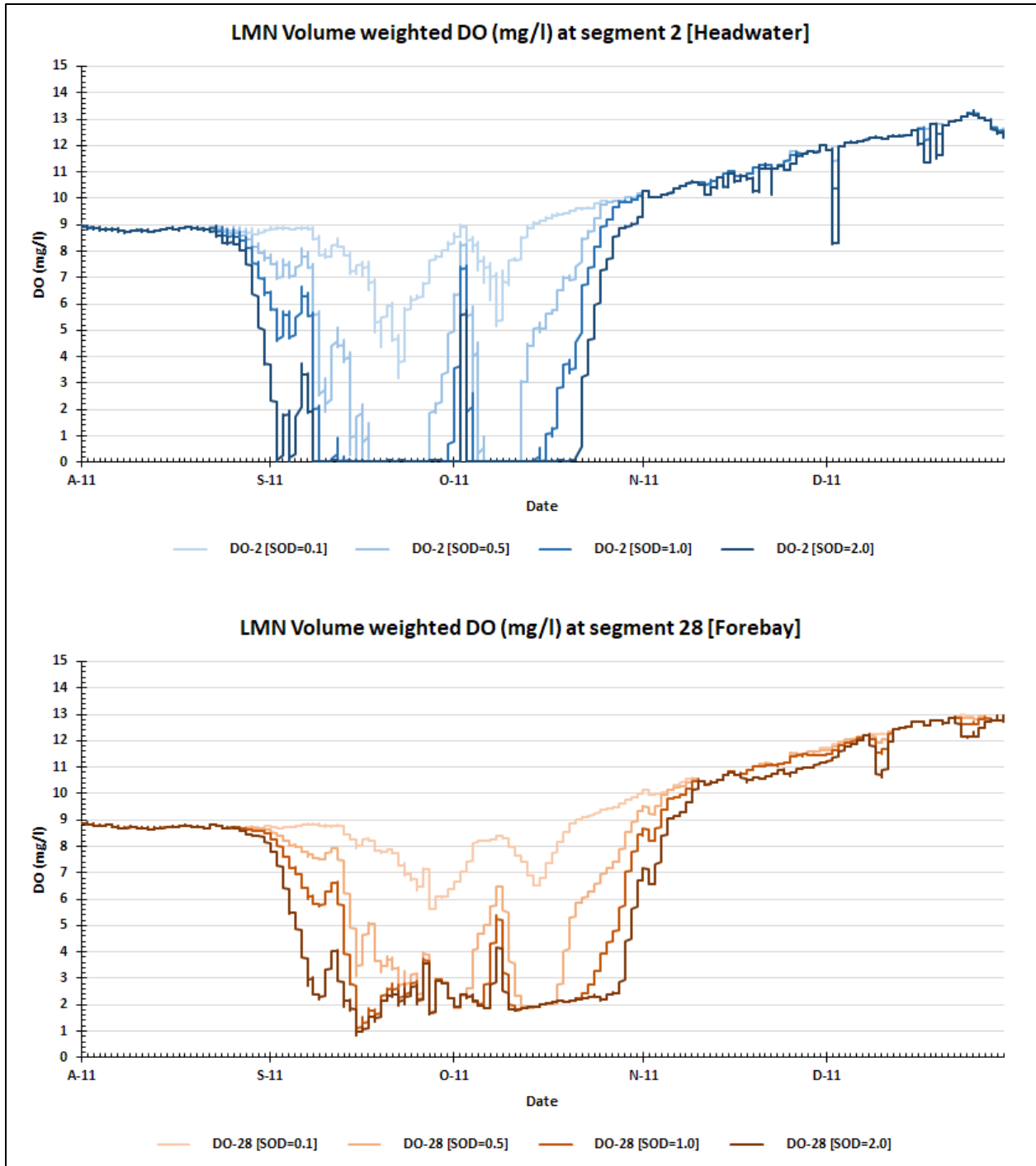
177 **Table 1-1. Lower Snake River Sediment Data**

Sample Date	Location	SOD g/m ² / d	Organic Matter (%)	Particle Size [mm]: Percent Composition							
				No. 6 >3.33	No. 10 3.33-2.00	No. 20 0.84-2.00	No. 35 0.42-0.84	No. 60 0.25-0.42	No. 140 0.11-0.25	No. 200 0.08-0.11	Bottom Pan < 0.08
08/06/97	SNR-50	0.9	6.8	0.0	0.0	0.0	0.1	0.4	1.8	1.8	95.7
	SNR-123	0.8	4.8	0.0	0.0	0.1	0.2	0.3	15.2	14.1	70.1
	SNR-132	0.9	2.2	0.0	0.0	0.0	0.1	0.1	33.1	33.1	34.0
10/03/97	SNR-50	2.2	5.3	0.0	0.0	0.1	0.1	0.4	5.6	6.3	87.3
	SNR-123	2.1	7.3	0.0	0.0	0.1	0.3	0.4	2.3	3.4	93.6
	SNR-132	1.9	7.0	0.0	0.0	0.3	0.4	1.0	36.6	14.5	46.9

178 Source: Normandeau Associates 1999



179
 180 **Figure 1-4. Lower Monumental Reservoir Habitat (DO) Analysis at Differing Sediment Oxygen**
 181 **Demand Levels (0.1, 0.5, 1.0, and 2.0 g/m²/d).**
 182 Note: The top figure shows percentage of whole reservoir volume greater than or equal to 2.5 mg/L DO at each
 183 SOD level, and the bottom shows percentage of whole reservoir volume greater than or equal to 5.0 mg/L DO at
 184 each SOD level.



185
186
187
188
189

Figure 1-5. Estimates of Volume Weighted DO Concentrations at the Lower Monumental Dam Headwater Segment (DO-2 [top]) and Forebay Segment (DO-28 [bottom])

Note: Figures shows data at differing sediment SOD levels (0.1, 0.5, 1.0, and 2.0 g/m²/d) following drawdown and breach.

190 **1.3 CONCLUSION**

191 A comparison of volume-weighted DO concentration results from both methods are
192 summarized for two model segments/locations (at the head of Lower Monumental Reservoir
193 and in the forebay) for each pulse of high total suspended solids following drawdown and
194 breach (Table 1-2).

195 Extended periods of anoxia would be greater in the headwater segment of the Lower
196 Monumental Reservoir as compared to the forebay, or area of reservoir just upstream of Lower
197 Monumental Reservoir. In addition, the first peak of sediment (during reservoir drawdown)
198 would likely create worse DO conditions as compared to the second peak (dam breach) based
199 on estimated total suspended sediment concentrations predicted by the sediment transport
200 model, HEC-RAS Version 5.0.7.

201 **Table 1-2. Number of Days when the Volume-Weighted Average Dissolved Oxygen**
202 **Concentration in Lower Monumental Reservoir is Estimated to be Below Selected Criteria**

TSS Pulses	DO Criteria (mg/L)	Headwater (Segment 2)				Forebay (Segment 28)					
		Method 1 Data Correlation	Method 2 SOD 0.1	Method 2 SOD 0.5	Method 2 SOD 1.0	Method 2 SOD 2.0	Method 1 Data Correlation	Method 2 SOD 0.1	Method 2 SOD 0.5	Method 2 SOD 1.0	Method 2 SOD 2.0
First Peak (August–September)	<5	21	5	23	32	37	17	1	20	27	29
	<2.5	15	1	19	27	33	4	0	7	14	22
	<0.5	11	0	17	23	32	0	0	0	0	0
Second Peak (October–December)	<5	10	2	14	19	22	14	1	18	26	28
	<2.5	7	0	10	18	20	8	0	9	19	23
	<0.5	6	0	7	15	19	0	0	0	0	0

203 Note: TSS = total suspended solids. Data is from during the two peaks in suspended sediment derived from a
204 hypothetical dam breach.

205 Very low DO concentrations of below 0.5 mg/L are anticipated in some portions of Lower
206 Monumental Reservoir under the first year of dam breaching. If actual anoxia is reached,
207 impacts could be severe and include mortality to other aquatic life typically thought of as
208 relatively tolerant to low DO, such as lamprey, aquatic invertebrates, and warm water fish.
209 Mobilization of contaminants could also be enhanced. If this alternative is moved forward for
210 potential implementation, mitigation will be necessary to at least prevent total anoxia.

211 Looking long term, DO concentrations that would occur during subsequent spring freshet
212 events were not modeled. However, concentrations are anticipated to be greater than the 8
213 mg/L Washington State standard after the free-flowing river state becomes established.

214

CHAPTER 2 - REFERENCES

- 215 Normandeau Associates. 1999. Lower Snake River juvenile salmon migration feasibility study-
216 Water quality appendix, final draft. Completed by Normandeau Associates in association
217 with Foster Wheeler Environmental Company, Washington State University, and the
218 University of Idaho for the US Army Corps of Engineers, Walla Walla District. Delivery
219 Order 011, Contract #DAC2W68-96-D-0003, Walla Walla: US Army Corps of Engineers.
- 220 USGS (U.S. Geological Survey). 2019. USGS Water-Quality Historical Instantaneous Data for the
221 Nation, USGS 14151000 FALL CREEK BLW WINBERRY CREEK, NEAR FALL CREEK, OR.
222 Accessed May 8, 2019, <https://waterdata.usgs.gov/nwis/uv?>. 13:40:39 EDT.