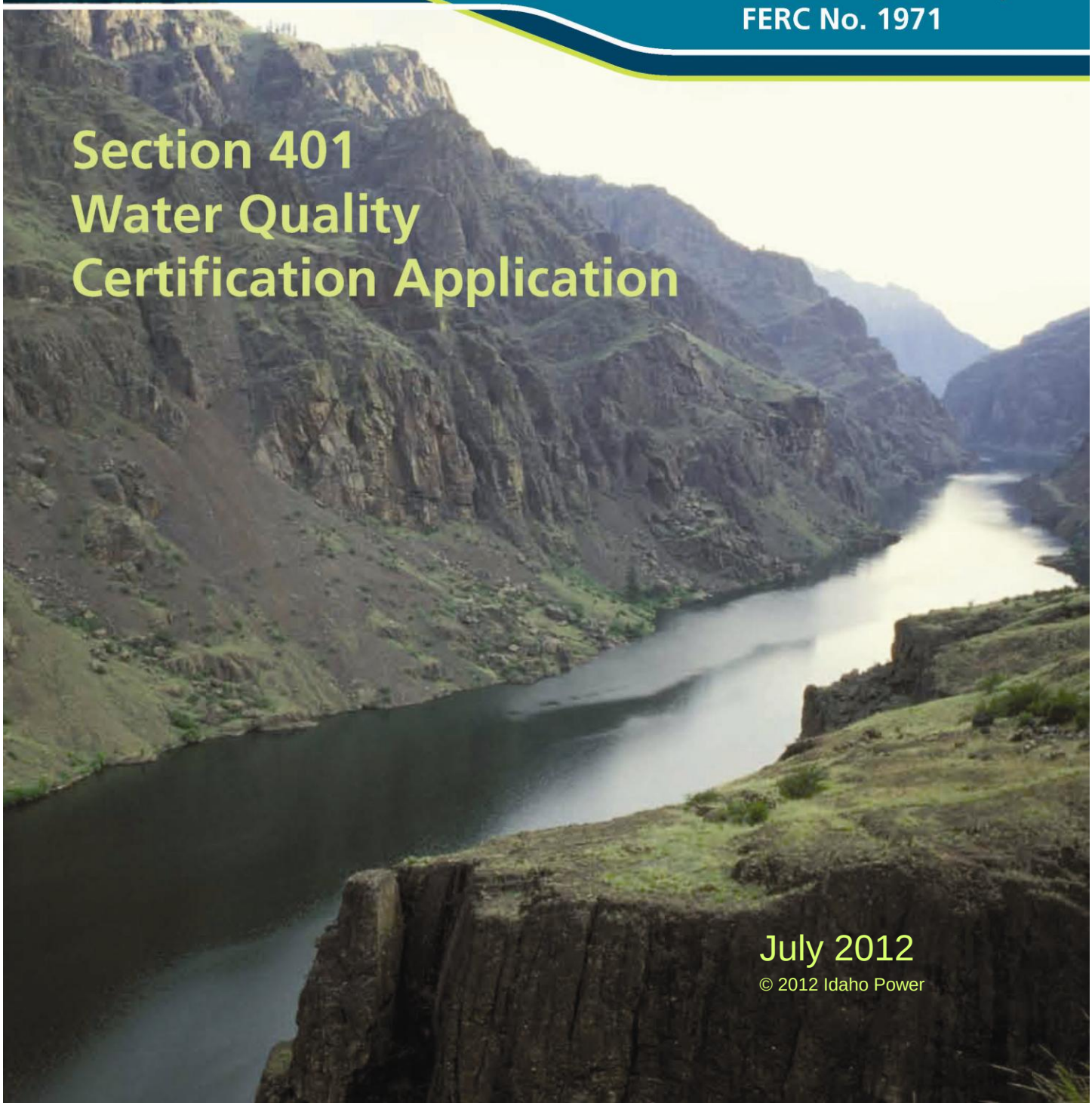
IDAHO POWER
An IDACORP Company

Hells Canyon Complex
FERC No. 1971

Section 401 Water Quality Certification Application



July 2012

© 2012 Idaho Power

TABLE OF CONTENTS

Table of Contents i

List of Tables viii

List of Figures xi

List of Exhibits xviii

List of Abbreviations and Acronyms xix

1. Introduction 1

1.1. Hells Canyon Complex 2

1.1.1. Location Description 2

1.1.2. Construction History 4

1.1.3. Features of Interest 4

1.2. Existing License 5

1.2.1. Year Issued 5

1.2.2. Year Expires 5

1.3. New License Filing Schedule 5

1.3.1. Intent to File 5

1.3.2. Draft License Application 5

1.3.3. Final License Application 5

1.3.4. Additional Information Requests Filings 5

2. CWA Certification Process 6

2.1. Oregon 6

2.2. Idaho 6

2.3. Other Potentially Applicable State Laws 6

2.3.1. Oregon HART Process 7

2.3.2. Laws Administered by the Oregon Department of Land Conservation and Development 7

2.3.3. Laws Administered by the Oregon Department of Fish and Wildlife 7

2.3.4. Laws Administered by the Oregon Department of State Lands 7

2.3.5. Laws Administered by the Oregon and Idaho Departments of Environmental Quality 7

2.4. IPC State Water Rights 8

3. Concurrent Watershed Water-Quality Processes 9

3.1. A Watershed-Based Approach 9

3.2. Development of TMDLs in the Watershed 10

3.3. The Snake River–Hells Canyon TMDL 10

4. Project Description 11

4.1. Legal Name and Address of Project Owner 11

4.2. Legal Name and Address of Owner's Official Representative 12

4.3. Adjacent Lands 12

4.3.1. Names and Addresses of Contiguous Property Owners 12

4.3.2. Adjacent Land Use 12

4.3.3. Evaluation of Consistency of IPC's Project with County Comprehensive Plans ...14

4.4. Project Overview 14

4.5. Project Operations 15

4.5.1. Brownlee Reservoir Operations 15

4.5.1.1. Winter—December through February 16

4.5.1.2. Spring—March through May 17

4.5.1.3. Summer—June through August 17

4.5.1.4. Fall—September through November 18

4.5.2. Oxbow Reservoir and Hells Canyon Reservoir Operations 18

5. Applicable Water-Quality Regulations 19
5.1. Beneficial Uses 19
5.2. Applicable SR-HC TMDL Targets 21
6. Water-Quality Standards Evaluation 23
6.1. Temperature 23
6.2. Dissolved Oxygen 23
6.2.1. DO Standards and SR-HC TMDL Targets 24
6.2.1.1. Aquatic Life and Salmonid Rearing 24
6.2.1.2. Salmonid Spawning 25
6.2.2. Conditions Relative to DO 29
6.2.2.1. Current Conditions 30
6.2.2.1.1. Reservoir DO 30
6.2.2.1.2. Outflow DO 32
6.2.2.1.3. Oxbow Bypass DO 39
6.2.2.2. SR-HC TMDL Conditions 39
6.2.2.2.1. Reservoir DO 41
6.2.2.2.2. Outflow DO 45
6.2.3. HCC Contribution to DO 47
6.2.3.1 SSWQ Target Development 47
6.2.3.1.1. Water-Column Conditions 50
6.2.3.1.2. Intergravel Conditions 50
6.2.3.1.3. Interconnection between Water Column and Intergravel Conditions 56
6.2.3.1.4. SSWQ Target 57
6.2.3.1.5. Assimilative Capacity of a Free-Flowing River Reach 61
6.2.3.2. Outflow DO with SSWQ Target 67

6.2.3.3. Appropriate HCC DO Responsibility 70

6.2.3.3.1. Reservoir 70

6.2.3.3.2. Downstream 70

6.2.3.3.3. Oxbow Bypass 74

6.3. Total Dissolved Gases....74

6.3.1. TDG Standards and SR-HC TMDL Targets....75

6.3.2. Conditions Relative to TDG 75

6.3.3. HCC Contribution to TDG....81

6.4. Nuisance Algae 81

6.4.1. Nuisance Algae Standards and SR-HC TMDL Targets 82

6.4.2. Conditions Relative to Nuisance Algae 82

6.4.2.1. Algal Biomass....82

6.4.2.2. Algal Communities 84

6.4.3. HCC Contribution to Nuisance Algae 85

6.4.3.1. Modeling Algae In Brownlee Reservoir 85

6.4.3.1.1. CE-QUAL-W2 Algal Biomass Simulations with SR-HC TMDL Implementation 86

6.4.3.1.2. Predicted Algal Community Structure....86

6.4.3.2. Nuisance Algae Reasonable Assurance 86

6.5. Hydrogen Ion (pH)....89

6.5.1. Hydrogen Ion (pH) Standards and SR-HC TMDL Targets 89

6.5.2. Conditions Relative to Hydrogen Ion (pH)....89

6.5.3. HCC Contribution to Hydrogen Ion (pH)....91

6.5.3.1. Modeling Hydrogen Ion (pH) 92

6.5.3.1.1. Mass Balance Model....92

6.5.3.1.2. CE-QUAL-W2 Model 93

6.5.3.2. Hydrogen Ion (pH) Reasonable Assurance....99
6.6. Toxics....100
6.6.1. Toxics Standards and SR-HC TMDL Targets....101
6.6.2. Conditions Relative to Toxics....101
6.6.3. HCC Contribution to Toxics....102
6.6.3.1. Mercury TMDL....103
6.6.3.2. Reasonable Assurance for Toxics....103
6.7. Turbidity....103
6.7.1. Turbidity Standards....104
6.7.2. Conditions Relative to Turbidity....104
6.7.3. HCC Contribution to Turbidity....104
6.8. Total Dissolved Solids....105
6.8.1. TDS Standards and SR-HC TMDL Targets....105
6.8.2. Conditions Relative to Total Dissolved Solids....105
6.8.3. HCC Contribution to TDS....105
6.9. Bacteria....106
6.9.1. Bacteria Standards and SR-HC TMDL Targets....106
6.9.2. Conditions Relative to Bacteria....106
6.9.3. HCC Contribution to Bacteria....106
6.10. Biocriteria....107
6.11. Narrative Standards....107
6.11.1. Narrative Standards and SR-HC TMDL Targets....107
6.11.2. Conditions Relative to Narrative Standards....108
6.11.3. HCC Contribution to Narrative Standards....108
7. Proposed PME Measures....109

7.1. Temperature Proposed Measures 109
7.2. DO Proposed Measures 109
7.2.1. Proposed Measures to Meet the SR-HC TMDL Allocation 110
7.2.1.1. Reservoir Aeration 110
7.2.1.1.1 Oxygen Supply Facility 110
7.2.1.1.2. Reservoir Diffuser System 112
7.2.1.1.3. System Location 113
7.2.1.1.4. Conceptual Operational Plan 121
7.2.1.2. Upstream Watershed Phosphorus Trading 124
7.2.1.2.1. Nutrient Ratios 125
7.2.2. Turbine Aeration at Hells Canyon Dam 127
7.2.2.1. Description 128
7.2.2.1.1. Proposed Design 128
7.2.2.1.2. Blower Sizing 130
7.2.2.2. Conceptual Operational Plan 132
7.2.2.3. Additional Study 133
7.2.3. Turbine Aeration at Brownlee Dam 134
7.2.3.1. Description 134
7.2.3.2. Preliminary Evaluation 134
7.2.4. Destratification Measure for Oxbow Bypass 135
7.2.4.1. Description 135
7.2.4.1.1. Proposed Design 136
7.2.4.2. Operational Plan 139
7.2.5. DO Reasonable Assurance 139
7.2.6. DO Monitoring Plan 140

7.2.7. DO Implementation Schedule 140
7.3. TDG Adaptive Management Plan 141
7.3.1. TDG Proposed Measures 142
7.3.1.1. Preferential Brownlee Dam Upper Gate Spill 142
7.3.1.2. Oxbow Dam Spillway Flow Deflector 142
7.3.1.3. Hells Canyon Dam Sluiceway Flow Deflectors 142
7.3.1.3.1. Proposed Action 142
7.3.1.3.2. Proposed Design 142
7.3.1.4. Brownlee Dam Spillway Flow Deflectors 145
7.3.1.4.1. Proposed Action 145
7.3.1.4.2. Proposed Design 146
7.3.1.5. Oxbow Dam TDG Reduction Structures 149
7.3.2. TDG Adaptive Measures 149
7.3.3. TDG Reasonable Assurance 151
7.3.3.1. Preferential Brownlee Dam Upper Gate Spill 151
7.3.3.2. HCC Flow Deflectors 152
7.3.4. TDG Monitoring 156
7.3.5. TDG Adaptive Management Schedule 156
8. Literature Cited 158

LIST OF TABLES

Table 2.3-1. Number of comfort stations (includes showers), restroom and vault toilets, and recreational vehicle (RV) dump station treatment type by project in the Hells Canyon Complex. 8

Table 4.3-1. Land ownership (acres) in the Hells Canyon Complex (HCC) project area. (Lands administered by the U.S. Forest Service are denoted as USFS; lands administered by the U.S. Bureau of Land Management are denoted as BLM; and lands owned by Idaho Power Company are denoted as IPC.) 13

Table 5.1-1. Oregon's designated uses (OAR 340-041 n.d.) and water quality limiting pollutants (ODEQ 2007a) for the mainstem Snake River. 19

Table 5.1-2. Idaho's designated uses (IDAPA 58.01.02. n.d.) and water quality limiting pollutants (IDEQ 2005) for segments of the Snake River. 20

Table 5.2-1. Levels indicating water-quality limitation for the Snake River from near Weiser, Idaho, to the confluence with the Salmon River (IDEQ and ODEQ 2004). 22

Table 6.2-1. State of Oregon dissolved oxygen (DO) criteria in milligrams per liter (mg/L) for the protection of aquatic life and salmonid rearing (OAR 340-041. n.d.). 25

Table 6.2-2. Summarized dissolved oxygen (DO) differentials in milligrams per liter (mg/L) between intergravel DO measured in artificially constructed redds and DO in the water column for sites on the Snake River below Hells Canyon Dam and above the Salmon River confluence. The time period between subsequent dates is approximately 2 weeks. 28

Table 6.2-3. Summarized site median dissolved oxygen (DO) differentials in milligrams per liter (mg/L) between intergravel DO measured in artificially constructed redds and DO in the water column for sites on the Snake River below Hells Canyon Dam and above the Salmon River confluence. The time period between subsequent dates is approximately 2 weeks....29

Table 6.2-4. Water-column dissolved oxygen (DO) criteria calculated from the 90th percentile of the summarized site median DO differentials. 29

Table 6.2-5. Number of annual and July dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) measured throughout the Hells Canyon Complex for selected years and the percent (%) of concentrations that were less than 6.5 mg/L. 31

Table 6.2-6. Absolute mean dissolved oxygen (DO) error in milligrams per liter (AME mg/L) summary for Brownlee Reservoir CE-QUAL-W2 model applications used in the Hells Canyon Complex Final License Application (HCC FLA), FERC additional information requests (AIR), and this CWA § 401 certification application. 40

Table 6.2-7. Hells Canyon Reservoir CE-QUAL-W2 model application absolute mean error (AME) and mean error (ME) summary for daily minimum outflow dissolved oxygen (DO) in milligrams per liter during selected periods. AME shows the average difference (either positive or negative), while ME shows the average difference with negative numbers, indicating model results were low compared to measured data. 41

Table 6.2-8. Selected parameters collected in 2002 and 2003 as part of a Snake River organic matter study.....48

Table 6.2-9. Medians (ranges) and percent reduction (based on medians) for particulate, dissolved, and total constituents at Brownlee inflow (RM 340) and Hells Canyon outflow (RM 247) from March–October 2002 (n = 13–14) or March 2002–April 2003 (n = 22–24). 51

Table 6.2-10. Survival of fall Chinook salmon eggs placed in artificial redds above and below the Hells Canyon Complex for the 2003/2004 and 2004/2005 seasons. 55

Table 6.2-11. Summary of chlorophyll *a* and particulate phosphorus concentrations.....60

Table 6.2-12. Comparison of key processes for selected water-quality constituents showing loss of inorganic suspended solids and phosphorus only occurring through sedimentation and burial processes. Processes modeled with CE-QUAL-W2 (W2) are also shown.....64

Table 6.2-13. River locations, elevation, and general percent (%) gradients.....66

Table 6.2-14. T-tests for difference of means between paired water-column data collected in the Snake River at Bliss and King Hill from 1994–2000. The number of paired measures is in parentheses; P values less than 0.05 indicate a significant difference. 66

Table 6.2-15. Summarized 1995 CE-QUAL-W2 Brownlee Reservoir inflow boundary conditions for 3 water quality conditions: current, SR-HC TMDL, and salmonid-spawning water quality (SSWQ).....68

Table 6.2-16. Estimated water-column dissolved oxygen (DO) loads needed to reach criteria based on SR-HC TMDL improvements. 70

Table 6.2-17. Estimated water column dissolved oxygen (DO) loads needed to reach criteria based on salmonid-spawning water quality (SSWQ) improvements. 71

Table 6.2-18. 2002 estimated water-column dissolved oxygen (DO) loads needed to reach multiple criteria based on SR-HC TMDL improvements. 74

Table 6.4-1. Median chlorophyll *a* and range in micrograms per liter (µg/L) measured from June through August in Brownlee Reservoir during 1991 to 1994 and 1995 to 2000. Inflow data not available (NA) during 1991 to 1994....84

Table 6.5-1. Hydrogen ion (pH) values in standard units resulting from CE-QUAL-W2 simulations of varying algal biomass initial conditions. 95

Table 6.5-2. Hydrogen ion (pH) values in standard units resulting from CE-QUAL-W2 simulations of varying algal growth-rate initial conditions. 97

Table 6.5-3. Hydrogen ion (pH) values in standard units resulting from CE-QUAL-W2 simulations of varying alkalinity initial conditions. 98

Table 6.7-1. Minimum, maximum, and mean turbidity measures in nephelometric turbidity units (NTU) for various reaches of the Snake River from 1992 through 1997 and the 10% cumulative increase threshold (thres.) as allowed by Oregon statute (OAR 340-041-0036). 104

Table 6.8-1. Minimum, maximum, and mean total dissolved solids (TDS) concentrations in milligrams per liter (mg/L) for inflow, Brownlee Reservoir outflow, and Hells Canyon Reservoir outflow in 1992 and 1995. 105

Table 7.2-1. Summary of measured profile transition zone dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) collected in July at or near RM 325, 1991−2003. 114

Table 7.2-2. Summary of measured profile transition zone dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) collected in July at or near RM 325, 1991–2003, and an example of the aeration allocation implementation approach using a 10-year average concept. 122

Table 7.2-3. Upstream phosphorus trading ratios and resultant loads over various time periods. 126

Table 7.2-4. Summary of variables used for modeling Hells Canyon powerhouse blower system. 131

Table 7.2-5. Simulated dissolved oxygen (DO) tons added with operation of a 2,000 standard cubic feet per minute (scfm) blower system at the Hells Canyon powerhouse from July through November. 131

Table 7.3-1. Total dissolved gases (TDG) percent (%) saturation levels at Wanapum Dam, Grant County, Washington, in 1998 (Weitkamp and Hagen 1999a). Ten-year, 7-day (7Q10) average flood flow is 12,916 cubic feet per second (cfs) per spillway (Jeske 1999). The Wanapum Dam powerhouse has the ability to increase flow passage, which would decrease the 7Q10 average flood flow to 8,333 cfs per bay. 154

Table 7.3-2. Total dissolved gases (TDG) percent (%) saturation levels at Wanapum Dam, Grant County, Washington, in 1999 (Weitkamp and Hagen 1999b). Ten-year, 7-day (7Q10) average flood flow is 12,916 cubic feet per second (cfs) per spillway (Jeske 1999). The Wanapum Dam powerhouse has the ability to increase flow passage, which would decrease the 7Q10 average flood flow to 8,333 cfs per bay. 154

LIST OF FIGURES

Figure 1.1-1. Vicinity map.....3

Figure 6.2-1. Map showing locations of artificial redds and water-column sampling sites on the Snake River from the Salmon River confluence upstream to King Hill. (Note: Green triangles also show artificial redd and piezometer sites.) 27

Figure 6.2-2. Mean daily averages and 95% confidence levels calculated from outflow dissolved oxygen (DO) levels measured in milligrams per liter (mg/L) in Brownlee, Oxbow, and Hells Canyon reservoirs (1991–2005). Also plotted are daily DO criteria. 33

Figure 6.2-3. Daily average dissolved oxygen (DO) in milligrams per liter (mg/L) from Hells Canyon Reservoir outflow and 3 locations in the Snake River downstream during September and October 2000. 34

Figure 6.2-4. Intergravel dissolved oxygen (DO) in milligrams per liter (mg/L) at sites downstream of Hells Canyon Dam with no eggs in the 2003/2004 and 2004/2005 seasons. Symbols show the median of 3 artificial redds or ambient piezometers, while error bars show the minimum and maximum values. 35

Figure 6.2-5. Intergravel dissolved oxygen (DO) in milligrams per liter (mg/L) concentrations at sites downstream of Hells Canyon Dam with green eggs in the 2004/2005 season. 36

Figure 6.2-6. Intergravel dissolved oxygen (DO) in milligrams per liter (mg/L) at sites downstream of Hells Canyon Dam with eyed eggs in the 2003/2004 and 2004/2005 seasons. Symbols show the median of 3 artificial redds, while error bars show the minimum and maximum values. 37

Figure 6.2-7. Water-column dissolved oxygen (DO) in milligrams per liter (mg/L) at sites downstream of Hells Canyon Dam compared with daily average (calculated from 10-minute readings) outflow DO measured in the penstock of Hells Canyon Dam (RM 247.6) in the 2003/2004 and 2004/2005 seasons. 38

Figure 6.2-8. Simulated percent (%) volume of Brownlee Reservoir zones and strata below the dissolved oxygen (DO) criterion of 6.5 milligrams per liter (mg/L) for medium-water-year conditions. Plots show 1995 current conditions (baseline) and anticipated conditions with full upstream implementation of the SR-HC TMDL allocations and IPC aeration. 43

Figure 6.2-9. Simulated percent (%) volume of Oxbow and Hells Canyon reservoirs below the dissolved oxygen (DO) criterion of 6.5 milligrams per liter (mg/L) for medium-water-year conditions. Plots show 1995 current conditions (baseline) and anticipated conditions with full upstream implementation of the SR-HC TMDL allocations and IPC aeration. 44

Figure 6.2-10. Comparison of simulated Hells Canyon Reservoir outflow dissolved oxygen (DO) with current conditions and SR-HC TMDL conditions. Total Maximum Daily Load (TMDL) improvements show the difference between the 2 simulations. 46

Figure 6.2-11. Water-column concentrations of particulate material at 7 sites in the Snake River. Dots showing medians and error bars are the 75th and 25th percentiles of data collected from March 2002 through April 2003. 49

Figure 6.2-12. Intergravel dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) at sites upstream of Brownlee Reservoir with no eggs in the 2003/2004 and 2004/2005 seasons. Symbols show the median of3 artificial redds or ambient piezometers, while error bars show the minimum and maximum values. 52

Figure 6.2-13. Intergravel dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) at sites upstream of Brownlee Reservoir with eyed eggs in the 2003/04 and 2004/05 seasons. Symbols show the median of 9 (2003/04) or 7 (2004/05) artificial redds, while error bars show the minimum and maximum values. 53

Figure 6.2-14. Intergravel dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) at sites upstream of Brownlee Reservoir with green eggs in the 2004/2005 season. 54

Figure 6.2-15. Total phosphorus concentration in milligrams per liter (mg/L) below Bliss Dam and King Hill, Idaho, and their difference (Bliss–King Hill). 58

Figure 6.2-16. Dissolved oxygen (DO) and relationships with the atmosphere and organic matter. 62

Figure 6.2-17. Schematic of ecosystem cycling and spiraling by Essington and Carpenter (2002). 65

Figure 6.2-18. Comparison of simulated Hells Canyon outflow dissolved oxygen (DO) in milligrams per liter (mg/L) with current conditions and salmonid-spawning water-quality (SSWQ) conditions. SSWQ improvements show the difference between the 2 simulations. 69

Figure 6.2-19. Hells Canyon outflow measured daily minimum dissolved oxygen (DO) in milligrams per liter (mg/L) and adjusted measured daily minimum DO based on SR-HC TMDL improvements. 72

Figure 6.2-20. Hells Canyon outflow measured daily minimum dissolved oxygen (DO) in milligrams per liter (mg/L) and adjusted measured daily minimum DO based on salmonid-spawning water quality (SSWQ) improvements. 73

Figure 6.3-1. The relationship of spill in cubic feet per second (cfs) and total dissolved gases (TDG) percent saturation (% Saturation) measured downstream of Brownlee Dam, 1997−1998. (Note: Add 35,000 cfs to spill for estimate of total Snake River flow. TDG percent saturation is measured near spillway prior to mixing with turbine flow.) 76

Figure 6.3-2. The relationship of spill in cubic feet per second (cfs) and total dissolved gases (TDG) percent saturation (% Saturation) measured downstream of Oxbow Dam, 1997–1998. (Note: Add 28,000 cfs to spill for estimate of total Snake River flow. TDG percent saturation is measured near spillway prior to mixing with turbine flow.) 77

Figure 6.3-3. Change in total dissolved gases (TDG) percent saturation (% Saturation) above and below Oxbow Dam over a range of spill in cubic feet per second (cfs), 1997–1998. (Note: Parenthetic numbers indicate a decrease in TDG levels below Oxbow Dam.) 77

Figure 6.3-4. The relationship of spill in cubic feet per second (cfs) and total dissolved gases (TDG) percent saturation (% Saturation) at Oxbow Dam in 2006 when inflow water to Oxbow spillway was less than 110% of saturation.....78

Figure 6.3-5. The relationship of spill in cubic feet per second (cfs) and total dissolved gases (TDG) percent saturation (% Saturation) measured at the Hells Canyon boat launch downstream of Hells Canyon Dam, 1997–1998. (Note: Add 30,500 cfs to spill for estimate of total Snake River flow. These data are presumed to represent a mix of turbine and spill waters.) 79

Figure 6.3-6. The relationship of spill in cubic feet per second (cfs) and total dissolved gases (TDG) percent saturation (% Saturation) measured below Hells Canyon Dam from March 3 through July 20, 1999. (Note: Add 30,500 cfs to spill for estimate of total Snake River flow. These data are presumed to represent a mix of turbine and spill waters.) 79

Figure 6.3-7. Downstream dissipation of total dissolved gases (TDG) in the Snake River within Hells Canyon relative to the 110% saturation target. (Note: Add 30,500 cfs to spill for estimate of total Snake River flow. TDG percent saturation (% Saturation) can be a combination of gas dissipation and mixing with turbine flows.).....80

Figure 6.3-8. Hells Canyon Dam daily average flow (Day Mean Q) in cubic feet per second (cfs) flow-duration curve for the October 1968 through February 2003 period of record. 80

Figure 6.4-1. Percent cumulative frequency for May through September chlorophyll *a* concentrations in micrograms per liter (µg/L) collected between 2001 and 2004 from the Snake River, immediately upstream of Brownlee Reservoir (RM 345.6).....83

Figure 6.4-2. Interquartile ranges (the box represents the median and the line the 75th and 25th percentiles) for May through September chlorophyll *a* concentrations in micrograms per liter (µg/L) from the Snake River at the Adrian, Oregon, bridge (RM 403), Nyssa, Oregon, bridge (RM 385), and immediately upstream of Brownlee Reservoir (RM 345.6). Adrian and Nyssa data were collected from 1995 through 2003. Data immediately upstream of Brownlee Reservoir were collected from 2001 through 2004. 84

Figure 6.4-3. Surface chlorophyll *a* concentrations in micrograms per liter (µg/L) measured year round, from 1991 through 2000, throughout the Hells Canyon Complex. River miles (RM) have been grouped into approximately 5-mile intervals. Concentrations at RM 1, 5, and 7.5 represent the Powder River arm.....85

Figure 6.4-4. Baseline simulation results showing modeled and measured chlorophyll *a* concentrations in micrograms per liter (µg/L) in the surface layer of Brownlee Reservoir for selected dates in 1995.....87

Figure 6.4-5. Modeled surface chlorophyll *a* concentrations in micrograms per liter (µg/L) in Brownlee Reservoir from March 31 through September 26, 1995. 88

Figure 6.4-6. Modeled surface chlorophyll *a* concentrations in micrograms per liter (µg/L) in Brownlee Reservoir from March 31 through September 26, 1995, with full Snake River-Hells Canyon Total Maximum Daily Load (SR-HC TMDL) implementation.....88

Figure 6.5-1. Percent (%) cumulative frequency curves for hydrogen ion (pH) in Brownlee, Oxbow, and Hells Canyon reservoirs (Myers et al. 2003). 90

Figure 6.5-2. Percent (%) cumulative frequency curves for hydrogen ion (pH) in Brownlee Reservoir zones and strata (Myers et al. 2003). 90

Figure 6.5-3. Upstream Snake River linear regression for daily average hydrogen ion (pH) in standard units and daily average chlorophyll *a* concentration in micrograms per liter (µg/L) at River Mile 345.6 for data collected April 2002–July 2003. 92

Figure 6.5-4. Modeled steady-state hydrogen ion (pH) standard units (su) at photosynthesis-dominated rates and 2 rates of alkalinity in micro-equivalents per liter. (Note: 1 micro-equivalent per liter is equal to 50 milligrams per liter as CaCO3). The initial conditions assume total inorganic carbon levels have increased due to respiration at 1.5 g O2/m^2/d. Model based on Chapra (1997). 93

Figure 6.5-5. Algal biomass in milligrams per liter (mg/L) with algal biomass initial conditions varying from 1–4 mg/L (i.e., approximately 15−60 micrograms per liter [µg/L] chlorophyll *a*). 95

Figure 6.5-6. Hydrogen ion (pH) standard units (SU) with algal biomass initial conditions varying from 1–4 milligrams per liter (mg/L) (i.e., approximately 15–60 micrograms per liter [µg/L] chlorophyll *a*). 96

Figure 6.5-7. Total inorganic carbon (TIC) in milligrams per liter (mg/L) with algal biomass initial conditions varying from 1–4 mg/L (i.e., approximately 15−60 micrograms per liter [µg/L] chlorophyll *a*). 96

Figure 6.5-8. Algal biomass as measured by chlorophyll *a* (chla) in micrograms per liter (µg/L) with algal growth rate initial conditions of 2 and 4 per day. 97

Figure 6.5-9. Hydrogen ion (pH) values in standard units (SU) with algal growth rate initial conditions of 2 and 4 per day.....98

Figure 6.5-10. Algae in milligrams per liter (mg/L) and hydrogen ion (pH) in standard units (SU) with algal biomass initial conditions of 4 mg/L and algal growth rate at 4 per day. 99

Figure 6.5-11. Chlorophyll *a* (chl a) in micrograms per liter (µg/L) and hydrogen ion (pH) in standard units (SU) with algal biomass initial conditions of 4 milligrams per liter (mg/L) and algal growth rate at 4 per day.....99

Figure 7.2-1. 50,000-gallon liquid oxygen storage tank.....111

Figure 7.2-2. Vaporizer/discharge piping.....112

Figure 7.2-3. Oxygen gas-regulator assembly 112

Figure 7.2-4. Dissolved oxygen (DO) in milligrams per liter (mg/L) profiles measured in the upper end of the transition zone in 1990....114

Figure 7.2-5. Vicinity plan for the Brownlee Reservoir transition zone aeration system 115

Figure 7.2-6. Site plan for the Brownlee Reservoir transition zone aeration system 116

Figure 7.2-7. Site detail for the Brownlee Reservoir transition zone aeration system 117

Figure 7.2-8. Simulated 1992 (low-water year) dissolved oxygen (DO) in milligrams per liter (mg/L) isopleth for the Brownlee Reservoir transition zone with no aeration....118

Figure 7.2-9. Simulated 1992 (low-water year) dissolved oxygen (DO) in milligrams per liter (mg/L) isopleth for the Brownlee Reservoir transition zone with 1,125-tons/year aeration at the proposed location. 119

Figure 7.2-10. Simulated 1992 (low-water year) sturgeon habitat suitability index (HSI) isopleth for the Brownlee Reservoir transition zone with no aeration....120

Figure 7.2-11. Simulated 1992 (low-water year) sturgeon habitat suitability index (HSI) isopleth for the Brownlee transition zone with 1,125-tons/year aeration at the proposed location. 121

Figure 7.2-12. Simulated 1992 (low-water year) dissolved oxygen (DO) in milligrams per liter (mg/L) isopleth for the Brownlee Reservoir transition zone with 2,250-tons/year aeration at the proposed location. 123

Figure 7.2-13. Simulated 1992 (low-water year) sturgeon habitat suitability index (HSI) isopleth for the Brownlee Reservoir transition zone with 2,250-tons/year aeration at the proposed location. 124

Figure 7.2-14. Conceptual diagram of Hells Canyon powerhouse blower system. 129

Figure 7.2-15. Simulated dissolved oxygen (DO) increase in milligrams per liter (mg/L) and percent (%) total dissolved gases (TDG) concentrations resulting from proposed Hells Canyon powerhouse blower operation for June through December. 132

Figure 7.2-16. Description of the compressor, piping, and diffuser system offered by Vertex Water Features. 137

Figure 7.2-17. Aerial photograph and description of the Oxbow Bypass Reach and deep pool. 138

Figure 7.2-18. Site layout of the compressor, piping, and diffuser system. 138

Figure 7.3-1. Plan view of 1:48-scale, 3-dimensional Hells Canyon Dam physical model. 143

Figure 7.3-2. Photograph of 1:48-scale, 3-dimensional Hells Canyon Dam physical model. 143

Figure 7.3-3. Sectional view of the Hells Canyon Dam model constructed by the Iowa Institute of Hydraulic Research (2000) showing the general location of sluiceway flow deflectors. 144

Figure 7.3-4. General view of the Hells Canyon Dam sluiceway flow deflector configuration developed by the Iowa Institute of Hydraulic Research (2000). 145

Figure 7.3-5. Plan view of 1:48-scale, 3-dimensional Brownlee Dam physical model (reproduced from Exhibit 7.3-2). 146

Figure 7.3-6. Photograph of 1:48-scale, 3-dimensional Brownlee Dam physical model. 147

Figure 7.3-7. Plan and sectional view showing the general location of the Brownlee Dam spillway flow deflectors and a detailed sectional view drawing of the proposed design (reproduced from Exhibit 7.3-1).....148

Figure 7.3-8. Measured total dissolved gases (TDG) percent saturation (% Sat) below Brownlee Dam during operation of upper and lower spillgates at 39,000 cubic feet per second (cfs). (Note: Add 35,000 cfs to spill to estimate total Snake River flow.) Data were collected concurrently with 2 probes: Common Sensing (CS) and Hydrolab (Surv).....151

Figure 7.3-9. Measured total dissolved gases (TDG) percent (%) saturation below Ice Harbor Dam, 1996–1998, with and without flow deflectors (USACE 2002). 153

Figure 7.3-10. Total dissolved gases (TDG) percent saturation (% Sat) at Wanapum Dam, Grant County, Washington, with no spillway deflector and a shallow horizontal design deflector (Weitkamp and Hagen 1999a, 1999b). 155

Figure 7.3-11. Sectional view photograph of a surface jet flow regime expected from both the Hells Canyon Dam sluiceway and Brownlee Dam spillway flow-deflector designs (Weber 2005). Note the lack of observed air bubbles at depth, either in the stilling basin or downstream. 155

LIST OF EXHIBITS

Exhibit 4.3-1 Names and addresses of contiguous property owners to the Hells Canyon Complex Project Boundary

Exhibit 4.3-2 Idaho Power Company's Hells Canyon Complex relicensing policies and activities in relation to Baker, Malheur, and Wallowa County plans

Exhibit 6.3-1 HCC gas-bubble trauma monitoring study

Exhibit 7.2-1 Dissolved Oxygen Augmentation in the Transition Zone (report by Mobley Engineering dated November 2004)

Exhibit 7.2-2 Discreet Bubble Model Overview (documentation prepared by Mobley Engineering)

Exhibit 7.3-1 Iowa Institute of Hydraulic Research Brownlee Dam spillway deflector design: Phase I two-dimensional model report

Exhibit 7.3-2 Iowa Institute of Hydraulic Research Brownlee Dam spillway deflector design: Phase II three-dimensional model report

LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation / Acronym	Definition
°C	degrees Centigrade
7Q10	10-year, 7-day discharge
AIR	additional information request
AME	absolute mean error
BLM	United States Bureau of Land Management
BOD	biochemical oxygen demand
BOD	biochemical oxygen demand
BOR	United States Bureau of Reclamation
BSP	bacteria secondary production
Btu	British thermal units
CFD	computational fluid dynamics
CFR	U.S. Code of Federal Regulations
cfs	cubic feet per second
CFU	colony-forming units
chl*a*	chlorophyll *a*
CIG	Climate Impacts Group
cm	centimeters
COD	chemical oxygen demand
CWA	Clean Water Act (formerly known as the Federal Power Act of 1935, as amended)
DART	Data Access in Real Time
DBOD	dissolved biochemical oxygen demand
DDT	diclorodiphenyltricleroethane
DO	dissolved oxygen
DOC	dissolved organic carbon
DSL	Oregon Department of State Lands
E. coli	*Escherichia coli*
EHist	estimated historic
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act of 1973
ESRPA	Eastern Snake River Plain Aquifer
ET	Evapotranspiration
FDA	United States Food and Drug Administration
FERC	Federal Energy Regulatory Commission
FLA	Final License Application
FPA	Federal Power Act of 1935, as amended (commonly known as the Clean Water Act [CWA])
ft msl	feet mean sea level
FWS	United States Fish and Wildlife Service
HART	Oregon Hydroelectric Application Review Team
HCC	Hells Canyon Complex
HCC FLA	Hells Canyon Complex Final License Application
HCNRA	Hells Canyon National Recreation Area
HCRMP	Hells Canyon Resource Management Plan
hp	horsepower
HPS	hypolimnatic pump system
HRT	hydraulic residence time
HSI	habitat suitability index
HUC	Hydrologic Unit Code

Abbreviation / Acronym	Definition
IDAPA	Idaho Administrative Procedures Act
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
IDWR	Idaho Department of Water Resources
IIHR	Iowa Institute of Hydraulic Research
IPC	Idaho Power Company
IWRRI	Idaho Water Resources Research Institute
kg	kilogram
kg/day	kilograms per day
km	kilometer
m	meter
m/s	meters per second
ME	mean error
mg	milligram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mi	mile
ml	milliliters
mm	millimeters
msl	mean sea level
NEPA	National Environmental Policy Act
ng/L	nanograms per liter
NHC	Northwest Hydraulic Consultants
NPDES	National Pollutant Discharge Elimination System
NREL	National Renewable Energy Laboratory
NSTP	natural seasonal thermal pattern
NTU	nephelometric turbidity units
O&M	operation and maintenance
OAR	Oregon Administrative Rules
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
OP	orthophosphate
ORS	Oregon Revised Statute
OTE	oxygen transfer efficiencies
OWEB	Oregon Watershed Enhancement Board
Ox/OM	oxygen to organic matter ratio
PBOD	particulate biochemical oxygen demand
pH	hydrogen ion
PME	protection, mitigation, and enhancement
PMF	probable maximum flood
PNV	potential natural vegetation
POC	particulate organic carbon
PP	particulate phosphorus
psi	pounds per square inch
PVC	polyvinyl chloride
RM	river mile
RV	recreational vehicle
scfm	standard cubic feet per minute
SED	first-order sediment oxygen demand
SOD	sediment oxygen demand

Abbreviation / Acronym	Definition
SR-HC TMDL	Snake River-Hells Canyon Total Maximum Daily Load
SRPM	Snake River Planning Model
SSWQ	salmonid spawning water quality
SU	standard unit
TCS	temperature control structure
t-DDT	1,1,1-trichloro-2,2-bis(p-chlorophenyl) ethane (total-DDT)
TDG	total dissolved gases
TDS	total dissolved solids
TEMP	Temperature Enhancement Management Program
TIC	total inorganic carbon
TMDL	total maximum daily load
TOC	total organic carbon
TOM	total organic matter
TP	total phosphorus
TP/OM	total phosphorus to organic matter ratio
TP/OX	total phosphorus to oxygen ratio
TSS	total suspended solids
TVA	Tennessee Valley Authority
UBOD	ultimate biochemical oxygen demand
µg/C	micrograms per xxxx
µg/G	micrograms per gram
µg/L	micrograms per liter
µg/M	micrograms per meter
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USC	United States Code
USFS	United States Forest Service
USGS	United States Geological Survey
VSS	volatile suspended solids
W2	CE-QUAL-W2
WAC	Watershed Advisory Committee
WWTF	wastewater treatment facility

This page left blank intentionally.

1. INTRODUCTION

Pursuant to the Federal Power Act of 1935, as amended (FPA), Idaho Power Company (IPC) filed an application with the Federal Energy Regulatory Commission (FERC) in July 2003 for a new license authorizing the continued operation and maintenance of the Hells Canyon Complex (HCC), a 3-dam hydroelectric project comprised of the Hells Canyon Project, the Brownlee Project, and the Oxbow Project (collectively, FERC Project No. 1971-079),. In the application, IPC proposed protection, mitigation, and enhancement (PME) measures to address effects associated with the HCC.

The Oregon Department of Environmental Quality (ODEQ) and the Idaho Department of Environmental Quality (IDEQ) advised IPC that a certification, pursuant to § 401 of the Federal Water Pollution Control Act of 1977 (more commonly known as the Clean Water Act) (CWA), is required from each state in connection with the relicensing of the HCC.Accordingly, IPC hereby applies for certification from ODEQ that any discharges originating in Oregon that may result from continued operation of the HCC will comply with applicable water quality requirements. An application prepared in accordance with ODEQ regulations follows.[1] IPC has this day also filed a request for certification before IDEQ in accordance with Idaho law that any discharges originating in Idaho that may result from continued operation of the HCC will comply with applicable water quality requirements of Idaho law.

IPC filed a CWA § 401 certification application (§ 401 application) with ODEQ and IDEQ in July 2003, which, following comments received from ODEQ, IPC subsequently withdrew for further analysis. Following the application submittal and withdrawal, IPC had active discussions with the ODEQ and IDEQ in an effort to better define the technical issues. Those discussions and the analysis of additional data gathered at the request of ODEQ, IDEQ, and other stakeholders resulted in a second application filed in December 2005 and additional information filed in March 2006. In response to issues raised during subsequent discussions, IPC withdrew that application in October 2006 and agreed to submit a revised § 401 application by the end of January 2007. The information in that application further defined the technical issues and addressed water quality concerns discussed during ongoing efforts. However, technical issues remained in relation to specific pollutants, and additional information was developed that required incorporation into the § 401 application. IPC subsequently withdrew the January 2007 application and submitted another application on November 2, 2007. The November 2, 2007, application was subsequently supplemented on February 2, May 30, and June 30, 2008. Despite these submittals, technical issues relative to IPC's previously proposed watershed temperature enhancement management program (TEMP) remained. To address the remaining TEMP issues, IPC submitted a revised § 401 application document on August 8, 2008, with additional information on February 20, 2009. Because of the complexity and novelty of IPC's TEMP proposal, completing the necessary process for an August 8, 2009, issuance of the CWA § 401

[1] ODEQ's regulatory requirement that a draft § 401 application be submitted 1 year before the final FERC application was not in effect in 2003 when IPC submitted its New License Application with FERC. OAR 340-48-0020(5).

certification was not practical. Therefore, IPC withdrew and resubmitted an application on May 15, 2009. Based on subsequent discussions with ODEQ and IDEQ concerning specific aspects of the TEMP proposal, IPC submitted additional information to supplement the May 15 submittal on October 12. Unfortunately, despite the additional information provided by IPC, the § 401 application was again withdrawn and resubmitted on December 23, 2009. Based on discussions with ODEQ and IDEQ since December 23, 2009, IPC repeated the withdrawal and resubmittal of its § 401 application on September 24, 2010. After additional discussions with parties involved in the § 401 certification process, IPC is again withdrawing and resubmitting its § 401 application in July 2011.

The HCC is located on the Snake River in Oregon and Idaho and consists of the Brownlee development, the Oxbow development, and the Hells Canyon development.[2] Because the HCC is located in Oregon and Idaho, IPC requests that ODEQ and IDEQ coordinate their respective certification proceedings to the maximum extent possible in an effort to avoid or minimize any conflicts or inconsistencies that may occur due to differences in Oregon and Idaho water-quality standards. It is IPC's understanding that each state's § 401 certification will only include conditions relating to discharges within that state.

IPC has proposed PME measures related to water quality in its new license application that are supplemented in this § 401 certification application. IPC believes the PME measures reasonably and satisfactorily address water-quality concerns related to the HCC. Specifically, PME measures are proposed to address temperature, dissolved oxygen (DO), and total dissolved gases (TDG). The PME measures are presented in Section 7 of this § 401 certification application.

1.1. Hells Canyon Complex

1.1.1. Location Description

Hells Canyon is situated in west-central Idaho and northeastern Oregon on the Snake River, a major tributary to the Columbia River and a border water of Oregon and Idaho. The HCC is located in the southern part of Hells Canyon and forms 3 reservoirs: Brownlee, Oxbow, and Hells Canyon. A more detailed description of the HCC location is available in Exhibit A of the *New License Application: Hells Canyon Hydroelectric Complex*.

The FERC project boundary for the HCC extends from just above Porter Island [River Mile (RM) 343], within Malheur County in the State of Oregon, approximately 5 miles northwest of Weiser, Idaho, to Hells Canyon Dam (RM 247.6) in Wallowa County, Oregon (Figure 1.1-1). [Figure E.6-2, Panels 1–11, of the *New License Application: Hells Canyon Hydroelectric Complex*, provides an area view at a larger scale.] The length of the project boundary extends just over 95 river miles. The width of the project boundary is typically several hundred feet, and is generally defined as the distance between the average high-water lines on each bank of the

[2] See State Engineer of Oregon, License for Project No. 189 (Hells Canyon); State Engineer of Oregon, License for Project No. 188 (Brownlee); State Engineer of Oregon, License for Project No. 161 (Oxbow).

reservoir. Exceptions to this typical width occur in the few specifc areas where IPC owns larger areas of property. Notable exceptions are on the lower Burnt River, near the Spring Recreation Area; Sturgill Creek; Daly Creek and the upper end of the Powder River pool; and at the Brownlee and Oxbow operators' villages (Brownlee Village and Oxbow Village, respectively).

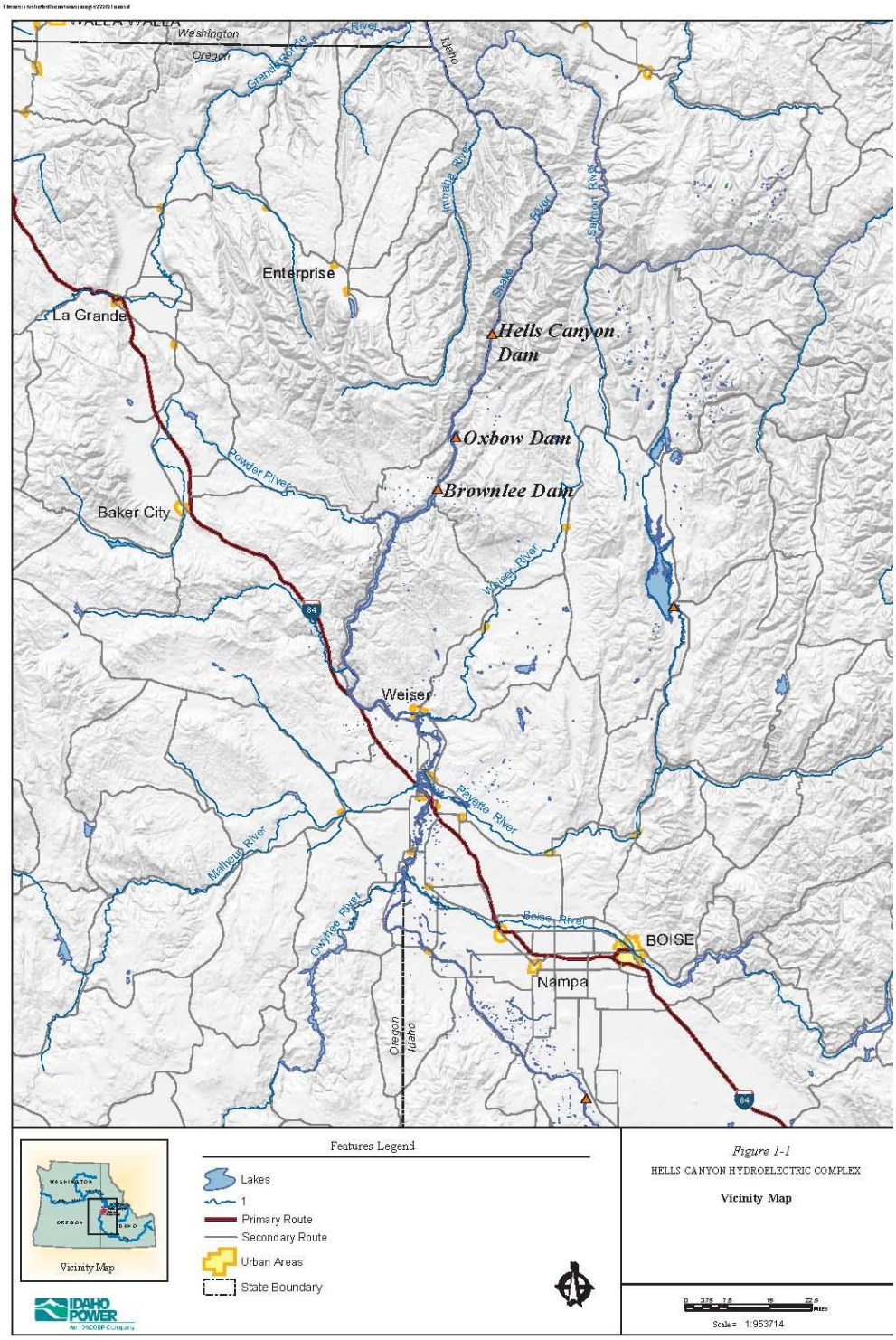


Figure 1.1-1. Vicinity map

The HCC is situated within and across the political boundaries of Malheur, Baker, and Wallowa counties in Oregon and Adams and Washington counties in Idaho, and, therefore, forms the border between these states. In Oregon, the upper approximately 10 miles of the project area (from just above Porter Island to the south side of Farewell Bend State Park) lie in Malheur County. Within this reach, approximately 10 islands in the Snake River lie entirely within the Oregon state border. From the state park northward to approximately 12 miles below Oxbow Dam, the project area lies within Baker County. The remainder to the north (approximately 13 miles) is within Wallowa County and is also almost completely within the Wallowa-Whitman National Forest and the Hells Canyon National Recreation Area (HCNRA). The delineation between Adams and Washington counties in Idaho occurs near Brownlee Dam.

1.1.2. Construction History

IPC started access and site preparation work for Brownlee Dam on November 10, 1955. Brownlee Dam was substantially completed on, and reservoir filling commenced, May 9, 1958. Excavation for Oxbow Dam began December 11, 1957. Oxbow Dam was completed on, and reservoir filling commenced, March 12, 1961. Excavation for Hells Canyon Dam began on August 27, 1964. Hells Canyon Dam was completed on, and reservoir filling commenced, October 10, 1967.

The first Brownlee generating unit went into operation on August 27, 1958. The last HCC generator went into service on December 28, 1967. An additional turbine, Brownlee Unit No. 5, was constructed and placed in service on March 31, 1980. More detail on project benchmarks and dates is available in Exhibit C of the *New License Application: Hells Canyon Hydroelectric Complex*.

1.1.3. Features of Interest

Prominent features of interest within the HCC in Oregon include the Oxbow and Hells Canyon dams. The Oxbow Village and Copperfield Park (RM 269.5) include the major developed areas for the HCC workforce. The village and park lie at the intersection of Oregon State Highway 86 and IPC's road along Oxbow and Hells Canyon reservoirs. Approximately 20 residences, a kitchen and dining facility, bunkhouse, classroom facility, school, post office, and a 72-space park comprise the village. Approximately a quarter- to a half-mile upstream from Oxbow Village is the Oxbow shop complex (Oxbow Shop) and the Oxbow fish hatchery. The hatchery is an adult holding and spawning facility and has the capacity to produce 200,000 fall Chinook salmon (*Oncorhynchus tschawytscha*). Continuing upstream, shortly before reaching the bridge near Brownlee Dam (RM 283.9), the smaller Brownlee Village and trailer park accommodate a smaller number of the HCC workforce (approximately 10 residences). The trailer park served as a camp during construction of Brownlee Dam. A number of other U.S. Bureau of Land Management (BLM), state, and county recreation facilities; private residences; and recreational concessions are located in Oregon within the project boundary. These include a BLM facility at Copper Creek; private residences in the Homestead area; Hewitt and Holcomb parks (Baker County) on the Powder River arm (RM 7.5); a number of residences and cabins on the Powder River arm; residences in the Douglas Creek area; Spring Recreation Area (BLM) at the Burnt River (RM 326.7); Farewell Bend State Park (State of Oregon; RM 333.5); and the

privately owned Snake River RV and Oasis Campground, as well as the adjoining BLM Oasis site (RM 340).

On the Idaho side of the river, several additional points of interest would be IPC's Brownlee Dam and Power Plant (RM 284.6), Woodhead Park (139 spaces) and caretaker's house (RM 287.3), McCormick Park (34 spaces and tent camping) (RM 283.3), and Hells Canyon Park (24 spaces and tent camping) and caretaker's house (RM 263.5). Other developments on the Idaho side not associated with IPC include the privately owned Mountain Man Lodge (RM 310.5); Steck Park (RM 327.9), cooperatively owned and run by the BLM and Idaho Department of Fish and Game (IDFG); and several private residences.

1.2. Existing License

1.2.1. Year Issued

The Federal Power Commission (FPC), predecessor agency to FERC, issued the HCC license on August 4, 1955, for the 3-dam complex that now exists.

1.2.2. Year Expires

The current HCC license expired July 31, 2005. The project currently operates under an annual license.

1.3. New License Filing Schedule

1.3.1. Intent to File

A notice of intent to file a new license application for the HCC was filed by IPC in July 2000.

1.3.2. Draft License Application

IPC distributed a draft license application for the HCC to federal and state resource agencies, Indian tribes, and other interested parties in September 2002.

1.3.3. Final License Application

IPC filed a final license application for the HCC with FERC on July 21, 2003.

1.3.4. Additional Information Requests Filings

On May 4, 2004, IPC received additional information requests (AIR) from FERC relative to water-quality issues. More detail on operational scenarios is available in the *New License Application: Hells Canyon Hydroelectric Complex*, AIR OP-1; on DO augmentation in AIR WQ-1; and on temperature control in AIRs WQ-2a, WQ-2b, and WQ-2c.

2. CWA CERTIFICATION PROCESS

CWA § 401 (33 United States Code [USC] § 1341) provides that any applicant for a federal license or permit to conduct any activity including, but not limited to, the construction or operation of facilities, which may result in any discharge into navigable waters, shall provide the licensing or permitting agency a certification from the state in which the discharge originates that any such discharge will comply with applicable provisions of the CWA. FERC regulations require an applicant to also file with FERC a copy of the request for § 401 certification pursuant to the U.S. Code of Federal Regulations (CFR) (18 CFR § 16.8(f)(7)).

The ODEQ is the agency of the State of Oregon designated to carry out the certification functions prescribed by § 401 of the CWA for Oregon waters. IDEQ is the agency of the State of Idaho designated to carry out the certification functions prescribed by § 401 of the CWA for Idaho waters.

2.1. Oregon

The Oregon Environmental Quality Commission adopted Oregon Administrative Rules (OAR) 340-048-0005 through 340-048-0055 to prescribe the procedures for receiving, evaluating, and taking final action upon a § 401 certification application. OAR 340-048-0020(2) identifies the information that must be included in an application for § 401 certification.

In addition, Oregon Revised Statute (ORS) Chapter 543A prescribes procedures for coordination among state agencies in the reauthorization of federally licensed hydroelectric projects, including state certification of water quality. The Oregon Hydroelectric Application Review Team (HART) is tasked with this responsibility, though ODEQ has lead responsibility on § 401 certification.

2.2. Idaho

The Idaho Board of Environmental Quality has not adopted rules specific to the § 401 certification process. IDEQ has, however, developed *Idaho 401 Guidance* (IDEQ n.d.) to foster a consistent statewide approach to § 401 certification.

2.3. Other Potentially Applicable State Laws

Consistent with CWA § 401(a) and (d), any certification issued by ODEQ should include such limitations necessary to assure compliance with water-quality standards and "other appropriate requirements of state law."[3] IPC provides the following information relative to compliance with other appropriate requirements of Oregon law.

[3] 33 USC 1341(d). Because there are no federal requirements, such as effluent limitations or new source performance standards, applicable to hydroelectric projects, ODEQ certification conditions will be based solely on state law.

2.3.1. Oregon HART Process

IPC has elected to seek state reauthorization of the project pursuant to ORS 543A.071 and 543A.075 concurrently with FERC licensing. IPC has voluntarily engaged in this reauthorization process, coordinated by HART, because of the opportunity for cooperation and coordination among the various Oregon agencies and FERC. IPC further understands that such reauthorization is intended to include a reauthorization of IPC's water rights for the project.

2.3.2. Laws Administered by the Oregon Department of Land Conservation and Development

ORS Chapter 197 contains provisions of state law regarding the development and acknowledgement of comprehensive land-use plans and requires that state agency actions be consistent with acknowledged local land-use plans and implementing ordinances. An evaluation of consistency with local use plans is provided in Section 4.3.3.

2.3.3. Laws Administered by the Oregon Department of Fish and Wildlife

The Oregon Department of Fish and Wildlife (ODFW) administers laws and policies regarding protection, restoration, and conservation of native fish including ORS 496.435 regarding native salmon and trout stocks, OAR 635-007-503 regarding native fish habitat, and OAR 635-500 regarding steelhead (*Oncorhynchus mykiss*) and trout habitat. PME measures associated with these issues have been proposed in IPC's final license application submitted to FERC.

2.3.4. Laws Administered by the Oregon Department of State Lands

If required by law, IPC will obtain a permit from the Oregon Department of State Lands (DSL) for streams under their jurisdiction, pursuant to ORS § 196.810, to implement conditions of the FERC license that require fill and removal of material from the beds or banks of a stream.

2.3.5. Laws Administered by the Oregon and Idaho Departments of Environmental Quality

ORS 454.605, et. seq., and OAR Chapter 340, Divisions 71 and 73, contain requirements that govern on-site disposal of sewage. The purpose of such rules is to prevent health hazards and protect the quality of surface water and groundwater. ODEQ contracts with local governments to administer the program pursuant to state rules.

IPC has received 2 permits for sewage disposal associated with the HCC. Permit number ID0020907 was originally issued, in part, for treated sanitary sewage at the Brownlee Project. This discharge was permanently eliminated on May 26, 2001, and replaced with a new, upland on-site disposal (septic) system permitted through the Idaho Department of Health and Welfare (IDHW), Southwest District Health Department (SWDHD). ODEQ has permitted (OR-002727-8) a sewage holding tank for the Hells Canyon Project. As such, no treated or untreated sewage is disposed directly to surface waters of either Oregon or Idaho.

IPC has 3 permits issued for disposal of non-contact cooling water and sump discharges: ID0020907, OR-002728-6, and OR-002727-8 at the Brownlee, Oxbow, and Hells Canyon projects, respectively. The constituents typically monitored and reported include flow rate, water temperature, oil and grease, hydrogen ion (pH), and total suspended solids (TSS).

Associated with the HCC, IPC maintains several comfort stations that include showers, restrooms and vault toilets, and recreational vehicle (RV) dump stations (Table 2.3-1). In addition, there is a fish-cleaning station located at Woodhead Park on Brownlee Reservoir. Similarly, there is no treated or untreated wastewater discharged directly to surface waters of either Oregon or Idaho. The largest facility, Woodhead Park, which was developed in 1994, disposes effluent by a land-application treatment system meeting IDEQ standards.

Table 2.3-1. Number of comfort stations (includes showers), restroom and vault toilets, and recreational vehicle (RV) dump station treatment type by project in the Hells Canyon Complex.

Project	Location	Comfort Stations	Restroom and Vault Toilets	RV Dump Station Treatment Type
Brownlee	Woodhead Park	2	4	Wastewater Treatment Lagoon
Oxbow	McCormick Park	1	0	Drain Field
	Carters Landing	0	1	Pump-Out
	Oxbow Boat Launch	0	1	Pump-Out
Hells Canyon	Copperfield Park	1	0	Drain Field
	Hells Canyon Park	1	0	Drain Field

2.4. IPC State Water Rights

IPC has a vested right to use the waters of the Snake River in connection with the Hells Canyon Project, pursuant to the terms and conditions of Oregon License No. 189, issued April 22, 1968, for the period ending December 31, 2017. Similarly, under Oregon License No. 161, issued December 19, 1961, IPC has a vested right to use the waters of the Snake River in connection with the Oxbow Project, pursuant to the terms and conditions of such license, for the period ending December 19, 2011. Finally, under Oregon License No. 188, issued June 5, 1961, as amended January 20, 1981, IPC has a vested right to use the waters of the Snake River in connection with the Brownlee Project, pursuant to the terms and conditions of such license, for the period ending December 31, 2010. The CWA does not supersede or abrogate rights to quantities of water that have been established by either state (CWA § 101(g), 33 USC § 1251(g)). By filing this application, IPC does not waive any such water rights. IPC requests that ODEQ include appropriate conditions in its certification that recognize and protect IPC's vested water rights under Oregon law.

3. CONCURRENT WATERSHED WATER-QUALITY PROCESSES

IPC supports the watershed approach used to develop and implement a total maximum daily load (TMDL) for the Snake River as an appropriate mechanism to improve the water quality of the Snake River and considers it particularly relevant to the § 401 certification process. As such, IPC supported development of the Middle Snake River TMDL, King Hill–C.J. Strike Reservoir TMDL, Middle Snake–Succor Creek TMDL, and the Snake River–Hells Canyon TMDL (SR-HC TMDL) and continues to actively participate in their implementation. The SR-HC TMDL includes the reach of the Snake River associated with the HCC.

IDEQ and ODEQ issued the SR-HC TMDL in July 2003, with revisions in June 2004 (IDEQ and ODEQ 2004). The U.S. Environmental Protection Agency (EPA) approved the individual bacteria, pH, pesticides, and TDG TMDLs in March 2004, and the rest of the TMDLs in September 2004[4].

3.1. A Watershed-Based Approach

CWA § 303 requires that states adopt water-quality standards necessary to protect designated beneficial uses, including fish, wildlife, and recreation. Subsection 303(d) establishes requirements for states to identify and prioritize waterbodies that are water-quality limited or impaired (i.e., water bodies that do not meet applicable water-quality standards). For waters identified on this list, states must develop a TMDL for each of the pollutants for which water-quality standards are exceeded. TMDLs define the amount of a particular pollutant that can be present in a waterbody without causing an exceedence of applicable water-quality standards or non-attainment of beneficial uses. TMDLs also define, based on the best available science, the amount of a pollutant that a waterbody can receive from all sources and still meet applicable water-quality standards. Natural sources of pollutants, as well as releases from point and nonpoint sources (anthropogenic sources), are taken into consideration in the development of TMDLs. Once all the sources of pollutants are accounted for, pollutant loads are then allocated or budgeted to the sources (including natural sources) in a manner that describes the total amount of pollutant load that can be released to the waterbody by each source without causing applicable water-quality standards to be exceeded. In this way, the ultimate "responsibility for improving water quality lies on the shoulders of everyone who lives, works or plays in a watershed that drains into an impaired waterbody" (IDEQ and ODEQ 2004).

In connection with the development of TMDLs, water-quality management plans (referred to as implementation plans in Idaho) are also developed to identify actions to achieve the TMDL load and wasteload allocations and improve the water quality of a listed waterbody. In Oregon, these management plans are to be submitted to the EPA with a draft TMDL for approval. In Idaho, implementation plans are to be developed within 18 months of the EPA's approval of the TMDL. The implementation of these management plans, which generally include periodic

[4] IPC filed a petition for judicial review of those portions of the SR-HC TMDL that impose a temperature load allocation on the HCC. This petition is pending in the Circuit Court for Baker County, Oregon.

reviews and revisions, is expected to result in the attainment of water-quality standards for a CWA § 303(d) listed waterbody.

3.2. Development of TMDLs in the Watershed

Segments of the Snake River, upstream and downstream of the HCC, are listed by Oregon and Idaho as water-quality limited under § 303(d) of the CWA. Information as to the segments listed and the water quality standards exceeded can be accessed on the ODEQ and IDEQ websites—http://www.deq.state.or.us/wq/assessment/rpt0406/search.asp and http://www.deq.state.id.us/water/data_reports/surface_water/monitoring/integrated_report.cfm#2002. Consistent with these listings, TMDL processes and related management plans are in place or are being developed for most of the upstream waterways: including the Weiser, Payette, Malheur, Owyhee, and Boise watersheds, as well as the Snake River upstream through American Falls Reservoir. The Snake River TMDLs include the Middle Snake–Succor Creek, King Hill–C.J. Strike Reservoir, Middle Snake, Upper Snake–Rock Creek, Lake Walcott, and American Falls. The management or implementation plans associated with these TMDL efforts contain mechanisms specifically targeted to reduce, among other pollutants, bacteria, sediment, nutrients, DO, and temperature impacts to tributary watersheds and the Snake River. In many cases, implementation plans have already begun upstream and are demonstrating positive results. While ODEQ and IDEQ expect that water quality in the Snake River will improve with implementation of the TMDLs and that these improvements will lead to corresponding water-quality benefits in the HCC, the agencies also note that, due to size of the watershed and the complexities involved, an extended period of time will be required to achieve the water-quality targets (IDEQ and ODEQ 2004). For purposes of this application, reasonable assurance of compliance with the water-quality standards assumes full implementation of TMDLs.

3.3. The Snake River–Hells Canyon TMDL

In addition to the TMDL processes referenced above, the ODEQ and IDEQ initiated a TMDL process in 2000 involving the reach of the Snake River associated with the HCC. This process was in response to CWA § 303(d) listings by Oregon or Idaho for sediment, pesticides, DO, nutrients, pH, temperature, and mercury. Additionally, TDG were assessed during the TMDL process.[5] The resulting SR-HC TMDL and Water Quality Management Plan were issued by IDEQ and ODEQ in July 2003 and revised in June 2004. The EPA approved bacteria, pH, pesticide, and TDG TMDLs in March 2004, and the rest of the SR-HC TMDLs in September 2004.[6] The SR-HC TMDL covers the mainstem Snake River from RM 409 near the town of Adrian, Oregon, to the inflow of the Salmon River at RM 188.2 and includes Brownlee, Oxbow, and Hells Canyon reservoirs.

---

[5] Since initiation of the SR-HC TMDL, Idaho has listed TDG and removed pH as pollutants impairing reaches of the Snake River and the HCC.

[6] IPC filed a petition for judicial review of those portions of the SR-HC TMDL that impose a temperature load allocation on the HCC. This petition is pending in the Circuit Court for Baker County, Oregon.

IPC supported and actively participated in the SR-HC TMDL process as part of a larger watershed water-quality approach initiated by ODEQ and IDEQ because improvement in water quality in the Snake River depends upon water-quality improvements throughout the Snake River watershed. Water quality within the HCC reservoirs, as well as the water quality of releases from those reservoirs, is in large part a function of the quality of the Snake River water flowing into Brownlee Reservoir. The ODEQ and IDEQ also recognized the interrelationship of the TMDL efforts on the Snake River with the HCC licensing and CWA § 401 certification processes and contemplated that the "recommendations for water quality improvements identified within the SR-HC TMDL and its accompanying management plan would be the foundation for the FERC licensing and CWA § 401 water-quality certification processes" (IDEQ and ODEQ 2004).

IDEQ and ODEQ (2004) describe the available database on water-quality conditions in the lower Snake River and Hells Canyon reaches of the Snake River as "robust" (much of the data being the result of the IPC's study and data collection efforts associated with the licensing of the HCC). However, the states recognized that achieving water-quality standards in a river as complex as the Snake River would require an iterative and extended process that will require several decades to respond completely to implementation projects and changes in management. The SR-HC TMDL specifically notes.

> *As demonstrated by the size and diversity of the issues addressed in this document, the SR-HC TMDL reach is a highly complex system and will no doubt yield unexpected results as implementation and further data collections proceeds. The challenges encountered in determining designated beneficial use support and system impairment are an outgrowth of this complexity and will require additional assessment and revisitation as our understanding of the system evolves. Additionally, due to the complexity encountered and the enormous geographic scope of the effort, an extended time period for implementation and system response will be required.*

4. PROJECT DESCRIPTION

4.1. Legal Name and Address of Project Owner

Idaho Power Company
1221 W. Idaho St.
P.O. Box 70
Boise, ID 83702
Phone: (208) 388-2676

4.2. Legal Name and Address of Owner's Official Representative

James C. Tucker
Senior Attorney
Idaho Power Company
1221 W. Idaho St.
P.O. Box 70
Boise, ID 83702

4.3. Adjacent Lands

4.3.1. Names and Addresses of Contiguous Property Owners

Names and addresses of contiguous property owners are included as Exhibit 4.3-1.

4.3.2. Adjacent Land Use

The project area includes 17,070 acres of land, including lands both above and below the normal high-water mark (Table 4.3-1). Of the total project acreage, 5,600 acres (33%) are federally owned; 340 acres (2%) are state owned; and 11,130 acres (65%) are privately owned. Of the privately owned land in the project area, IPC owns 9,660 acres (57% of the total acreage).

Of the total project acreage, 6,850 acres (40%) are above the normal high-water mark. Federal and state lands comprise 1,930 acres (28%) and 230 acres (3%), respectively, of the total unflooded acreage. Private lands make up 4,690 acres, or 68% of the unflooded lands in the project area. Of these lands, IPC owns 3,450 acres, or half of all the unflooded lands in the project area.

At the upstream end of the project area near Weiser, Idaho, agriculture and private ownership are extensive. As the canyon steepens along Brownlee Reservoir, more lands come under federal ownership, primarily managed by the BLM. Significant state ownership associated with the Cecil D. Andrus Wildlife Management Area occurs on the Idaho side just upstream of Brownlee Dam. On the Powder River arm, BLM and private lands are interspersed until agriculture and corresponding private ownership predominate around Richland, Oregon.

Along Oxbow Reservoir, BLM-managed land and private lands continue to be intermixed. IPC's land ownership in fee is focused on Brownlee and Oxbow reservoirs, with several larger parcels on the Powder River arm of Brownlee Reservoir.

On the Idaho side, the Payette National Forest reaches down to Hells Canyon Reservoir just downstream of Oxbow Village and continues on to Hells Canyon Dam, where the HCNRA begins. Private ownership predominates on the Oregon side of Hells Canyon Reservoir with a few larger parcels of BLM-managed lands interspersed down to Copper Creek, which forms the boundary of the HCNRA and wilderness area.

Table 4.3-1. Land ownership (acres) in the Hells Canyon Complex (HCC) project area. (Lands administered by the U.S. Forest Service are denoted as USFS; lands administered by the U.S. Bureau of Land Management are denoted as BLM; and lands owned by Idaho Power Company are denoted as IPC.)

Land Ownership	Hells Canyon	Oxbow	Brownlee	Total HCC	% of Total
All Lands (Flooded and Non-flooded Lands)					
Federal Lands					
USFS	1,360			1,360	7.97
BLM	240	570	3,430	4,240	24.84
∑ Federal Lands	1,600	570	3,430	5,600	32.81
State Lands	0	10	330	340	1.99
IPC Lands					
Limited Use Rights	30	0	1,140	1,170	6.85
Full Use Rights	330	1,100	7,060	8,490	49.74
∑ Idaho Power Lands	360	1,100	8,200	9,660	56.59
Other Private Lands	100	610	760	1,470	8.61
Total Acreage in Project Boundary	**2,060**	**2,290**	**12,720**	**17,070**	**100.00**
Flooded Lands					
Federal Lands					
USFS	970			970	9.49
BLM	220	300	2,180	2,700	26.42
∑ Federal Lands	1,190	300	2,180	3,670	35.91
State Lands	0	0	110	110	1.08
IPC Lands	90	120	6,000	6,210	60.76
Other Private Lands	0	80	150	230	2.25
Total Acreage Flooded	**1,280**	**500**	**8,440**	**10,220**	**100.00**

Land in the HCC is used for 6 primary purposes: 1) cultivated agriculture, 2) livestock grazing, 3) hydroelectric power generation, 4) recreation, 5) wildlife habitat, and 6) residential and rural residential use. In the past, industrial mining and timber harvest also occurred. Any mining remaining in the area is believed to be recreational, rather than industrial. Although timber sales and harvest may still occur at higher elevations, no harvest is known to have recently taken place. Interstate 84 (I-84) passes near the upper end of the project area on the Oregon side. A small area of commercial use occurs adjacent to I-84 at Farewell Bend, Oregon. The distribution of these land uses and the aesthetic character of the area are largely determined by the canyon's geography. More detail on land use throughout the HCC is available in Exhibit E.6 of the *New License Application: Hells Canyon Hydroelectric Complex*.

4.3.3. Evaluation of Consistency of IPC's Project with County Comprehensive Plans

Per Oregon regulations, OAR 340-048-0020(2)(i)(A) and (C), an applicant must provide an exhibit that "includes land use compatibility findings for the activity prepared by the local planning jurisdiction" and "discuss the potential direct and indirect relationship to water quality of each finding or land use provision." The HCC is within or adjacent to Malheur, Baker, and Wallowa counties in Oregon. Although the Federal Power Act may preempt county plans, IPC provides, as Exhibit 4.3-2 to this application, the findings and an evaluation of such plans in accordance with the Oregon regulations.

More detail is available in the *New License Application: Hells Canyon Hydroelectric Complex*. Proposed PME measures are included in Section E.6.4., and the *Hells Canyon Resource Management Plan* is included as Technical Report E.6-1., also summarized in Section E.6.4 of Exhibit E.

4.4. Project Overview

The HCC includes the Snake River from Farewell Bend, Oregon, downstream approximately 95 river-miles to Hells Canyon Dam. The HCC is comprised of Brownlee, Oxbow, and Hells Canyon dams and reservoirs. The reservoirs were constructed primarily for power production, although Brownlee Reservoir has operational requirements related to flood control. The three-dam complex was initiated in 1958 with the construction of Brownlee Dam. The contemporary Oxbow Project was constructed in 1961, and Hells Canyon Dam was constructed in 1967. Together, the 3 hydroelectric projects have a total nameplate generating capacity of 1,166.9 megawatts, or enough electric energy to supply 758,485 homes. As such, the HCC is the centerpiece of IPC's generating portfolio and critical to the economies of Idaho and eastern Oregon. More detail on IPC's hydroelectric resources is available in Exhibit H of the *New License Application: Hells Canyon Hydroelectric Complex*.

The combined water volume of the 3 HCC reservoirs is approximately 1,647,500 acre-feet, while the usable storage is 1,009,198 acre-feet. All of the reservoirs can be characterized as relatively deep, with mean depths ranging from 50 ft (Oxbow Reservoir) to 100 ft (Brownlee Reservoir). Maximum depth in Brownlee Reservoir is 300 feet. More detail on the physical characteristics of the HCC reservoirs is available in Technical Report E.2.2-2 of the *New License Application: Hells Canyon Hydroelectric Complex*. Both Oxbow and Hells Canyon reservoirs have normal water-level fluctuations of approximately 5 feet with an additional 5 feet for atypical circumstances. In contrast, the water-level fluctuation of Brownlee Reservoir is approximately 100 ft. Most of the water-level fluctuation in Oxbow and Hells Canyon reservoirs is related to power production, while flood control accounts for most of the annual change in water surface elevation in Brownlee Reservoir.

Brownlee Reservoir is the largest of the 3 reservoirs, with a total volume of approximately 1,420,000 acre-feet and a usable storage of 975,318 acre-feet. Average annual flow into Brownlee Reservoir is approximately 13,000,000 acre-feet. Despite the large volume of Brownlee Reservoir, retention times are relatively low (approximately 30 days) because of the large amount of flow into the reservoir.

Snowmelt runoff dominates the project area's hydrology. Based on records of the U.S. Geological Survey (USGS) gage 13269000, Brownlee Reservoir receives its highest inflows in May (Brennan et al. 2000). The lowest rate of inflow occurs in August when precipitation levels are lowest and irrigation diversions in the Snake River are highest (USBR 1999). This general hydrologic regime is typical of most major tributaries to the HCC. However, this regime probably does not reflect the natural hydrologic processes because many of the tributaries are regulated by reservoirs for flood control, agricultural water supplies, power generation, and recreation (IDWR 1971). Many of the drains discharge small volumes of water (less than one cubic meter per second) from irrigated cropland adjacent to the Snake River (Myers et al. 1998).

The use of Brownlee Reservoir to meet flood-control requirements may result in slightly higher flows from January through April and slightly lower flows in May and June than would occur without the flood-control requirements. Because Oxbow Reservoir receives flows primarily from Brownlee Reservoir, and Hells Canyon Reservoir, in turn, receives discharged flows primarily from Oxbow Reservoir, the hydrologic regimes of Oxbow and Hells Canyon reservoirs are very similar to that of Brownlee Reservoir.

4.5. Project Operations

The HCC includes the dams, reservoirs, and power plants associated with the Brownlee, Oxbow, and Hells Canyon projects. Operations of the 3 projects of the HCC are closely coordinated to generate electricity and serve many other public purposes.

Currently, 471,779 customers rely on IPC's hydro and thermal generation system for power. The HCC is a critical part of IPC's generation system. Its winter and summer operations are particularly important because energy needs are highest during those seasons. In wintertime, customers need extra electricity for lighting and heating. During the summer, they need extra electricity for air conditioning and irrigation pumping.

IPC operates the HCC to comply with its existing FERC license, as well as voluntary arrangements to accommodate other interests, such as recreational use and environmental resources. Among these arrangements are the *Fall Chinook Interim Recovery Plan and Study* (IPC 1991), voluntarily adopted by IPC in 1991 to protect spawning and incubation of fall Chinook salmon below Hells Canyon Dam, which are listed as a threatened species under the Endangered Species Act, and, most recently, the *Hells Canyon Hydroelectric Project Settlement Process Interim Agreement* (Interim Agreement) that IPC entered into with multiple parties relating to the operation of the HCC pending the issuance of a new license. While portions of the Interim Agreement have expired, other portions remain in effect pending the issuance of a new license for the HCC.

4.5.1. Brownlee Reservoir Operations

Brownlee Reservoir is only one of the 3 HCC developments and is IPC's only project with significant storage. It has 101 vertical feet of active storage capacity that equals approximately 1 million acre-feet of water. Brownlee Dam's hydraulic capacity is also the

largest of the 3 HCC developments. Its powerhouse capacity is approximately 35,000 cubic feet per second (cfs).

Brownlee Reservoir is a multiple-use, year-round resource for the Northwest. Although its primary purpose is to provide a stable power source, Brownlee Reservoir is also used for flood control, fish and wildlife mitigation, and recreation. Brownlee Dam is one of several Northwest dams that cooperate to provide springtime flood control on the lower Columbia River.

For flood control, IPC operates the reservoir cooperatively with the U.S. Army Corps of Engineers (USACE) North Pacific Division, according to Article 42 of the existing license. After flood-control requirements have been met in early summer, the reservoir is refilled to meet peak summer electricity demands and provide suitable habitat for spawning bass (*Micropterus* spp.) and crappie (*Pomoxis* spp.). The full reservoir also offers optimal recreational opportunities through the Fourth of July holiday.

The U.S. Bureau of Reclamation (USBR) periodically releases water from its storage reservoirs in the Snake River watershed to assist with the migration of anadromous fish, species that ascend rivers from oceans to spawn, past the lower Snake River Federal Columbia River Power System projects, established as a reasonable and prudent alternative by the Federal Columbia River Power System biological opinion. As part of the Interim Agreement among multiple parties filed with FERC in January 2005, IPC agreed to provide up to 237,000 acre-feet of water from Brownlee Reservoir in June and July of 2005 and 2006, provided such operation did not cost more than $2 million annually or jeopardize the reliability of the electrical system. IPC provided these flow augmentation releases in 2005 and 2006. The portion of the Interim Agreement relating to annual flow augmentation releases has expired, however, IPC continues to engaged in discussions with the federal resource agencies with regard to annual flow augmentation releases. FERC staff included a recommendation for flow augmentation releases from the HCC in the Draft Environmental Impact Statement issued in July 2006 (FERC 2006). IPC subsequently submitted comments to the Draft Environmental Impact Statement questioning the efficacy of flow augmentation, as well as the responsibility of IPC to provide flows to mitigate for the effects of federal projects downstream of the HCC (IPC 2006).

In late fall, Brownlee Reservoir's releases are managed to maintain constant flows below Hells Canyon Dam. These flow requirements, which are based on the *Fall Chinook Interim Recovery Plan and Study* (IPC 1991), as well as the minimum flow required by Article 43 of the existing license, help ensure sufficient water levels to protect even the shallowest spawning nests, or redds. After fall Chinook salmon spawn, IPC attempts to have a full reservoir by the first week of December to meet winter peak demands.

4.5.1.1. Winter—December through February

Electricity demands are critical during the winter in IPC's service area and throughout the Northwest. To meet peak winter demands and maintain system reliability, the water level in Brownlee Reservoir should be at elevation 2,075 ft mean sea level (msl) by the first week in December. If the reservoir is filled to that level, the system can provide stable, reliable energy through the winter and reduce operating costs by minimizing the need for purchasing outside power.

During the months of December through February, IPC maintains minimum flows below Hells Canyon Dam to ensure sufficient water levels for fall Chinook salmon redds. By January or February, IPC begins to draft the reservoir to meet elevation targets for flood control.

4.5.1.2. Spring—March through May

The USACE North Pacific Division defines flood-control requirements and coordinates flood-control efforts with IPC. During the spring, IPC complies with Article 42 of the existing license and responds to the USACE request to lower the water level in Brownlee Reservoir. The lower water level provides space for excess spring runoff and helps prevent flooding, primarily on the lower Columbia and Snake rivers.

IPC's existing license requires that the reservoir's elevation be at or below 2,034 feet mean sea level (ft msl) by March 1, a level that provides approximately 500,000 acre-feet of storage space for flood control. The license also stipulates that USACE may request an additional 500,000 acre-feet of storage space, if necessary. However, in past years when snowpack was less than normal, USACE reduced the storage space requirement.

In the mid-1980s, USACE examined the reservoir's flood-control operations and developed a rule curve table for Brownlee Reservoir's target elevations. These target elevations define the space in the reservoir needed for flood control and are based on forecasted runoff at both the Brownlee and The Dalles (Oregon) projects. More recently, the rule curve procedure was improved. This new rule curve now provides a more gradual change in reservoir elevations to reach required storage volumes by targeted dates.

IPC initiated the new rule curve for water year 2000 flood-control requirements. Depending on the water year and USACE mandates, flood-control requirements for Brownlee Reservoir may continue through June. To meet mandated target elevations for flood control, IPC may need to spill water through the HCC. Although there are no official refill target elevations, USACE controls how quickly the reservoir can be refilled once flood-control requirements are met.

4.5.1.3. Summer—June through August

After IPC is released from flood-control responsibilities, the company begins refilling Brownlee Reservoir. The refill target is 2,069 ft msl (approximately 8 feet below the full reservoir capacity of 2,077 ft msl) toward the end of May and full by the end of June. Meeting these targets ensures that enough water is stored in Brownlee Reservoir to meet peak summer electricity demands, provide suitable spawning habitat for bass and crappie, and offer optimal recreational opportunities.

In an attempt to cooperate with federal efforts to meet flow objectives at Lower Granite Dam established by the Federal Columbia River Power System biological opinion, IPC has, in the past, provided flow augmentation releases from Brownlee Reservoir. For example, IPC provided flow augmentation releases in 2005 and 2006 pursuant to an Interim Agreement among multiple parties filed with FERC in January 2005. The relevant portions of that agreement provided that IPC will draft Brownlee Reservoir in June and July to an elevation of 2,059 ft msl, which, if the reservoir is full at the beginning of the draft, will result in the release of up to 237,000 acre-feet

of water, provided such operation does not cost more than $2 million annually or jeopardize the reliability of the electrical system. The portion of the Interim Agreement relating to annual flow augmentation releases has expired. However, IPC continues to engage in discussions with the federal resource agencies with regard to the potential for similar flow augmentation releases in years prior to the issuance of a new license for the HCC. FERC staff included a recommendation for flow augmentation releases from the HCC in the Draft Environmental Impact Statement issued in July 2006 (FERC 2006). IPC subsequently submitted comments to the Draft Environmental Impact Statement questioning the efficacy of flow augmentation, as well as the responsibility of IPC to provide flows to mitigate for the effects of federal projects downstream of the HCC (IPC 2006).

4.5.1.4. Fall—September through November

During the fall, Brownlee Reservoir is largely operated to benefit fall Chinook salmon below the HCC. After the delivery of flow augmentation water, Brownlee Reservoir releases are managed to maintain a constant flow below Hells Canyon Dam to provide stable conditions for spawning fall Chinook salmon. The spawning flow is based on a minimum reservoir elevation of approximately 2,040 ft msl when the program starts in October and forecasted inflows so that Brownlee Reservoir is full, around 2,075 ft msl, by the first week in December. The minimum flow below Hells Canyon Dam is maintained through fry emergence in the spring and established by maintaining water over the shallow-most redd (IPC 1991). Once this flow is set, it is considered the minimum flow necessary to keep embryos from desiccating until they emerge as fry in the spring. In other words, the spawning flow is maintained as a minimum flow until emergence is complete. It should also be pointed out that the lower the reservoir elevation in Brownlee Reservoir, the lower the power production capability of the plant. Therefore, implementation of the *Fall Chinook Interim Recovery Plan and Study* may require IPC to purchase power from other sources if the load demand cannot be met due to the loss in net head at the reservoir.

4.5.2. Oxbow Reservoir and Hells Canyon Reservoir Operations

Target elevations for Brownlee Reservoir define the flow of water and, therefore, operations through Oxbow and Hells Canyon reservoirs. Oxbow and Hells Canyon reservoirs have much smaller active storage capacities, approximately 0.5% and 1.0%, respectively, of Brownlee Reservoir's volume, with slightly smaller hydraulic capacities of 28,000 and 30,500 cfs, respectively.

When flows through the HCC are below hydraulic capacity, all 3 projects operate closely together to reregulate flows through the Oxbow and Hells Canyon projects so that they remain within the one-foot-per-hour ramp rate requirement (measured at Johnson Bar below Hells Canyon Dam) and meet the daily peak load demands. However, when flows exceed powerhouse capacity for any of the projects, water is released over the spillways at those projects.

In addition to maintaining the ramp rate, IPC maintains minimum flow rates in the Snake River downstream of Hells Canyon Dam. These minimum flow rates are for navigation purposes as specified under Article 43 of the existing license. Neither the Brownlee Project or the Oxbow Project has a minimum flow requirement below its powerhouse. However, because of

the Oxbow Project's unique configuration, a flow of 100 cfs is maintained through the bypassed reach of the Snake River below the dam (a segment called the Oxbow Bypass).

5. APPLICABLE WATER-QUALITY REGULATIONS

5.1. Beneficial Uses

As border water, the Snake River has designated uses established by both Oregon and Idaho. ODEQ has designated fish and aquatic life, recreation, water supply, wildlife habitats, aesthetics, commercial navigation and transportation, and hydro power uses for the main-stem Snake River (Table 5.1-1). In addition, anadromous fish migration corridors and salmon and steelhead spawning are designated uses downstream of Hells Canyon Dam to the Washington border. Redband trout (*Oncorhynchus mykiss*) rearing is a designated use in the HCC upstream to the Idaho border.

Table 5.1-1. Oregon's designated uses (OAR 340-041 n.d.) and water quality limiting pollutants (ODEQ 2007a) for the mainstem Snake River.

Snake River Segment	Designated Uses	Pollutants
Snake River: Washington Border to Hells Canyon Dam	salmon and steelhead spawning anadromous fish migration corridors resident fish and aquatic life water contact recreation public/private domestic water supply irrigation livestock watering industrial water supply wildlife and hunting fishing and boating aesthetics commercial navigation and transportation hydro power	temperature[1] toxics (mercury)
Snake River: Hells Canyon Dam to Idaho Border	redband trout rearing resident fish and aquatic life water contact recreation public/private domestic water supply irrigation livestock watering industrial water supply wildlife and hunting fishing and boating aesthetics commercial navigation and transportation hydro power	temperature[1] toxics (mercury)

[1]Temperature was originally listed in 1998 and is only listed as a pollutant limiting water quality during the summer.

IDEQ has designated similar uses (Table 5.1-2). In addition, Idaho has designated the Snake River a special resource water. A designation of special resource water is applied to waters recognized as needing intensive protection to maintain current uses or to preserve outstanding or unique characteristics.

Table 5.1-2. Idaho's designated uses (IDAPA 58.01.02. n.d.) and water quality limiting pollutants (IDEQ 2005) for segments of the Snake River.

Snake River Segment	Designated Uses	Pollutants
Snake River: Salmon River inflow to Hells Canyon Dam	cold-water aquatic life salmonid spawning primary contact recreation domestic water supply agricultural water supply industrial water supply wildlife habitats aesthetics special resource water	temperature[1] dissolved oxygen total dissolved gases
Snake River: Hells Canyon Dam to Oxbow Dam (Hells Canyon Reservoir)	cold-water aquatic life primary contact recreation domestic water supply agricultural water supply industrial water supply wildlife habitats aesthetics special resource water	temperature total dissolved gases
Snake River: Oxbow Dam to Brownlee Dam (Oxbow Reservoir)	cold-water aquatic life primary contact recreation domestic water supply agricultural water supply industrial water supply wildlife habitats aesthetics special resource water	temperature nutrients total dissolved gases pesticides sediment
Snake River: Brownlee Dam to Scott Creek inflow (Brownlee Reservoir)	cold-water aquatic life primary contact recreation domestic water supply agricultural water supply industrial water supply wildlife habitats aesthetics special resource water	temperature dissolved oxygen nutrients sediment mercury
Snake River: Scott Creek to Weiser River	cold-water aquatic life primary contact recreation domestic water supply agricultural water supply industrial water supply wildlife habitats aesthetics	temperature dissolved oxygen nutrients Sediment

[1]Temperature is listed as a pollutant on the U.S. Environmental Protection Agency's additions to Idaho's 1998 § 303(d) list (USEPA 2001a).

5.2. Applicable SR-HC TMDL Targets

The Snake River has been identified as water-quality limited under § 303(d) of the CWA. This designation indicates that the appropriate agencies have identified the water quality in the Snake River as not meeting applicable water-quality standards (USEPA 2001a, IDEQ 2005, ODEQ 2007a). Tables 5.1-1 and 5.1-2 list the pollutants identified as limiting water quality in the HCC Reach of the Snake River.

Because the Snake River is border water, the SR-HC TMDL addresses both Oregon and Idaho water-quality standards. The SR-HC TMDL uses the more conservative standard from either state to identify appropriate water quality targets (Table 5.2-1). The states have both numeric and narrative standards, so both quantitative and qualitative levels may apply. IPC was issued allocations in the SR-HC TMDL for temperature, DO, and TDG.

Table 5.2-1. Levels indicating water-quality limitation for the Snake River from near Weiser, Idaho, to the confluence with the Salmon River (IDEQ and ODEQ 2004).

Measures	Levels Indicating Water Quality Limitation
water temperature[1]	A 7-day average maximum temperature greater than 17.8 °C for desiganted uses: fish and aquatic life, anadromous fish passage, and salmonid rearing. A maximum weekly maximum temperature greater than 13 °C when and where salmonid spawning occurs, or greater than a 0.14 °C increase from anthropogenic sources when site potential is greater than the target temperature.
dissolved oxygen[2]	A single water-column measure less than 6.5 milligrams per liter (mg/L) for fish and aquatic life designated uses upstream of Hells Canyon Dam. A single water-column measure less than 8.0 mg/L or less than 90% saturation applies below Hells Canyon Dam. A single water-column measure less than 11.0 mg/L or less than 95% saturation; with a single intergravel measure less than 8.0 mg/L, measured as a spatial median, when and where salmonid spawning occurs.
total dissolved gas	A single water-column measure greater than 110% saturation for designated uses: fish and aquatic life, anadromous fish passage, salmonid rearing, and salmonid spawning (when and where it occurs). In the absence of site-specific data, gas bubble disease in fish may indicate water quality limitation.
nutrients	A growing season total phosphorus concentration greater than 0.07 mg/L.
nuisance algae	A mean growing season concentration greater than 14 micrograms per liter (µg/L) chlorophyll *a* (a surrogate for algal mass) and a nuisance threshold of 30 µg/L exceeded greater than 25%.
hydrogen ion (pH)	A single water-column measure less than 7 and/or greater than 9 pH units for designated uses: fish and aquatic life, anadromous fish passage, salmonid rearing, and salmonid spawning (when and where it occurs).
mercury	A single total mercury water-column measure greater than 0.012 µg/L and/or methylmercury in fish tissue greater than 0.35 milligrams per killogram (mg/kg) for designated uses: fish and aquatic life, salmonid rearing, and salmonid spawning (when and where it occurs).
bacteria	A single sample greater than 406 *Escherichia coli* (E. coli) organisms per 100 millileters (ml) and a 30-day logarithmic mean greater than 126 E. coli organisms per 100 ml based on a minimum of 5 samples for the primary contact recreation designated use.
sediment	A 14-day average total suspended sediment greater than 80 mg/L and a monthly average greater than 50 mg/L for designated uses: fish and aquatic life, salmonid rearing, and salmonid spawning (when and where it occurs).
pesticides	Single water-column measure greater than 0.024 nanograms per liter (ng/L) DDT, 0.83 ng/L DDD, 0.59 ng/L DDE, and/or 0.07 ng/L dieldrin for designated uses: fish and aquatic life, salmonid rearing, and salmonid spawning (when and where it occurs).

[1] ODEQ numeric criteria (OAR 340-041 n.d.) have changed since approval of the SR-HC TMDL. Anadromous fish migration corridors and redband trout criteria are a 7-day average maximum temperature of 20.0 °C. The seasonal thermal pattern of the Snake River must reflect the natural seasonal thermal pattern. All point sources and nonpoint sources are restricted to a cumulative increase no greater than 0.3 °C above the applicable criteria.

Idaho numeric criteria (IDAPA 58.01.02 n.d.) have changed since submission of the SR-HC TMDL. A maximum weekly maximum of 13.0 °C to protect fall Chinook salmon spawning and incubation applies from October 23 through April 15 in the Snake River from Hells Canyon Dam to the Salmon River.

A 7-day average cannot be calculated until there are 7 consecutive days of record. The first day is October 29.

Both Oregon and Idaho have natural conditions criterion. Natural thermal potential conditions supersede numeric criteria.

[2] Lower levels are allowed when conditions of barometric pressure, altitude, and temperature preclude attainment of the numeric criteria.

6. WATER-QUALITY STANDARDS EVALUATION

Since the HCC is border water, IPC assessed HCC water quality data against Oregon temperature standards or the most conservative standards in both Oregon and Idaho. This approach is consistent with the approach used to establish water-quality targets in the SR-HC TMDL (IDEQ and ODEQ 2004). Further, IPC will identify any temperature load allocations issued to IPC in the SR-HC TMDL and an analysis of those allocations. In Section 7, IPC proposes measures to provide reasonable assurance that such load allocations will be addressed.

6.1. Temperature

Section 6.1 has been withdrawn and will be submitted in the next application.

6.2. Dissolved Oxygen

Physical, chemical, and biological processes control the oxygen content of water. The solubility of DO decreases as water temperature increases, so changes in seasonal water temperatures substantially change the saturation level for DO. Reaeration, another physical process, tends to add DO to the water column when DO levels are low, and release DO to the atmosphere when levels are above saturation. DO concentrations can also be affected by several biological processes related to elevated nutrient, organic matter, or algal levels. Nutrients promote algal growth that, in turn, generate oxygen during photosynthesis and consume oxygen during respiration. Aerobic decomposition of dead algae, organic sediments, and other organic matter further depletes oxygen. Municipal, industrial, and agricultural wastes can also create a biochemical oxygen demand (BOD) as these wastes oxidize.

Oregon does not list the Snake River as being impaired by DO (Table 5.1-1). Idaho lists Brownlee Reservoir (Table 5.1-2) and the Snake River upstream (IDEQ 2005) as impaired. IDEQ and ODEQ evaluated available data for the SR-HC TMDL and reported excessive total phosphorus (TP) concentrations in the Snake River upstream of the HCC (RM 409 to RM 335) and routinely observed nuisance algal growths in this reach and the upper end (riverine zone) of Brownlee Reservoir (IDEQ and ODEQ 2004). These findings corroborated those reported by Webb (1964) and Worth (1994). The IDEQ and ODEQ concluded from the analysis of data that most phosphorus promoting the nuisance growths originated from sources upstream of the HCC (IDEQ and ODEQ 2004). Myers et al. (1998) and Hoelscher and Myers (2003) reported similar findings. The SR-HC TMDL linked nutrients and chlorophyll *a* with low DO levels downstream and set targets for both TP and algae for the attainment of DO criteria and the protection of beneficial uses (IDEQ and ODEQ 2004). They predicted that upstream reductions in TP loading, based on SR-HC TMDL allocations, would improve water quality in the Snake River and DO levels in Brownlee Reservoir. Specifically, low DO levels within the HCC are attributable to in-reservoir processing of inflow organic matter loads. The organic matter is a source of energy for bacteria. When the heterotrophic bacteria decay organic matter, oxygen is consumed from the water (Maier et al. 2000). Analysis has shown that upstream water-quality conditions influence water quality within and below the HCC, including oxygen demand and DO concentrations (Harrison et al. 1999, Myers et al. 2003). To address the remaining DO deficit relative to the

aquatic life criterion in the HCC, a DO load allocation of 1,125 tons of DO per year was established for Brownlee Reservoir (IDEQ and ODEQ 2004).

The SR-HC TMDL did not establish a TMDL for DO below Hells Canyon Dam. Beneficial uses below Hells Canyon Dam include salmonid rearing and spawning (Tables 5.1-1 and 5.1-2). These uses require more stringent targets than those for which the upstream SR-HC TMDL targets were developed. In the absence of a TMDL and resulting allocations, and in order to determine whether continued operation of the HCC could result in an exceedence of Oregon or Idaho DO water quality standards, it is necessary to determine the appropriate HCC DO responsibility for downstream DO conditions. In order to determine the appropriate HCC DO responsibility for downstream, IPC first assessed a DO load needed to address these more stringent downstream criteria assuming full upstream SR-HC TMDL implementation.
The resultant load would need to be allocated among all sources, including the HCC, in any future downstream DO TMDL. For purposes of this § 401 certification application, IPC also identified the portion of the DO load that is the appropriate HCC DO responsibility. This estimate is referred to in this Section 6.2. and in Section 7.2. as "the appropriate HCC DO responsibility."

6.2.1. DO Standards and SR-HC TMDL Targets

The application of DO standards applies to specified river reaches and times depending on the species present and life cycle. Oregon and Idaho both have standards specific to aquatic life and salmonid rearing and spawning (IDAPA 58.01.02. n.d., OAR 340-041 n.d.). Salmonid spawning standards further differentiate between water column and intergravel environments. The intergravel environments are essential as eggs are deposited within the gravels for development.

While both Oregon and Idaho similarly apply DO standards, the biologically-based criteria differ. The SR-HC TMDL established the most conservative criteria as the targets for attainment of water-quality standards and protection of designated beneficial uses (IDEQ and ODEQ 2004). While the SR-HC TMDL did not determine salmonid rearing or spawning targets, IPC determined that Oregon's DO standards are the most conservative and were applied below the HCC. Idaho has DO criteria specific for waters discharged from dams, reservoirs, and hydroelectric facilities (IDAPA 58.01.02.276.). These criteria are not considered in the following analysis.

6.2.1.1. Aquatic Life and Salmonid Rearing

The IDEQ and ODEQ determined in the SR-HC TMDL that resident fish and aquatic life (i.e., cool-water aquatic life) standards apply to the HCC (IDEQ and ODEQ 2004). This was based on the resident fish community dominance of smallmouth bass, black crappie, and white crappie. The SR-HC TMDL target for the HCC is Oregon's criterion of not less than 6.5 mg/L as an absolute minimum (OAR 340-041-0016(3)). When ODEQ determines, at its discretion, that adequate data exist, the DO may not be less than 6.5 mg/L as a 30-day average minimum, 5.0 mg/L as a 7-day minimum mean, and 4.0 mg/L as a daily minimum (Table 6.2-1). Idaho DO criteria are similar; however, the criteria are excluded from certain strata in lakes and reservoirs (IDAPA 58.01.02. n.d.). These exclusions are not considered in the following analysis.

Table 6.2-1. State of Oregon dissolved oxygen (DO) criteria in milligrams per liter (mg/L) for the protection of aquatic life and salmonid rearing (OAR 340-041. n.d.).

Criteria	Cold-Water Aquatic Life or Salmonid Rearing	Aquatic Life (Cool Water)
Absolute minimum criteria[a]	8.0 or 90% saturation	6.5
Multiple criteria[b]		
Daily minimum	6.0	4.0
7-day minimum mean	6.5	5.0
30-day mean minimum	8.0	6.5

[a] Applicable criterion when data are limited
[b] Applicable criterion when adequate data exist

Oregon designates waters downstream of the HCC for, among other uses, salmonid rearing (Table 5.1-1). This use is consistent with the designated use in Idaho (Table 5.1-2). The Oregon DO criteria protective of salmonid rearing or cold-water aquatic life are not less than 8.0 mg/L as an absolute minimum (OAR 340-041-0016(2)). Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 8.0 mg/L, DO may not be less than 90% of saturation (Table 6.2-1). When ODEQ determines, at its discretion, that adequate data exist, the DO may not be less than 8.0 mg/L as a 30-day average minimum, 6.5 mg/L as a 7-day minimum mean, and 6.0 mg/L as a daily minimum. Idaho has a site-specific water-column criterion of not less than 6.5 mg/L as an absolute minimum (IDAPA 58.01.02.285.). The SR-HC TMDL did not address DO downstream of the HCC. As such, IPC determined Oregon's DO criteria to be the more conservative of either Oregon or Idaho and evaluated data against those criteria.

6.2.1.2. Salmonid Spawning

Salmonid spawning is a designated use of the Snake River downstream of the HCC (Tables 5.1-1 and 5.1-2). IDEQ and ODEQ did not address DO downstream of the HCC in the SR-HC TMDL (IDEQ and ODEQ 2004). However, as part of the SR-HC TMDL temperature evaluation, salmonid-spawning criteria were to apply only to that portion of the Snake River below Hells Canyon Dam (RM 247 to 188) from October 23 through April 15 for fall Chinook salmon and November 1 through March 30 for mountain whitefish. IPC then assumed that DO criteria applicable for the protection of the salmonid-spawning beneficial use also applies in the Snake River below Hells Canyon Dam (RM 247 to 188) from October 23 to April 15 for fall Chinook salmon and November 1 through March 30 for mountain whitefish.

As mentioned above, both Oregon and Idaho have salmonid-spawning standards for water column, as well as intergravel, environments. Oregon's water-column DO criteria are not less than 11.0 mg/L; however, if the minimum intergravel DO, as measured as a spatial median, is 8.0 mg/L or greater, then the water column DO criterion can be a minimum of 9.0 mg/L (OAR 340-041-0016(1)(a)). Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 11.0 mg/L or 9.0 mg/L criteria, DO may not be less than 95% of saturation (OAR 340-041-0016(1)(b)). The spatial median intergravel DO criterion is not less

than 8.0 mg/L (OAR 340-041-0016(1)(c)). Idaho's general water-column criterion is not less than 6 mg/L or 90% of saturation (IDAPA 58.01.02.250.f.i.2.a.). The intergravel criteria are not less than 5.0 mg/L as an absolute minimum, and not less than 6.0 mg/L as a 7-day average mean (IDAPA 58.01.02.250.f.i.1.). The Oregon standards are the more conservative and are used in the following analysis.

The Oregon salmonid spawning standards for water-column levels are designed to attain intergravel levels of 8.0 mg/L. Therefore, the water-column criterion of 11.0 mg/L assumes a differential (i.e., water-column DO minus intergravel DO) of 3.0 mg/L. There is a sufficient amount of water column and intergravel DO data for the area below the HCC to determine a water-column DO level that would result in meeting the intergravel criterion of 8.0 mg/L based on measured differentials. This type of evaluation is consistent with the approach used for the Oregon standard that allows water-column levels of 9.0 mg/L, provided that intergravel levels are not less than 8.0 mg/L.

Water column and intergravel DO measurements have been collected by IPC biologists as part of a much-larger study to evaluate incubation survival of fall Chinook salmon above and below the HCC (Groves and Chandler 2005, Hanrahan et al. 2005, P. Groves, IPC, unpubl. data). As part of this study, DO measurements in the water column, artificial redds, and ambient hyporheic zone were collected approximately every 2 weeks throughout the 2003/2004 and 2004/2005 spawning seasons. In 2003/2004, 8 sites were sampled below Hells Canyon Dam (5 above the confluence of the Salmon River and 3 below). In 2004/2005, 6 sites were sampled (4 above the confluence of the Salmon River and 2 below). Figure 6.2-1 illustrates the location of the sampling sites. Sample sites were located at observed spawning areas below Hells Canyon Dam. At each site, a cluster of 3 artificial redds was constructed. Artificial redd locations at each site were chosen at random. The locations exhibited the habitat use criteria described for fall Chinook salmon within the Snake River (Groves and Chandler 1999). Artificial redds were constructed in shallow water (approximately 0.6 m depth), where water velocities averaged 0.7 meters per second (m/s), to facilitate construction and ensure personnel safety.

Artificial redds were constructed using a shovel to lift and toss substrate downstream. This activity mimics the action of a salmon digging (Chapman 1988) and helps winnow fines from the gravels (based on methods described by Burton et al. 1990, McHenry et al. 1994, and Clayton et al. 1996). A characteristic depression (approximately 1 m in diameter) and "tailspill" is constructed using this technique. An intergravel sampling tube or an intergravel sampling tube and egg basket were placed within each artificial redd. The egg basket was buried to a depth of approximately 20 centimeters (cm) (measured from the top surface of the basket to the surface of the substrate). The eggs were, therefore, within a hyporheic stratum approximately between 20−35 cm below the gravel surface. This depth is similar to that of a fall Chinook salmon egg pocket at a depth between 18–43 cm below the substrate surface (Chapman et al. 1986, Chapman 1988).

Periodic intergravel water samples representative of conditions surrounding the developing embryos were collected through an intergravel sampling tube. Intergravel DO was measured using a peristaltic pump and a flow cell on a Hydrolab® Minisonde Multiprobe maintained and calibrated per manufacturer's specifications.

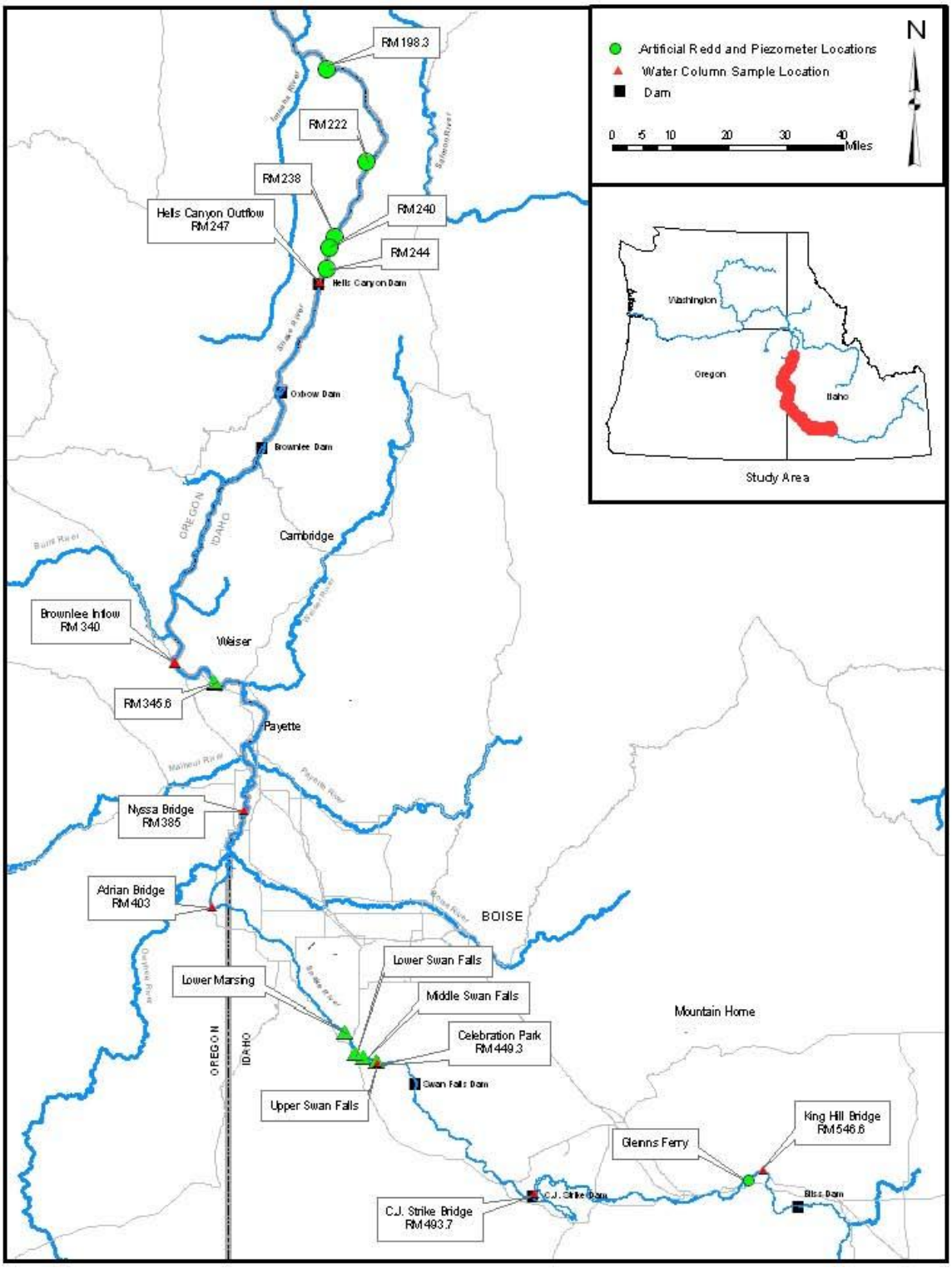


Figure 6.2-1. Map showing locations of artificial redds and water-column sampling sites on the Snake River from the Salmon River confluence upstream to King Hill. (Note: Green triangles also show artificial redd and piezometer sites.)

A DO differential was calculated for each sample event by subtracting the intergravel DO (from each artificial redd) from the water-column DO (measured at the same time at each site). The summarized differentials from the artificial redds above the Salmon River confluence are generally lower than 3.0 mg/L with 90% of all the measurements below 2.0 mg/L 8 weeks following redd construction (Table 6.2-2). Not all artificial redds were constructed on the same date; therefore, differentials are summarized by sample timing following construction (i.e., first date is immediately after construction, second date is 2 weeks later). Sampling occurred approximately every 2 weeks. The differentials generally increased over time due to processes that affect intergravel DO levels after redd construction, such as the plugging of the gravels by organic and inorganic materials.

Table 6.2-2. Summarized dissolved oxygen (DO) differentials in milligrams per liter (mg/L) between intergravel DO measured in artificially constructed redds and DO in the water column for sites on the Snake River below Hells Canyon Dam and above the Salmon River confluence. The time period between subsequent dates is approximately 2 weeks.

Upper Hells Canyon	First Date	Second Date	Third Date	Fourth Date	Fifth Date	Sixth Date	Seventh Date	Eighth Date	Ninth Date
Minimum	0.0	0.1	0.2	0.2	0.3	0.3	0.5	0.5	0.5
10th percentile	0.2	0.2	0.2	0.3	0.5	0.5	0.5	0.6	0.5
25th percentile	0.4	0.4	0.5	0.7	0.7	0.8	0.6	0.7	0.9
Median	0.5	0.7	0.8	0.9	1.0	1.3	1.2	1.3	1.5
75th percentile	0.6	0.8	1.3	1.3	1.5	1.8	1.6	1.8	2.1
90th percentile	1.3	1.5	1.7	1.6	1.7	2.3	2.0	2.1	2.3
Maximum	1.8	2.0	2.0	2.9	2.3	3.5	2.1	3.3	3.0
N	30	30	30	30	30	30	21	15	9

Note: Summary includes both 2003/2004 and 2004/2005 datasets for below the HCC and above the confluence with the Salmon River.

Oregon's standards reference a spatial median intergravel DO level. In order to compare the differentials summarized in Table 6.2-2 to the Oregon standard, the median differential of each site (i.e., a cluster of 3 artificial redds) was calculated. This median value, when added to the intergravel DO criterion of 8.0 mg/L, represents a water-column DO target that would result in meeting the spatial median intergravel criterion at that site. The maximum median differentials were below 2.0 mg/L and changed through the season (Table 6.2-3). The 90th percentile of these median differentials was selected as a level that was appropriate to apply in determining a water-column criterion. The first 5 sample dates were used, and the value on the fifth date carried through the remainder of the salmonid spawning period. The resulting water column criteria ranged from 9.1 mg/L on October 23 to 9.6 mg/L through the end of the season (Table 6.2-4). These water-column criteria were applied to the Snake River below Hells Canyon Dam from October 23 through April 15.

Table 6.2-3. Summarized site median dissolved oxygen (DO) differentials in milligrams per liter (mg/L) between intergravel DO measured in artificially constructed redds and DO in the water column for sites on the Snake River below Hells Canyon Dam and above the Salmon River confluence. The time period between subsequent dates is approximately 2 weeks

Upper Hells Canyon	First Date	Second Date	Third Date	Fourth Date	Fifth Date
Minimum	0.2	0.2	0.2	0.3	0.5
10th percentile	0.2	0.3	0.2	0.6	0.6
25th percentile	0.3	0.4	0.4	0.8	0.7
Median	0.5	0.6	0.9	0.9	0.9
75th percentile	0.6	0.8	1.2	1.1	1.5
90th percentile	1.1	1.5	1.7	1.5	1.6
Maximum	1.7	1.5	1.7	1.5	1.7
N	9	9	9	9	9

Note: Summary includes both 2003/2004 and 2004/2005 datasets for below Hells Canyon Dam and above the confluence with the Salmon River.

Table 6.2-4. Water-column dissolved oxygen (DO) criteria calculated from the 90th percentile of the summarized site median DO differentials.

	First Date 10/23	Second Date 11/7	Third Date 11/22	Fourth Date 12/7	Fifth Date 12/21–4/15
Water column DO criteria mg/L	9.1	9.5	9.7	9.5	9.6

6.2.2. Conditions Relative to DO

Both Oregon and Idaho have numeric DO criteria. The following discussion assesses measured data and model results relative to either the SR-HC TMDL DO target of 6.5 mg/L for aquatic life in the HCC or what IPC believes is the most conservative DO target for salmonid rearing and spawning below the HCC. IPC believes this is Oregon's salmonid rearing criterion of 8.0 mg/L (Table 6.2-1) and a salmonid spawning criterion based on a water column and intergravel DO differential (Table 6.2-4). Oregon's standards allow for other criteria if adequate data exists. IPC did not evaluate data relative to multiple targets unless those targets were specifically identified. Nor did IPC evaluate data at a level less than saturation if the conditions of barometric pressure, altitude, and temperature precluded attainment of the criteria. IPC believes these are conservative assumptions and, as such, incorporate an implicit margin of safety.

Evaluations relative to both measured data and model results are needed because current conditions are less than criteria, and current criteria exceedences are not solely attributable to the HCC. This is supported by the SR-HC TMDL allocations assigned to upstream nutrient sources for the attainment of DO standards and protection of the beneficial uses (IDEQ and

ODEQ 2004). Conditions relative to standards address using model results representing conditions with full implementation of the SR-HC TMDL.

6.2.2.1. Current Conditions

6.2.2.1.1. Reservoir DO

The aquatic-life criterion established in the SR-HC TMDL as the DO target for the HCC, and which was applied throughout the HCC, is Oregon's criterion of not less than 6.5 mg/L as an absolute minimum (IDEQ and ODEQ 2004). The minimum DO target of 6.5 mg/L applies unless adequate data are available, in which case multiple targets apply (Table 6.2-1). Instantaneous reservoir (profile) DO data were insufficient for estimating multiple targets and were, therefore, compared with the SR-HC TMDL target of 6.5 mg/L as an absolute minimum.

Currently, DO levels in the HCC do not always meet the 6.5 mg/L criterion. DO in Brownlee Reservoir can become severely degraded, especially during July (Table 6.2-5), a condition that has occasionally caused fish mortality (Myers et al. 2003). In particular, low-DO conditions in the transition zone of Brownlee Reservoir have been identified as potentially limiting for survival of the white sturgeon (*Acipenser transmontanus*) population in the river from Brownlee Dam upstream to Swan Falls Dam (Jager et al. 2003).

The frequency DO levels exceeded the criterion were consistently greater in the metalimnion and hypolimnion zones of Brownlee Reservoir. All of the July measurements were less than the criterion (Table 6.2-5). While Idaho excludes some strata of lakes and reservoirs from attaining standards due to natural limnological processes, Oregon does not. These strata receive waters from the inflowing Snake River that were identified in the SR-HC TMDL as having excess TP concentrations and routinely observed nuisance algal growths (IDEQ and ODEQ 2004). IDEQ and ODEQ linked these conditions to low DO in the Snake River and Brownlee Reservoir. This is best illustrated in the frequency DO criterion is exceeded in both the riverine and transition zones of Brownlee Reservoir. Therefore, degraded current conditions are a result of the degraded upstream Snake River, as well as conditions in the HCC.

Like temperature, DO is related to hydrologic conditions. Low DO appeared to be more widespread and longer in duration during low-water years (Table 6.2-5). Over one-half of the July DO measurements were less than 6.5 mg/L in the riverine zone (that zone directly receiving Snake River waters) in a low-water year; whereas, all measures were greater than the criterion in medium- and high-water years. These depressed DO concentrations continued throughout the HCC.

Table 6.2-5. Number of annual and July dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) measured throughout the Hells Canyon Complex for selected years and the percent (%) of concentrations that were less than 6.5 mg/L.

	Annual			July		
Location	**Number of DO Measures**	**Number of DO Measures < 6.5 mg/L**	**Annual DO Exceedence (%)**	**July Number of DO Measures**	**July Number of DO Measures < 6.5 mg/L**	**July DO Exceedence (%)**
1992						
Brownlee Reservoir	1,415	846	60	127	103	81
Riverine	260	78	30	21	11	52
Transition	747	536	72	79	70	89
Lacustrine	408	232	57	27	24	89
Epilimnion	208	96	46	13	10	77
Metalimnion	67	49	73	6	6	100
Hypolimnion	133	86	65	8	8	100
Oxbow Reservoir	110	57	52	10	8	80
Hells Canyon Reservoir	191	104	54	9	6	67
1995						
Brownlee Reservoir	1,221	513	42	242	149	62
Riverine	161	0	0	22	0	0
Transition	562	186	33	113	63	56
Lacustrine	498	327	66	107	86	80
Epilimnion	272	128	47	50	29	58
Metalimnion	118	105	89	24	24	100
Hypolimnion	108	94	87	33	33	100
Oxbow Reservoir	115	27	23	8	2	25
Hells Canyon Reservoir	177	31	18	20	11	55
1997						
Brownlee Reservoir	976	368	38	135	75	56
Riverine	71	0	0	25	0	0
Transition	371	101	27	85	47	55
Lacustrine	534	267	50	97	60	62
Epilimnion	347	121	35	52	15	29
Metalimnion	86	62	72	18	18	100
Hypolimnion	101	84	83	27	27	100
Oxbow Reservoir	89	52	58	18	6	33
Hells Canyon Reservoir	578	292	51	79	8	10

Notes: Brownlee Zones and Strata: Riverine ≥ RM 324–RM 335, Transition = RM 324–RM 308, Lacustrine ≤ RM 308–RM 285, Epilimnion = depth < 35 m, Metalimnion = depth 35–43.6 m, Hypolimnion = depth > 43.6 m

Oxbow Reservoir: RM 272.6–RM 284.4

Hells Canyon Reservoir: RM 247.6–RM 269.5

6.2.2.1.2. Outflow DO

6.2.2.1.2.1. Aquatic Life and Salmonid Rearing

Salmonid-rearing criteria apply to the Snake River below Hells Canyon Dam. The DO standards protective of cold-water aquatic life or salmonid rearing are not less than 8.0 mg/L as an absolute minimum (OAR 340-041-0016(2)). Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 8.0 mg/L, DO may not be less than 90% of saturation. When ODEQ determines, at its discretion, that adequate data exist, the DO may not be less than 8.0 mg/L as a 30-day average minimum, 6.5 mg/L as a 7-day minimum mean, and 6.0 mg/L as a daily minimum (Table 6.2-1). While continuous DO data are available to evaluate multiple targets, IPC did not evaluate multiple targets; therefore, conditions relative to standards are conservative.

DO levels released from Brownlee Reservoir influence DO levels in Oxbow and Hells Canyon reservoirs and in the outflow from Hells Canyon Dam. Consistent within the reservoirs, the lowest DO levels in the Snake River below Hells Canyon Dam occurred in late August and September (Figure 6.2-2). Hells Canyon outflow levels can be approximately 4.0 mg/L in September; however, reaeration occurs through several large rapids immediately downstream of Hells Canyon Dam. DO levels substantially increased within 10 miles of the dam (Figure 6.2-3).

6.2.2.1.2.2. Salmonid Spawning

Salmonid-spawning criteria apply to the Snake River downstream of Hells Canyon Dam during the salmonid-spawning period. IPC determined appropriate water-column targets to range from 9.1 mg/L on October 23 to 9.6 mg/L in late December through April 15 (Table 6.2-4). These targets were based on the DO differential between the water column and intergravel environments to maintain an intergravel criterion of 8.0 mg/L as measured as a spatial median. IPC did not evaluate conditions relative to the 95% of saturation standard where conditions of barometric pressure, altitude, and temperature preclude attainment of the criteria.

As stated above, Brownlee Reservoir outflow influences DO levels in the Oxbow and Hells Canyon reservoirs and in the outflow from Hells Canyon Dam. Typically, the lowest DO levels of approximately 4.0 mg/L are measured in late August and September (Figure 6.2-2). Reaeration occurs quickly and, in some years, can be greater than 8 mg/L 20 miles downstream by October 23 (Figure 6.2-3).

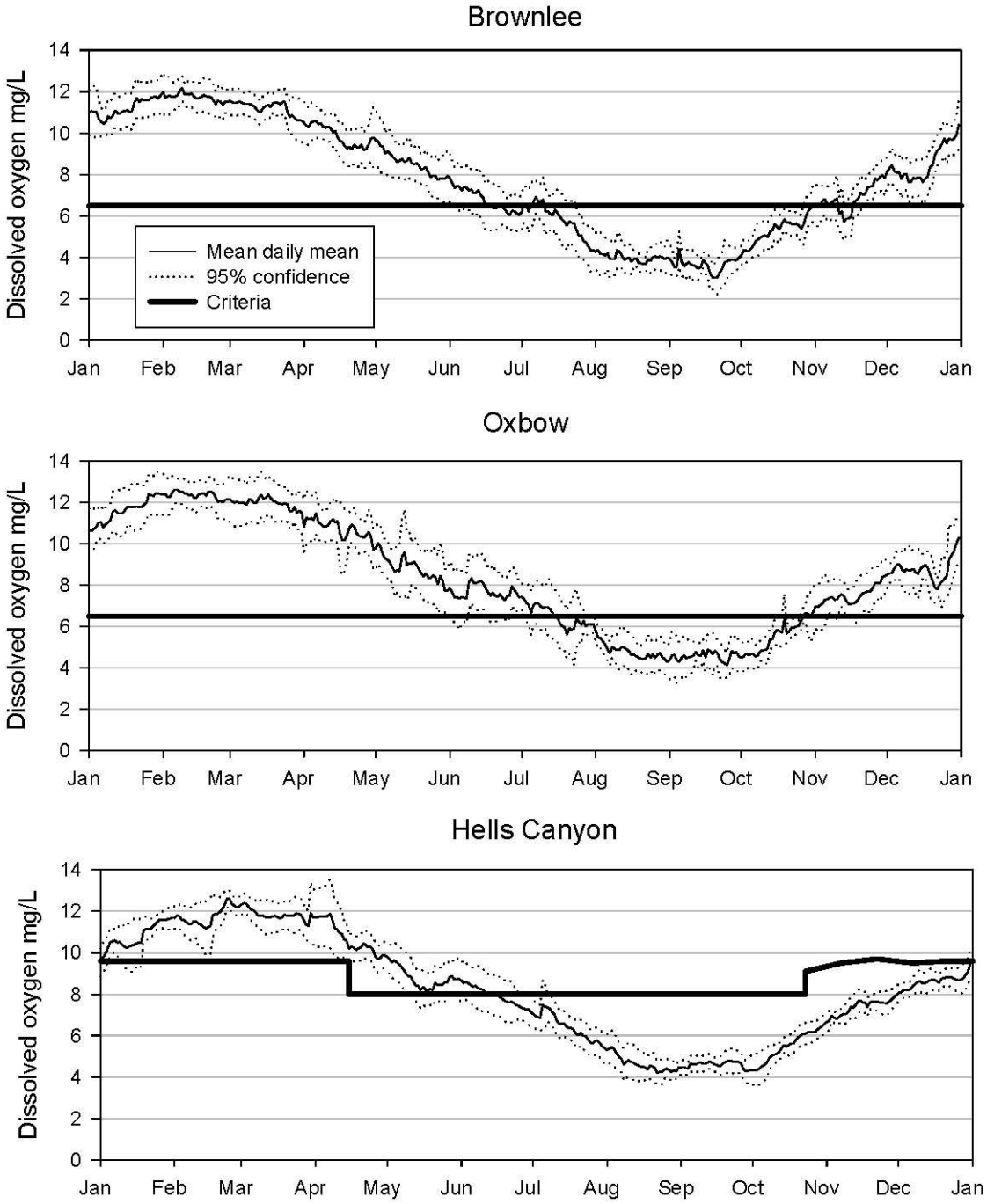


Figure 6.2-2. Mean daily averages and 95% confidence levels calculated from outflow dissolved oxygen (DO) levels measured in milligrams per liter (mg/L) in Brownlee, Oxbow, and Hells Canyon reservoirs (1991–2005). Also plotted are daily DO criteria.

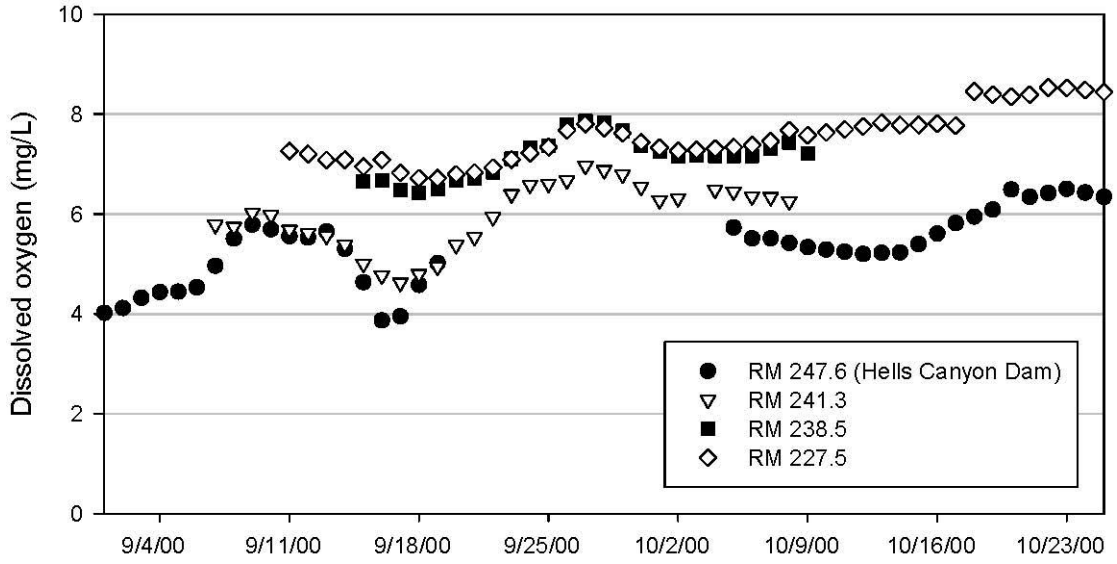


Figure 6.2-3. Daily average dissolved oxygen (DO) in milligrams per liter (mg/L) from Hells Canyon Reservoir outflow and 3 locations in the Snake River downstream during September and October 2000.

Intergravel DO concentrations are critical to support salmonid spawning. While water-column DO is often relied upon as an indicator of suitable salmonid-spawning habitat, it is concentrations of intergravel DO that directly affect egg survival in salmonid redds (Alderice et al. 1958, Cobel 1961, Maret et al. 1993). IPC evaluated DO concentrations and egg survival in 3 different types of artificial redds over 2 spawning seasons. The following were the 3 types of artificial redds.

1. Empty redds are artificial redds that contained only an intergravel sampling tube. Empty redds were constructed during the last 2 weeks of October (early spawning period).

2. Green-egg redds are artificial redds and egg baskets that contained “green” eggs. Green-egg redds were constructed during the first week of November (peak spawning period).

3. Eyed-egg redds are artificial redds and egg baskets that contained “eyed” eggs. Eyed-egg redds were constructed during the first week of December (end of the spawning period).

Intergravel DO concentrations measured in artificial redds below the HCC were generally below criteria at the initiation of the spawning season, approximately October 23 each year, and increased as the season progressed and the embryos developed (Figures 6.2-4, 6.2-5, and 6.2-6). , With respect to permeability and transport capability, the substrate quality within the Hells Canyon Reach of the Snake River was relatively high when compared to other regional samples and literature values (Arntzen et al. 2001). Therefore, when intergravel DO was below criteria below the HCC, it was a result of low water-column DO levels. Low water-column DO leaving the HCC in the beginning of the salmonid-spawning season is reaerated through a few

large rapids that increase levels by 1 to 2 mg/L within 10 miles of the dam (Figures 6.2-3 and 6.2-7). This illustrates the correlation between the intergravel and the water-column DO below the HCC, related to relatively high permeability and other water-quality characteristics.
A relatively small difference is consistently seen between water-column and intergravel DO. Therefore, as water-column DO increases below the HCC, intergravel DO also increases.

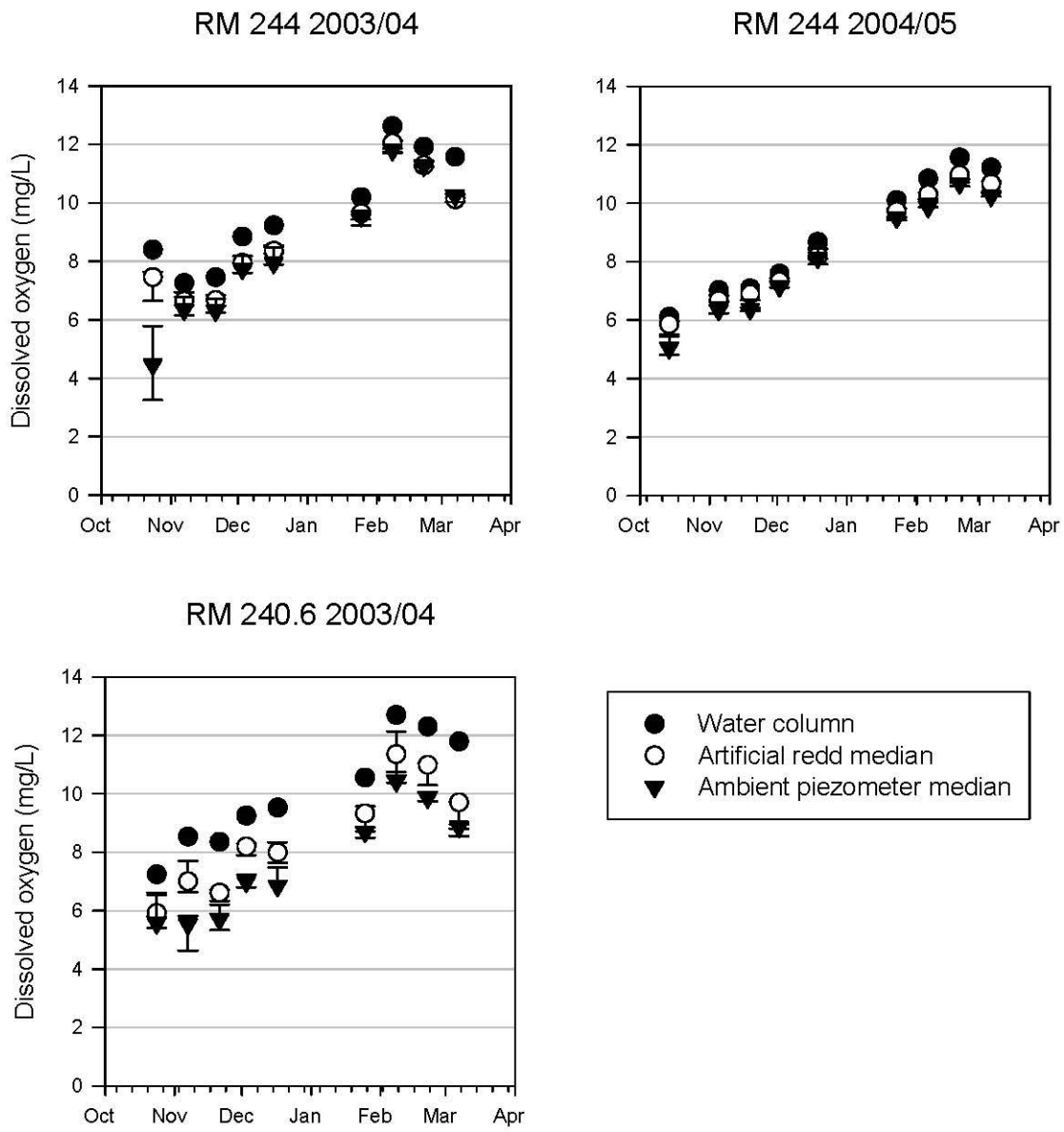


Figure 6.2-4. Intergravel dissolved oxygen (DO) in milligrams per liter (mg/L) at sites downstream of Hells Canyon Dam with no eggs in the 2003/2004 and 2004/2005 seasons. Symbols show the median of 3 artificial redds or ambient piezometers, while error bars show the minimum and maximum values.

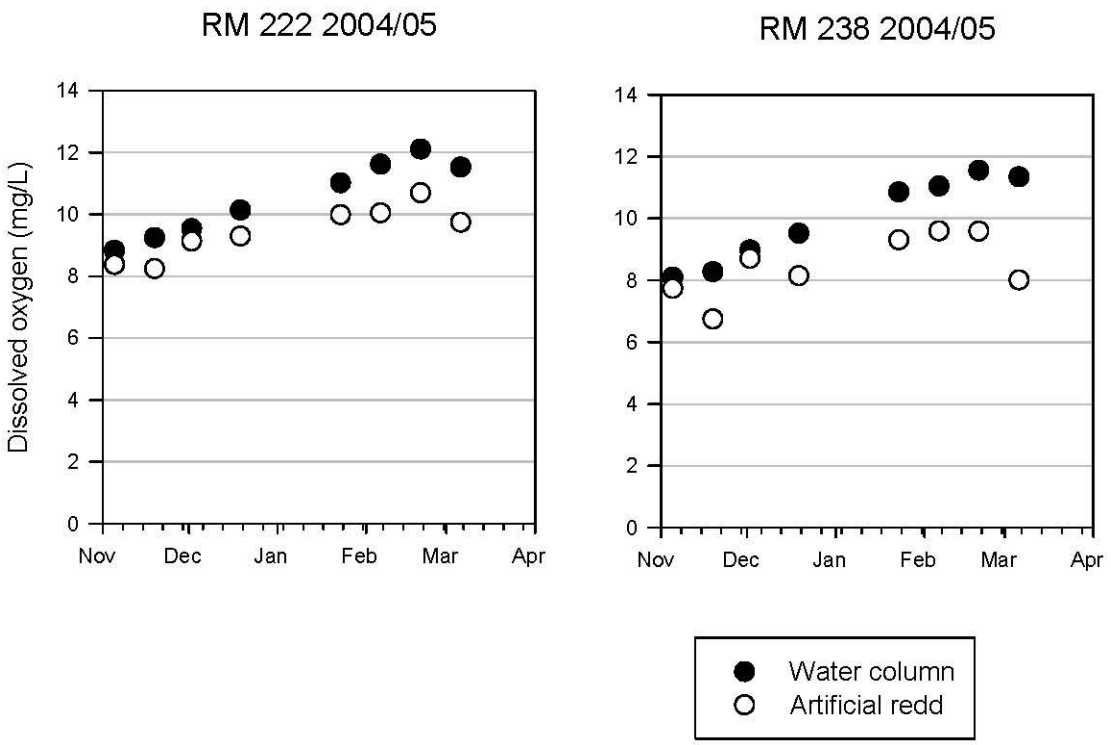


Figure 6.2-5. Intergravel dissolved oxygen (DO) in milligrams per liter (mg/L) concentrations at sites downstream of Hells Canyon Dam with green eggs in the 2004/2005 season.

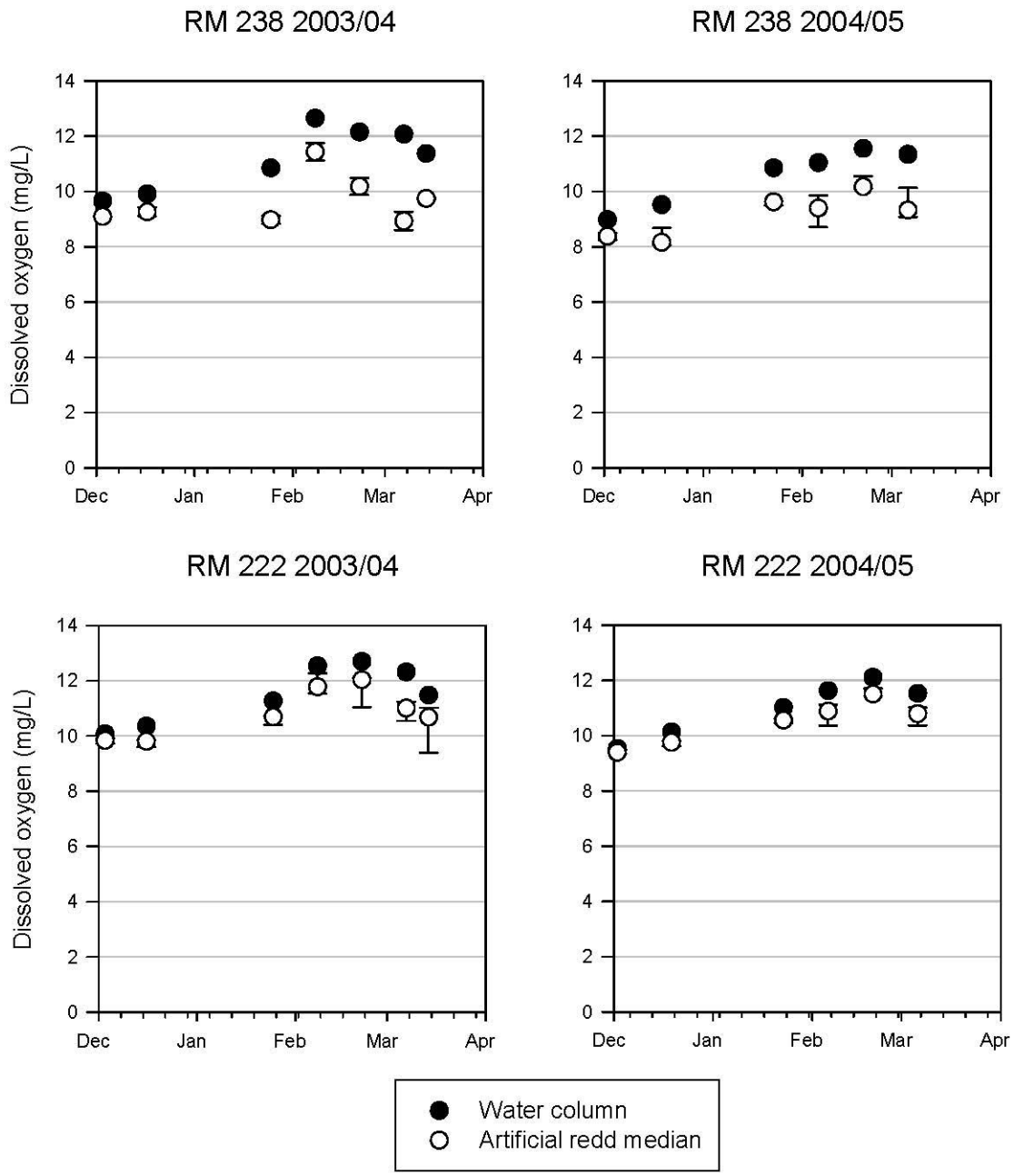


Figure 6.2-6. Intergravel dissolved oxygen (DO) in milligrams per liter (mg/L) at sites downstream of Hells Canyon Dam with eyed eggs in the 2003/2004 and 2004/2005 seasons. Symbols show the median of 3 artificial redds, while error bars show the minimum and maximum values.

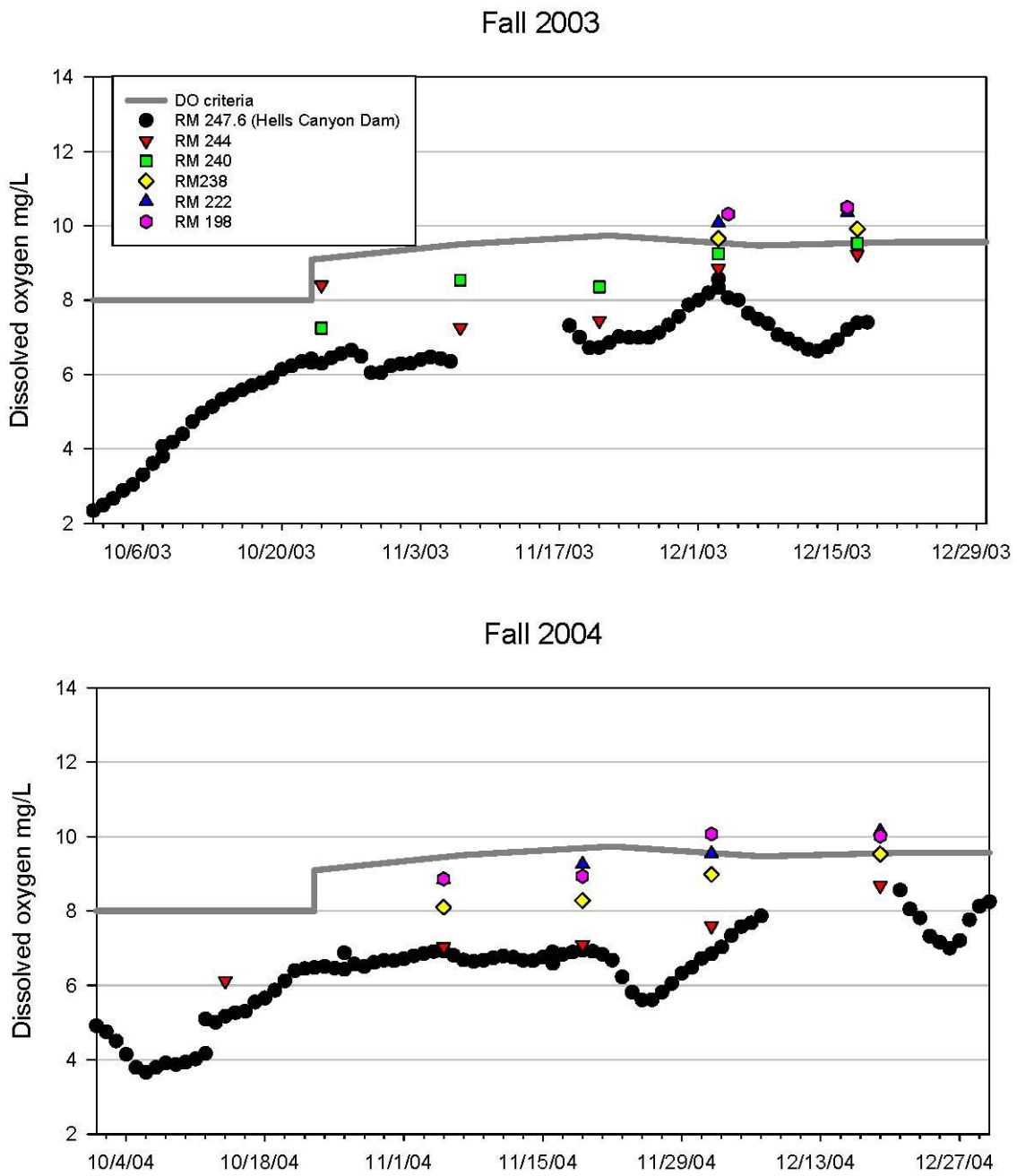


Figure 6.2-7. Water-column dissolved oxygen (DO) in milligrams per liter (mg/L) at sites downstream of Hells Canyon Dam compared with daily average (calculated from 10-minute readings) outflow DO measured in the penstock of Hells Canyon Dam (RM 247.6) in the 2003/2004 and 2004/2005 seasons.

As discussed in Section 6.2.2.2.2., this correlation does not always exist. In some locations, such as upstream of Brownlee Reservoir, plugging of the artificial redd interstices and biological processes in the gravels over the life of a redd strongly control intergravel DO levels (Groves and Chandler 2005). In these situations, water column DO can be high and increasing, while intergravel DO in an artificial redd can be low and decreasing.

6.2.2.1.3. Oxbow Bypass DO

The Oxbow Bypass is a short, 2.5-mile section of the Snake River below Oxbow Dam. The bypass extends from Oxbow Dam (RM 272.5) downstream to the powerhouse (RM 270.0). A minimum flow of 100 cfs is maintained through the bypass by drawing water from Oxbow Reservoir approximately 30 feet below full pool and passing it over the Oxbow spillway. The Oxbow Bypass is also subject to inundation by Hells Canyon Reservoir due to the backwater effect of Hells Canyon Dam. Indian Creek (RM 271.3) is the only perennial tributary to the bypass.

A deep-water pool exists just upstream of the Indian Creek confluence, approximately 1.2 miles downstream of Oxbow Dam. The pool is approximately 50-feet-deep and roughly 2 acres in surface area. The 100 cfs flow rate is not enough to completely mix this deep pool and at times the pool thermally stratifies during the summer (Myers and Chandler 2003). The thermal stratification results in the deeper, cooler water becoming anoxic during some parts of the summer season. More detail on the water quality of the Oxbow Bypass is available in Technical Report E.3.2-1 of the *New License Application: Hells Canyon Hydroelectric Complex*.

6.2.2.2. SR-HC TMDL Conditions

The CE-QUAL-W2 Model, Version 3.1 (Cole and Wells 2002), was used to model water-quality conditions throughout the HCC. CE-QUAL-W2 is a two-dimensional, longitudinal and vertical, hydrodynamic, water-quality model best suited for relatively long and narrow waterbodies, such as Brownlee Reservoir. The model is supported by the USACE Waterways Experiment Station and has been under continuous development since 1975. Since development, CE-QUAL-W2 has been applied to over 400 waterbodies and is undergoing continuous improvement. Recent modifications include reformulation of the hydrodynamic code to improve the ability to model multiple waterbodies and gradually sloping rivers, such as the Snake River of southwestern Idaho (Wells and Cole 2000).

IPC has applied the CE-QUAL-W2 model to the Snake River immediately upstream of Brownlee Reservoir and the 3 HCC reservoirs. A series of revisions and improvements were applied to the HCC model applications following development and optimization of the 2002 model application.

An absolute mean error (AME) analysis was used in Brownlee Reservoir as the primary quantitative means of assessing model optimization. The AME used was the absolute difference between measured data and model predictions and is a statistic often used to assess model performance (Cole and Wells 2002). Outflow model constituents were also compared to measured constituents; however, in-reservoir error calculations were the focus during model optimization. The current Brownlee Reservoir model applications produce averaged errors for DO below 2.0 mg/L (Table 6.2-6). This is within levels typically reported for other similar

CE-QUAL-W2 model applications (Cole and Wells 2002). Like temperature, the Brownlee Reservoir CE-QUAL-W2 model applications used in additional information requests (AIR) and this CWA § 401 certification application produced lower average errors after revisions. Brownlee outflow DO simulation improved following addition of the Brownlee turbine intake channel and improvements with in-reservoir simulation. All error estimates were lower for the improved model applications (Table 6.2-6).

Table 6.2-6. Absolute mean dissolved oxygen (DO) error in milligrams per liter (AME mg/L) summary for Brownlee Reservoir CE-QUAL-W2 model applications used in the Hells Canyon Complex Final License Application (HCC FLA), FERC additional information requests (AIR), and this CWA § 401 certification application.

Year	DO AME mg/L
1992	
HCC FLA	1.86
AIRs/401	1.39
1995	
HCC FLA	1.61
AIRs/401	1.31
1997	
HCC FLA	1.87
AIRs/401	1.47
2002[a]	
HCC FLA	NA
401	1.17

Note: NA = not applicable

[a] The 2002 model was not yet developed for the license application. Also, 2002 modeling was not used in the AIRs.

Brownlee Reservoir model outflows were linked through the Oxbow Reservoir model. Oxbow Reservoir model outflows were then linked through the Hells Canyon Reservoir model. DO error summaries for the Hells Canyon Reservoir outflow showed that modeled DO daily minimums were within 2.0 mg/L of measured DO daily minimums (Table 6.2-7). Modeled DO results in summer were generally low, compared to measured data in all years except high-water years. In the fall, model results were low in low-water years and high in medium- and high-water years compared to measured data.

Table 6.2-7. Hells Canyon Reservoir CE-QUAL-W2 model application absolute mean error (AME) and mean error (ME) summary for daily minimum outflow dissolved oxygen (DO) in milligrams per liter during selected periods. AME shows the average difference (either positive or negative), while ME shows the average difference with negative numbers, indicating model results were low compared to measured data.

Year	Summer AME (4/15–10/22)	Summer ME	Fall AME (10/23–12/1)	Fall ME
1992	1.2	–1.0	1.6	–1.3
1995	0.9	–0.7	0.6	0.5
1997	1.3	0.2	1.1	1.1
2002	0.7	–0.6	0.7	–0.6

Hells Canyon Reservoir outflow error estimates were based on daily minimum DO. This method characterizes model error as it relates to DO criteria, which were based on DO minimums. The measured daily minimum DO, which was compared with model results, was based on measurements recorded every 10 minutes. The 10-minute measurements were available for the majority of the comparisons; however, there were data gaps during the summer of 2002. For these time periods, instantaneous measurements taken every 2 weeks were compared with daily minimum modeled DO for error estimates. Since model results were lower than instantaneous measured data during these periods, the summer error estimate for 2002 is conservative.

6.2.2.2.1. Reservoir DO

Long-term reservoir DO conditions were simulated using the CE-QUAL-W2 model. Dissolved phosphorus and organic phosphorus sources (e.g., labile and refractory organic matter) were reduced in the Brownlee Reservoir inflows to simulate how the reservoir would respond to the SR-HC TMDL total phosphorus (TP) target of 0.070 mg/L (Myers et al. 2003, IDEQ and ODEQ 2004). This was accomplished by reducing dissolved phosphorus and organic phosphorus (organic matter, including algae) from current conditions or baseline boundary conditions, so inflowing TP levels did not exceed 0.070 mg/L. In addition, total organic matter (TOM) loads and sedimentation are expected to decrease as watershed management actions are implemented to meet the TP target. As loads decrease and existing TOM decays through natural processes, sediment oxygen demand (SOD) will decrease. The simulated long-term reservoir conditions included reductions in SOD. Response to these long-term improvements was simulated by reducing SOD to 0.1 g O_2/m^2/day throughout Brownlee Reservoir. This SOD level is more typical of naturally occurring levels (Cole and Wells 2002). The first-order sediment oxygen demand (SED), resulting from settling of inflowing organic matter, was left at optimized rates (Harrison et al. 1999).

Additionally, IPC will implement measures to meet the load allocation of 1,125 tons of DO per year in Brownlee Reservoir (IDEQ and ODEQ 2004). For analysis of long-term conditions, reservoir aeration was simulated by adding DO to model cells near the upper end of the transition zone. To incorporate reservoir aeration, some additional assumptions to the basic model package

were required. The effects of the reservoir aeration system were modeled in CE-QUAL-W2 using customized coding developed for IPC. The coding allows DO to be added at a specified rate to a specified number of model cells for a range of days. The desired amount of DO per year was converted into a kilogram-per-day (kg/day) rate (i.e., 1,125 tons/year equals 15,727 kg/day over the 65 days included from Julian day 182 to 247), and that mass was added equally into the specified model segments and layers.

Three model segments were aerated, representing 1.8 miles (mi) of diffusers centered near RM 325 (see Section 7.2.). Eight layers of these segments were aerated, representing 40 ft (12.2 m) of depth. The layers aerated began slightly off the bottom, representing the ability to float the diffuser line from anchors. The number of layers aerated represented the predicted distribution of oxygen absorption through the water column as bubbles rise (see Section 7.2.1.1. for more detail on Brownlee Reservoir aeration). At the anticipated depths and oxygen flow rates, the oxygen is expected to be dissolved within this depth. In the CE-QUAL-W2 model, DO was equally distributed through all the specified segments and layers. Modeling indicated that the DO would be nearly equally distributed throughout this depth and along the diffuser lines. To represent rising bubbles, the CE-QUAL-W2 model coding also includes a factor by which vertical mixing between model layers could be increased. This factor was set to increase mixing since the diffuser design at the oxygen flow rates was anticipated to cause some relatively small amount of mixing.

CE-QUAL-W2 model DO simulation results indicated that when the SR-HC TMDL is fully implemented, DO levels in Brownlee Reservoir are expected to improve dramatically (Figure 6.2-8). These simulation results showed that the greatest improvements in DO conditions are expected to occur in late summer. The simulations included reduction of algae (and other organic matter components), as anticipated with full implementation of upstream allocations, and an associated decrease in SOD (long-term improvements).[7] Outflow from Brownlee Reservoir was used as the inflow boundary condition for Oxbow Reservoir that was, in turn, used as inflow boundary conditions for Hells Canyon Reservoir, and SOD was reduced to Brownlee levels (0.1 g O_2/m^2/day). Again, SED generated due to inflowing organic matter was left unchanged. Simulation results for Oxbow and Hells Canyon reservoirs showed that improving DO conditions in Brownlee Reservoir would lead to substantially improved water quality in the downstream reservoirs (Figure 6.2-9).

[7] It should be noted that the EHist temperature boundary condition was not used in this simulation.

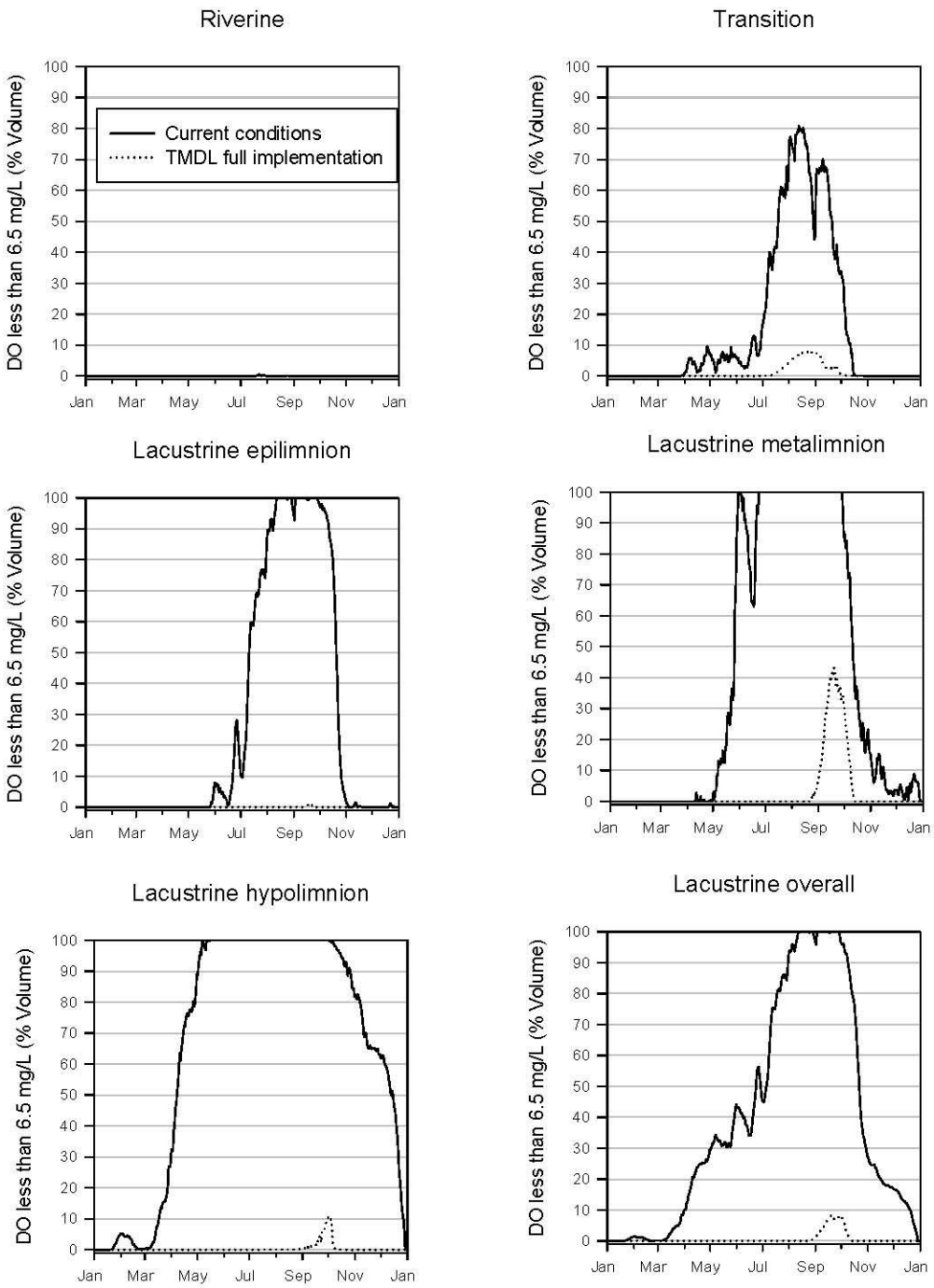


Figure 6.2-8. Simulated percent (%) volume of Brownlee Reservoir zones and strata below the dissolved oxygen (DO) criterion of 6.5 milligrams per liter (mg/L) for medium-water-year conditions. Plots show 1995 current conditions (baseline) and anticipated conditions with full upstream implementation of the SR-HC TMDL allocations and IPC aeration.

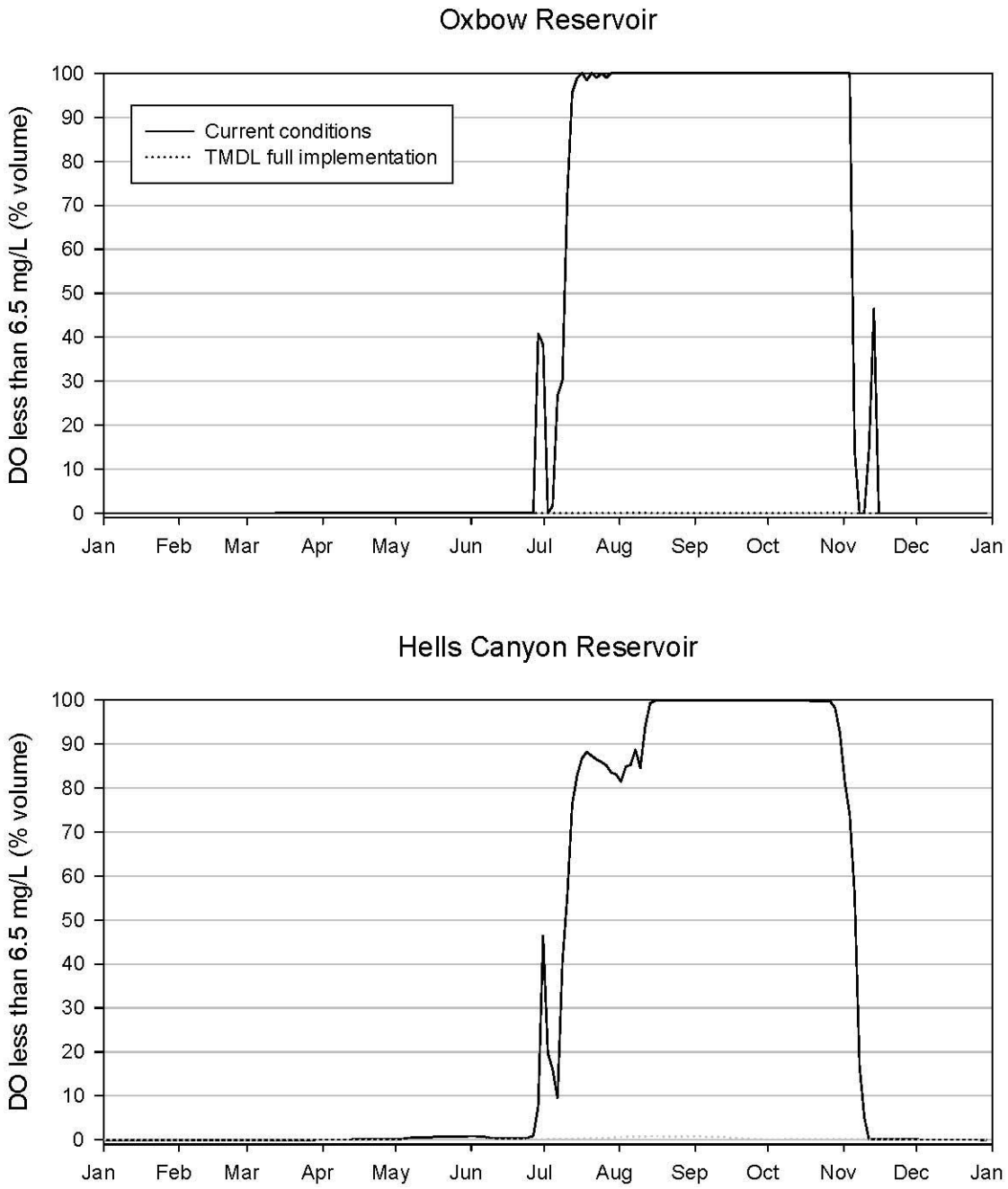


Figure 6.2-9. Simulated percent (%) volume of Oxbow and Hells Canyon reservoirs below the dissolved oxygen (DO) criterion of 6.5 milligrams per liter (mg/L) for medium-water-year conditions. Plots show 1995 current conditions (baseline) and anticipated conditions with full upstream implementation of the SR-HC TMDL allocations and IPC aeration.

6.2.2.2.2. Outflow DO

The SR-HC TMDL did not address DO downstream of the HCC and targets were not developed to meet the salmonid rearing and spawning criteria. The SR-HC TMDL assigned upstream TP allocations so the Snake River flowing into the HCC met aquatic-life criteria and protected those beneficial uses (IDEQ and ODEQ 2004). The SR-HC TMDL did not develop targets or allocations based on more-stringent downstream criteria for the protection of salmonid rearing and spawning. It did identify that the HCC's contribution to any DO deficit was related only to the impoundments.

The water quality improvements resulting from full implementation of the SR-HC TMDL are expected to improve DO below the HCC (Figures 6.2-8 and 6.2-9). The CE-QUAL-W2 model was used to simulate improvements in Hells Canyon Reservoir outflow DO following full upstream SR-HC TMDL implementation. Improvements are based on the difference between simulated HCC outflow DO with current conditions and with full SR-HC TMDL implementation.

To summarize, simulated DO levels below the HCC resulting from full implementation of the SR-HC TMDL were assessed by modifying the Brownlee Reservoir boundary conditions and the CE-QUAL-W2 model (see Section 6.2.2.2.1.).

- Reduce inflowing nutrients and organic matter at the Brownlee Reservoir boundary conditions (RM 340) to meet the SR-HC TMDL TP target of 0.070 mg/L.
- Increase inflow DO at the Brownlee Reservoir boundary conditions to meet the SR-HC TMDL DO target of 6.5 mg/L.
- Set SOD at long-term levels of 0.1 g O2/m2/day throughout Brownlee Reservoir.
- Inject oxygen into Brownlee Reservoir at a rate of 17.3 tons/day beginning July 1 and ending on September 4 (Julian days 182 through 247).
- Redefine temperature boundary conditions using estimated historic (EHist) temperatures.
- Use outflow from the upstream reservoir as the inflow boundary condition to the downstream reservoir (referred to as linked simulations), and set SOD to 0.1 g O2/m2/day.

The linked simulation modeling outflow from the HCC after full implementation of the SR-HC TMDL showed DO improvements from SR-HC TMDL implementation may be 2–5 mg/L during the summer and 2–4 mg/L during fall (Figure 6.2-10). This was compared to summarized, measured DO data collected in water being discharged from Hells Canyon Dam of approximately 4–5 mg/L (Figure 6.2-2). Comparing SR-HC TMDL improvements with summarized measured data shows that full upstream SR-HC TMDL implementation would likely not improve HCC outflow DO enough to meet the downstream criterion of 8.0 mg/L for the protection of salmonid rearing or the water-column salmonid-spawning criteria.

[See Section 6.2.3. for a detailed discussion of the total DO load needed to meet these downstream criteria.]

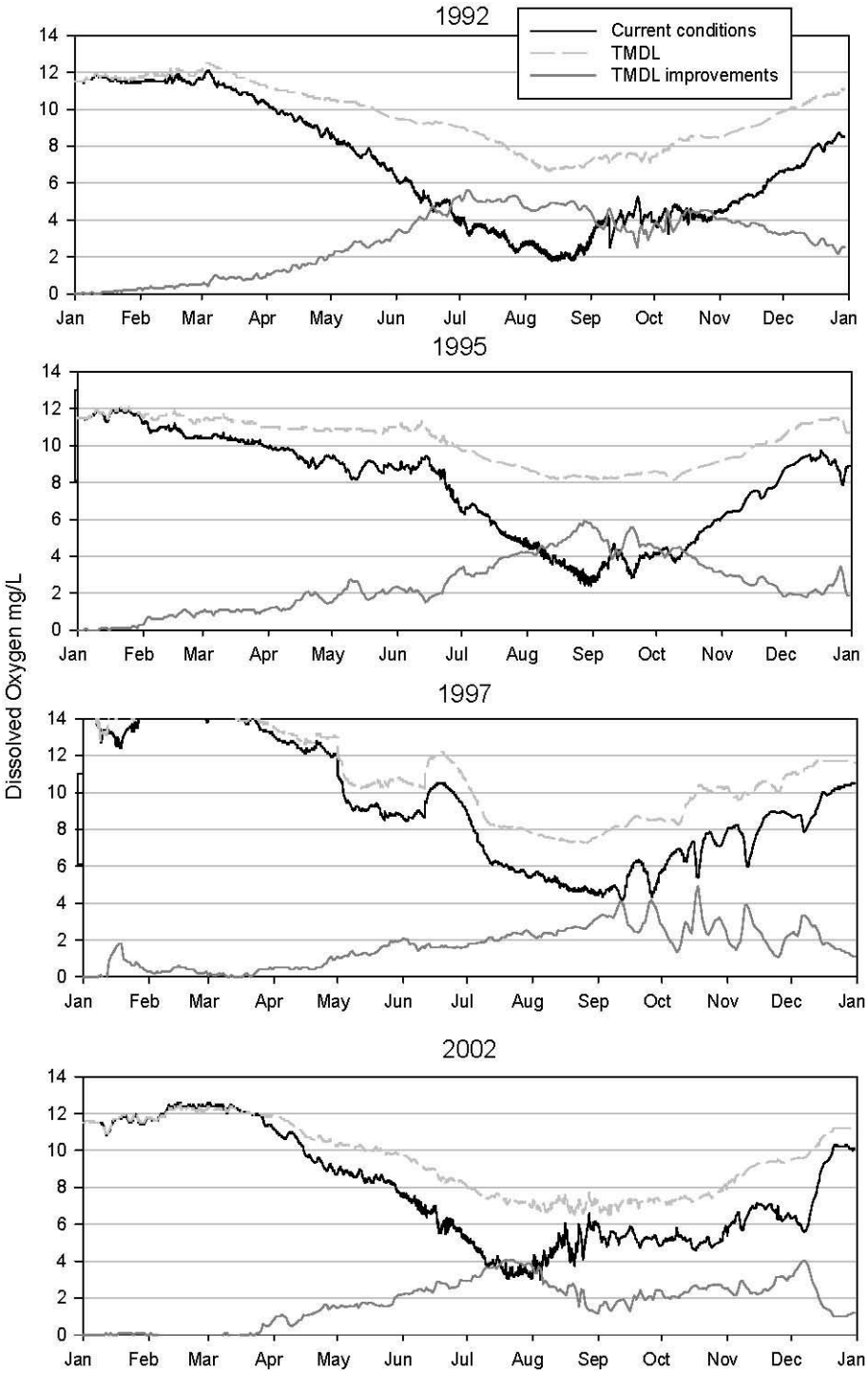


Figure 6.2-10. Comparison of simulated Hells Canyon Reservoir outflow dissolved oxygen (DO) with current conditions and SR-HC TMDL conditions. Total Maximum Daily Load (TMDL) improvements show the difference between the 2 simulations.

6.2.3. HCC Contribution to DO

DO conditions below the HCC are expected to improve substantially following full upstream SR-HC TMDL implementation. However, a DO deficit from downstream criteria is likely, as shown in Figure 6.2-10, due to more stringent criteria downstream of the HCC. IPC has conducted an analysis to quantify the total DO load that may be needed to reach downstream criteria following full SR-HC TMDL implementation and the portion of the total DO load that is the appropriate HCC DO responsibility. The appropriate HCC DO responsibility downstream was estimated using a water-quality target developed to support the salmonid-spawning intergravel DO criterion in a free-flowing river reach. This water quality target, referred to as the salmonid-spawning water-quality (SSWQ) target, was developed using an approach similar to that used in the SR-HC TMDL and is based on available Snake and Columbia rivers data. The analysis of the appropriate HCC DO responsibility, using the SSWQ target, assumes that if water-quality conditions in the free-flowing Snake River supported the intergravel salmonid-spawning criterion, any deficit from the water-column salmonid rearing or salmonid-spawning criteria caused by adding the HCC impoundments is the appropriate HCC DO responsibility. The steps of IPC's analysis are outlined below:

1. Develop SSWQ targets that would support salmonid-spawning intergravel criteria in a free-flowing river reach. SSWQ targets establish acceptable levels of organic matter needed to meet intergravel DO criterion in the Snake River. The SSWQ targets are below those anticipated with full implementation of SR-HC TMDL because the beneficial uses to be protected are more stringent. To account for assimilative capacity of a free-flowing river reach from RM 340 to RM 247, SSWQ targets are developed to support intergravel salmonid-spawning criteria at RM 247 (below the HCC) without the HCC in place.

2. Use the CE-QUAL-W2 model to simulate improvements in Hells Canyon Reservoir outflow DO with inflow water quality meeting SSWQ targets. Improvements are the modeled improvements based on the difference between simulated HCC outflow DO with current conditions and with inflow meeting SSWQ targets.

3. Estimate DO loads (tons/year) needed to reach criteria using SR-HC TMDL improvements and SSWQ improvements. DO loads with SR-HC TMDL improvements represent the total DO load that would need to be supplied by all sources, including IPC, in any future downstream DO TMDL. DO loads with SSWQ improvements represent the appropriate HCC DO responsibility; that is, the effect the HCC would have on water-column DO if Snake River water quality was sufficient to support the intergravel salmonid-spawning criteria with the HCC removed.

6.2.3.1 SSWQ Target Development

IPC presents the following data, discussion, and analysis to develop information needed to define the effect that the presence of the HCC has, as it relates to deficits from downstream salmonid-spawning DO criteria. The development of SSWQ targets are critical for this analysis since water-quality conditions needed to support the intergravel criterion have not previously been developed. Intergravel DO is related to water-column DO through the connection between the water-column and intergravel environments and the processing of organic matter in the gravels. The following approach uses water-column data collected from March 2002 through

April 2003 at 7 sites along the Snake River from King Hill (RM 546), Idaho, to below Hells Canyon Dam (Harrison 2005) to provide a broad perspective of water quality and relate water-column conditions to intergravel DO levels (Table 6.2-8, Figure 6.2-11). Using these relationships, data from 3 Snake River reaches (Hells Canyon, Swan Falls, and Glenns Ferry) and 1 Columbia River Reach (Vernita) were then used to estimate water-quality conditions needed to support the salmonid-spawning intergravel DO criterion and develop appropriate SSWQ targets.

Table 6.2-8. Selected parameters collected in 2002 and 2003 as part of a Snake River organic matter study.

Parameter	Units	Sample Size	Description
Chlorophyll *a*	µg/L	22–24	Indicator of algal biomass
Total Organic Carbon (TOC)	mg/L	22–24	Total carbon concentration per L of sample
Dissolved organic carbon (DOC)	mg/L	22–24	Total carbon concentration per L of filtered (0.45-µm) sample
Particulate organic carbon (POC = TOC – DOC)	mg/L	22–24	TOC minus DOC. The amount of carbon per liter that is retained on the 0.45 µm filter
Total suspended solids (TSS)	mg/L	22–24	Dry weight of material retained on a filter
Volatile suspended solids (VSS)	mg/L	22–24	Weight of TSS material that will combust at 550 °C
5-day and 30-day biochemical oxygen demand (BOD5, BOD30)	mg/L	13–16	Oxygen consumed per L in 5 or 30 days
5-day and 30-day dissolved biochemical oxygen demand (DBOD5, DBOD30)	mg/L	13–16	Oxygen consumed per L of filtered sample in 5 or 30 days
5-day and 30-day particulate biochemical oxygen demand (PBOD5, PBOD30) (equals BOD – DBOD)	mg/L	13–16	BOD minus DBOD. The amount of oxygen consumed in 5 or 30 days that is attributable to the material retained on the 0.45-µm filter
Chemical oxygen demand (COD)	mg/L	22–24	Oxygen consumed per L following complete oxidation of the sample with strong oxidizing agent
Bacteria (heterotropic plate counts)	#/100mL	13–16	Number of colony-forming units (CFU) per 100 mL of sample
Bacteria secondary production (BSP)	µgC/L/hr	13–16	Rate of carbon incorporation due to bacterial secondary production
Total phosphorus (TP)	mg/L	22–24	Total phosphorus per L sample
Orthophosphate (OP)	mg/L	22–24	Dissolved orthophosphate per L sample
Particulate phosphorus (PP)	mg/L	22–24	TP – OP the amount of phosphorus retained on the filter

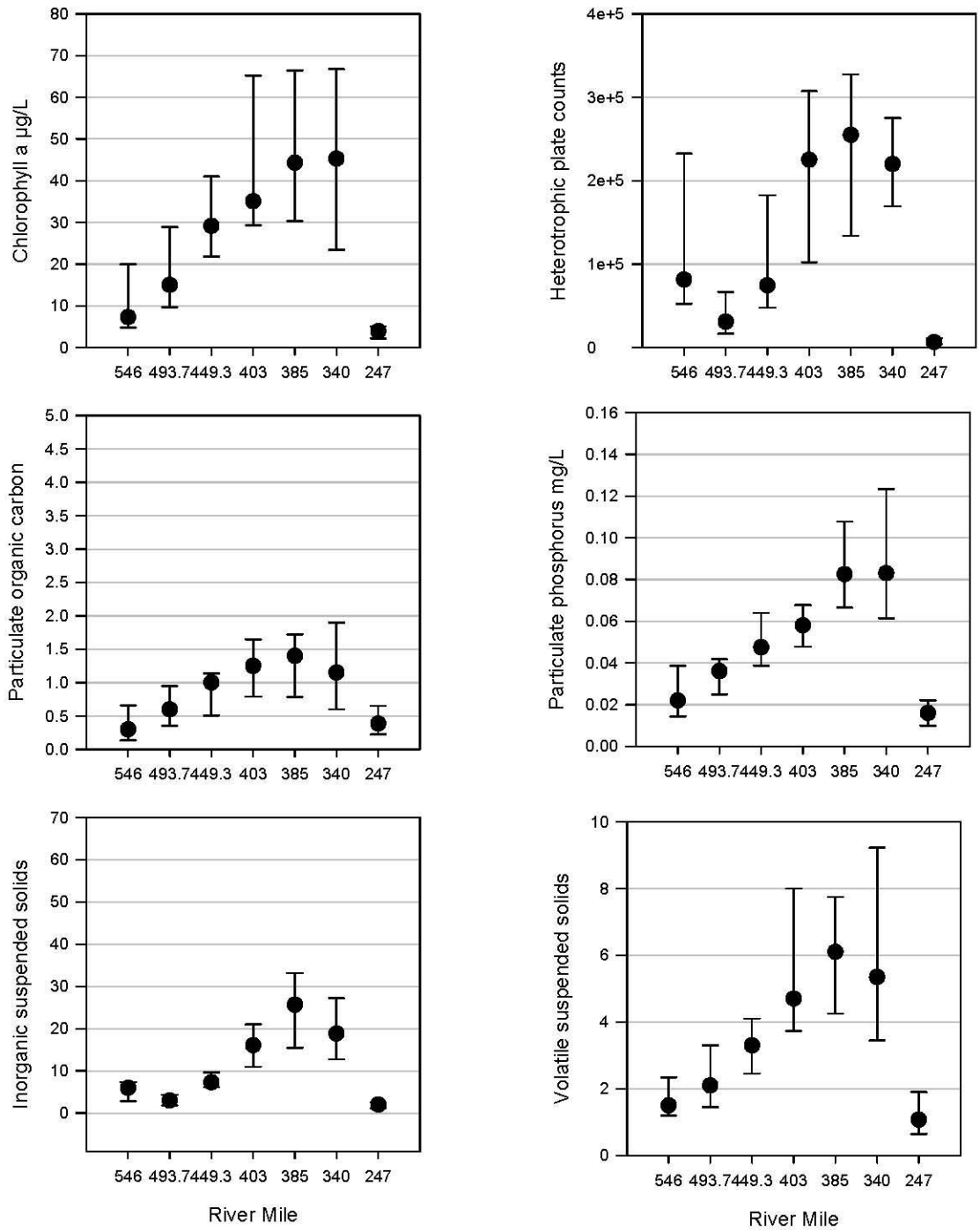


Figure 6.2-11. Water-column concentrations of particulate material at 7 sites in the Snake River. Dots showing medians and error bars are the 75th and 25th percentiles of data collected from March 2002 through April 2003.

6.2.3.1.1. Water-Column Conditions

As discussed above, water-column DO below the HCC is related to releases from the HCC and changes that occur due to reaeration and other DO-related processes. Relatively high water-column DO upstream of the HCC was related to elevated primary productivity (IDEQ and ODEQ 2004). Algal levels change considerably from King Hill to below the HCC. Figure 6.2-11 shows algal levels, as indicated by chlorophyll *a*, were approximately 10 micrograms per liter (µg/L) near King Hill (RM 546) and increased to approximately 45 µg/L at Brownlee Reservoir inflow (RM 340). These increases were followed by substantial decreases to less than 10 µg/L in the HCC outflow (RM 247).

Levels of particulate organic material (including algae) and inorganic sediment also increased from King Hill to the Brownlee Reservoir inflow. Similar trends were also reported in the Snake River by IDEQ (Worth 1994). Substantial decreases again occurred throughout the HCC (Figure 6.2-11). The levels of particulate material released from the HCC were 67–97% less than Brownlee Reservoir inflow levels (Table 6.2-9). The highest reduction observed, 97%, was for heterotrophic bacteria. Bacterial secondary production, algae (i.e., chlorophyll *a*), and particulate phosphorus were all reduced by more than 80%. Particulate organic carbon (POC) showed the lowest reduction at 67%.

Dissolved constituents decreased less compared to particulate constituents as they moved through the HCC, ranging from 6% for dissolved organic carbon (DOC) to 36% for dissolved 5-day biochemical oxygen demand (BOD) (Table 6.2-9). The higher level of reduction for dissolved 5-day BOD suggests a shift in the nature of dissolved organic carbon (DOC), with more refractory material being released downstream of the HCC. Dissolved inorganic phosphorus and nitrogen levels increased, while total nutrient levels decreased 29% and 45%, respectively.

These water-column data showed relatively low levels of particulate organic matter and inorganic sediment released from the HCC compared to levels upstream. As discussed below, these differences are directly related to differences in the observed intergravel conditions upstream and downstream of the HCC.

6.2.3.1.2. Intergravel Conditions

Water-column DO concentrations and intergravel DO concentrations measured in artificial redds below the HCC were both below criteria (i.e., 11 mg/L, or 95% saturation in the water column and 8 mg/L in the gravels) at the initiation of the fall Chinook salmon spawning season and increased as the season progressed and the embryos developed (Figures 6.2-4, 6.2-5, and 6.2-6). Counter to this, at sites sampled by IPC in 2003/2004 and 2004/2005 above the HCC (Figure 6.2-1), intergravel DO concentrations measured in artificial redds were generally below criteria, even though water-column DO levels often met criteria (Figures 6.2-12, 6.2-13, and 6.2-14). Similar data collected during the 1999/2000 and 2000/2001 seasons by Groves and Chandler (2005) at these same sites (and others) showed that intergravel DO in artificial redds dropped below 8 mg/L at sites above the HCC (near 2 mg/L at some sites). DO levels in the undisturbed ambient gravels (i.e., adjacent gravels not disturbed by the construction of artificial redds) above the HCC were generally less than 2 mg/L through the whole season (Figure 6.2-12).

Table 6.2-9. Medians (ranges) and percent reduction (based on medians) for particulate, dissolved, and total constituents at Brownlee inflow (RM 340) and Hells Canyon outflow (RM 247) from March–October 2002 (*n* = 13–14) or March 2002–April 2003 (*n* = 22–24).

	Brownlee Inflow RM 340	HC Outflow RM 247	% Reduction	*N*
Particulate				
Chlorophyll *a* µg/L	45.28 (8.22–114.21)	3.93 (0.44–22.49)	91%	23
Heterotrophic plate counts CFU/100 mL	220000 (3900–670000)	6650 (1600–270000)	97%	14
Particulate organic carbon mg/L	1.15 (0.2–3.6)	0.39 (0.08–0.98)	67%	24
Particulate phosphorus mg/L	0.083 (0.026–0.145)	0.016 (<0.005–0.059)	81%	24
Total suspended solids mg/L	24.3 (4.3–72.9)	3.2 (0.8–38.0)	87%	22
Volatile suspended solids mg/L	5.4 (1.3–11.6)	1.1 (0.5–3.7)	80%	22
Inorganic suspended solids mg/L	18.9 (3.0–61.7)	1.9 (0.5–35.8)	90%	22
PBOD 5-day mg/L	1.9 (1.1–5.5)	0.5 (0.2–1.0)	74%	13
PBOD 30-day mg/L	4.7 (2.3–7.4)	0.9 (0.2–2.8)	81%	13
Bacterial production µgC/L/hr	0.93 (0.31–2.20)	0.12 (0.0–0.25)	87%	14
Dissolved				
DOC mg/L	2.75 (1.62–3.80)	2.58 (1.82–3.2)	6%	24
Orthophosphate mg/L	0.027 (0.006–0.072)	0.060 (0.036–0.105)	–123%	24
Nitrate mg/L as N	0.63 (0.13–1.71)	0.74 (0.25–1.74)	–19%	24
Ammonia mg/L as N	0.01 (<0.01–0.11)	0.06 (<0.01–0.19)	–450%	24
DBOD 5-day mg/L	1.1 (0.5–2.7)	0.7 (0.5–1.3)	36%	13
DBOD 30-day mg/L	3.3 (1.6–5.8)	2.2 (1.4–3.5)	33%	13
Total				
TOC mg/L	4.14 (1.98–7.4)	3.10 (2.02–4.0)	25%	24
Total phosphorus mg/L	0.115 (0.054–0.195)	0.081 (0.052–0.115)	29%	24
Total nitrogen mg/L	1.33 (1.03–2.23)	1.24 (0.63–2.14)	45%	24
BOD 5-day mg/L	3.7 (2.4–7.1)	1.2 (0.7–2.1)	68%	13
BOD 30-day mg/L	8.1 (6.9–10.4)	3.2 (1.4–3.5)	60%	13
COD mg/L	16 (5–29)	10 (<3–15)	38%	22

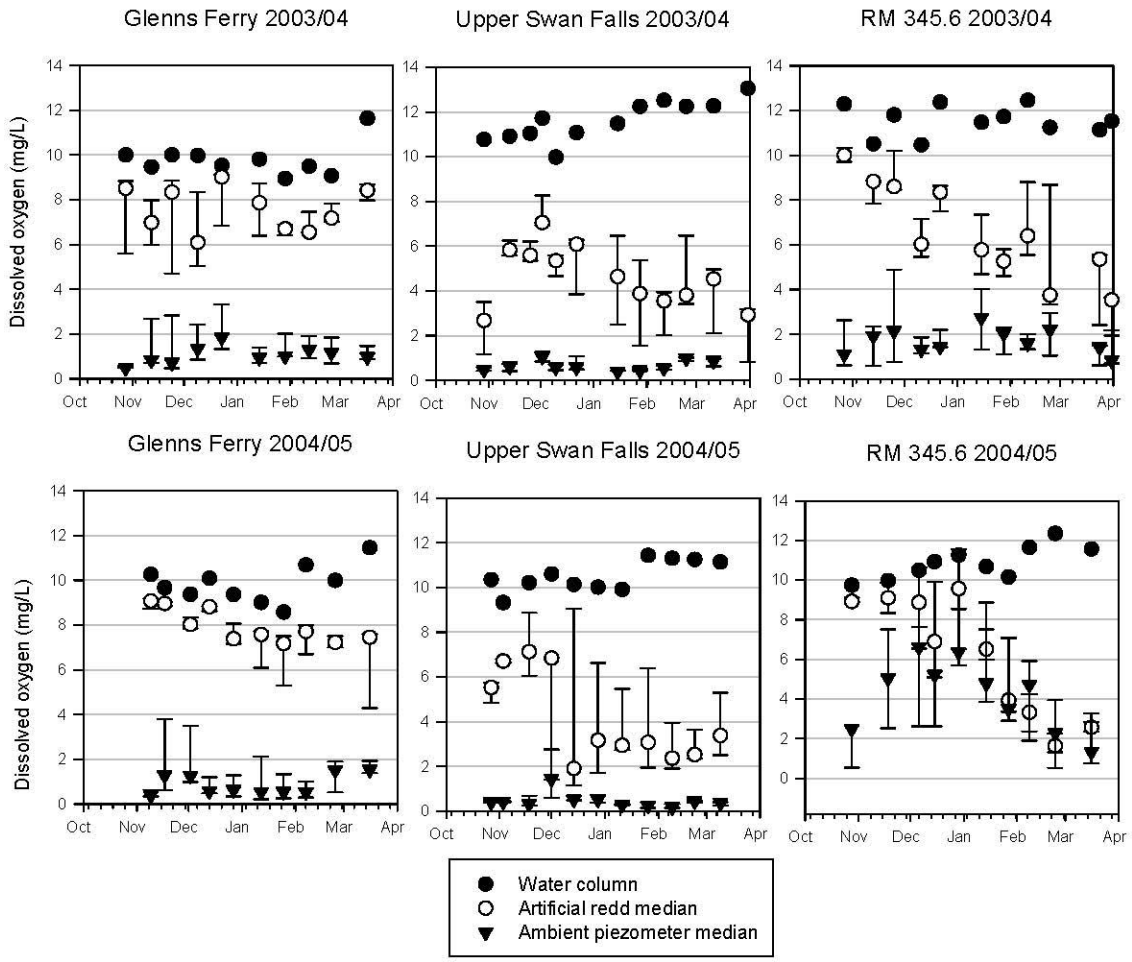


Figure 6.2-12. Intergravel dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) at sites upstream of Brownlee Reservoir with no eggs in the 2003/2004 and 2004/2005 seasons. Symbols show the median of3 artificial redds or ambient piezometers, while error bars show the minimum and maximum values.

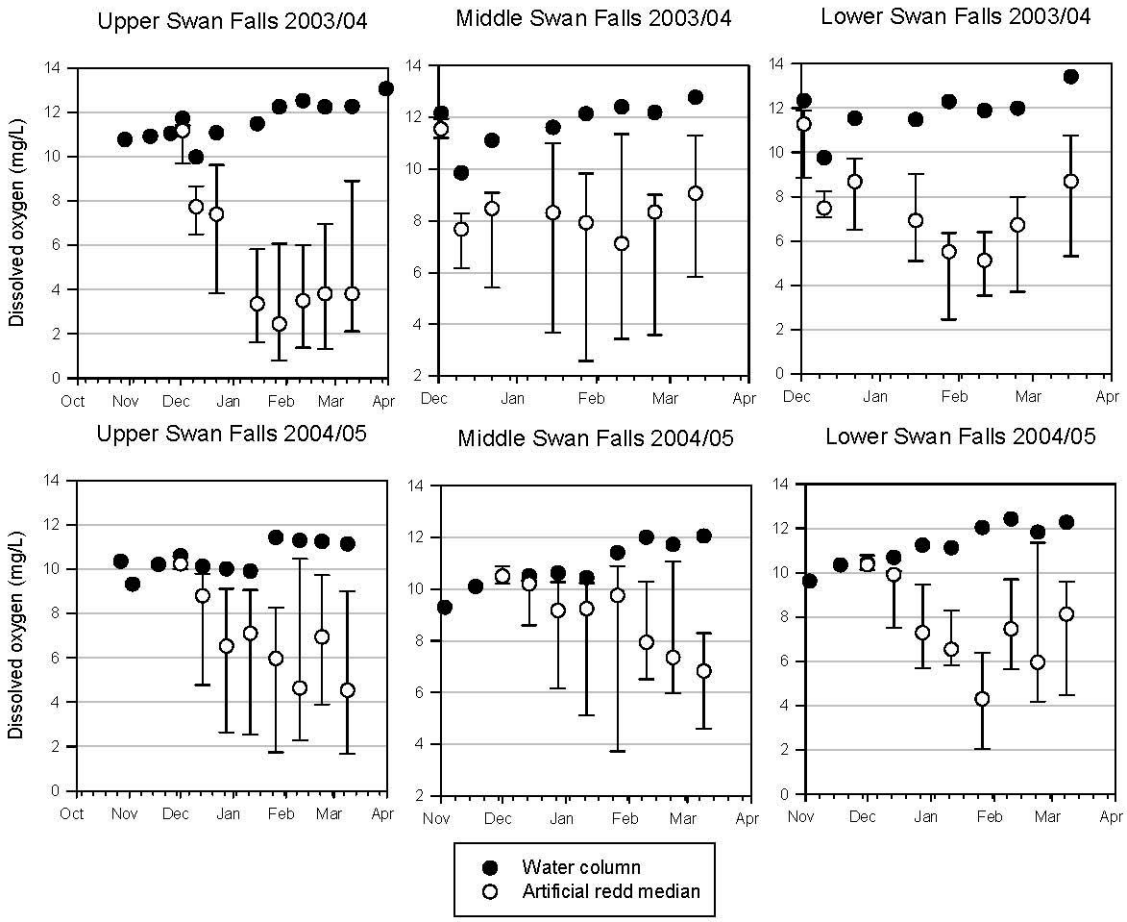


Figure 6.2-13. Intergravel dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) at sites upstream of Brownlee Reservoir with eyed eggs in the 2003/04 and 2004/05 seasons. Symbols show the median of 9 (2003/04) or 7 (2004/05) artificial redds, while error bars show the minimum and maximum values.

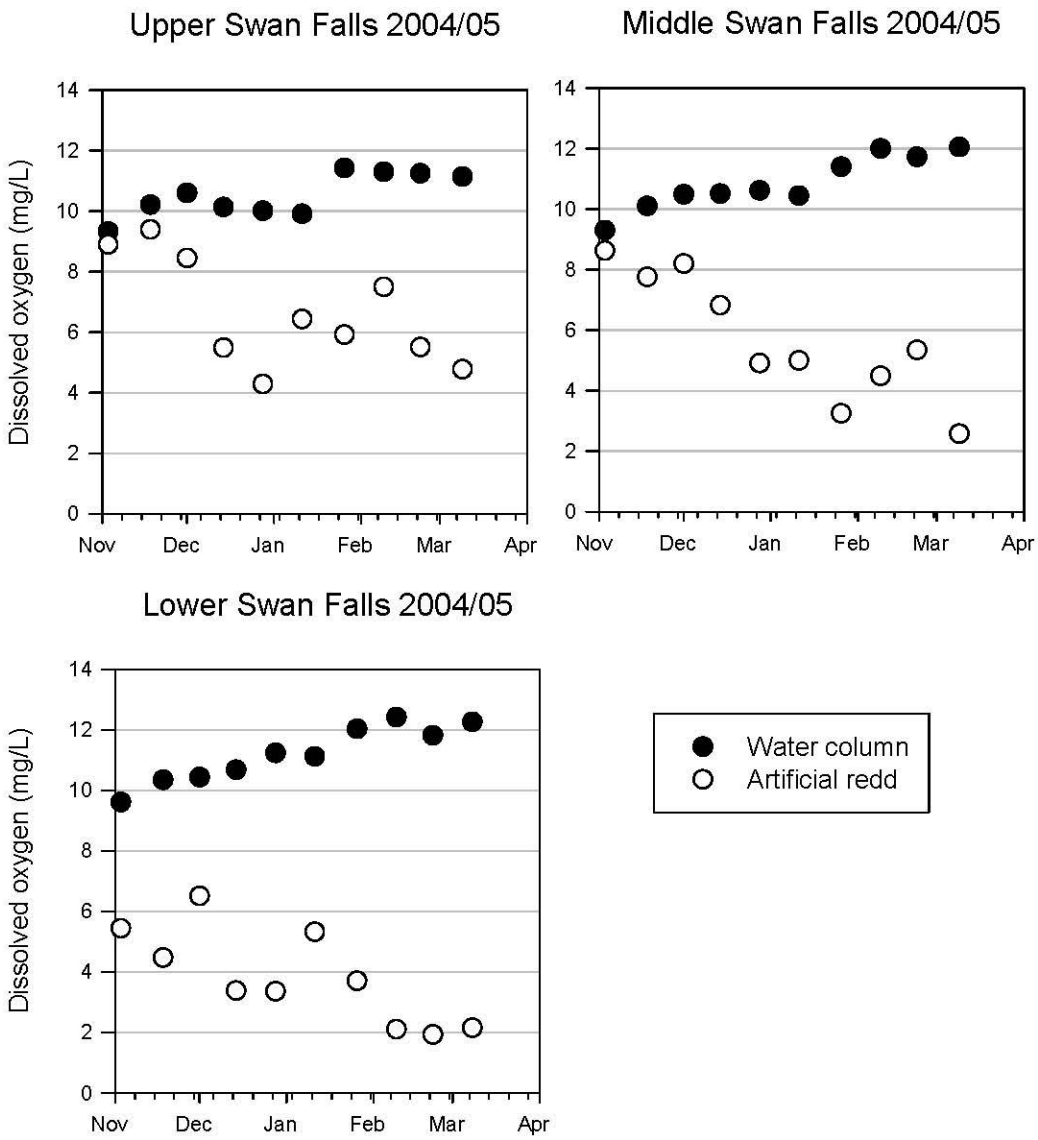


Figure 6.2-14. Intergravel dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) at sites upstream of Brownlee Reservoir with green eggs in the 2004/2005 season.

Unlike locations below the HCC, most locations above the HCC had higher intergravel DO in the beginning, shortly after artificial redd construction, and concentrations declined thereafter. Median intergravel DO levels dropped below 8 mg/L in artificial redds constructed near Brownlee Reservoir inflow (RM 345) and near the city of Glenns Ferry, Idaho (Figures 6.2-12, 6.2-13, and 6.2-14). Median intergravel DO levels also declined following artificial redd construction in the Swan Falls Reach[8]; however, initial concentrations were less than 8.0 mg/L.

[8] The sites in this reach are the same sites sampled in 1999/2000 and 2000/2001 and reported in Groves and Chandler (2005).

Differences in ambient gravel characteristics do not explain the differences in intergravel DO. Using freeze core and hydraulic slug test techniques, Hanrahan et al. (2005) examined ambient gravel characteristics at 2 historic spawning locations in the Swan Falls Reach and showed that hydraulic conductivity in gravels at the Swan Falls sites was comparable to rates measured in spawning gravel in the Hells Canyon Reach of the Snake River and the Hanford Reach of the Columbia River. Using a temperature-modeling approach showed that velocities in the artificial redds in the Hells Canyon Reach can be reduced from initial levels immediately after construction but remained relatively high through the spawning season (T. Hanrahan, Battelle-Pacific Northwest Division, pers. comm.). Similar analysis above the HCC showed that construction of an artificial redd dramatically increased intergravel velocities from what occurred in the ambient gravels. However, following artificial redd construction, intergravel velocities rapidly decreased.

In addition to intergravel DO measurements from the artificial redds, fertilized eggs were incubated in egg baskets in some artificial redds constructed in the Swan Falls Reach. The baskets were retrieved just prior to calculated emergence based on degree days and survival (among other variables) recorded. Overall survival in the Swan Falls Reach was very poor in both seasons (Table 6.2-10). The middle site in the Swan Falls Reach showed the highest survival, although no survival was seen for green eggs at this site (Table 6.2-10).

Table 6.2-10. Survival of fall Chinook salmon eggs placed in artificial redds above and below the Hells Canyon Complex for the 2003/2004 and 2004/2005 seasons.

Study Year and Location	Average Survival for Eyed Eggs	Average Survival for Green Eggs	No. of Egg Baskets	Total No. of Eyed Eggs	Total No. of Green Eggs
2003/2004					
Swan Falls overall	0.23	—	27	2,700	—
Upper Swan Falls	0.00	—	9	900	—
Middle Swan Falls	0.68	—	9	900	—
Lower Swan Falls	0.00	—	9	900	—
Downstream of HCC overall	0.83	—	18	1,800	—
2004/2005					
Swan Falls overall	0.17	0.00	28 eyed, 4 green	2,800	600
Upper Swan Falls	0.12	0.00	7 eyed, 1 green	700	150
Middle Swan Falls	0.42	0.00	7 eyed, 1 green	700	150
Lower Swan Falls	0.00	0.00	7 eyed, 1 green	700	150
Lower Swan Falls	0.02	0.00	7 eyed, 1 green	700	150
Downstream of HCC overall	0.79	0.55	18 eyed, 6 green	1,800	900

6.2.3.1.3. Interconnection between Water Column and Intergravel Conditions

Oregon's salmonid-spawning water-column DO criteria require levels designed to ensure that intergravel DO levels of 8.0 mg/L are attained. Water column and intergravel DO data collected below the HCC showed a strong correlation between water-column DO and intergravel DO and suggest that water column levels need to be at sufficient levels to maintain intergravel DO criterion. However, Snake River data collected above the HCC show that high water column DO levels (e.g., at or above saturation) do not always result in intergravel DO levels that meet the criterion. The following are factors that affect intergravel DO concentrations:

- Exchange rate between surface and subsurface waters
- Residence time of water in the subsurface
- Processing of nutrients (including organic matter, nitrogen, and phosphorus) in the hyporheic zone

Two dominant factors controlling nutrient processing in the hyporheic zone are 1) surface-to-subsurface water-exchange rate, and 2) residence time of water within gravels (Findlay 1995, Mulholland and DeAngelis 2000). Physical plugging of gravels by inorganic and organic (detrital) matter is one of the many processes that reduces water exchange rates and leads to increased residence times. Physical plugging occurs as water-column particulate matter infiltrates gravels either through settling or from surrounding surface-water velocities. During high-water events, these materials can also become mixed with gravels as streambeds are eroded and redeposited. It is likely that low intergravel DO levels are related to the reduction in intergravel velocities in artificial redds due to physical plugging of gravels (T. Hanrahan, Battelle-Pacific Northwest Division, pers. comm.). Water-column sampling showed that much-higher levels of particulate matter occurred upstream of HCC (Figure 6.2-11) and is a likely reason intergravel DO levels decreased after initial artificial redd construction.

Plugging can also be caused by the production of either periphyton on the substrate surface or biofilm within the gravels (Battin and Sengschmitt 1999). Biofilms are primarily layers formed by bacteria on substrate surfaces. Bacteria secrete extracellular polysaccharides (glycocalyx) that form a visible slime layer and provide a matrix for building the "biofilm community" (Marshall 1997). Periphyton, which forms in the polysaccharide matrix produced by bacteria, is generally considered to be autotrophic algae (Welch and Lindell 1996). However, heterotrophic bacteria and fungi can dominate if there is a source of dissolved organic matter or if light is restricted. Extensive areas of periphyton, which can include protozoa and insects, have been observed by IPC biologists in the Snake River above the HCC. Additionally, formation of heterotrophic biofilm within gravels is likely, considering the relatively high organic-matter levels and heterotrophic bacteria levels observed in the Snake River above the HCC (Harrison 2005).

The other dominant factor is the level of organic matter in hyporheic zone water, which is influenced by organic-matter levels in the water column. Decay of DOC and POC consumes DO in the gravels (Findlay et al. 1993). While plugging can reduce water-exchange rates and the flux of DO and organic matter entering the gravels, lower velocities within the gravels increase the

residence time, allowing more time for organic-matter processing and related DO depletion (Kaplan and Newbold 2000).

Low intergravel DO levels above the HCC can be related to the rapid recycling of the more labile dissolved organic matter (Romani et al. 2004) produced in this eutrophic reach of the Snake River (IDEQ and ODEQ 2004, Harrison 2005). Downwelling water-column water with elevated levels of dissolved organic matter will deplete intergravel DO through increased bacterial activity (Kaplan and Newbold 2000). Depletion of DO was also evidenced by the occurrence of anoxic or anaerobic conditions in the gravel (Figure 6.2-12).

Additionally, relatively high nutrient levels support algal, periphyton, and macrophytic production of extracellular dissolved organic matter that stimulates respiration of polysaccharide-producing bacteria in the sediments (Bell and Sakshaug 1980, Kaplan and Newbold 2000). The secondary production in the sediments can increase organic-matter levels within gravels. And, while most organic matter is produced in the warmer periods, materials produced during the growing season are susceptible to sloughing during the colder winter periods (Park and Clough 2004) and then settle and are resuspended as river velocities fluctuate.

Dissolved organic matter that infiltrates a redd can greatly affect DO dynamics in the redd (Soulsby et al. 2001a, 2001b). Also, when vertical movement of water through the redd is slowed due to plugging, the hydrodynamics change, allowing for more ambient hyporheic water to influence the redd (Soulsby et al. 2001a). This process is detrimental in reaches where ambient hyporheic water is anoxic or very low in DO (e.g., upstream of the HCC). Particulate organic matter (i.e., POC) produced or buried in sediments (including biofilms) can cause anaerobic layers that contribute oxygen-demanding material to nearby sediments (Kaplan and Newbold 2000). Data showed generally increasing levels of POC in the water column above the HCC (Figure 6.2-11) that can mix with gravels under higher water conditions. Decay of organic matter in the gravels was indicated by anoxic conditions that are prevalent upstream of the HCC (Figures 6.2-12, 6.2-13, and 6.2-14).

6.2.3.1.4. SSWQ Target

The SR-HC TMDL established TP and chlorophyll *a* targets to support designated uses in the HCC and Snake River upstream. No targets were established for the protection of salmonid spawning downstream of the HCC. Snake River water-column TP data from Bliss Dam outflow (RM 560) and King Hill (RM 546) indicated that TP levels fluctuated widely but, in recent years, approached the SR-HC TMDL TP target of 0.070 mg/L (Figure 6.2-15). Chlorophyll *a* levels at King Hill were also near the 14 µg/L target (Figure 6.2-11). Water column and gravel conditions at Glenns Ferry (approximately 8 miles downstream of King Hill), although improved when compared to the other locations above the HCC, still resulted in intergravel DO in artificial redds below the criterion and ambient intergravel DO less than 2 mg/L (Figure 6.2-12). This indicated that the SR-HC TMDL targets may not be sufficient, and lower targets are needed to support the intergravel DO criterion.

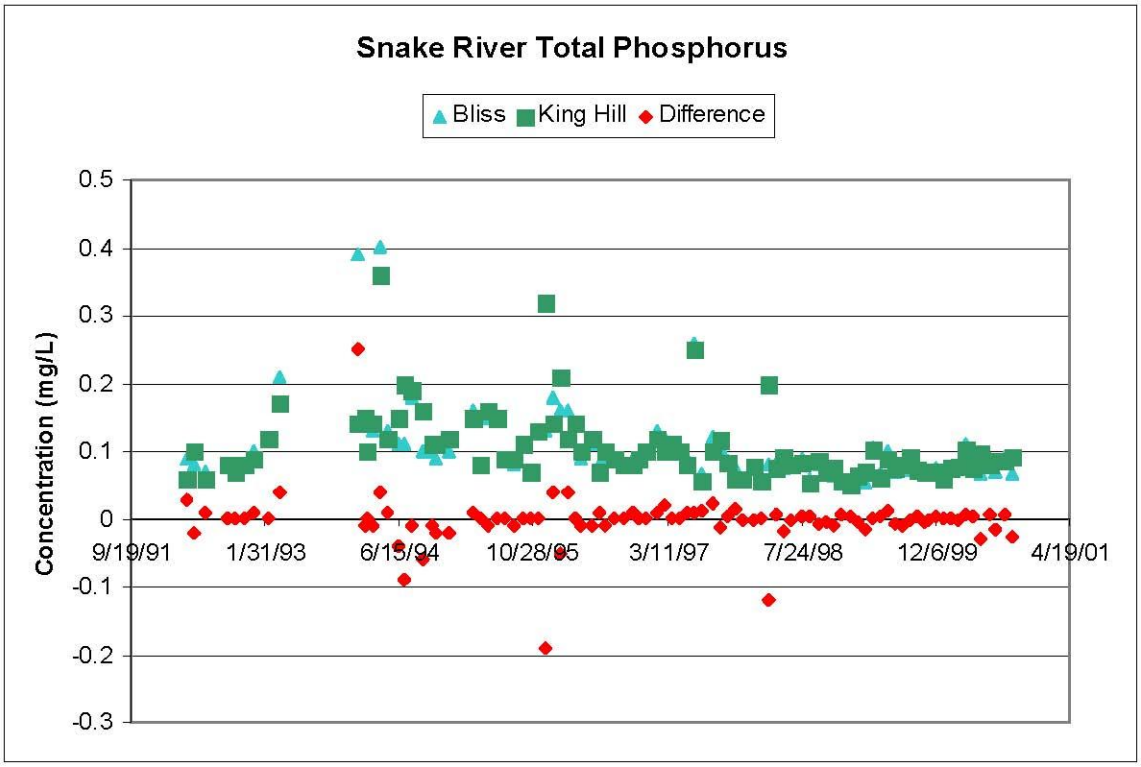


Figure 6.2-15. Total phosphorus concentration in milligrams per liter (mg/L) below Bliss Dam and King Hill, Idaho, and their difference (Bliss–King Hill).

Large reductions in particulate organic matter (e.g., near 90%) occurred as water passed through the HCC (Table 6.2-9). This reduction likely reduced plugging and organic-matter processing in the gravels and explains some of the contrast observed in DO levels measured in the intergravel environments above and below the HCC (Figures 6.2-4, 6.2-5, 6.2-6, 6.2-12, 6.2-13, and 6.2-14). Below the HCC, there was relatively good interconnection between the water column and intergravel environments. This produces sufficient intergravel DO levels when water-column DO is sufficient. The data presented and discussed in the above sections support the following summarized conclusions:

1. Intergravel salmonid-spawning criteria (8.0 mg/L intergravel DO as a spatial median) were not met upstream of the HCC from Glenns Ferry to Brownlee Reservoir even though water-column DO was often near saturation levels (Figures 6.2-12, 6.2-13, and 6.2-14).
2. Data in the Glenns Ferry Reach indicated that future water-quality conditions (as required by SR-HC TMDL to meet the target of 0.070 mg/L) may not result in the intergravel criteria being met in the free-flowing RM 409 through RM 340 reach (Figure 6.2-15). This observation was relevant to general Snake River water quality needed to support the intergravel DO criterion. Since salmonid spawning is not a designated use in the Glenns Ferry Reach, this observation is not relevant to conditions needed in this reach.

3. Current water-quality conditions below the HCC (low particulate material) allow a relatively high level surface/subsurface water exchange, producing gravel conditions that allow the intergravel criterion to be met when water column DO levels are adequate (Figure 6.2-8).
4. Low levels of particulate organic and inorganic materials and labile organic matter in the water column, as observed below the HCC (Table 6.2-9), are critical to maintaining adequate intergravel DO to support intergravel criterion (Figures 6.2-4, 6.2-5, and 6.2-6).

With this understanding, chlorophyll *a* and particulate phosphorus (PP) were used as surrogates to develop SSWQ targets that focus on levels of labile particulate organic matter needed to meet intergravel DO criteria. To develop SSWQ target ranges, IPC applied the same approach used in the SR-HC TMDL (to determine a range of TP targets) to chlorophyll *a* and PP data from the Columbia River at Vernita (USGS 2005) and the Snake River at Brownlee Reservoir inflow (RM 340), King Hill (RM 546), and the HCC outflow (RM 247). The approach was based on EPA guidance that recommends the use of three concentration ranges based on frequency distributions as starting points for determining a range from reference to impaired conditions (USEPA 2000a, 2000b).Vernita is at the upstream end of the Hanford Reach where salmon and steelhead populations are designated as one of 99 “healthy native stocks” in the Pacific Northwest and California (Dauble and Geist 2000). In relation to gravel conditions and suspended particulate material, Brownlee Reservoir inflow was considered heavily impaired, King Hill moderately impaired, the HCC outflow acceptable, and the Columbia River at Vernita as a reference. The basic approach involves the following:

- Minimize the effect of outliers by only using data between the 5th and 95th percentiles.
- Divide the datasets from individual locations (three Snake River reaches in the SR-HC TMDL) into 3 categories based on the 35th and 65th percentiles. Levels below the 35th percentile defined reference conditions for that reach while levels above the 65th percentile defined potential for impairment.

Applying EPA guidance (USEPA 2000a, 2000b) as used in the SR-HC TMDL (IDEQ and ODEQ 2004), chlorophyll *a* from 3.6 to 11.70 µg/L and PP from 0.027 to 0.050 mg/L (Table 6.2-11) are appropriate ranges for SSWQ targets. These values represent levels for potential water quality impairment (i.e., 65th percentile) at the HCC and King Hill locations, which represent acceptable and moderately impaired conditions, respectively. The midpoint of the PP range (i.e., 0.038 mg/L) was selected to estimate a target. This level is appropriate, as the HCC levels are likely conservative, while the King Hill levels are likely liberal. This assumption was supported by the phosphorus and intergravel DO measured data. These data indicated that the King Hill PP levels (Figure 6.2-15) did not support meeting the intergravel DO criterion in the Glenns Ferry Reach even with high water-column DO (Figure 6.2-12), while the HCC PP levels (Figure 6.2-11) do support meeting the intergravel criterion when water-column DO is sufficient (Figures 6.2-4, 6.2-5, and 6.2-6).

Table 6.2-11. Summary of chlorophyll *a* and particulate phosphorus concentrations.

Parameter	Range	35th Percentile	50th Percentile	65th Percentile	*N*
Chlorophyll *a* (µg/L)					
Vernita	Na	Na	Na	Na	Na
HCC outflow	0.45–16.13	1.72		3.6	255
King Hill	1.79–54.15	5.70		11.70	222
Brownlee inflow	5.01–81.94	14.93		31.23	224
Particulate phosphorus (mg/L)					
Vernita	0–0.040	0.008		0.015	161
HCC outflow	0.001–0.070	0.015	0.020	0.027	200
King Hill	0.006–0.100	0.029	0.038	0.050	221
Brownlee inflow	0.021–0.175	0.065		0.100	233

Note: Vernita data are USGS Columbia River at Vernita Bar monitoring data. Na indicates that no data were available for this parameter.

Dissolved phosphorus levels, which can be highly dynamic and variable based on algal growth and other factors (IDEQ and ODEQ 2004), are an integral component of any phosphorus target. A reasonable dissolved phosphorus level, when added to the PP target, produces a TP target that would be expected to provide water column and gravel conditions supporting the intergravel DO criterion. Columbia River data collected at Vernita suggested a level of 0.020 mg/L may be a reasonable dissolved phosphorus level. This is well above levels observed in upper reaches of the Snake River watershed. For example, a median dissolved phosphorus level of 0.005 mg/L has been measured upstream of Arrowrock Reservoir on the Boise River at the Twin Springs site (USGS 2005).

Using the identified PP target of 0.038 mg/L and a dissolved-phosphorus level of 0.020 mg/L, a SSWQ TP target of 0.058 mg/L was calculated. This TP target was based on acceptable levels of particulate organic matter and linked to the intergravel DO criterion. It lies within the range (0.053–0.077 mg/L) identified in the SR-HC TMDL as a starting point for TP target determination (IDEQ and ODEQ 2004). While the TP target of 0.058 mg/L is at the lower end of this range, the value reflects the higher level of water quality needed to support salmonid spawning. The SSWQ TP target is well above the natural background level of 0.020 mg/L, as identified in the SR-HC TMDL, and is above levels measured at Vernita in the Columbia River (the Hanford Reach, a known fall Chinook salmon spawning area). It is also above the TP criterion of 0.042 mg/L developed by USEPA (2000c) for rivers and streams in Ecoregion III, which includes the Snake River Basin of Idaho.

6.2.3.1.5. Assimilative Capacity of a Free-Flowing River Reach

Salmonid-spawning criteria apply below the HCC, and the SSWQ targets are representative of water-quality levels needed to meet the intergravel DO criterion. If the HCC did not exist, it is possible that some improvements in water quality could occur in the reach between RM 340 and RM 247, and less stringent SSWQ targets would apply. It should be noted that this is true unless salmonid spawning occurred at RM 340, which is likely without the HCC and with acceptable water quality.

An analysis of how assimilative capacity of this reach relates to the SSWQ target is necessary to determine if the SSWQ targets are appropriate for inflow boundary conditions to the HCC CE-QUAL-W2 model applications. As an example of how less-stringent targets might be appropriate, consider the SR-HC TMDL TP target of 0.070 mg/L, which currently applies at RM 340. If this target were met and river processing between RM 340 and RM 247 without the HCC in place reduced TP to the SSWQ target, then the SSWQ target would not be appropriate to use as the HCC boundary condition. The following discussion shows that, while water column DO could improve in a free-flowing river between RM 340 and RM 247, intergravel DO would not necessarily follow that trend.

In general, DO levels in rivers tend to equilibrate with atmospheric conditions (Figure 6.2-16). The equilibrium with the atmosphere is controlled by the rate of reaeration, which is generally higher in rivers compared to lakes and reservoirs. The reaeration rate is empirically related to velocity, slope, and channel depth. Cole and Wells (2002) summarized the equations relating average velocity and slope for a range of flows. Using these equations, it was shown that river reaeration can be more than an order of magnitude higher than reservoir reaeration (due in part to greater depths in reservoirs) and that rates in rivers increased with increasing slopes.
This process is evident in the Snake River below the HCC where water-column DO levels well below saturation were observed to increase within a relatively short distance (Figure 6.2-3).

Primary production and decay of organic matter also influence DO levels (Figure 6.2-16). Primary production can increase DO above levels controlled by reaeration and result in supersaturation of DO. These processes were evident in the Snake River above the HCC where relatively high water-column DO levels (Figures 6.2-12, 6.2-13, and 6.2-14) are linked to high nutrient and related algal levels (IDEQ and ODEQ 2004, Harrison 2005).

Reaeration and primary production extended periods of depressed DO levels in free-flowing rivers, except under extreme loading of oxygen-demanding materials, and contribute to the relatively high nutrient assimilative capacity of a river relative to water-column DO.
The difference in assimilative capacity is also evident when comparing the EPA Snake River Basin TP criteria for rivers and streams of 0.042 mg/L (USEPA 2000c) versus the criteria for lakes of 0.020 mg/L (USEPA 2001b).

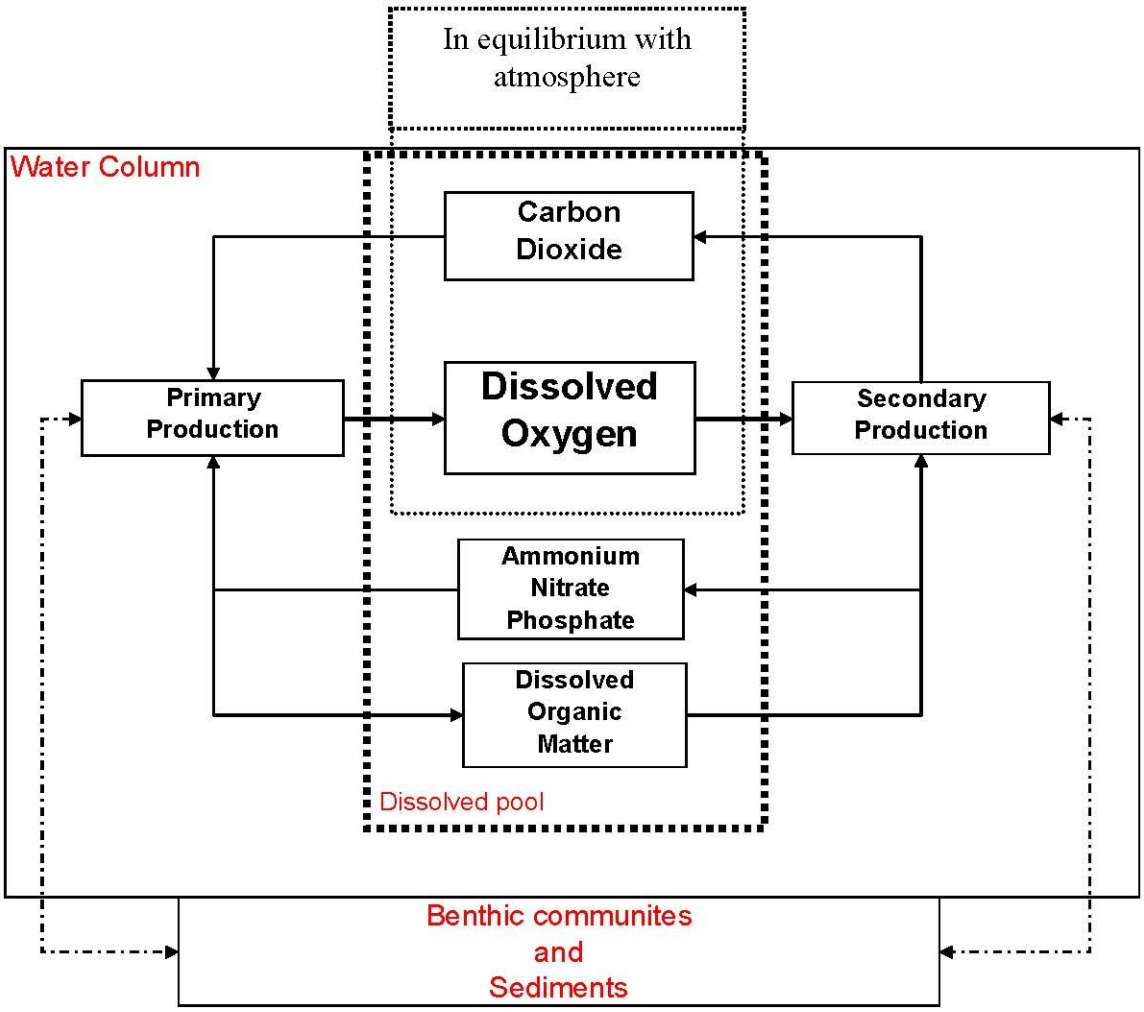


Figure 6.2-16. Dissolved oxygen (DO) and relationships with the atmosphere and organic matter.

Assimilative capacity, based on acceptable intergravel DO, is related to water column and intergravel water exchange and nutrient spiraling (Mulholland and DeAngelis 2000). In rivers, the combined transport and nutrient-cycling processes are referred to as nutrient spiraling (Allan 1995). Nutrient cycling is the conversion of inorganic elements (i.e., carbon, nitrogen, and phosphorus) into organic matter through biological uptake, and the subsequent conversion back to the inorganic form through decay and release. Nutrient cycling occurs in all freshwater aquatic systems but is more dominant (compared to nutrient transport) in lakes and reservoirs with longer residence times. Essington and Carpenter (2002) compared nutrient cycling and spiraling between systems and summarized the general movement of material and processes.

- Rivers and steams are typified by unidirectional flow and high flushing rates with cycling through benthic productivity.
- Lakes and reservoirs are typified by turbulent mixing and low flushing rates with cycling primarily through pelagic productivity.

Essington and Carpenter (2002) acknowledged that an average phosphorus level exported from streams (e.g., 66%) may indicate possible accumulation, but that situation was generally based on a relatively short temporal scale (i.e., less than one year). For long time periods, particulate flushing increased due to infrequent, high-water flood events. This resulted in a dynamic equilibrium where nutrients and organic material were moved downstream at a varying short-term rate but a more constant long-term rate.

Key river and reservoir processes, as summarized in Table 6.2-12, show how constituents cycle and spiral and, most importantly, where losses occur. Note that inorganic carbon and nitrogen are lost from the system to the atmosphere through equilibrium with the atmosphere, denitrification, and burial. However, phosphorus and inorganic suspended matter are lost only through the settling and burial that occurs in reservoirs, but not rivers, over the long term.

Inorganic suspended solids are transported downstream as washload and as suspended and bedload sediment (Yang 1996). While downstream flushing may limit adverse effects in reaches with higher velocities, fine-grain inorganic sediments produced in agricultural areas can adversely impact spawning gravels in reaches with lower gradients (Soulsby et al. 2001a).

During the growing season and low-water periods, storage can exceed transport in rivers. The production of biomass within the system moves dissolved matter from the dissolved pool into the particulate pool (Figure 6.2-17). Periphyton uptake removes dissolved nutrients from the water column, while macrophytes obtain nutrients from the water column and sediments. Bertilsson and Jones (2003), in a review of literature on the supply of organic matter to aquatic systems, stated that macrophytes can be the dominant primary producer in some water bodies. Falter and Burris (1996), in a study on the Middle Snake River, showed that macrophytes dominated biomass in the early growing season and epiphytes dominated later. This promotes short-term storage within a system, which is further enhanced by the trapping of particulate organic matter in macrophyte beds. Also, settling of particulate matter occurs at higher rates in lower-gradient rivers and backwater areas or pools where velocities are lower. These processes are evident in rivers that tend to discharge higher relative fractions of dissolved matter during average- and low-water periods.

Table 6.2-12. Comparison of key processes for selected water-quality constituents showing loss of inorganic suspended solids and phosphorus only occurring through sedimentation and burial processes. Processes modeled with CE-QUAL-W2 (W2) are also shown.

Constituent		Key Processes	Modeled with W2
Dissolved Oxygen			
	Loss/gain	Reaeration and equilibrium with atmosphere	Yes
	Gain	Photosynthesis	Yes
	Loss	Respiration	Yes
Carbon			
Inorganic	Cycling	Biological uptake through primary (and secondary) production	Yes
	Loss/gain	Equilibrium with atmosphere	Yes
Organic	Cycling	Biological degradation	Yes
Reservoir	Loss	Settling and burial	Yes
River	Spiraling	Settling and resuspension/uptake of particulate organic matter	No
Nitrogen			
Inorganic	Cycling	Biological uptake through primary (and secondary) production	Yes
	Loss/gain	Denitrification/nitrogen fixation and equilibrium with atmosphere	Yes
Organic	Cycling	Biological degradation	Yes
Reservoir	Loss	Settling and burial	Yes
River	Spiraling	Settling and resuspension/uptake of particulate organic matter	No
Phosphorus			
Inorganic	Cycling	Biological uptake through primary (and secondary) production	Yes
Organic	Cycling	Biological degradation	Yes
Reservoir	Loss	Settling and burial	Yes
River	Spiraling	Settling and resuspension/uptake of particulate organic matter	No
TSS			
Inorganic		Includes silt, sand, and gravel	
Reservoir	Loss	Settling and burial	~Yes
River	Spiraling	Settling and resuspension of inorganic material	No
Organic	Cycling	Degradation and production of particulate organic matter	Yes
Reservoir	Loss	Settling and burial	Yes
River	Spiraling	Settling and resuspension/uptake of particulate organic matter	No

At other times, transport can exceed storage. Downstream transport of nutrients increases through breakage and mortality into the particulate pool and through excretions into the dissolved pool. Mortality is highest at low and high temperatures, while breakage increases as velocities increase (Park and Clough 2004). High velocities can also limit macrophyte and periphyton production through continuous breakage. This material is often not included in water-column samples collected using standard protocols (J. Naymik, IPC, unpubl. data).

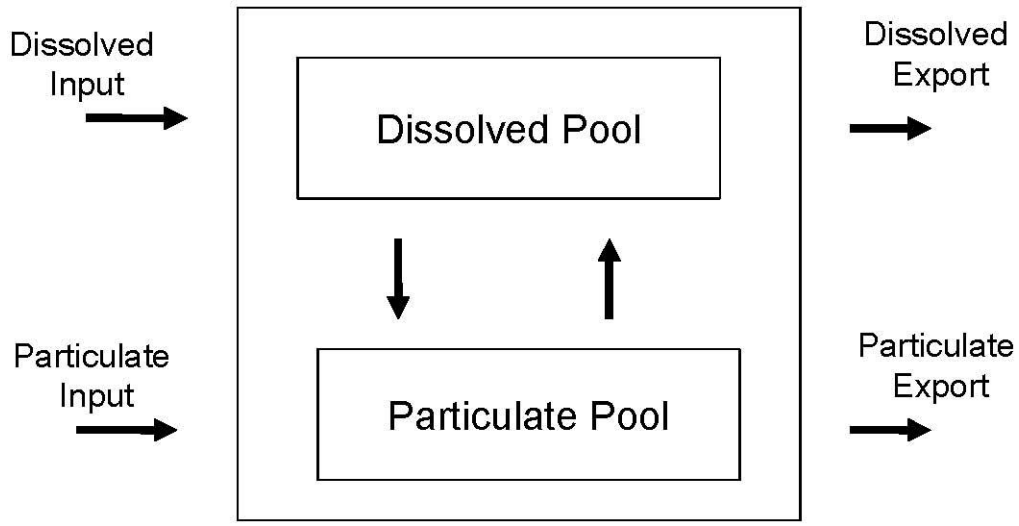


Figure 6.2-17. Schematic of ecosystem cycling and spiraling by Essington and Carpenter (2002).

Over longer time periods (e.g., years) that include both high- and low-water periods, a dynamic equilibrium exists between storage and transport, and loss of nutrients and sediments is more limited. Furthermore, steeper river reaches tend to have lower potential for short-term storage due to the normally higher velocities.

Existing Snake River data in the reach from Bliss Dam to King Hill, when viewed relative to river gradients, provides insight into cycling and spiraling of TP in a relatively steep river reach. Average gradients between selected sampling locations in the Snake River showed that the gradient between Bliss Dam and King Hill was similar to the gradient between Porter's Island (Brownlee Reservoir inflow) and the Hells Canyon outflow (Table 6.2-13). Snake River data collected below Bliss Dam and at King Hill indicated that TP levels were relatively unchanged through the reach (Figure 6.2-15). Analysis of these and other data from a reach having similar gradients to the HCC showed no significant differences in TP at King Hill compared to Bliss Dam (Table 6.2-14). This supported the concept of spiraling, where total (dissolved and particulate) nutrients are transported through the Snake River at relatively constant rates over long-term periods. This also indicated that processing in a free-flowing river reach would not be expected to reduce TP levels with full SR-HC TMDL implementation upstream to the SSWQ target needed at RM 247 to meet the salmonid-spawning intergravel DO criterion.

Rivers tend to have a relatively high assimilative capacity relative to water column DO due to reaeration and primary production when nutrients are not limited. However, the primary production contributes to particulate organic matter that can adversely affect intergravel DO levels. Because nutrients spiral through rivers in a state of dynamic equilibrium, reductions in nutrients and related organic matter are not expected. Thus, would be no anticipated change in TP levels through a free-flowing HCC river reach.

Table 6.2-13. River locations, elevation, and general percent (%) gradients.

Location	River Mile	Elevation	% Gradient
Bliss	560	2,581	
			0.118
King Hill	546	2,492	
			0.034
Indian Cove	525	2,455	
			0.063
C.J. Strike	494	2,350	
			0.032
Celebration	448	2,271	
			0.034
Porter's Island	340	2,077	
			0.124
Hells Canyon	247	1,467	

Table 6.2-14. T-tests for difference of means between paired water-column data collected in the Snake River at Bliss and King Hill from 1994–2000. The number of paired measures is in parentheses; *P* values less than 0.05 indicate a significant difference.

	Difference of Means		Probability Value	
A Overall comparison				
Chlorophyll *a* (*n* = 79)	No		0.9450	
Ammonia (*n* = 95)	Yes		0.0023	
Nitrate (*n* = 95)	No		0.6604	
Total Kjeldahl nitrogen (*n* = 95)	No		0.3525	
Orthophosphate (*n* = 95)	No		0.9363	
Total phosphorus (*n* = 95)	No		0.4256	
Total dissolved solids (*n* = 23)	No		0.7879	
Total suspended solids (*n* = 28)	No		0.0615	
B Seasonal comparison	**Apr–Sept**	**Oct–Mar**	**Apr–Sept**	**Oct–Mar**
Chlorophyll *a*	No	No	0.6345	0.4676
Total phosphorus	No	No	0.1244	0.9955
Orthophosphate	No	No	0.1767	0.2920
Total dissolved solids	No	No	0.1410	0.5254
Total suspended solids	No	No	0.2657	0.1446

The combined cycling and transport processes that produce a dynamic equilibrium in rivers do not normally occur in relatively long residence-time lakes and reservoirs, where most export is in

dissolved form due to settling and processing. Data collected above and below the HCC demonstrated that organic matter (andPP) assimilation was higher in a reservoir reach compared to a river reach. The data showed that the HCC improved intergravel DO downstream of the HCC even though water-column levels were depressed (Figures 6.2-4, 6.2-5, 6.2-6, 6.2-12, 6.2-13, and 6.2-14). This was caused by the higher level of settling in the HCC reservoirs than in a river. Lower suspended solids and POC levels downstream of reservoirs (Figure 6.2-11) reduced inorganic and organic plugging and organic matter decay in gravels. Data collected above and below the HCC demonstrated this difference and the positive effects on intergravel DO (Figures 6.2-4, 6.2-5, 6.2-6, 6.2-12, 6.2-13, and 6.2-14).

It is evident that the SSWQ targets would be needed in a free-flowing river reach with similar gradients to the reach below the HCC in order to meet SSWQ targets further downstream. Therefore, the SSWQ TP target of 0.058 mg/L described previously would be an appropriate HCC boundary condition to assess the effects of the HCC on downstream Snake River DO relative to meeting the salmonid-spawning intergravel criterion.

6.2.3.2. Outflow DO with SSWQ Target

The effects the presence of the HCC would have on water column DO if the free-flowing Snake River water quality supported the salmonid spawning intergravel criterion were modeled using CE-QUAL-W2 and the SSWQ target. The modeled changes in water column, referred to as SSWQ improvements, are the modeled improvements based on the difference between simulated HCC outflow DO with current conditions and with inflow meeting SSWQ targets. The CE-QUAL-W2 model was adjusted as follows:

- Inflowing nutrients were reduced at the boundary conditions (RM 340) to meet the SSWQ TP target of 0.058 mg/L.
- Inflow DO was increased at the boundary conditions to meet the SR-HC TMDL target of 6.5 mg/L).
- SOD was set at long-term levels (no change from the SR-HC TMDL simulation).
- DO was injected into Brownlee Reservoir at a rate of 17.3 tons/day beginning July 1 and ending on September 4 (Julian days 182 through 247).
- Temperature boundary conditions used EHist temperatures.

Other assumptions were made relative to CE-QUAL-W2 model boundary conditions. Snake River data showed a 91% reduction in chlorophyll *a* from the inflow to Brownlee Reservoir to below the HCC (Table 6.2-9). Other constituents related to labile particulate organic matter showed a similar level of reduction. Using these measured reductions as a general guide, the following reductions to boundary conditions were used to represent the SSWQ targets:

- 90% algae;
- 90% labile particulate phosphorus; and
- 67% soluble reactive phosphorus (no change from the SR-HC TMDL).

The 1995 Snake River inflow boundary conditions, based on the 90% reductions, were summarized to show median and maximum concentrations for the year (Table 6.2-15). The calculated maximum TP level in the boundary condition matched the SSWQ TP target of 0.058 mg/L. The maximum chlorophyll *a* concentration of 10 µg/L equaled the 90% reduction, which was near the upper end of the identified SSWQ target range of 3.6–11.70 µg/L.

Table 6.2-15. Summarized 1995 CE-QUAL-W2 Brownlee Reservoir inflow boundary conditions for 3 water quality conditions: current, SR-HC TMDL, and salmonid-spawning water quality (SSWQ).

	Current		SR-HC TMDL		SSWQ	
	Median	**Maximum**	**Median**	**Maximum**	**Median**	**Maximum**
CE-QUAL-W2 boundary condition (mg/L)						
ISS	10.7	20.6	NC	NC	NC	NC
PO_4	0.04	0.09	0.01	0.03	NC	NC
NH_4	0.08	0.17	0.02	0.05	NC	NC
NO_3	0.94	1.88	0.29	0.58	NC	NC
LDOM	0.50	0.74	0.16	0.23	NC	NC
RDOM	4.91	8.55	1.52	2.65	NC	NC
LPOM	0.16	0.36	0.05	0.11	0.02	0.04
RPOM	0.79	2.31	0.24	0.72	NC	NC
Algae	2.51	6.58	0.78	2.04	0.25	0.66
DO	11.30	13.70	NC	NC	NC	NC
Values calculated from CE-QUAL-W2 boundary conditions						
Organic P (mg/L)	0.09	0.16	0.03	0.05	0.02	0.04
Total P (mg/L)	**0.133**	**0.221**	**0.041**	**0.069**	**0.036**	**0.058**
Chlorophyll (µg/L)	37.7	98.7	11.7	30.6	3.8	10.0

Note: NC indicates no change from current or SR-HC TMDL condition

Figure 6.2-18 illustrates the simulated improvements in DO below the HCC from inflow meeting the SSWQ targets. CE-QUAL-W2 model simulations showed that SSWQ target improvements may be as high as 4–6 mg/L during summer and 3–4 mg/L in fall. This is compared to summarized measured DO data discharged from Hells Canyon Dam of approximately 4–5 mg/L (Figure 6.2-2). Comparing SSWQ improvements with summarized measured data showed that if water-quality conditions in a free-flowing Snake River supported the intergravel salmonid spawning criterion, the presence of the HCC may still create deficits from the water-column DO criterion of 8.0 mg/L for the protection of salmonid rearing and the water-column salmonid-spawning criteria.

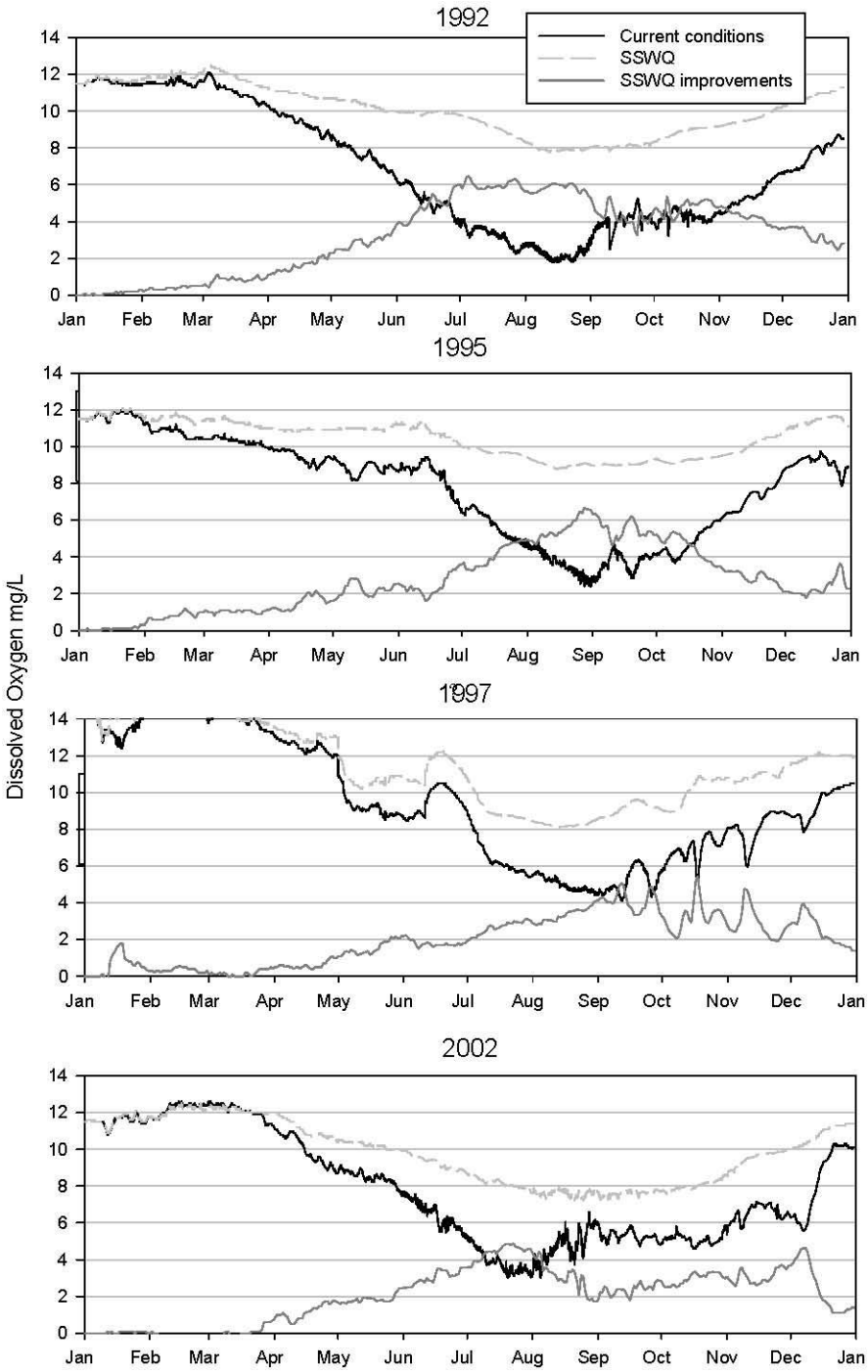


Figure 6.2-18. Comparison of simulated Hells Canyon outflow dissolved oxygen (DO) in milligrams per liter (mg/L) with current conditions and salmonid-spawning water-quality (SSWQ) conditions. SSWQ improvements show the difference between the 2 simulations.

6.2.3.3. Appropriate HCC DO Responsibility

6.2.3.3.1. Reservoir

The SR-HC TMDL linked nutrients and chlorophyll *a* with low DO levels and set targets for both TP and algae for the attainment of DO criteria and the protection of beneficial uses (IDEQ and ODEQ 2004). They predicted that upstream reductions in TP loading, based on SR-HC TMDL allocations, would improve water quality in the Snake River and DO levels in Brownlee Reservoir. Specifically, low DO levels within the HCC are attributable to in-reservoir processing of inflow organic matter loads. To address the remaining DO deficit relative to the aquatic-life criterion in the HCC, a DO load allocation of 1,125 tons of DO per year was established for Brownlee Reservoir.

6.2.3.3.2. Downstream

DO load estimates presented in Tables 6.2-16 and 6.2-17 show the estimated DO load needed to meet water-quality criteria below the HCC. Model results are best used to assess relative changes between simulations or relative effectiveness of management options. Comparing model results directly to criteria can be appropriate and conservative, depending on model error estimates, desired level of resolution, and case-specific considerations. In this situation, comparing model results directly to criteria to estimate deficits and the appropriate HCC DO responsibility was problematic. Although error estimates of the HCC model applications reported in Section 6.2.2.2.2 are not uncommon in similar model applications, an error of 1–2 mg/L would result in substantial over or underestimation of deficits and responsibilities. For these reasons, SR-HC TMDL improvements and SSWQ target improvements were used to adjust measured DO data to account for DO effects that were not the responsibility of the HCC. SR-HC TMDL and SSWQ target improvements are the relative DO improvements between 2 model simulations. The adjusted measured data was then compared with criteria to determine a DO concentration deficit. This deficit was then used with daily average flow to calculate a DO load in tons. The DO load is an estimate of the mass of DO needed to reach criteria.

Table 6.2-16. Estimated water-column dissolved oxygen (DO) loads needed to reach criteria based on SR-HC TMDL improvements.

Year	Summer Load (4/16–10/22)	Number of Days	Fall Load (10/23–12/31)	Number of Days	Total Load
1992	361	43	4	2	365
1995	53	8	189	21	242
1997	414	12	709	21	1,123
2002	1,569	77	164	15	1,733

Table 6.2-17. Estimated water column dissolved oxygen (DO) loads needed to reach criteria based on salmonid-spawning water quality (SSWQ) improvements.

Year	Summer Load (4/16–10/22)	Number of Days	Fall Load (10/23–12/31)	Number of Days	Total Load
1992	5	1	0	0	5
1995	0	0	44	8	44
1997	105	2	281	16	386
2002	620	40	17	6	637

Measured daily minimums were adjusted using SR-HC TMDL improvements to evaluate the DO load that may still be needed to reach criteria following SR-HC TMDL implementation. The adjustment represents accounting for changes in outflow DO anticipated by upstream SR-HC TMDL improvements. Adjusted measured data showed that, following SR-HC TMDL improvements, outflow DO may still fall below criteria in both summer and fall (Figure 6.2-19). The estimated loads ranged from 242 to 1,733 tons/year and represent the additional DO load that needs to be provided by all sources, including the HCC, to meet criteria (Table 6.2-16).

The portion of the total load that is the appropriate HCC DO responsibility was estimated by adjusting daily minimums using SSWQ target improvements (Figure 6.2-20). The SSWQ targets are estimated Snake River water quality sufficient to support the intergravel salmonid-spawning criterion in a free-flowing river reach. Therefore, the results of this adjustment showed the effect the presence of the HCC would have on water column DO if Snake River water quality was sufficient to support the intergravel salmonid spawning criterion with the HCC removed. The resulting loads ranged from 5–637 tons/year, with 637 tons/year representing the maximum upper limit of the appropriate HCC DO responsibility (Table 6.2-17).

DO load estimates presented in Tables 6.2-16 and 6.2-17 are conservative based on 2 additional considerations: 1) the use of daily minimum DO and 2) the use of the 8.0 mg/L criterion in the summer instead of multiple criteria (see Section 6.2.1.1). Daily minimum DO, based on 10-minute measurements, was the measured data adjusted and used for the majority of the estimates. The exception to this was in July and August of 2002 when 10-minute measurements were not available and instantaneous measurements every 2 weeks were used. When 10-minute data were used, a conservative DO load estimate resulted since it was assumed that the daily minimum DO occurred for the whole day. The HCC outflow DO fluctuated over the day, so if more frequent DO measurements, or daily average DO were used, lower DO loads would be estimated.

Second, summer DO load estimates for all years are also conservative based on comparison with multiple DO criteria as outlined in Oregon's DO standards (see Section 6.2.1.1.). Applying these multiple criteria in 2002, when the largest loads are needed following full upstream SR-HC TMDL implementation, showed much lower loads may be needed to reach multiple criteria (Table 6.2-18).

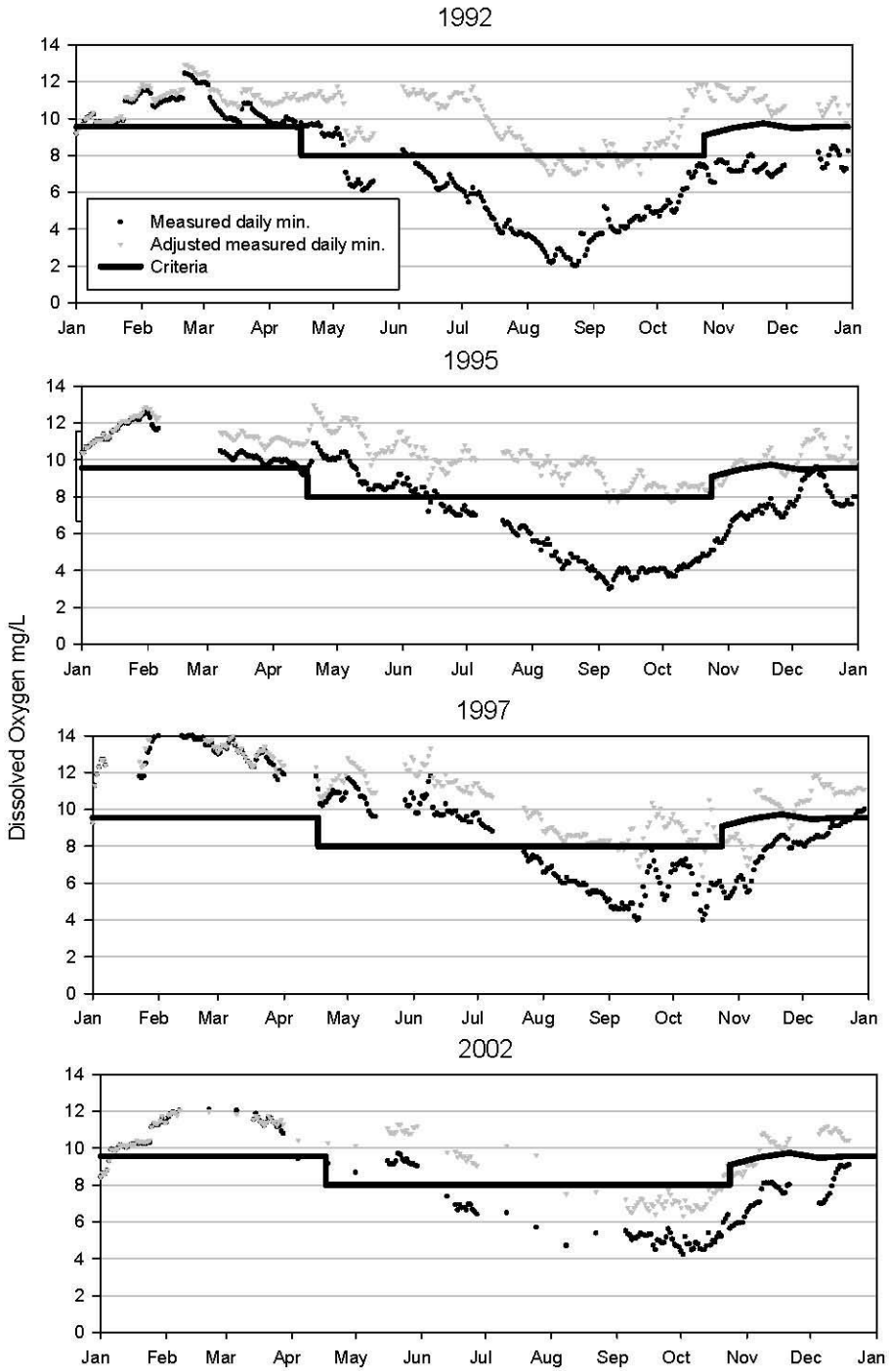


Figure 6.2-19. Hells Canyon outflow measured daily minimum dissolved oxygen (DO) in milligrams per liter (mg/L) and adjusted measured daily minimum DO based on SR-HC TMDL improvements.

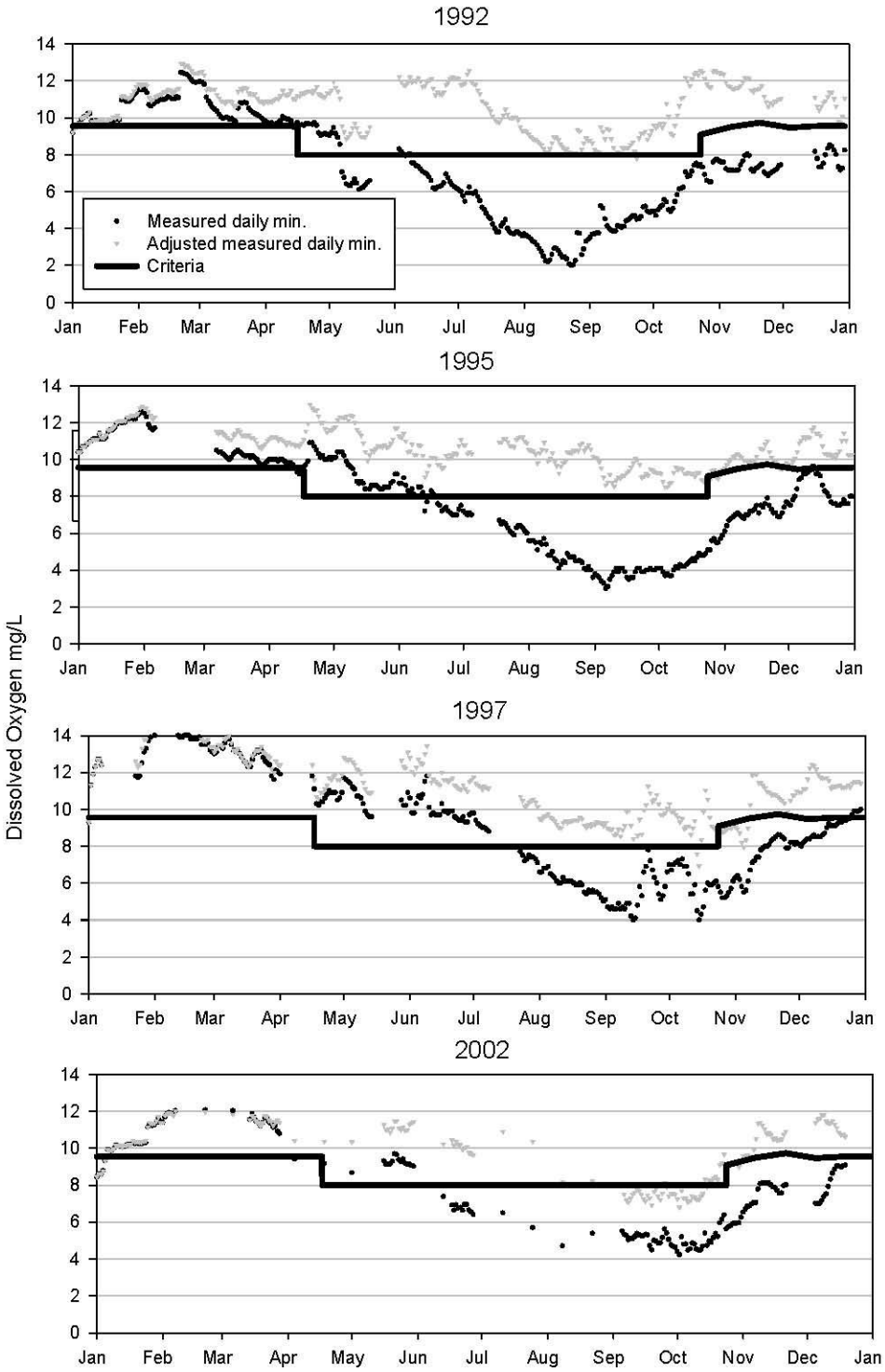


Figure 6.2-20. Hells Canyon outflow measured daily minimum dissolved oxygen (DO) in milligrams per liter (mg/L) and adjusted measured daily minimum DO based on salmonid-spawning water quality (SSWQ) improvements.

Table 6.2-18. 2002 estimated water-column dissolved oxygen (DO) loads needed to reach multiple criteria based on SR-HC TMDL improvements.

Criteria	Summer Load (4/16–10/22)	Fall Load (10/23–12/31)	Total Load
8 mg/L absolute minimum	1,569	164	1,733
Multiple criteria			
8 mg/L 30-day mean minimum	1,265	164	1,429
6.5 mg/L 7-day minimum mean	0	164	164
6 mg/L absolute minimum	0	164	164

6.2.3.3.3. Oxbow Bypass

The deep pool in the Oxbow Bypass was not specifically included in DO simulations following full SR-HC TMDL implementation. Currently, this deep pool becomes thermally stratified and anoxic conditions develop in the deep cooler water at times during the summer season. Improved DO conditions in Oxbow and Hells Canyon reservoirs following SR-HC TMDL implementation suggest that anoxic conditions may not develop in this pool. However, this is not known to be the case. Therefore, IPC will address development of anoxic conditions in the deep pool in the Oxbow Bypass.

6.3. Total Dissolved Gases

Total dissolved gases (TDG) are a measure of the sum of partial pressures of all dissolved gases in water, including water vapor. Typically, in most natural waters, TDG is a measure of how much nitrogen, oxygen, argon, carbon dioxide, and water vapor are dissolved in a given amount of water. Although slightly elevated TDG levels can occur naturally, a TDG saturation of 100% means that the water is saturated relative to atmospheric conditions. Levels exceeding 100% of saturation, or supersaturation, can be detrimental or lethal to aquatic life.

The solubility of atmospheric gases in water is primarily affected by temperature and pressure. Increased pressure on a liquid enhances its capacity to hold dissolved gases. Pressure at depth, caused by greater hydrostatic pressure, allows deeper water to hold more dissolved gas than shallow water (Weitkamp and Katz 1980). Each meter of depth increases the solubility of the dissolved gases to compensate for approximately 10% of the supersaturation. For example, a surface measurement of 120% of saturation corresponds to a compensated effect to aquatic life of 110% of saturation 1 m below the surface. Consequently, the depth distribution of the organisms determines the effects of TDG levels on aquatic life. In reservoirs and large rivers, such as the HCC and Snake River downstream, little of the water volume is likely to have supersaturation gas effects on aquatic organisms (Weitkamp 1974).

The Oregon CWA § 303(d) list does not have the Snake River or the HCC reservoirs listed as impaired by TDG (Table 5.1-1). After development of the SR-HC TMDL, Idaho listed TDG as a pollutant impairing beneficial uses in Oxbow and Hells Canyon reservoirs and the Snake River downstream of Hells Canyon Dam to the confluence with the Salmon River (Table 5.1-2). Loading analysis performed by IDEQ and ODEQ for the SR-HC TMDL identified that elevated

TDG levels in the Snake River from Brownlee Dam to the confluence with the Salmon River were the result of releasing water over spillways of dams in the HCC, stating that spills at Brownlee and Hells Canyon dams were the sources of elevated TDG (IDEQ and ODEQ 2004). As such, the entire load was allocated to IPC. The load allocation is less than 110% of saturation at the edge of the aerated zone and applies to each location where spill occurs except when flow exceeds the 10-year, 7-day (7Q10) average flood.

6.3.1. TDG Standards and SR-HC TMDL Targets

Oregon and Idaho both have numeric criterion not to exceed 110% of saturation at atmospheric pressure at the point of sample collection (OAR 340-041-0031(2)[9] and IDAPA 58.01.02.250.01.b.). This criterion does not apply with respect to excess flows. In Oregon, the criterion does not apply when flows exceed the 7Q10 average flood. In Idaho, the Director of the IDEQ has the authority to specify the applicability of the gas supersaturation criterion with respect to excess flow (IDAPA 58.01.02.300.01.a.).[10] The SR-HC TMDL identified excess flow as the Oregon standard and the point of sample collection to be the edge of the aerated zone (IDEQ and ODEQ 2004).

6.3.2. Conditions Relative to TDG

Spilling at the HCC projects is almost exclusively involuntary, occurring usually as a result of flood-control constraints or high-runoff events (IDEQ and ODEQ 2004). Spilling typically occurs between December and July in higher water years when Snake River flows exceed the project's flood-storage capacity, as mandated by USACE, or the hydraulic capacity of generation turbines. Other unusual situations, including emergencies or unexpected unit outages, can induce a spill episode at any of the projects.

Spilling water at any of the 3 projects within the HCC can increase TDG to supersaturation levels that exceed the 110% of saturation criterion. TDG levels were measured immediately downstream of the spillway and do not necessarily represent levels at the edge of the aerated zone. During spills above 3,000 cfs at Brownlee Dam, TDG levels in spilled water consistently exceeded the 110% of saturation criterion and were measured as high as 128% (Figure 6.3-1) TDG levels downstream of the spillway were significantly higher than reservoir levels ($P < 0.005$). The configuration of the Brownlee powerhouse and spillway creates separation of spill and turbine flows. Monitoring at the bridge immediately below Brownlee Dam indicates limited mixing of spill and powerhouse flows at that location until spill flows reached 35,000 cfs (Exhibit 6.3-1). Assuming full hydraulic capacity of the turbines (approximately 35,000 cfs), this flow (i.e., approximately 70,000 cfs) was higher than the 7Q10 average flood flow of

[9] Oregon also has a 105% of saturation criterion specific to hatchery-receiving waters and waters less than 2 feet in depth that does not apply to the HCC.

[10] With respect to gas supersaturation, the IDEQ Director also has authority to 1) direct that all known and reasonable measures be taken to assure protection of the fishery resources and 2) require that operational procedures or project modifications do not contribute to increased mortalities of juvenile migrants or impose serious delays in adult migrant fishes (IDAPA 58.01.02.300).

67,898 cfs. Exhibit 6.3-1 also indicated that TDG levels measured below Brownlee Dam can be higher than the maximum of 128% measured in 1997 and 1998, with little dissipation downstream through Oxbow Reservoir.

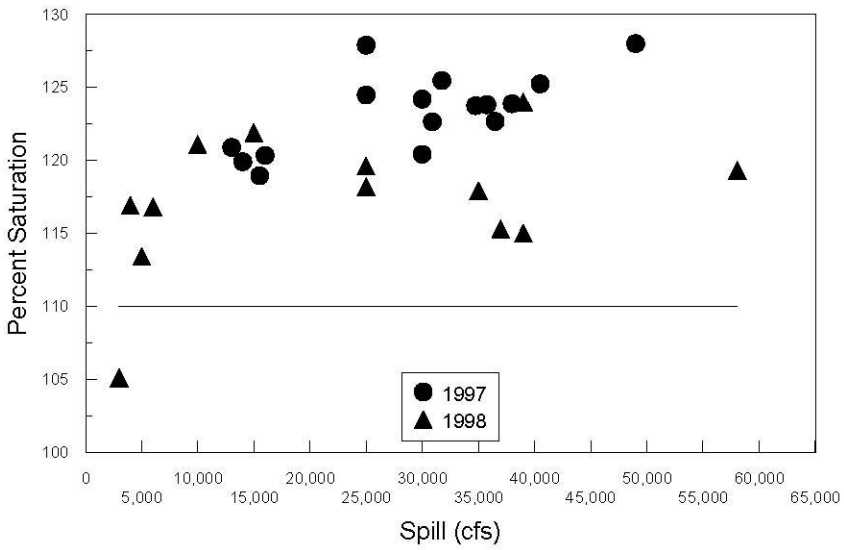


Figure 6.3-1. The relationship of spill in cubic feet per second (cfs) and total dissolved gases (TDG) percent saturation (% Saturation) measured downstream of Brownlee Dam, 1997−1998. (Note: Add 35,000 cfs to spill for estimate of total Snake River flow. TDG percent saturation is measured near spillway prior to mixing with turbine flow.)

TDG levels measured in the spill of Oxbow Dam were similar to those measured in the spill of Brownlee Dam and exceeded the criterion (Figure 6.3-2). In 1997 and 1998, the TDG levels measured at Oxbow Dam, did not necessarily represent independent Oxbow Dam spill events, as water was also being spilled at Brownlee Dam. The TDG levels in Oxbow Reservoir ranged upwards to 125% of saturation. Evaluation of these data and those collected downstream of Oxbow Dam indicated that both increases and decreases in TDG levels were measured (Figure 6.3-3). The largest increase in saturation (approximately 20%) occurred during a spill rate of 12,000 cfs. The largest decrease in saturation (approximately 13%) occurred during a spill rate of 2,000 cfs. At Oxbow Dam, spill rates less than 2,000 cfs and greater than 24,000 cfs lowered TDG levels in the spilled water, while spill rates between 5,000 and 24,000 cfs increased TDG levels. Seattle Marine Laboratories (1972) found that dissolved nitrogen levels decreased on all days sampled as a result of spill at Oxbow Dam, but they did not address rates of spill.

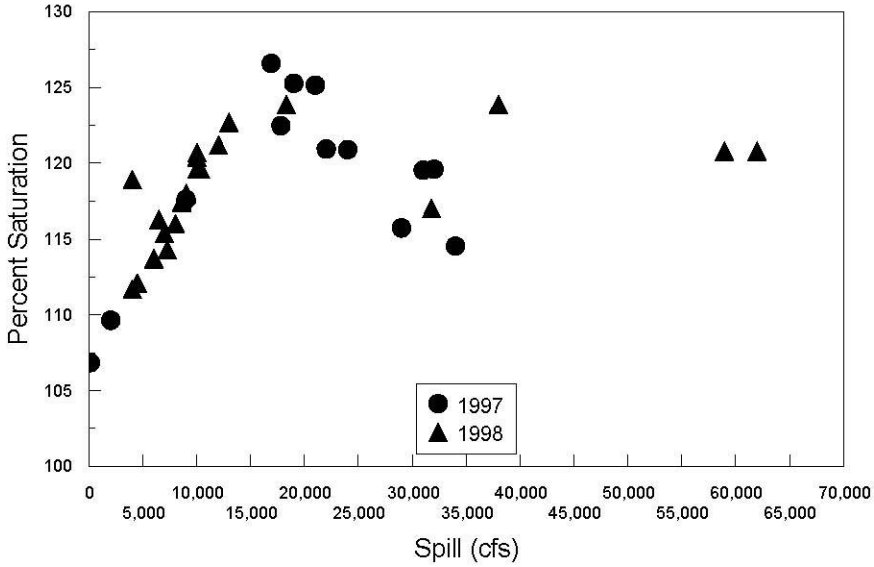


Figure 6.3-2. The relationship of spill in cubic feet per second (cfs) and total dissolved gases (TDG) percent saturation (% Saturation) measured downstream of Oxbow Dam, 1997–1998. (Note: Add 28,000 cfs to spill for estimate of total Snake River flow. TDG percent saturation is measured near spillway prior to mixing with turbine flow.)

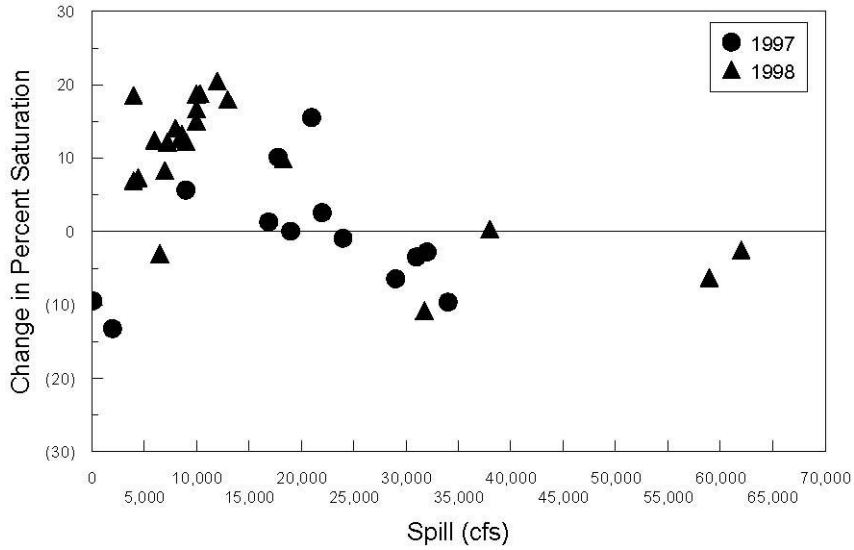


Figure 6.3-3. Change in total dissolved gases (TDG) percent saturation (% Saturation) above and below Oxbow Dam over a range of spill in cubic feet per second (cfs), 1997–1998. (Note: Parenthetic numbers indicate a decrease in TDG levels below Oxbow Dam.)

Monitoring in 2006 allowed evaluation of spill at Oxbow Dam independent of Brownlee Dam spill; that is, when Oxbow Reservoir forebay TDG levels were less than 110% of saturation. These data showed that when the Oxbow Reservoir forebay was below the criterion, spill at Oxbow Dam increased TDG levels to approximately 128% of saturation in the bypassed reach (Figure 6.3-4). As in 1997 and 1998, similar patterns of increases and decreases in TDG levels resulting from spill at Oxbow Dam were also measured (Exhibit 6.3-1).

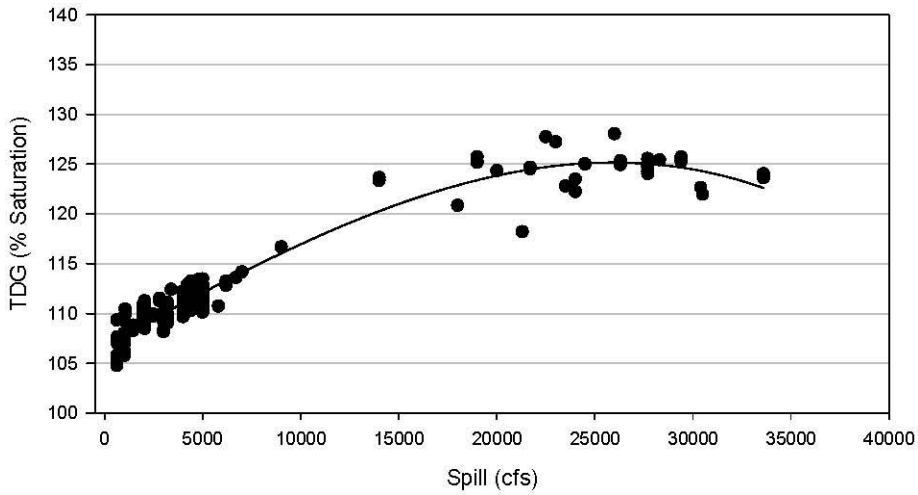


Figure 6.3-4. The relationship of spill in cubic feet per second (cfs) and total dissolved gases (TDG) percent saturation (% Saturation) at Oxbow Dam in 2006 when inflow water to Oxbow spillway was less than 110% of saturation.

TDG levels in the Hells Canyon Dam tailwater were significantly higher than reservoir levels during periods of spill ($P < 0.005$), ranging up to 133% of saturation (Figure 6.3-5). Hourly measures taken in 1999 ranged up to 136% of saturation, showing a clear relationship between spill and TDG levels, despite considerable variability in TDG at similar spill rates (Figure 6.3-6). Nearly all rates of spill produced TDG levels exceeding the criterion. Supersaturation declined in the Snake River as water flowed downstream of Hells Canyon Dam (Figure 6.3-7). Levels in excess of 110% of saturation persisted downstream to the confluence with the Salmon River (RM 188) when spilling approximately 20,000 cfs or greater at Hells Canyon Dam. More detail on HCC TDG is available in Technical Report E.2.2-4 (Myers and Parkinson 2003), which accompanied the *New License Application: Hells Canyon Hydroelectric Complex*.

Daily average flow from Hells Canyon Dam from 1968 through 2003 was used to generate a flow-duration curve (Figure 6.3-8). The 7Q10 average flood, as calculated below Hells Canyon Dam, is 71,498 cfs. This represents less than 1% of the flows at Hells Canyon Dam. Similar average flood statistics were estimated for both Oxbow and Brownlee dams by subtracting major tributary flows. The 7Q10 average flood is 69,062 cfs at Oxbow Dam and 67,898 cfs at Brownlee Dam.

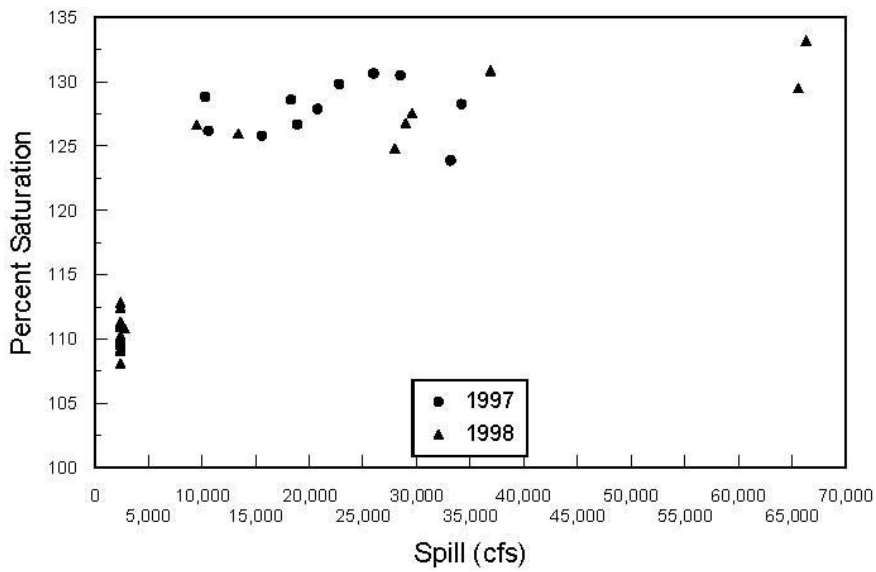


Figure 6.3-5. The relationship of spill in cubic feet per second (cfs) and total dissolved gases (TDG) percent saturation (% Saturation) measured at the Hells Canyon boat launch downstream of Hells Canyon Dam, 1997–1998. (Note: Add 30,500 cfs to spill for estimate of total Snake River flow. These data are presumed to represent a mix of turbine and spill waters.)

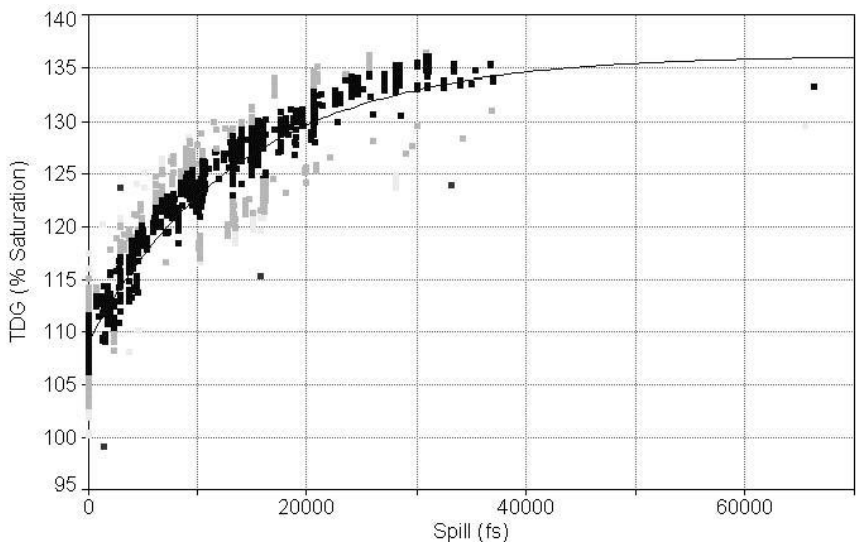


Figure 6.3-6. The relationship of spill in cubic feet per second (cfs) and total dissolved gases (TDG) percent saturation (% Saturation) measured below Hells Canyon Dam from March 3 through July 20, 1999. (Note: Add 30,500 cfs to spill for estimate of total Snake River flow. These data are presumed to represent a mix of turbine and spill waters.)

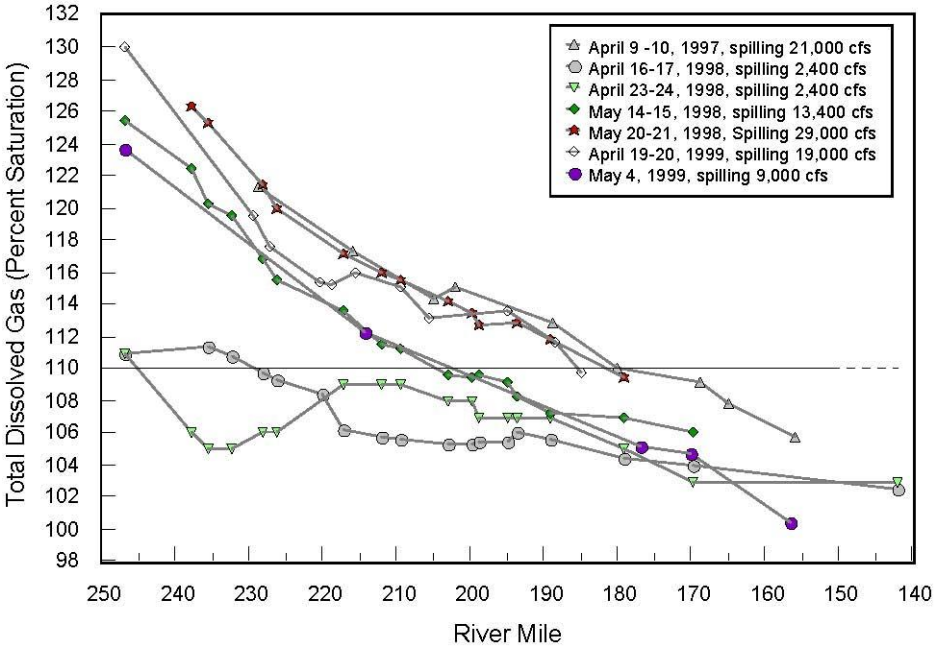


Figure 6.3-7. Downstream dissipation of total dissolved gases (TDG) in the Snake River within Hells Canyon relative to the 110% saturation target. (Note: Add 30,500 cfs to spill for estimate of total Snake River flow. TDG percent saturation (% Saturation) can be a combination of gas dissipation and mixing with turbine flows.)

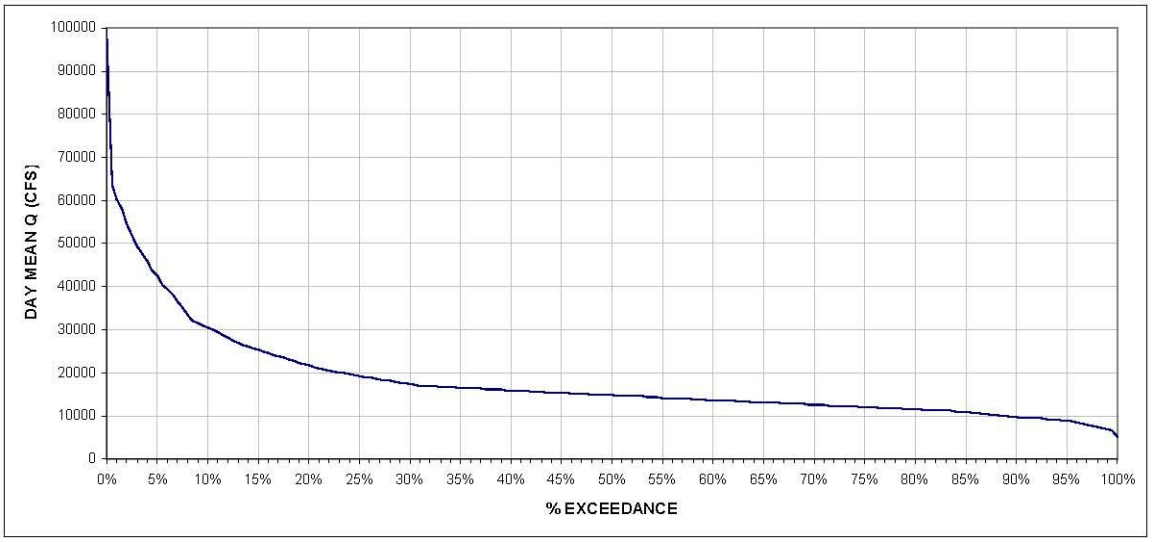


Figure 6.3-8. Hells Canyon Dam daily average flow (Day Mean Q) in cubic feet per second (cfs) flow-duration curve for the October 1968 through February 2003 period of record.

6.3.3. HCC Contribution to TDG

The SR-HC TMDL defined the load allocation for TDG as less than 110% of saturation at the edge of the aerated zones below Brownlee, Oxbow, and Hells Canyon dams (IDEQ and ODEQ 2004). The load applies to all flows not exceeding the 7Q10 average flood. The entire load was allocated to IPC because spill at Brownlee and Hells Canyon dams are the source of elevated TDG in the SR-HC TMDL reach.

IPC recognizes that spillway releases from the HCC projects elevate TDG levels that have the potential for negative effects on aquatic life. External symptoms of gas bubble trauma have been observed on returning adult anadromous salmonids captured at Hells Canyon Dam during periods of spill. These fish must migrate through the lower Columbia and Snake River hydroelectric projects on their way to Hells Canyon Dam. The effects on fish of Columbia River elevated TDG levels from these projects have been well documented (McGrath et al. 2006).

No symptoms of gas bubble trauma have been observed on juvenile fall Chinook salmon collected downstream of the HCC in sampling conducted by the U.S. Fish and Wildlife Service (FWS) (W. Connor, U.S. Fish and Wildlife Service, pers. comm.). The uppermost sampling location was approximately 20 miles downstream of Hells Canyon Dam (RM 227.6). TDG levels measured near that location in April and May from 1997 through 1999 during spill over 9,000 cfs ranged from approximately 116% to 122% of saturation (Figure 6.3-7). The lack of gas bubble trauma symptoms observed in juvenile fall Chinook salmon in Hells Canyon corroborated recent literature. McGrath et al. (2006) reviewed recent research on the effects of TDG levels on migratory juvenile and adult salmonids in the Columbia River. They concluded that the newer research supports the previous research, indicating that short-term exposure, up to 120% of saturation does not produce significant effects on migratory juvenile or adult salmonids when compensating depths are available.

HCC resident fish were monitored for signs of gas bubble trauma during spill in the spring of 2006 (Exhibit 6.3-1). Gas bubble trauma symptoms were observed only when TDG levels were greater than 120% of saturation within at least 12 hours prior to sampling. Severe gas bubble trauma signs were observed when TDG exceeded 125% of saturation (daily average near 130%). Again, these results corroborated the research reviewed in McGrath et al. (2006).

Under current operations, IPC minimizes spilling of water. Therefore, further decreased spill flow to manage TDG levels is not possible. Spilling of water typically occurs only in association with high spring runoff events, USACE-mandated flood control operations, or unplanned equipment failure.

6.4. Nuisance Algae

Oregon has not listed the Snake River as water-quality limited due to nuisance algal growths (Table 5.1-1). Idaho, however, has listed Brownlee and Oxbow reservoirs as impaired by nutrients (Table 5.1-2), as well as the Snake River upstream to the Oregon and Idaho border (IDEQ 2005). The SR-HC TMDL presented data on excessive TP concentrations in the Snake River inflow to Brownlee Reservoir and reported that nuisance algal growths have been routinely observed in the Snake River and the upper end of Brownlee Reservoir (IDEQ and

ODEQ 2004). ODEQ and IDEQ concluded that the excessive nutrients were not wholly attributable to natural sources and established a 0.070 mg/L TP target, which correlated to an average chlorophyll *a* concentration of 14 µg/L for protection of the designated aquatic-life use. Since water quality needed to protect aquatic life is likely more stringent than needed to protect water supply and recreation uses, the 14 µg/L target was assumed to also be protective of these uses.

6.4.1. Nuisance Algae Standards and SR-HC TMDL Targets

Oregon has numeric criteria for nuisance algal growths. Specifically, natural lakes that do not stratify, reservoirs, rivers, and estuaries may not exceed 15 µg/L (OAR 340-041-0019(1)(B)). Upon determination by ODEQ that the criterion is exceeded, ODEQ may conduct studies to describe water quality, determine the probable causes of the exceedence and beneficial use impact, and develop a proposed control strategy for attaining compliance where technically and economically practicable (OAR 340-041-0019(2)(a); in other words, ODEQ may develop a TMDL and water-quality management plan. Idaho has narrative criteria. Specifically, IDAPA 58.01.02.200.06 states "waters of the state shall be free from excess nutrients that can cause visible slime growths or other nuisance aquatic growths impairing designated beneficial uses."

A TMDL was developed that established a TP target not to exceed 0.070 mg/L (IDEQ and ODEQ 2004). This nutrient target correlated to a 14 µg/L chlorophyll *a* mean growing season (May through September) concentration that was established as the nuisance algae target. Further, chlorophyll *a* concentrations were not to exceed a nuisance threshold of 30 µg/L more than 25% of the time.

6.4.2. Conditions Relative to Nuisance Algae

Nuisance algal growths are often defined by chlorophyll *a* concentration or cell density; however, certain algae taxa have been identified as having possible negative effects. One such taxon is Cyanophyta (blue-green algae). The following sections will discuss conditions relative to both concentration and community structure.

6.4.2.1. Algal Biomass

Algal biomass is often estimated using chlorophyll *a* measures. Because algal cell volumes and weights vary by orders of magnitude (Reynolds 1984), biomass estimates can indicate different trends compared to density measurements (e.g., high densities in areas with low biomass).

Chlorophyll *a* measured in the Snake River immediately upstream of Brownlee Reservoir (RM 345.6) indicated frequent nuisance growths. This corroborated the SR-HC TMDL note that nuisance algal growth was routinely observed in the Snake River and the upper end of Brownlee Reservoir (IDEQ and ODEQ 2004). Figure 6.4-1 illustrates that the 30 µg/L chlorophyll *a* nuisance threshold was exceeded more than one-half of the time from May through September. IPC has previously commented on similar TMDLs that the May through September growing season may not reasonably assure protection of the use (IPC 2003). For example, 4 consecutive chlorophyll *a* concentrations, measured immediately upstream of Brownlee Reservoir

(RM 345.6) during March and April 2004, averaged 146.21 µg/L. Chlorophyll *a* concentrations further upstream (RM 385 and RM 403) also exceeded the chlorophyll *a* targets (Figure 6.4-2).

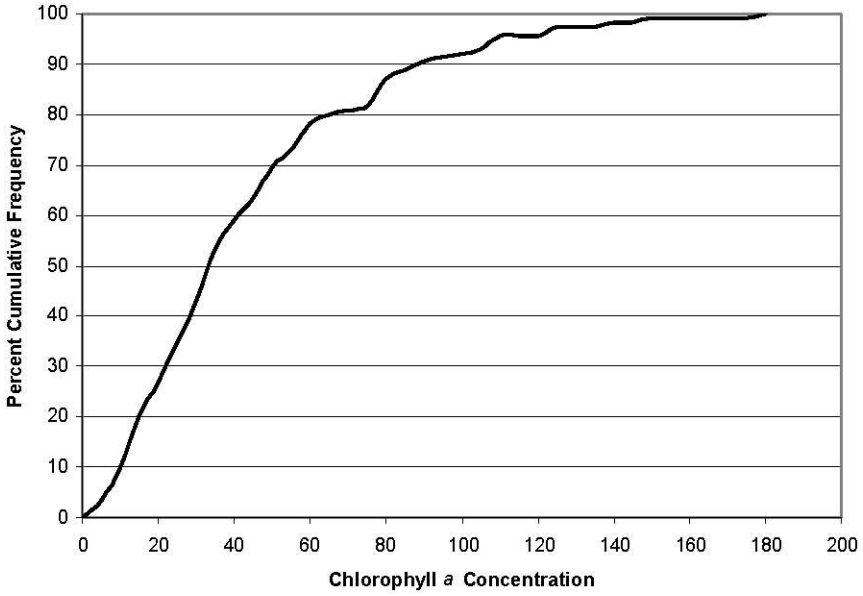


Figure 6.4-1. Percent cumulative frequency for May through September chlorophyll *a* concentrations in micrograms per liter (µg/L) collected between 2001 and 2004 from the Snake River, immediately upstream of Brownlee Reservoir (RM 345.6).

Chlorophyll *a* measured in Brownlee Reservoir showed a general decreasing trend from the riverine zone (approximately RM 340 to RM 324) through the transition zone (approximately RM 324 to RM 308) and into the lacustrine zone (Figure 6.4-3). Low chlorophyll *a* concentrations were thereafter maintained downstream throughout the HCC. Concentrations in the upper end of Brownlee Reservoir, represented by RM 340 in Figure 6.4-3, likely were low due to sampling biases. When summer concentrations (June through August) were segregated by period of years, it was apparent that measures taken from 1991 to 1994, when RM 340 were not sampled, tended to be higher than those measured from 1995 to 2000 (Table 6.4-1). From 1995 to 2000, median chlorophyll *a* concentrations were comparable at RM 340 and in the riverine zone of Brownlee Reservoir. It may then be assumed that inflow median chlorophyll *a* concentrations from 1991 to 1994 may be similar to those measured in the riverine zone (RM 325.0–335.0).

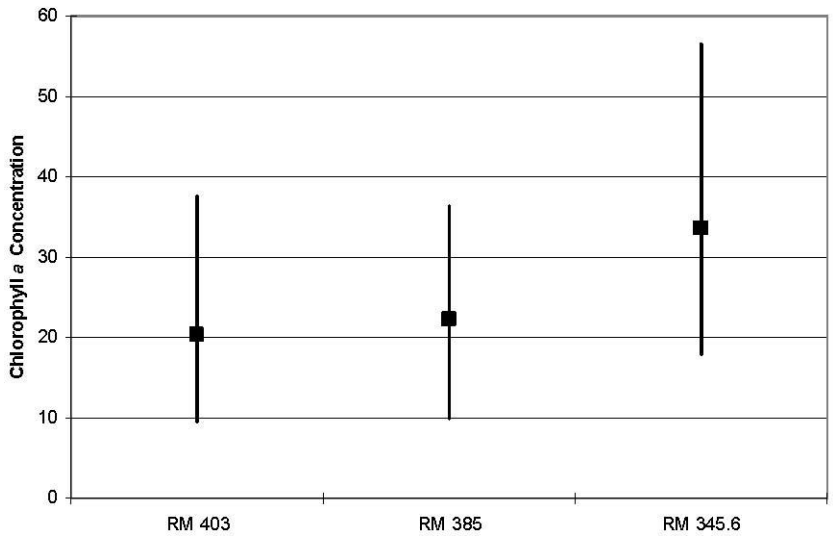


Figure 6.4-2. Interquartile ranges (the box represents the median and the line the 75th and 25th percentiles) for May through September chlorophyll *a* concentrations in micrograms per liter (µg/L) from the Snake River at the Adrian, Oregon, bridge (RM 403), Nyssa, Oregon, bridge (RM 385), and immediately upstream of Brownlee Reservoir (RM 345.6). Adrian and Nyssa data were collected from 1995 through 2003. Data immediately upstream of Brownlee Reservoir were collected from 2001 through 2004.

Table 6.4-1. Median chlorophyll *a* and range in micrograms per liter (µg/L) measured from June through August in Brownlee Reservoir during 1991 to 1994 and 1995 to 2000. Inflow data not available (NA) during 1991 to 1994.

	1991 to 1994		1995 to 2000	
Location	**Number of Observations**	**Median (Range)**	**Number of Observations**	**Median (Range)**
Brownlee Reservoir (RM 285.0–335.0)	197	17.1 (0.1–727.1)	435	6.5 (0.1–155.4)
Lacustrine Zone (RM 285.0–308.0)	78	6.1 (0.1–84.5)	211	3.3 (0.1–117.1)
Transition Zone (RM 309.0–324.0)	66	19.3 (0.1–231.8)	136	8.1 (0.6–155.4)
Riverine Zone (RM 325.0–335.0)	54	63.0 (4.5–727.1)	88	40.2 (4.6–121.5)
Inflow (RM 340.0)	NA	NA	37	41.5 (5.1–92.5)

6.4.2.2. Algal Communities

Chrysophyta taxa (diatoms) dominated spring assemblages in and upstream of Brownlee Reservoir with the highest algal cell densities in the upper section of Brownlee Reservoir from RM 305 to RM 329 (Myers et al. 2003). More detail on algal communities of the HCC reservoirs

is available in Technical Report E.2.2-2 of the *New License Application: Hells Canyon Hydroelectric Complex*. An assemblage shift typically occurs from spring to summer, resulting in heavy dominance by Cyanophyta (blue-green) taxa. Thick surface scums of blue-green algae have been observed in the upper end of Brownlee Reservoir, especially in low-water years. High densities of blue-green algae were measured at RM 320 during the summers of 1993 and 1994.

During the fall of 1993 and 1994, a longitudinal pattern similar to the spring was observed, with the highest densities in the upper section of Brownlee Reservoir. Chrysophyta taxa (*Melosira granulata* var. *angustissima* and *Stephanodiscus hantzschii)* dominated the more riverine zone of Brownlee Reservoir at RM 334 and RM 322. High densities and dominance by blue-green algae, primarily *Aphanizomenon flos-aqua*, were apparent at RM 312 and RM 302.

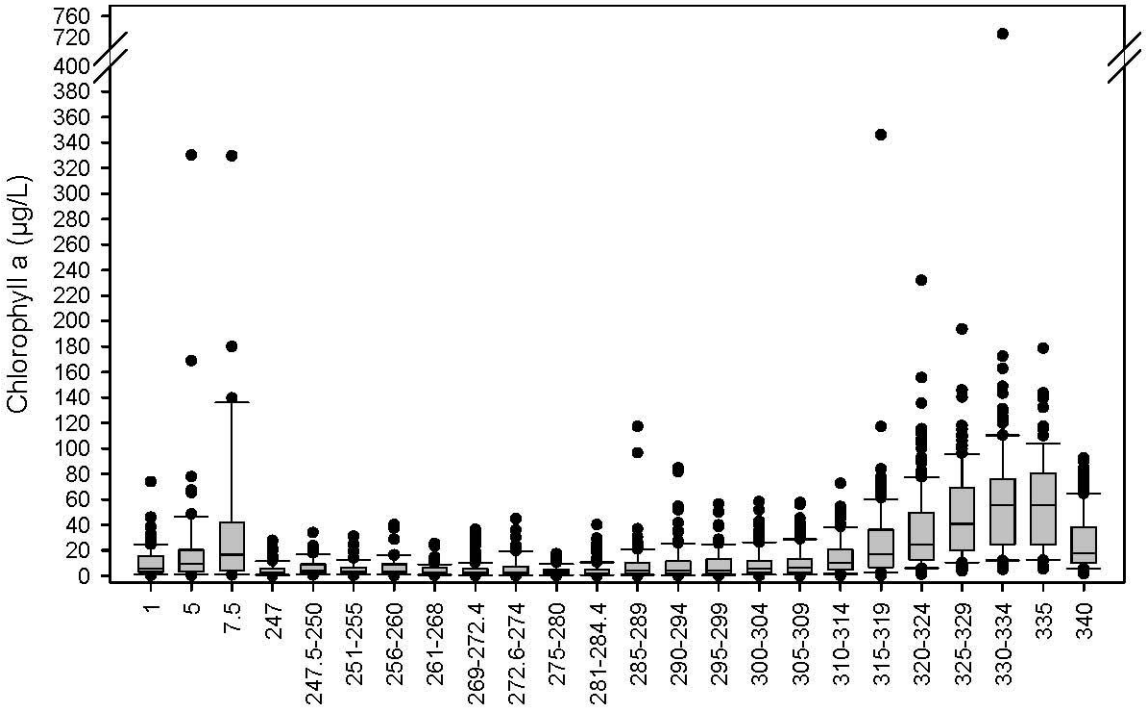


Figure 6.4-3. Surface chlorophyll *a* concentrations in micrograms per liter (µg/L) measured year round, from 1991 through 2000, throughout the Hells Canyon Complex. River miles (RM) have been grouped into approximately 5-mile intervals. Concentrations at RM 1, 5, and 7.5 represent the Powder River arm.

6.4.3. HCC Contribution to Nuisance Algae

6.4.3.1. Modeling Algae In Brownlee Reservoir

CE-QUAL-W2 (Cole and Wells 2002), a 2-dimensional model, was used to assess algal biomass in Brownlee Reservoir. Version 3.1 allows for model applications with multiple algal groups; however, estimating boundary conditions and optimizing performance requires considerable data and effort. For example, to model community shifts under SR-HC TMDL conditions would

require some estimate of the community shift in the Snake River inflow to Brownlee Reservoir. The current Brownlee Reservoir model application has not been set up and optimized for multiple groups because of this added complexity. Instead, available data and literature were used to predict shifts in the algal community structure with full implementation of the SR-HC TMDL.

6.4.3.1.1. CE-QUAL-W2 Algal Biomass Simulations with SR-HC TMDL Implementation

The CE-QUAL-W2 model simulated Brownlee Reservoir algae with full implementation of the SR-HC TMDL. This included reducing nutrients and organic matter inflow to Brownlee Reservoir (approximately 69% reduction in TP, nitrogen, and organic matter), reducing SOD (set at 0.1g-O_2/m^2/day), and SED (unchanged), and implementing IPC's DO load allocation of 1,125 tons DO per year (IDEQ and ODEQ 2004) through implementation of in-reservoir aeration near RM 325. Selected simulation conditions from the optimized model showed predicted algal biomass compared to measured data (Figure 6.4-4). The model predicted that chlorophyll *a* concentrations well on June 6, 1995; under-predicted concentrations on both May 3, 1995, and August 9, 1995; and over-predicted concentrations in the upper end of the transition zone on July 5, 1995. Simulated conditions indicated the model represented general algal processes, as indicated by dynamic algal biomass estimates, not just settling (Figure 6.4-5). These processes were illustrated by increased concentrations downstream of the inflow and reduced concentrations further downstream.

6.4.3.1.2. Predicted Algal Community Structure

Diatoms typically tend to dominate in more riverine conditions, especially in the spring. In eutrophic systems, blue-green algae tend to dominate in lower velocity waters, like the lacustrine zone, with taxa such as *Microcystis*, *Anabaena*, and *Aphanizomenon* forming blooms in still, windless conditions (Reynolds 1984). This is caused partly by differences in density and buoyancy. However, Webb (1964) concluded that the Snake River above Brownlee Reservoir carried heavy loads of organic matter in the form of suspended algae, dominated by blue-green algae (*Anabaena, Pediastrum, Spirogyra, Aphanizomenon, Staurastrum,* and *Anacystis*), which were produced in the 120-mile reach upstream of Brownlee Reservoir. Worth (1994) observed *Anabaena* and *Microcystis* in the Snake River above Brownlee Reservoir in 1992.

Potential changes in Brownlee Reservoir algal taxa after implementation of the SR-HC TMDL would depend partly on changes that occurred upstream in the Snake River. Lower nutrient loads could result in a shift from blue-green algae to green algae (or other groups) during the summer (Reynolds 1984). Because these changes are highly speculative and would have to be set in the model as boundary conditions, algal taxa shifts in Brownlee Reservoir cannot be fully modeled.

6.4.3.2. Nuisance Algae Reasonable Assurance

The SR-HC TMDL did not establish nuisance algae allocations (IDEQ and ODEQ 2004). Rather, the SR-HC TMDL presented analysis that develops a TP target of 0.070 mg/L for the stated purpose of attaining the mean growing season chlorophyll *a* target of 14 µg/L and a nuisance threshold of 30 µg/L, not to be exceeded more than 25% of the time, for the Snake River and the HCC. The Snake River TP target provides reasonable assurance the upstream boundary will not exceed the chlorophyll *a* target and threshold levels, and the community structure will shift toward less problematic taxa.

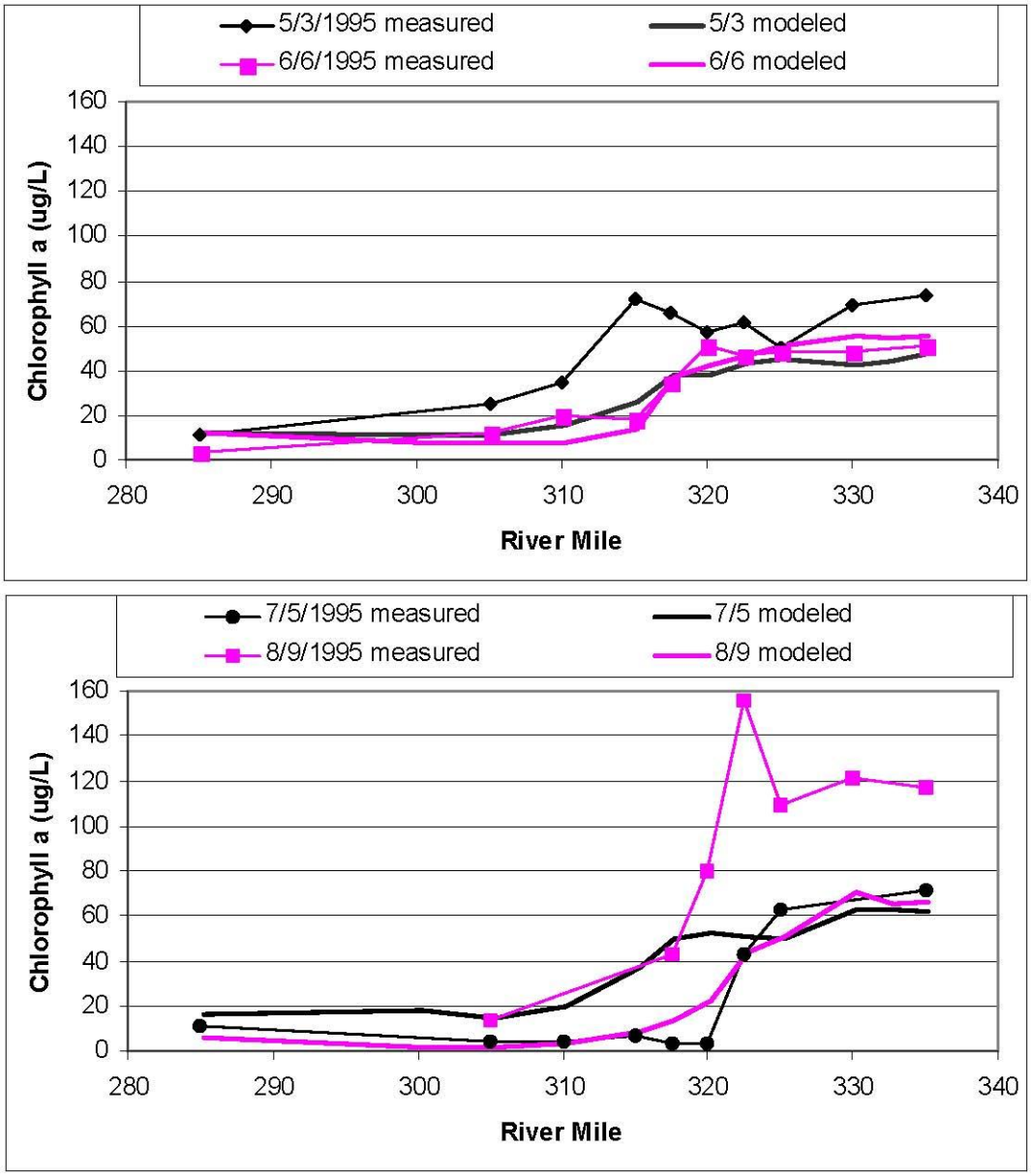


Figure 6.4-4. Baseline simulation results showing modeled and measured chlorophyll *a* concentrations in micrograms per liter (µg/L) in the surface layer of Brownlee Reservoir for selected dates in 1995.

The optimized CE-QUAL-W2 model was used to simulate full implementation of the SR-HC TMDL. The simulations showed maximum chlorophyll *a* concentrations would be less than 30 µg/L (Figure 6.4-6). This was consistent with the conclusions in the SR-HC TMDL that state " …the 0.07 mg-TP/L target will eliminate the large peaks in chlorophyll *a* observed in the upper part of the reservoir" (IDEQ and ODEQ 2004). May through September average concentrations were as high as approximately 20 µg/L through the transition zone. More importantly, chlorophyll *a* concentrations did not increase in Brownlee Reservoir. It is expected that if the 14 µg/L chlorophyll *a* target was met at the inflow to Brownlee Reservoir, then chlorophyll *a* concentrations would not exceed the target in the reservoir.

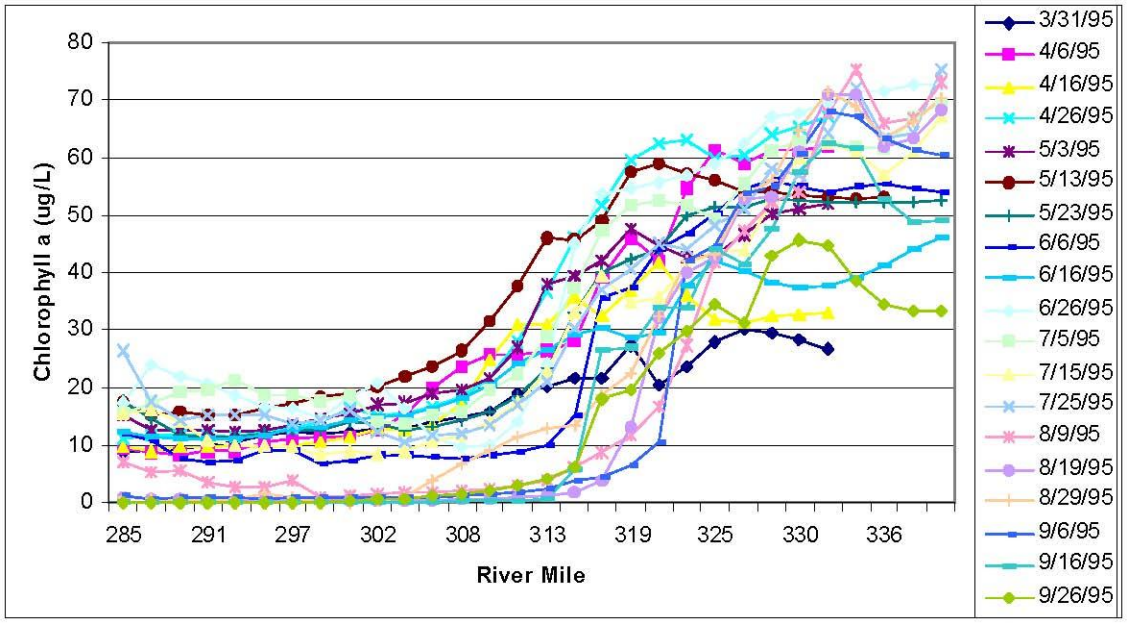


Figure 6.4-5. Modeled surface chlorophyll *a* concentrations in micrograms per liter (µg/L) in Brownlee Reservoir from March 31 through September 26, 1995.

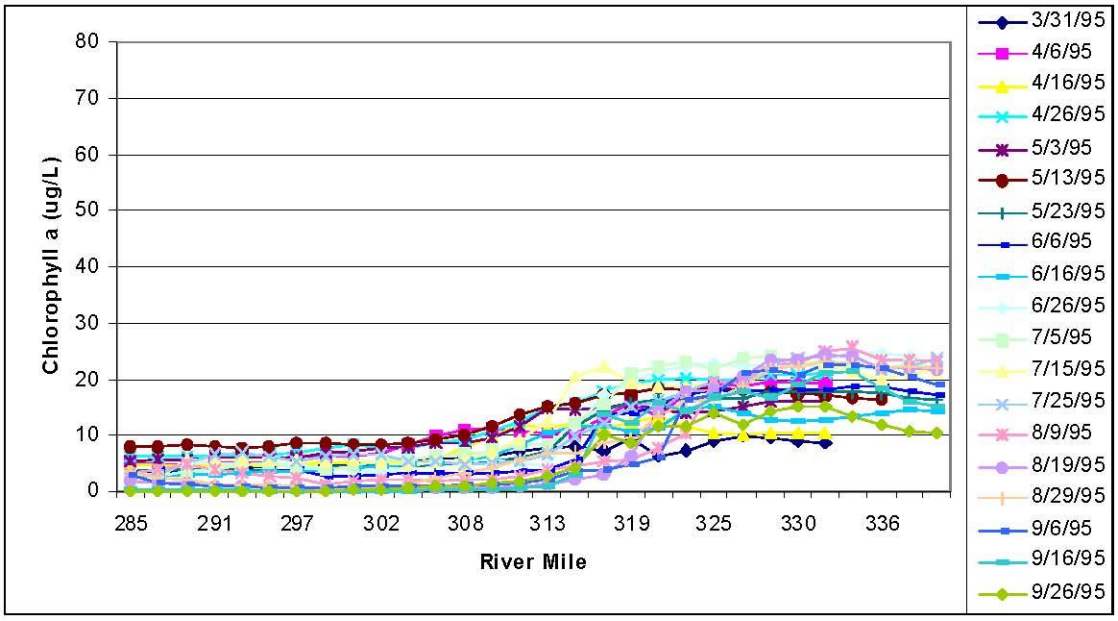


Figure 6.4-6. Modeled surface chlorophyll *a* concentrations in micrograms per liter (µg/L) in Brownlee Reservoir from March 31 through September 26, 1995, with full Snake River-Hells Canyon Total Maximum Daily Load (SR-HC TMDL) implementation.

Further, IPC evaluated data from both impounded and unimpounded waters of the Snake River to determine nuisance chlorophyll *a* concentration thresholds and targets. IPC's findings indicated a nuisance threshold of approximately 30 µg/L and a target between 15 µg/L and 20 µg/L would provide reasonable assurance that designated beneficial uses would be protected in the southwest Snake River and Brownlee Reservoir (Hoelscher 2002). This corroborated with the CE-QUAL-W2 model simulated conditions.

6.5. Hydrogen Ion (pH)

Oregon has not listed pH as a pollutant limiting this reach of the Snake River (Table 5.1-1). Idaho originally had listed Brownlee Reservoir water quality as impaired by pH, as well as the Snake River upstream to the Oregon and Idaho border. As a result of the SR-HC TMDL analysis, Idaho removed pH from the CWA § 303(d) list (Table 5.1-2). The SR-HC TMDL concluded that pH § 303(d) listings are not supported by the available data (IDEQ and ODEQ 2004).

> *Based on these findings, the SR-HC TMDL process recommends that the mainstem Snake River from RM 409 to 347 and from RM 335 to 285 [Brownlee Reservoir] be delisted for pH by the State of Idaho.*

6.5.1. Hydrogen Ion (pH) Standards and SR-HC TMDL Targets

Oregon's criteria for pH in fresh waters is 6.5 to 8.5 standard units (OAR 340-041-0021(1)(b)). However, waters impounded by dams existing on January 1, 1996, that have pH values that exceed the criteria are not in violation of the standard if ODEQ determines that the exceedence would not occur without the impoundment and all practicable measures have been taken to bring the pH in the impounded waters into compliance (OAR 340-0410-0021(2)). Idaho's criteria for pH in fresh waters is 6.5 to 9.0 standard units (IDAPA 58.01.02.250.01.a.).

A pH range of 7.0 to 9.0 standard units has been established as the target for the SR-HC TMDL to support aquatic life (IDEQ and ODEQ 2004). This target applies year-round from RM 409 throughout the HCC to RM 188.

6.5.2. Conditions Relative to Hydrogen Ion (pH)

Most of the pH measured throughout the HCC was within the SR-HC TMDL target range of 7.0 to 9.0 standard units. Brownlee Reservoir had approximately 4% of the measured pH values exceed the target range with values above 9.0 standard units. Values less than the 7.0 standard units criteria were less common than high values (Figure 6.5-1). This corroborated with the SR-HC TMDL findings that the lowest pH value observed in Brownlee Reservoir was 7.4 standard units, while the highest was 9.6 (IDEQ and ODEQ 2004). Almost all pH measures were within the target range in Oxbow Reservoir, while exceedences increased slightly in Hells Canyon Reservoir.

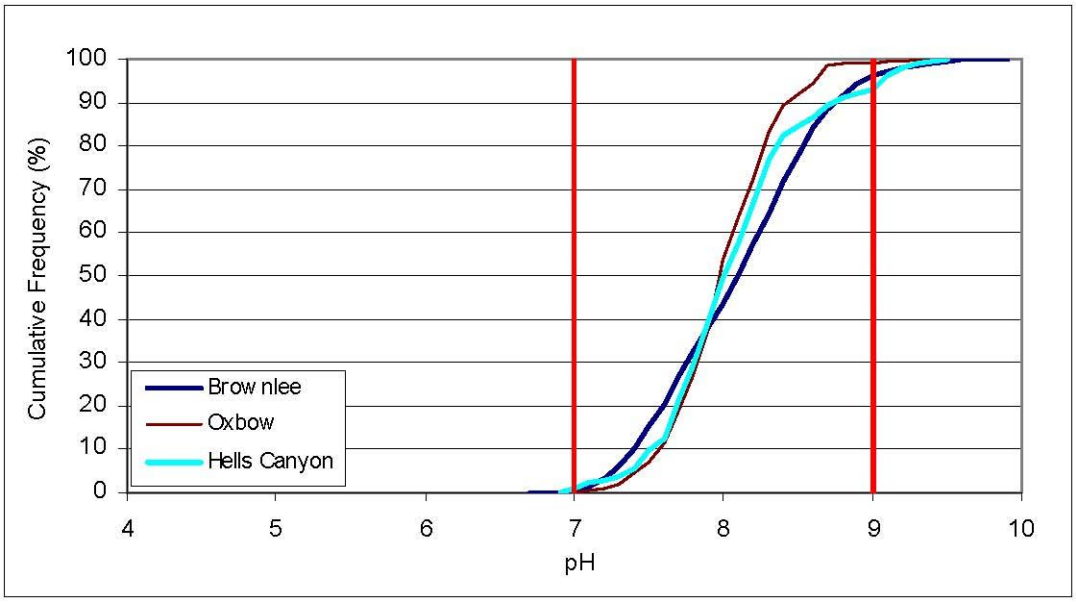


Figure 6.5-1. Percent (%) cumulative frequency curves for hydrogen ion (pH) in Brownlee, Oxbow, and Hells Canyon reservoirs (Myers et al. 2003).

The frequency that pH was above or below the target range was approximately 10% in the riverine zone of Brownlee Reservoir (Figure 6.5-2). The riverine zone receives inflowing water from the Snake River. The other zones of Brownlee Reservoir had exceedences of the target range, although they were less than 10% of the measurements, and the frequency of exceedence decreased with both distance and depth from the Snake River inflow.

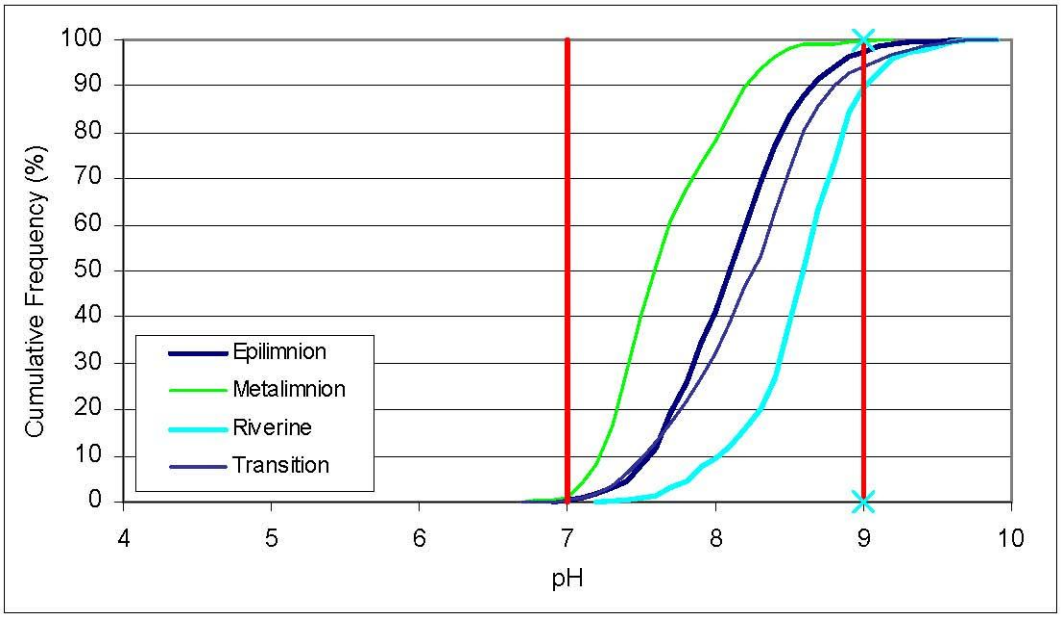


Figure 6.5-2. Percent (%) cumulative frequency curves for hydrogen ion (pH) in Brownlee Reservoir zones and strata (Myers et al. 2003).

6.5.3. HCC Contribution to Hydrogen Ion (pH)

The pH of natural waters is governed to a large extent by the interaction of hydrogen ions (H+) arising from dissociation of carbonic acid (H_2CO_3) and hydroxide ions (OH^-) produced during hydrolysis of bicarbonate (HCO_3^-). Carbonic acid (H_2CO_3) formed from hydration of dissolved carbon dioxide (CO_2) solubilizes calcium-rich rock, producing calcium bicarbonate ($Ca(HCO_3)_2$) that exists in solution (as Ca^{2++} and HCO_3^-) in equilibrium with CO_2, $H_2CO_3^-$, and CO_3^{2-}. When this equilibrium is disrupted by removal of carbon dioxide, calcium bicarbonate enters into another important equilibrium reaction that results in precipitation of calcium carbonate (Wetzel 2001). Evidence of calcium carbonate ($CaCO_3$) precipitation is commonly seen on substrate in the Snake River (e.g., white calcium carbonate deposits [marl] on the rocks).

Removal of carbon dioxide, caused by photosynthesis, can cause increases in pH through the above reactions. Wetzel (2001) stated that the rate of calcium carbonate precipitation is slow unless increases are induced by photosynthetic carbon dioxide removal. When the rate of precipitation is rapid, it results in a temporary supersaturation of calcium and bicarbonate. To maintain equilibrium, supersaturated bicarbonate reacts with hydrogen ions to form carbonic acid, and dissociates to release hydroxide ions. Both of these reactions (i.e., a decrease in hydrogen or an increase in hydroxide) increase pH.

In addition to the above process, pH change can be affected through changes in alkalinity following nutrient assimilation during photosynthesis. Since alkalinity is associated with a charge balance, assimilation of NH_4^+, NO_3^-, and HPO_4^{2-} ions are accompanied by the uptake or release of hydrogen and hydroxide ions through alkalinity changes (Stumm and Morgan 1995). Therefore, assimilation of NH_4^+, NO_3^-, and HPO_4^{2-} is accompanied by assimilation of hydrogen ions, lowering the hydrogen ion concentration, and increasing pH.

In summary, 2 key biochemical processes occurring in the Snake River are associated with photosynthesis that causes pH to increase: 1) removal of carbon dioxide (inorganic carbon) occurring when algae grow, and 2) removal of nutrients also occurring when algae grow.

Exceedence of the pH targets in the HCC appears to be related to inflowing Snake River water with elevated primary productivity. Data collected in the Snake River upstream of Brownlee Reservoir (RM 345.6) indicated that as chlorophyll *a* increased (a surrogate for algal biomass) average pH also increased (Figure 6.5-3). A linear regression of these data showed that, when daily average chlorophyll *a* concentrations were greater than 70 µg/L—which was a common occurrence in the Snake River inflow to Brownlee Reservoir—daily average pH values were above the 9.0 standard unit target. The SR-HC TMDL set a chlorophyll *a* target of 14 µg/L, with a nuisance threshold of 30 µg/L not to be exceeded more than 25% of the time (IDEQ and ODEQ 2004). Daily average pH levels would be predicted to drop to approximately 8.5 standard units when chlorophyll *a* concentrations are near the SR-HC TMDL nuisance threshold target and are predicted to be slightly lower when the 14 µg/L target is achieved.

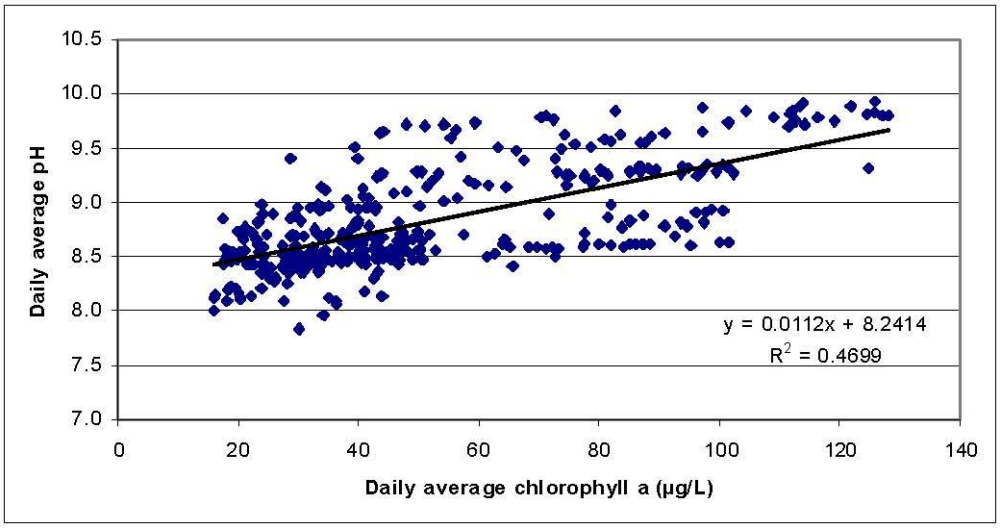


Figure 6.5-3. Upstream Snake River linear regression for daily average hydrogen ion (pH) in standard units and daily average chlorophyll *a* concentration in micrograms per liter (µg/L) at River Mile 345.6 for data collected April 2002–July 2003.

The variability and relatively low correlation evident in the chlorophyll *a* and pH regression is due to natural variability and the presence of other factors that contribute to pH changes, such as alkalinity, reaeration rate (related to velocity and depth), algal growth rate (varies by season and daily climatic conditions), and benthic productivity (photosynthesis by periphyton and macrophytes). Benthic productivity may be a primary source of variability in the relationship between water column chlorophyll *a* and pH. Periphyton and attached macrophytes are abundant in the Snake River upstream of Brownlee Reservoir, especially during low-water conditions. The SR-HC TMDL noted that reductions in attached periphyton and macrophyte growth were anticipated with the implementation of the TP target (IDEQ and ODEQ 2004).

6.5.3.1. Modeling Hydrogen Ion (pH)

Various models are available to simulate pH in natural systems. Most models are based on the equilibrium chemistry for carbonate systems, as discussed in Section 6.5.3. Among these, a simplistic mass balance model (Chapra 1997) and the more sophisticated CE-QUAL-W2 model (Cole and Wells 2002) were used to demonstrate the link between elevated algal biomass and high pH. The CE-QUAL-W2 model, being a 2-dimensional model, requires additional information, including initial boundary conditions and assumptions regarding alkalinity and total inorganic carbon. The importance of knowing initial boundary conditions and assumptions will also be demonstrated.

6.5.3.1.1. Mass Balance Model

The mass balance model assumes total inorganic carbon varies due to respiration, photosynthesis, and atmospheric exchange (Chapra 1997). Respiration and photosynthesis respectively increase or decrease the carbon dioxide in solution. Based on this change, atmospheric exchange occurs at rates proportional to a transfer coefficient that is proportional to the transfer coefficient for oxygen. Because atmospheric exchange lags respiration or

photosynthesis, there is a net increase or decrease in total inorganic carbon producing a local equilibrium. A steady-state pH is calculated for any alkalinity once the new total inorganic carbon is known. This is referred to as steady-state pH, based on the local equilibrium assumption that reactions between inorganic carbon species react faster than atmospheric and biotic reactions. The steady-state pH would represent the maximum pH when photosynthesis rates are at peak levels.

The mass balance model was used to estimate pH for various rates of photosynthesis and 2 levels of alkalinity. Results from the mass balance model indicated lower rates of photosynthesis produced lower steady-state pH values (Figure 6.5-4). The model also showed that changes in alkalinity affected steady state pH. Snake River data reported by the USGS (2003) showed alkalinity can range from 100 to 200 mg/L (as CaCO3). This was comparable to the 2–4 micro-equivalents per liter curves shown for the mass-balance analysis. As stated above, algae growth can induce changes in alkalinity through removal of nutrient ions (i.e., assimilation of NO_3^- and HPO_4^{2-}). Lower nutrient-removal rates and pH values would be anticipated with lower rates of photosynthesis through implementation of the nutrient TMDL.

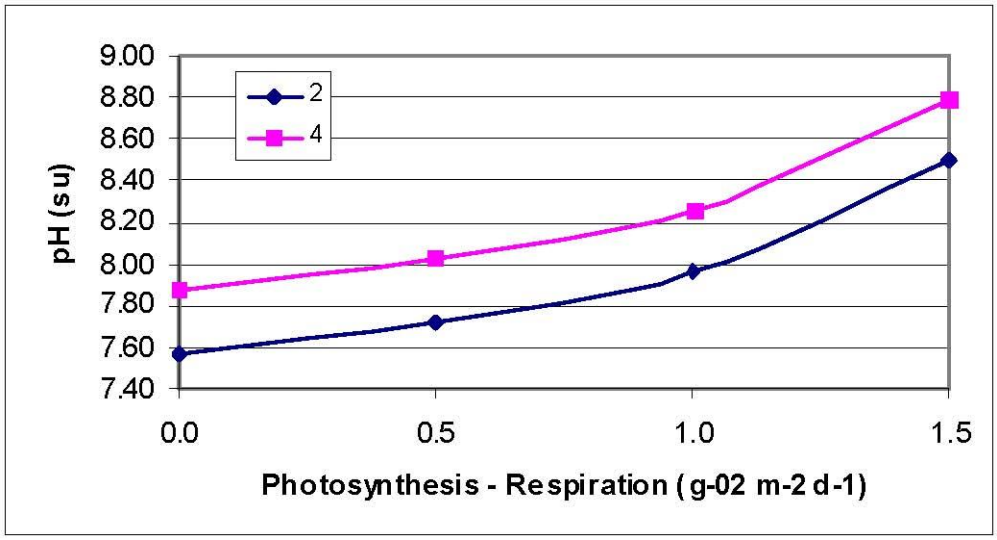


Figure 6.5-4. Modeled steady-state hydrogen ion (pH) standard units (su) at photosynthesis-dominated rates and 2 rates of alkalinity in micro-equivalents per liter. (Note: 1 micro-equivalent per liter is equal to 50 milligrams per liter as CaCO3). The initial conditions assume total inorganic carbon levels have increased due to respiration at 1.5 g O2/m^2/d. Model based on Chapra (1997).

6.5.3.1.2. CE-QUAL-W2 Model

The CE-QUAL-W2 model algorithms for pH are based on a total carbon balance and carbon dioxide equilibrium with the atmosphere (Cole and Wells 2002). The model applies the following assumptions when modeling pH.

Alkalinity is conservative. Instances, however, are observed in the Snake River and Brownlee Reservoir where this is not the case.

- Precipitation of calcium carbonate has been observed in the Snake River; for example, white calcium carbonate deposits on the rocks. Referred to as marl, these deposits form when aqueous carbon dioxide is in equilibrium with the atmosphere and carbon dioxide is removed due to photosynthesis (Wetzel 2001). This results in a temporary excess of bicarbonate, which reacts with calcium.

- There potentially is carbonate release from anoxic and anaerobic sediments.

- Alkalinity can decrease during photosynthesis with uptake of ammonia, increase during respiration with the release of ammonia, or increase during photosynthesis with uptake of nitrate (Stumm and Morgan 1995).

Calcium and magnesium carbonate do not contribute to alkalinity. Again, observations in the Snake River indicate this is not the case.

- Calcium levels are relatively high in the Snake River.

- Precipitated marl is commonly observed on substrate.

Acidity is only due to carbonic acid concentration. In the Snake River and most natural waters, organic and inorganic ions can contribute to acidity, including NH_4, HPO_4, and organic ligands.

In addition to the above assumptions, IPC would need to develop boundary conditions in order to model pH using the CE-QUAL-W2 model. These would include alkalinity, total dissolved solids (TDS), and total inorganic carbon. These constituents were not routinely monitored during the years simulated with the CE-QUAL-W2 model. Therefore, development of boundary conditions to model pH using the Brownlee Reservoir applications of the CE-QUAL-W2 model would be difficult.

More importantly, how these boundary conditions change with nutrient and algae reductions after implementation of the SR-HC TMDL would require further assumptions. For example, to develop necessary boundary conditions for total inorganic carbon, the alkalinity and pH would have to be assumed. The total inorganic carbon and alkalinity would then be used in the model to "predict" pH.

As an alternative to pH simulation using the Brownlee Reservoir CE-QUAL-W2 model application, pH was simulated using the CE-QUAL-W2 model setup as an open system; that is, a batch reactor. This batch reactor (single cell) application only requires initial conditions. Diel data collected in the Snake River (RM 345.6) upstream from Brownlee Reservoir indicated chlorophyll *a* concentrations in mid-July 2002 ranged from approximately 30 to 60 µg/L and pH ranged from approximately 7.9 to 8.3 standard units. To simulate this general range of algae, initial algal biomass conditions were set at 4 mg/L, which corresponds to 60 µg/L chlorophyll *a* (assuming 1 mg/L algae equals 15 µg/L chlorophyll *a*). Other initial conditions were estimated using data collected upstream of Brownlee Reservoir on the Snake River in the summer of 2002. Brownlee Reservoir model meteorological data were used to represent solar inputs and temperatures. There were no inflows or outflows in this application.

6.5.3.1.2.1. Hydrogen Ion (pH) Simulations with Varying Algal Levels

Simulated maximum pH varied with differing initial conditions for algal biomass resulting in maximum pH values occurring when algal levels were highest (Table 6.5-1). However, there is only a slight change in average pH levels.

Table 6.5-1. Hydrogen ion (pH) values in standard units resulting from CE-QUAL-W2 simulations of varying algal biomass initial conditions.

	Initial Condition				pH	
	Algal Biomass	Alkalinity	Total Inorganic Carbon	Algal Growth Rate	Average	Maximum
Simulation 1	4.00	100	23.4	4.00	8.64	8.85
Simulation 2	2.00	100	23.4	4.00	8.64	8.74
Simulation 3	1.00	100	23.4	4.00	8.66	8.74

Simulation results showed daily algal biomass fluctuations with maximums occurring in response to maximum photosynthesis rates (Figure 6.5-5). Corresponding pH and total inorganic carbon fluctuations also occurred (Figure 6.5-6 and Figure 6.5-7). For these simulations, total inorganic carbon was set to produce levels that remained relatively constant over the period (i.e., at equilibrium with algae, alkalinity, and the atmosphere). Consistent with levels observed in the Snake River, alkalinity was set at 100 g/m-3 as calcium carbonate (USGS 2003).

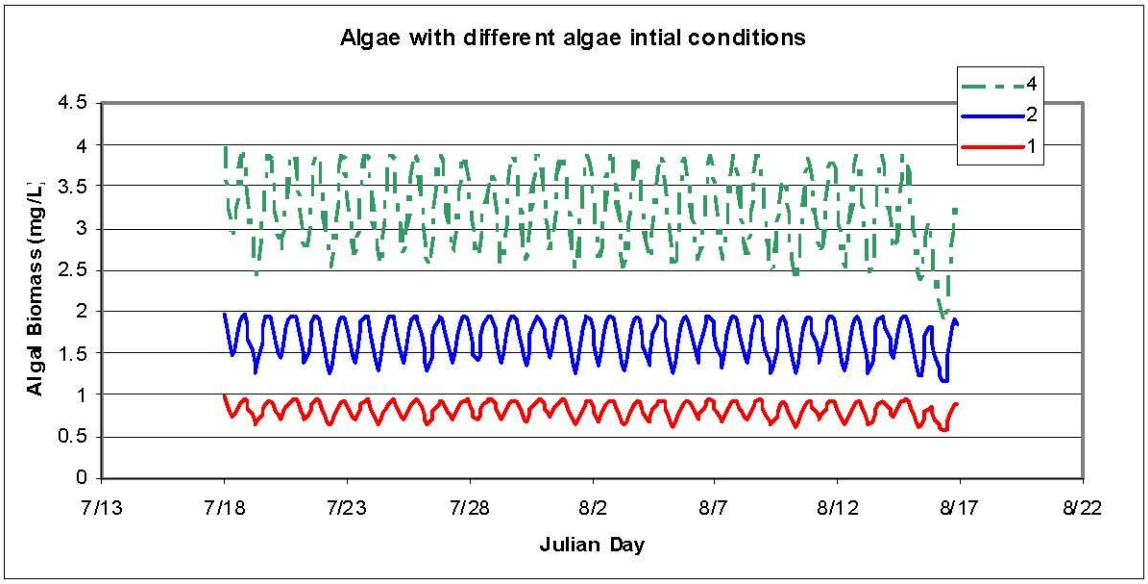


Figure 6.5-5. Algal biomass in milligrams per liter (mg/L) with algal biomass initial conditions varying from 1–4 mg/L (i.e., approximately 15−60 micrograms per liter [µg/L] chlorophyll *a*).

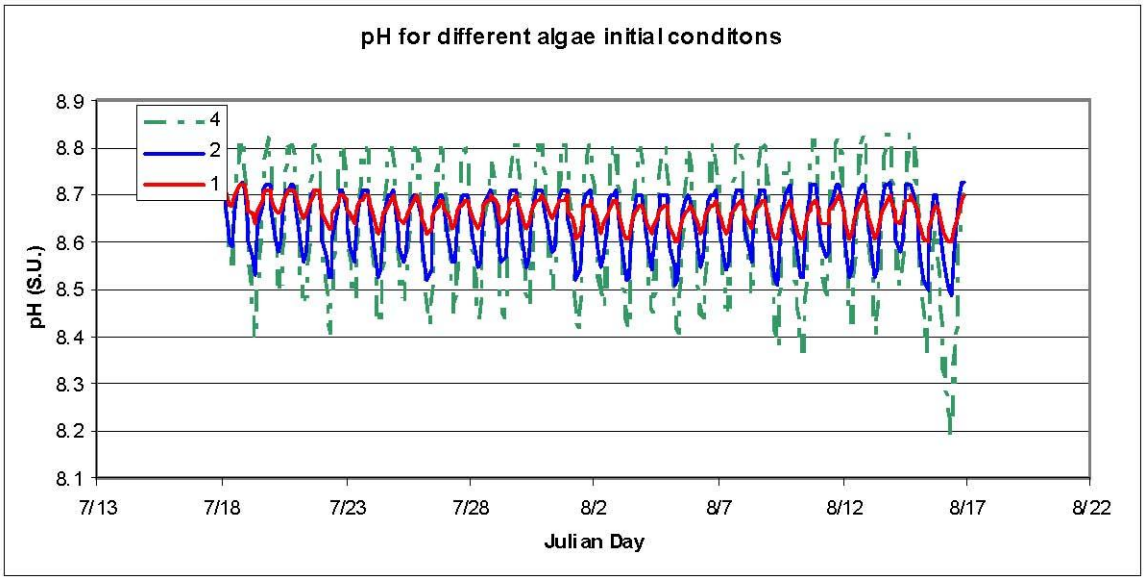


Figure 6.5-6. Hydrogen ion (pH) standard units (SU) with algal biomass initial conditions varying from 1–4 milligrams per liter (mg/L) (i.e., approximately 15–60 micrograms per liter [µg/L] chlorophyll *a*).

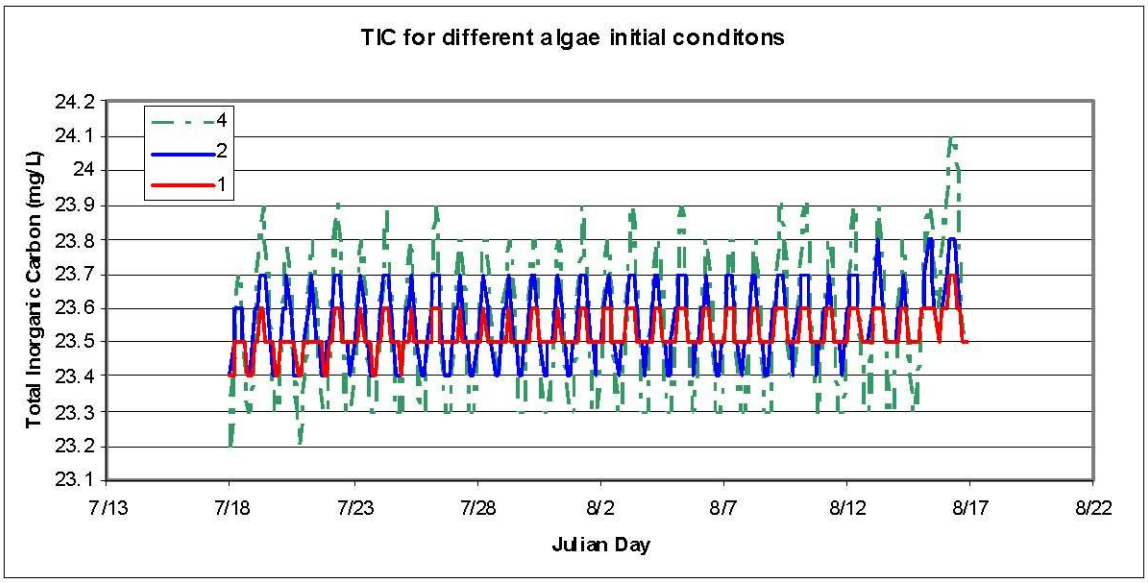


Figure 6.5-7. Total inorganic carbon (TIC) in milligrams per liter (mg/L) with algal biomass initial conditions varying from 1–4 mg/L (i.e., approximately 15−60 micrograms per liter [µg/L] chlorophyll *a*).

6.5.3.1.2.2. Hydrogen Ion (pH) Simulations with Varying Algal Growth Rates

The CE-QUAL-W2 model simulation results (Table 6.5-2, Figure 6.5-8, and Figure 6.5-9) showed the related daily range of algae as chlorophyll *a* and pH for mid-July with 2 growth rates (4 and 2 per day, respectively). The algal growth rate was set at four per day to simulate the relatively large daily fluctuation (Figure 6.5-8) representative of those observed in the measured data (Figure 6.5-3). This growth rate was double the rate used in the 1995 Brownlee Reservoir optimized model application (Harrison et al. 1999).

Table 6.5-2. Hydrogen ion (pH) values in standard units resulting from CE-QUAL-W2 simulations of varying algal growth-rate initial conditions.

	Initial Condition				pH	
	Algal Biomass	Alkalinity	Total Inorganic Carbon	Algal Growth Rate	Average	Maximum
Simulation 1	4.00	100	23.4	4.00	8.64	8.85
Simulation 2	4.00	100	23.4	2.00	8.61	8.74

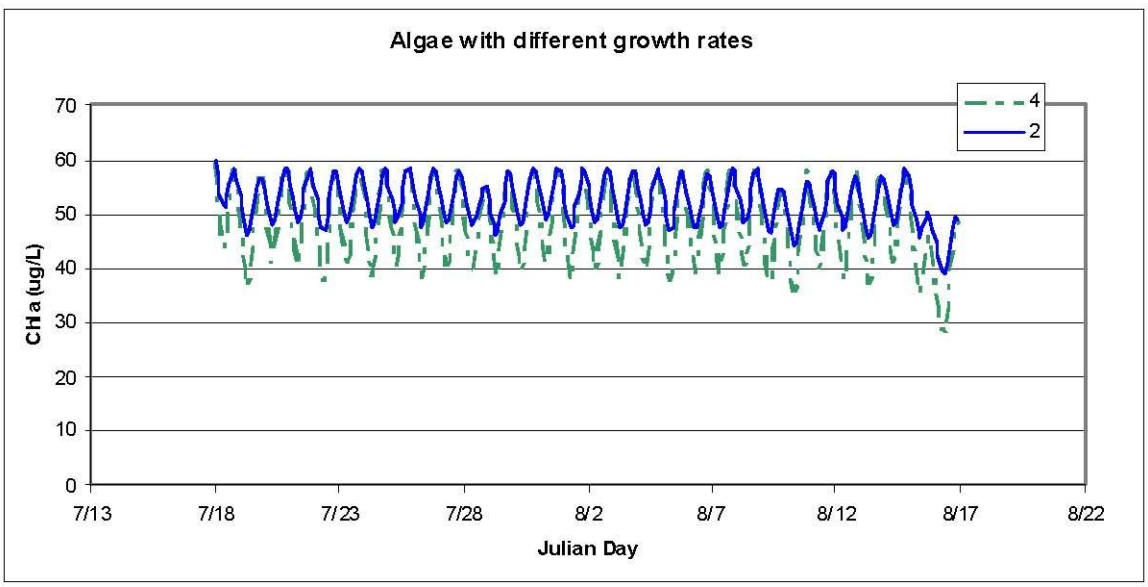


Figure 6.5-8. Algal biomass as measured by chlorophyll *a* (chla) in micrograms per liter (µg/L) with algal growth rate initial conditions of 2 and 4 per day.

These results showed that algal growth rates also affected pH levels. In the model, algal biomass was multiplied times the growth rate. Thus, a higher algal biomass can drive a higher rate of photosynthesis and higher pH values if other factors are not limiting; for example, light and nutrients (Table 6.5-2). Higher algal biomass produced higher pH values. This was consistent with the mass balance model results (Figure 6.5-4).

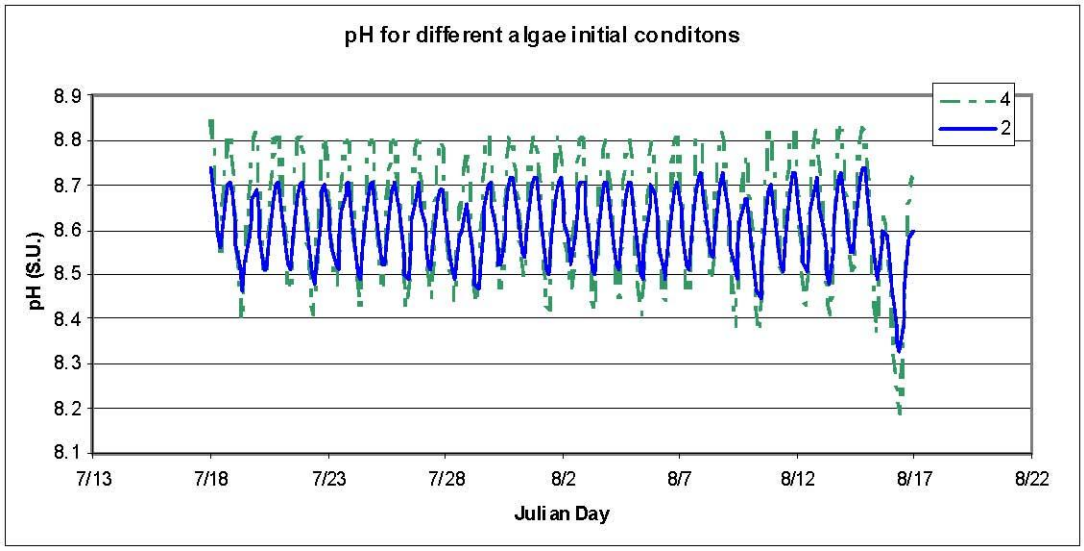


Figure 6.5-9. Hydrogen ion (pH) values in standard units (SU) with algal growth rate initial conditions of 2 and 4 per day.

6.5.3.1.2.3. Hydrogen Ion (pH) Simulations with Varying Alkalinity

The effects of alkalinity on pH values were modeled while keeping algae conditions constant (Table 6.5-3). The higher alkalinity produced slightly lower maximum pH values (Figures 6.5-10 and 6.5-11). However, average pH was higher with the higher alkalinity because minimum pH values were higher. The mass balance model (Figure 6.5-4) showed higher, steady-state pH values when alkalinity was higher, as would be expected. Changes in alkalinity can occur with nutrient assimilation by algae, a process not included in the CE-QUAL-W2 model (Cole and Wells 2002).

Table 6.5-3. Hydrogen ion (pH) values in standard units resulting from CE-QUAL-W2 simulations of varying alkalinity initial conditions.

	Initial Condition				pH	
	Algal Biomass	Alkalinity	Total Inorganic Carbon	Algal Growth Rate	Average	Maximum
Simulation 1	4.00	10	2.2	4.00	7.93	9.01
Simulation 2	4.00	20	4.6	4.00	8.09	8.90
Simulation 3	4.00	30	7.2	4.00	8.18	8.84
Simulation 4	4.00	40	9.2	4.00	8.30	8.86
Simulation 5	4.00	100	23.2	4.00	8.60	8.85

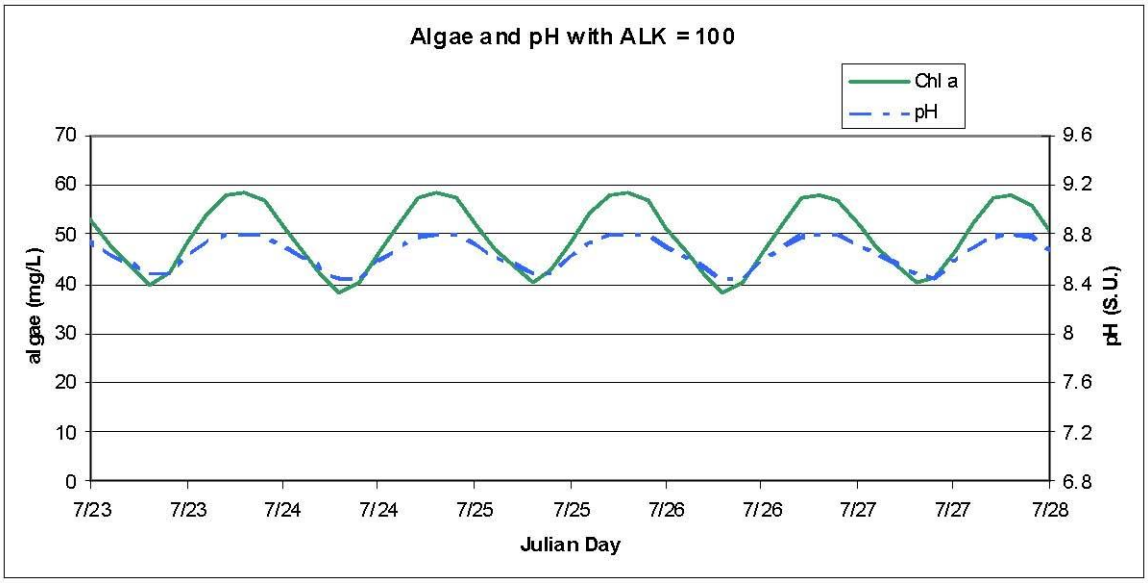


Figure 6.5-10. Algae in milligrams per liter (mg/L) and hydrogen ion (pH) in standard units (SU) with algal biomass initial conditions of 4 mg/L and algal growth rate at 4 per day.

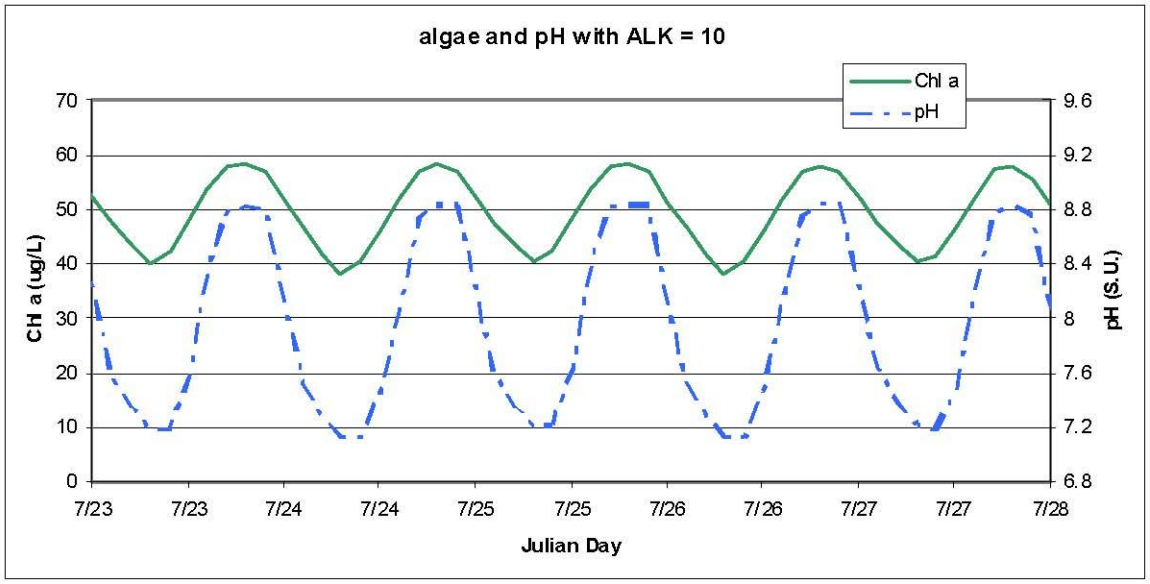


Figure 6.5-11. Chlorophyll *a* (chl a) in micrograms per liter (µg/L) and hydrogen ion (pH) in standard units (SU) with algal biomass initial conditions of 4 milligrams per liter (mg/L) and algal growth rate at 4 per day.

6.5.3.2. Hydrogen Ion (pH) Reasonable Assurance

IPC was not issued a pH allocation as part of the SR-HC TMDL (IDEQ and ODEQ 2004). Rather, nuisance algal targets and TP allocations to support the targets were expected to provide reasonable assurance that the few pH exceedences would be ameliorated. The SR-HC TMDL presented analysis that developed a TP target of 0.070 mg/L for the stated purpose of attaining

the mean growing season chlorophyll *a* target of 14 µg/L and a nuisance threshold of 30 µg/L, not to be exceeded more than 25% of the time for the Snake River and the HCC. When reduced primary production is realized, following full implementation of the SR-HC TMDL and attainment of both TP and chlorophyll *a* targets, the potential for pH values above targets will decrease.

This SR-HC TMDL conclusion was supported by IPC's modeling, which demonstrated lower maximum pH values are expected as algal levels and growth rates are reduced. As stated above, algal growth can induce changes in alkalinity through removal of nutrient ions (i.e., assimilation of NO_3^- and HPO_4^{2-}). With lower rates of photosynthesis through implementation of the nutrient TMDL, lower nutrient-removal rates and lower pH would be anticipated. While model boundary conditions are variable and future conditions difficult to predict, it is apparent that management actions designed to reduce algae production in the Snake River upstream of Brownlee Reservoir can have a positive influence on pH values, lowering maximum values and the potential for exceedence of the pH targets. The Brownlee Reservoir data showed that a reduction of less than one pH standard unit (SU) was needed to fully meet the target of 9.0. Models indicated that this level of reduction can occur with SR-HC TMDL reduced algal levels and growth rates.

6.6. Toxics

Oregon standards define toxics as "those pollutants or combinations of pollutants, including disease-causing agents that, after introduction to waters of the state and upon exposure, ingestion, inhalation, or assimilation, either directly from the environment or indirectly by ingestion through the food chains will cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations in any organism or its offspring." (OAR 340-041-0002(64)). Oregon has listed the Snake River from the Oregon and Idaho border through the HCC downstream to the confluence with the Salmon River as impaired by toxics; namely, mercury (Table 5.1-1).

Idaho also has a narrative standard for toxics (IDAPA 58.01.02.200.02.) Idaho lists Brownlee Reservoir for mercury, and Oxbow Reservoir for pesticides (Table 5.1-2). The primary concern is the methylation of mercury (IDEQ and ODEQ 2004). Low DO and the presence of substantial amounts of organic matter near the sediment and water interface can result in higher rates of methylmercury production as hydrocarbon materials from the organic matter are available to bond with elemental mercury. Methylmercury represents a significantly greater risk for bioaccumulation than elemental or mineralized mercury compounds as it is much more soluble in water and, therefore, much more mobile within both the physical environments and the metabolic systems of organisms.

Both Oregon (ODHS 2005) and Idaho (IDHW 2005) have issued fish consumption advisories for mercury in Brownlee Reservoir. The SR-HC TMDL identified the primary sources of mercury as legacy mining and natural loading, both associated with geological deposits within the Owyhee and Weiser river watersheds (IDEQ and ODEQ 2004). Based on these findings, a mercury TMDL was considered needed, which in turn will be the basis for load and wasteload allocations for nonpoint and point sources, respectively, contributing to mercury in these waters.

The SR-HC TMDL identified 1,1,1-trichloro-2,2-bis(p-chlorophenyl) ethane (total-DDT), hereafter referred to as t-DDT, and dieldrin as pesticides of concern (IDEQ and ODEQ 2004). Similar to mercury, pesticides have a diffuse and widespread legacy. Both t-DDT and dieldrin have been banned for use: t-DDT in 1973 and dieldrin in 1987.

6.6.1. Toxics Standards and SR-HC TMDL Targets

Oregon has both narrative standards and numeric criteria for toxics. Narrative standards prohibit the introduction of potentially harmful toxics substances above natural background levels (OAR 340-041-0033(1)) and the creation of tastes, odors, or toxic conditions that are deleterious to fish or other aquatic life or affect the potability of drinking water or the palatability of fish or shellfish (OAR 340-041-0007(12)). Mercury numeric criteria are for the protection of both aquatic life and human health and apply year-round throughout the Snake River and the HCC, while t-DDT and dieldrin criteria are for the protection of human health and are applicable year-round in Oxbow Reservoir and upstream.

The SR-HC TMDL established toxics targets similar to Oregon's numeric criteria (OAR 340-041 Table 20). Specifically, mercury may not exceed 0.012 µg/L in the water column and 0.35 milligrams per kilogram (mg/kg) in fish tissue (IDEQ and ODEQ 2004). Only water-column concentrations were established for pesticides: Not to exceed 0.024 nanograms (one billionth) per liter (ng/L) t-DDT and 0.07 ng/L dieldrin.

6.6.2. Conditions Relative to Toxics

Many of the toxics targets established by the SR-HC TMDL are water-column targets. Because of the paucity of water-column data, the following discussion focuses on the wet-weight mercury fish-tissue target of 0.35 mg/kg. Mercury fish-consumption advisories have been issued by both states. More detail on metals and pesticides in fish tissue and bed sediments of the HCC reservoirs is available in Technical Report E.2.2-2 of the *New License Application: Hells Canyon Hydroelectric Complex*, and Clark and Maret (1998).

In general, concentrations of most trace elements were greater in largescale sucker (*Catostomus macrocheilus*) and carp (*Cyprinus carpio*) liver samples than in sportfish fillets. Mercury, however, was generally greater in sportfish fillets. Mercury concentrations ranged from an average of 0.04 to an average of 0.11 mg/kg wet weight in largescale suckers collected in the Snake River at Pittsburg Landing and in Brownlee Reservoir at the Burnt River, respectively, to an average of 0.32 mg/kg wet weight in both common carp and channel catfish (*Ictalurus punctatus*) fillets in Brownlee Reservoir at the Burnt River. Smallmouth bass and white crappie fillets also had relatively high average mercury concentrations: 0.29 mg/kg and 0.27 mg/kg, respectively. These levels corroborate with the Oregon classification for Brownlee Reservoir of "moderate mercury levels" (ODHS 2005).

None of the average mercury concentrations exceeded the SR-HC TMDL target of 0.35 mg/kg. Nor did the concentrations exceed either the mean international standard of 0.5 mg/kg (Nauen 1983, as cited in Clark and Maret 1998) or the U.S. Food and Drug Administration (FDA) action level of 1.0 mg/kg for mercury in edible fish tissue (Nowell and Resek 1994, as cited in Clark and Maret 1998). However, mercury concentrations of 0.32 micrograms

per gram (μg/g) wet weight in both common carp and channel catfish fillets in Brownlee Reservoir at the Burnt River slightly exceeded the EPA-recommended criterion of 0.3 mg/kg wet weight for the protection of human health (USEPA 2001c).

The Burnt River enters Brownlee Reservoir at RM 328.0. This is only 15 miles downstream of the upper end of the reservoir and near the lower boundary of the riverine zone. Average mercury concentrations in largescale sucker decreased two-thirds from this location (0.11 mg/kg) to the Snake River at Pittsburg Landing (0.04 mg/kg), approximately 32 miles downstream of Hells Canyon Dam. This corroborated with the interpretation of transport forwarded in the SR-HC TMDL (IDEQ and ODEQ 2004); being that the heavier sediments delivered to Brownlee Reservoir are contained in the reservoir and most mercury adsorbed or contained in those sediments are retained in Brownlee Reservoir.

Additionally, heavy metal and organochlorine pesticide contamination was studied in bald eagles (*Haliaeetus leucocephalus*) nesting in the HCC. Researchers reported all adult feather samples collected in the HCC had levels of mercury that exceeded the accepted level of concern (Bechard et al. 2005). Nevertheless, the levels of mercury contamination reported did not appear to be lethal and all bald eagles sampled were breeding successively. All nestling blood samples collected in the HCC contained measurable levels of t-DDT and dieldrin. Again, the results did not indicate that organochlorine pesticide contamination occurred at levels sufficiently high to cause reproductive failures or other toxic effects in bald eagles in the HCC.

6.6.3. HCC Contribution to Toxics

The SR-HC TMDL has identified toxics as pollutants of concern—not only in the HCC, but also throughout the Snake River watershed (IDEQ and ODEQ 2004). Specifically, the need for a mercury TMDL has been identified. Fish tissue data collected from Brownlee Reservoir documented mercury concentrations at similar levels as those reported from other western states. Smallmouth bass and white crappie fillets collected from Brownlee Reservoir averaged 0.29 mg/kg and 0.27 mg/kg mercury, respectively. Peterson et al. (2006) collected and analyzed over 2,700 large fish from more than 600 stream and river sites throughout 12 western states to assess regional distribution of whole-fish mercury concentrations. They reported an average mercury concentration in fillets from piscivorous fishes (e.g., smallmouth bass and white crappie) of 0.26 mg/kg. Further, they reported no correlation between mercury concentrations and site disturbance. These findings suggested that large-scale atmospheric transport, and not local anthropogenic effects, was the key factor relative to mercury in fish across the western states.

The cycling of mercury among its many pools and forms in aquatic environments is complex. Inorganic mercury and highly toxic bioaccumulative methylmercury compounds are partitioned among the sediment, water, and biota pools in both organic and inorganic and dissolved and particulate forms. The majority of inorganic mercury is typically stored in sediments (Meili 1997). Concentrations of methylmercury and proportions of methylmercury to inorganic mercury depend on the balance of methylation, demethylation, and chemical stabilization in the system. Methylmercury is formed by methylation of inorganic mercury in the presence of organic matter. Methylation is thought to be a microbial process highly dependent on methanogenic and sulfate-reducing bacteria in anoxic conditions, although it can also occur in

oxic conditions (Miskimmin et al. 1992). Demethylation, which is also controlled directly by microbial activity or abiotically by sunlight, is highest in oxic photic zones (Meili 1997).

Organic matter concentrations and cycling exert strong control on the transport and transformations of mercury in aquatic environments. Concentrations of methylmercury and total mercury typically increase with the concentration of dissolved organic carbon (Driscoll et al. 1994). Other important parameters influencing the cycle include concentrations and redox states of iron, manganese, chloride, and sulfur compounds.

Methylation appears highest in layers of the water column and sediments with steep redox gradients and high microbial activity (i.e., the metalimnion of eutrophic lakes and top centimeters of sediment). Oxic sediments can be a sink for inorganic mercury and methylmercury, while anoxic sediments can be a source. A build-up of methylmercury is often seen in anoxic water, where conditions slow demethylation and anoxic sediments increase methylmercury release.

6.6.3.1. Mercury TMDL

The SR-HC TMDL identified a need for a mercury TMDL (IDEQ and ODEQ 2004). To date, a mercury TMDL has not been developed.

6.6.3.2. Reasonable Assurance for Toxics

The average fish-tissue mercury concentrations in Brownlee Reservoir fishes were currently less than the SR-HC TMDL target of 0.35 mg/kg and less than either the mean international standard of 0.5 mg/kg or the FDA action level of 1.0 mg/kg for mercury in edible fish tissue. This corroborated with Oregon's classification for Brownlee Reservoir as having moderate mercury levels. The highly toxic bioaccumulative methylmercury compound is correlated to both concentrations of DO and organic matter. Under anoxic conditions with elevated levels of organic matter, inorganic mercury is converted via methylation to methylmercury.

The SR-HC TMDL has load and wasteload allocations for sediment, nutrients, and nuisance algae (organic matter) that are expected to improve water-quality conditions throughout the Snake River and the HCC (IDEQ and ODEQ 2004). Reductions in sediment should reduce new sources of inorganic mercury while improvements in DO and nuisance algae should reduce the methylation of inorganic mercury to methylmercury. In addition, interim measures, such as fish-consumption advisories, are in place to deal with mercury contamination until completion of the mercury TMDL.

Organochlorine insecticides, like t-DDT and dieldrin, are man-made compounds. These compounds have been banned and, therefore, are no longer being manufactured or used. Both are expected to become less prevalent in the environment as SR-HC TMDL controls beneficial to mercury, as previously stated, are implemented and persistent compounds are metabolized.

6.7. Turbidity

Turbidity is an expression of the optical property of water that causes light to be scattered and absorbed rather than transmitted in straight lines (APHA 1999). Turbidity is frequently used as

a surrogate measure of suspended inorganic particles; however, turbidity can be affected by organic particles, such as detritus and tannins, as well. Neither Oregon or Idaho has listed Snake River waters as being limited by turbidity (Table 5.1-1 and Table 5.1-2).

6.7.1. Turbidity Standards

Oregon has a turbidity standard measured in nephelometric turbidity units (NTU). No more than a 10% cumulative increase in natural stream turbidities may be allowed, as measured relative to a control point immediately upstream of the turbidity causing activity (OAR 340-041-0036). Idaho similarly identifies turbidity criteria relative to a background: "Turbidity, below any applicable mixing zone set by the Department, shall not exceed background turbidity by more than fifty (50) NTU instantaneously or more than twenty-five (25) NTU for more than ten (10) consecutive days" (IDAPA 58.01.02.250.02.e.).

6.7.2. Conditions Relative to Turbidity

IPC has routinely measured turbidities in the Snake River and throughout the HCC in association with other water-quality monitoring efforts. The maximum turbidities, as measured between 1992 and 1997, were less than each immediately preceding upstream reach of the Snake River (Table 6.7-1). A more representative measure is mean turbidity. Mean turbidities between 1992 and 1997 decreased from 39.0 NTU inflow to Brownlee Reservoir to 13.5 NTU in the reservoir, a 65% reduction in turbidity. A similar percent reduction occurred in Oxbow Reservoir, resulting in a mean turbidity of 4.1 NTU. Turbidities then remained low throughout the remainder of the HCC and in the Snake River downstream of Hells Canyon Dam.

Table 6.7-1. Minimum, maximum, and mean turbidity measures in nephelometric turbidity units (NTU) for various reaches of the Snake River from 1992 through 1997 and the 10% cumulative increase threshold (thres.) as allowed by Oregon statute (OAR 340-041-0036).

	Snake River Upstream (RM 409.0–343.1)		Brownlee Reservoir (RM 343.0–284.6)		Oxbow Reservoir (RM 284.5–272.5)		Hells Canyon Reservoir (RM 272.4–247.6)		Snake River Downstream (RM 247.5–247.0)	
	NTU	Thres.	NTU	Thres.	NTU	Thres.	NTU	Thres.	NTU	Thres.
Count	213.0		978.0		265.0		434.0		174.0	
Minimum	0.9	1.0	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.6
Maximum	291.0	320.1	213.0	234.3	50.2	55.2	48.9	53.8	41.7	45.9
Mean	39.0	42.9	13.5	14.8	4.1	4.5	5.4	6.0	5.0	5.5

6.7.3. HCC Contribution to Turbidity

IPC does not contribute to turbidity in the Snake River. In fact, the HCC acts to reduce turbidity through settling suspended inorganic and organic solids.

6.8. Total Dissolved Solids

TDS is a measure of dissolved ions in water that includes the major inorganic ions (e.g., calcium, magnesium, sodium, potassium, chloride, sulfate, carbon, and bicarbonate) and other trace soluble organic and inorganic materials. Neither Oregon or Idaho has listed the Snake River or the HCC as limited (IDEQ 2005, ODEQ 2007a; also Tables 5.1-1 and 5.1-2). TDS data were not frequently available; however, limited analysis indicated the TDS criterion was exceeded both in the Snake River immediately upstream of the HCC as well as below.

6.8.1. TDS Standards and SR-HC TMDL Targets

Oregon has a TDS criterion not to exceed 100.0 mg/L unless otherwise authorized by the ODEQ (OAR 340-041-0032). Idaho does not have a criterion specific to dissolved ions. Nor did the SR-HC TMDL identify a TDS target (IDEQ and ODEQ 2004).

6.8.2. Conditions Relative to Total Dissolved Solids

IPC has periodically measured TDS in the Snake River and throughout the HCC in association with other water-quality monitoring. TDS concentrations measured in 1992 and 1995 exceeded the Oregon criterion both above and below the HCC. In 1992, levels inflowing the HCC averaged 321 mg/L, while the levels in the Hells Canyon Reservoir outflow averaged 301 mg/L (Table 6.8-1). In 1995, levels inflowing the HCC averaged 335 mg/L, while levels in the Brownlee Reservoir outflow averaged 285 mg/L. Outflow average and maximum TDS levels were lower than inflow levels.

Table 6.8-1. Minimum, maximum, and mean total dissolved solids (TDS) concentrations in milligrams per liter (mg/L) for inflow, Brownlee Reservoir outflow, and Hells Canyon Reservoir outflow in 1992 and 1995.

	1992			1995		
TDS Concentrations	**Inflow (RM 330) (mg/L)**	**Brownlee Reservoir Outflow (RM 284.4) (mg/L)**	**Hells Canyon Reservoir Outflow (RM 247) (mg/L)**	**Inflow (RM 340) (mg/L)**	**Brownlee Reservoir Outflow (RM 284.4) (mg/L)**	**Hells Canyon Reservoir Outflow (RM 247) (mg/L)**
Count	9	7	7	10	11	Na
Minimum	240	265	274	173	138	Na
Maximum	375	340	325	450	413	Na
Mean	321	309	301	335	283	Na

Na—Data not available.

6.8.3. HCC Contribution to TDS

TDS levels in the HCC are affected by sources to, and losses from, the complex, as well as abiotic process within the complex. The inputs include TDS inflowing the HCC, both wet and

dry precipitation (i.e., rainfall and wind-blown dust), and weathering of soils and rock. While precipitation has not been assessed, it is expected to be relatively low. Weathering would be expected to exceed precipitation, but still be much less than inflowing loads. A likely primary source contributing to the high inflow loads is runoff from surface irrigation. Losses from the HCC would include outflow of surface water and the much-smaller loss related to groundwater discharge.

Besides the abiotic processes discussed above, biotic uptake and release can also affect TDS levels. Biological processing of organic matter releases TDS, while primary and secondary production uptakes constituents included in TDS.

TDS levels in the HCC are likely primarily related to levels in the Snake River inflow to Brownlee Reservoir or sources not associated with the HCC. Therefore, as levels in the Snake River and other tributaries are reduced and attain the criterion, TDS levels in the HCC and Snake River downstream similarly should be reduced. As previously stated, TDS is a measure of dissolved ions in water. While TDS is not a measure of sediment or organic matter, it can be assumed that some portion of TDS is derived from these constituents. Therefore, as sediment and organic matter are reduced, TDS levels correspondingly will be reduced. TMDLs upstream of the HCC have established sediment and nutrient load and wasteload allocations. These allocations, in part, targeted the reduction of runoff from surface irrigation. Therefore, as these TMDLs are implemented, dissolved ions (i.e., TDS) will be reduced.

6.9. Bacteria

Neither Oregon or Idaho has listed Snake River waters as being limited by bacteria (Tables 5.1-1 and 5.1-2). Bacteria analysis has shown that available data do not exceed criteria and designated recreational uses are not impaired (IDEQ and ODEQ 2004).

6.9.1. Bacteria Standards and SR-HC TMDL Targets

The SR-HC TMDL bacteria target is Oregon's and Idaho's (except "specified public swimming beaches") criteria to protect recreational uses. Specifically, no single sample may exceed 406 E. coli organisms per 100 ml or a 30-day logarithmic mean of 126 E. coli organisms per 100 ml, based on a minimum of 5 samples.

6.9.2. Conditions Relative to Bacteria

The SR-HC TMDL evaluated bacteria data and reported no samples exceeded the criteria (IDEQ and ODEQ 2004). They concluded bacteria did not impair the recreational uses of the Snake River or the HCC.

6.9.3. HCC Contribution to Bacteria

IPC does not contribute to bacteria of surface waters. Treated sanitary sewage disposal associated with the Brownlee Project was permanently eliminated on May 26, 2001. It was replaced with a new, upland on-site disposal (septic) system permitted through the

Idaho Department of Health and Welfare (IDHW), Southwest District Health Department (SWDH). ODEQ has permitted (OR-002727-8), a sewage holding tank for the Hells Canyon Project. As such, no treated or untreated sewage is disposed directly to surface waters of either Oregon or Idaho.

Associated with the HCC, IPC maintains several comfort stations that include showers, restrooms and vault toilets, and RV dump stations (Table 2.3-1). Similarly, there is no treated or untreated wastewater discharged directly to surface waters of either Oregon or Idaho. The largest facility, Woodhead Park, which was developed in 1994, disposes effluent by a land application treatment system meeting IDEQ standards.

6.10. Biocriteria

In addition to the specific numeric criteria addressed above, ODEQ established a general biocriteria standard that requires all waters to be "of sufficient quality to support aquatic species without detrimental changes in the residential communities" (OAR 340-041-0011). This general standard is addressed through each of the more-specific numeric criteria, targets, and allocations. Therefore, reasonable assurance that water quality is sufficient to support aquatic species without detrimental changes in the residential communities is inherent in the reasonable assurance that numeric criteria will be met.

6.11. Narrative Standards

ODEQ has numerous narrative standards, that is, descriptive standards for the protection of designated beneficial uses. In general, narrative standards strive to provide the best water quality given "the highest and best practicable treatment and/or control of wastes, activities, and flows" (OAR 340-041-0007(1)). Neither Oregon or Idaho has identified Snake River waters as limited relative to narrative standards (IDEQ 2005, ODEQ 2007a; also Table 5.1-1 and Table 5.1-2).

6.11.1. Narrative Standards and SR-HC TMDL Targets

Oregon narrative standards address many activities that do not directly apply to a CWA § 401 certification application for the HCC; for example, logging and forest-management activities. The following are narrative standards directly related to water-quality certification associated with the HCC.

- For any new waste sources, alternatives that utilize re-use or disposal with no discharge to public waters must be given highest priority for use wherever practicable. New source discharges may be subject to the criteria in Section OAR 340-041-0004(9) (OAR 340-041-0007(4)).

- No discharges of wastes to lakes or reservoirs may be allowed except as provided in section OAR 340-041-0004(9) (OAR 340-041-0007(5)).

- Road building and maintenance activities must be conducted in a manner so as to keep waste materials out of public waters and minimize erosion of cut banks, fills, and road surfaces (OAR 340-041-0007(9)).

- The development of fungi or other growths having a deleterious effect on stream bottoms, fish, or other aquatic life, or that are injurious to health, recreation, or industry may not be allowed (OAR 340-041-0007(11)).

- The creation of tastes or odors or toxic or other conditions that are deleterious to fish or other aquatic life or affect the potability of drinking water or the palatability of fish or shellfish may not be allowed (OAR 340-041-0007(12)).

- The formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry may not be allowed (OAR 340-041-0007(13)).

- Objectionable discoloration, scum, oily sheens, or floating solids, or coating of aquatic life with oil films may not be allowed (OAR 340-041-0007(14)).

- Aesthetic conditions offensive to the human senses of sight, taste, smell, or touch may not be allowed (OAR 340-041-0007(15).

- Radioisotope concentrations may not exceed maximum permissible concentrations in drinking water, edible fishes or shellfishes, wildlife, irrigated crops, livestock and dairy products, or pose an external radiation hazard (OAR 340-041-0007(16)).

6.11.2. Conditions Relative to Narrative Standards

As stated in OAR 340-041-0007(1), the intent of narrative standards, notwithstanding numeric criteria, is to “maintain dissolved oxygen and overall water quality at the highest possible levels and water temperatures, coliform bacteria concentrations, dissolved chemical substances, toxic materials, radioactivity, turbidities, color, odor, and other deleterious factors at the lowest possible levels.” As such, conditions relative to narrative standards have been addressed in preceding discussions of conditions relative to numeric criteria.

6.11.3. HCC Contribution to Narrative Standards

Narrative standards relevant to the HCC relate to the discharge of wastes to public waters, nuisance growths and the formation of organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry, oily sheens or the coating of aquatic life with oil films, creation of tastes, odors, or other toxic conditions, and land management activities.

Narrative standards have been addressed in previous sections of this application or point source permits specific to point source discharge activities. The discharge of wastes to public waters is addressed by specific point-source discharge permits for appropriate HCC related activities that

are issued by EPA and ODEQ. IPC does not directly discharge treated or untreated sanitary wastes to surface waters (see Section 6.9.3.). The SR-HC TMDL addressed narrative standards associated with nuisance growths and the formation of organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry. IPC has identified its contribution in Section 6.4.3. The EPA and ODEQ point-source discharge permits address oily sheens or the coating of aquatic life with oil films. IPC must not exceed levels or requirements as stated in permits. The creation of tastes, odors, or other toxic conditions are discussed in Section 6.6. IPC will cooperate in development of the mercury TMDL and implement appropriate measures to address its allocations. The *Hells Canyon Resource Management Plan*, developed by IPC as part of the HCC license application to FERC, establishes guidelines for management of its lands. Road building and maintenance activities and aesthetic conditions narrative standards are addressed directly in the *Hells Canyon Resource Management Plan* while other narrative standards are indirectly addressed. Exhibit 4.3-2 discusses compatibility with local land-use plans.

7. PROPOSED PME MEASURES

7.1. Temperature Proposed Measures

Section 7.1 has been withdrawn and will be submitted in the next application.

7.2. DO Proposed Measures

The SR-HC TMDL established a DO allocation for Brownlee Reservoir of 1,125 tons of oxygen per year (IDEQ and ODEQ 2004). The SR-HC TMDL did not address DO below Hells Canyon Dam. IPC conducted analyses to determine the HCC's contribution to low DO downstream of the HCC. IPC modeling indicates that, with anticipated water quality following full SR-HC TMDL implementation, a DO load of 1,733 tons per year is needed during the summer and fall to meet criteria. This load represents the unallocated additional DO load that would need to be addressed and allocated to upstream sources, including the HCC, in a future DO TMDL. Of this total 1,733 tons, an appropriate allocation to the HCC, based on its contribution, would be a maximum of 637 tons (see Section 6.2.). However, the final allocation cannot be known with certainty until such time as a downstream TMDL for DO is established.

IPC proposes the following measures to address DO concerns:

- Implement 1 of 2 measures to fully meet the SR-HC TMDL Brownlee Reservoir DO allocation: 1) in-reservoir aeration, or 2) upstream phosphorus trading.

- In order to address DO deficits below Hells Canyon Dam, IPC proposes to aerate Hells Canyon outflows using a forced air (blower) system at the Hells Canyon powerhouse. Such a blower would add 1,500 tons/year of DO downstream. This level of downstream DO augmentation is substantially higher than that which IPC considers proportionate to its actual contribution. However, because of the uncertainty of the correct load in the absence of a TMDL, and because the additional DO would provide

tangible benefits to downstream aquatic life pending establishment of a TMDL, IPC proposes to provide 1,500 tons/year of DO augmentation.

- IPC also proposes to install and operate a destratification system in the deep pool in the Oxbow Bypass to address thermal stratification and resulting anoxic conditions at this location.

7.2.1. Proposed Measures to Meet the SR-HC TMDL Allocation

Two potential measures have been developed that would meet the SR-HC TMDL DO load allocation of 1,125 tons of oxygen per year in Brownlee Reservoir. The first is a reservoir diffuser system that would add DO directly to the transition zone of Brownlee Reservoir. The second is upstream phosphorus trading that would remove phosphorus sources upstream equivalent to the required DO load in Brownlee. Because trading offers the potential for enhanced resource benefits over mechanical aeration, IPC proposes to devote a limited period of time to first identify an appropriate trading partner and, if that fails, to then proceed to the design and installation of the reservoir diffuser system. Both measures are described in detail in this section. An implementation plan is proposed that outlines the detail and timeline needed in order to select and implement the appropriate measure that will address the SR-HC TMDL allocation.

7.2.1.1. Reservoir Aeration

The goal of this measure is to provide 1,125 tons per year of DO, which would meet the allocation for Brownlee Reservoir assigned by the SR-HC TMDL. Based on ODEQ and IDEQ analyses in the SR-HC TMDL, implementation of IPC's allocation and other SR-HC TDML load allocations would improve DO conditions within the HCC and meet the appropriate DO targets.

The proposed reservoir aeration system would employ a porous hose-line diffuser design originally developed for the Tennessee Valley Authority (TVA) (Mobley and Brock 1995, Mobley 1997). This type of system is currently operating at 6 TVA hydropower projects, Duke Energy, and Pennsylvania Power and Light hydropower projects, the USACE's Richard B. Russell Dam, and 5 water-supply reservoirs (Mobley et al. n.d.). The porous hose-line diffuser design has been successful in meeting goals of DO improvement and reduction of anoxic products in reservoirs (Mobley and Brock 1996). The aeration system consists of an oxygen-supply facility and a reservoir diffuser system. Specifics of both facilities are presented in this section, and additional information related to the reservoir diffuser system is presented in Exhibit 7.2-1.

7.2.1.1.1 Oxygen Supply Facility

The use of pure oxygen gas for supply of the diffusers is proposed because it reduces secondary TDG effects of aeration using atmospheric air and is more cost effective. The use of compressed air would require significantly higher expense for the installation of approximately 5 times the number of diffusers to handle air. Additionally, injection of air at relatively high pressures in the reservoir increases concerns regarding TDG.

A variety of systems are available to supply pure oxygen, including liquid oxygen delivery or self-contained generation. The use of self-contained generation was eliminated from consideration because of high capital cost, electrical requirements, and location.

An oxygen supply facility would be located on flat terrain near the distribution site. The facility would consist of an oxygen storage tank, vaporizers, a pressure-regulating assembly, control valves, distribution piping, and truck access. The site would be screened and fenced.

The system capacity would be sized to place oxygen at the following 2 design criteria: 1) 17.3 tons/day (equivalent to 1,125 tons/year when applied for 65 days) and 2) 34.6 tons/day (equivalent to 2,250 tons/year when applied for 65 days). These 2 levels of oxygen supply would be necessary based on a conceptual operational plan described in Section 7.2.1.1.4. Based on oxygen transfer efficiencies (OTE) around 85% and a safety factor of 1.15, the amount of liquid oxygen delivered to the site would be increased to 23.4 tons/day and 46.8 tons/day.

An experienced gas supplier would provide a 50,000-gallon liquid oxygen tank (Figure 7.2-1), ambient air vaporizers (Figure 7.2-2), a pressure-regulating assembly (Figure 7.2-3), cryogenic piping, and control valves. Supply piping from the facility to the reservoir would be routed across the Snake River Road. Supply piping would measure approximately 1,000 ft, be placed in a trench, and be routed in a protective carrier pipe. This carrier pipe provides protection from ultraviolet light and vandalism. The oxygen flow-setting would be manual. Electric power (110V) and an alarm system are typically required at the facility.

Figure 7.2-1. 50,000-gallon liquid oxygen storage tank

The gas supplier would deliver liquid oxygen to the system during regular operational hours. For the two design criteria established, deliveries would be 3 trucks every 2 days and 3 trucks every day, respectively. At least a 20,000-gallon tank would be used to provide storage capacity for 2 days.

7.2.1.1.2. Reservoir Diffuser System

Mobley Engineering, Inc., prepared a detailed design for an oxygen diffuser system for the Brownlee Reservoir transition zone (Exhibit 7.2-1). The line-diffuser design is well suited for the transition zone, and the design for this application uses standard line-diffuser details to efficiently place oxygen at the designed water depths.

Figure 7.2-2. Vaporizer/discharge piping

Figure 7.2-3. Oxygen gas-regulator assembly

There are several advantages of the line-diffuser design:

- It is a proven system. Such systems are currently in operation at 9 hydropower installations.
- Its high OTE minimizes operating costs. The OTE would range from 85% to 90% at depths available at the proposed location.
- It provides a wide range of oxygen flow rates, while maintaining OTE and uniform distribution.
- It can be supplied with oxygen supplied from a cryogenic tank.

The proposed design provides for 2 diffusers to allow control of oxygen-input distribution over approximately 2 river miles. The diffuser system for the transition zone would place up to 34.6 tons of oxygen per day into the reservoir. Two diffuser lines would be routed upstream of the oxygen-supply facility to directly place oxygen into approximately 2 miles of the reservoir. Supply lines from the oxygen-supply facility would be routed in a trench under the road and then underwater to the deepest part of the reservoir.

7.2.1.1.3. System Location

Under current conditions (i.e., before substantial upstream water-quality improvements from SR-HC TMDL implementation), the most-extensive low-DO concentrations in Brownlee Reservoir were found in the transition zone and the metalimnion and hypolimnion of the lacustrine zone. During medium- to low-water years (1995 and 1992, respectively), extensive hypoxic (< 2.0 mg/L) and anoxic (< 0.5 mg/L) conditions developed in the transition zone. The most extreme hypoxia that IPC has measured in the transition zone occurred on July 20, 1990, shortly after a large fish kill in the upper segment of the reservoir. Low DO levels (< 1 mg/L) extended to the surface at RM 324.4 in the transition zone (Figure 7.2-4). On this date, DO below 3 mg/L throughout the water column occurred upstream of RM 324.4 for approximately 3 miles. This episode of low DO led to the mortality of at least 28 white sturgeon and several other species. While collecting the DO measurements, IPC biologists observed dead fish throughout the upper reach of the reservoir (RM 337 to RM 317), including white sturgeon, channel catfish, crappie, and suckers (*Catostomus* spp.) (Myers et al. 2003). Although this episode in 1990 was extreme, IPC has measured low DO (< 4 mg/L) at or near RM 325 in other years. Summarized profile data collected over 13 years through the water column at RM 325 show that anoxic conditions were common in low-water years, while in high-water years, this area relatively remains well oxygenated (Table 7.2-1).

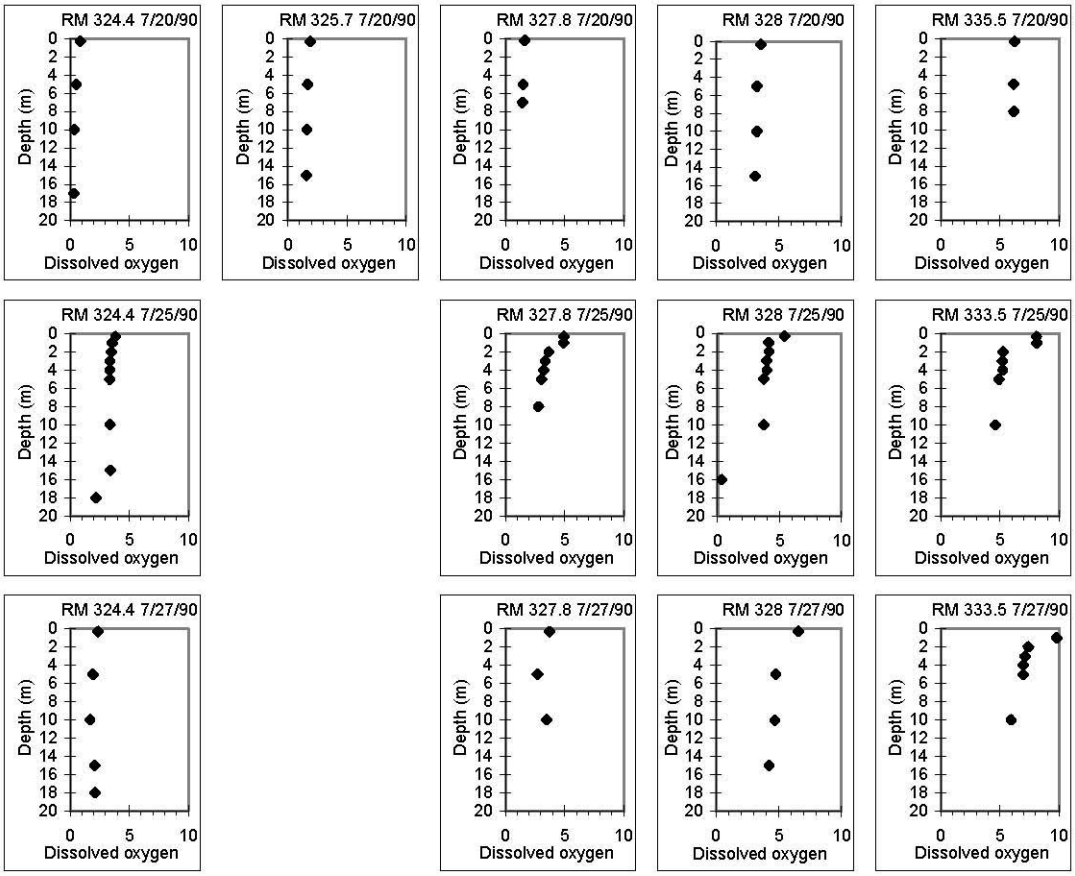


Figure 7.2-4. Dissolved oxygen (DO) in milligrams per liter (mg/L) profiles measured in the upper end of the transition zone in 1990.

Table 7.2-1. Summary of measured profile transition zone dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) collected in July at or near RM 325, 1991−2003.

Year	Water Year Conditions	Mean (Range) DO mg/L	Dates Sampled
1991	Low	2.8 (0.2–5.1)	7/9, 7/23
1992	Low	4.8 (0.2–9.6)	7/7, 7/21
1993	Medium	9.3 (5.4–13.6)	7/8, 7/22
1994[a]	Low	6.2 (3.5–10.8)	7/11
1995	Medium	10.7 (9.1–15.1)	7/5, 7/17
1996	High	10.8 (8.4–12.8)	7/2, 7/17
1997	High	10.0 (9.0–12.1)	7/9, 7/22
1998	High	7.2 (2.1–11.3)	7/8, 7/22
1999	Medium–high	10.7 (7.9–13.8)	7/7, 7/28
2000	Medium–low	7.2 (5.6–10.2)	7/6
2001	Low	2.3 (0.1–4.6)	7/12, 7/25
2002	Low	4.1 (0.2–7.0)	7/1
2003	Low	3.8 (0.1–10.0)	7/23

[a] Data collected at RM 323; none collected at RM 325 in 1994

The system location would be centered near RM 325 and cover approximately 1.8 miles of reservoir (Figures 7.2-5, 7.2-6, and 7.2-7). This location was identified to provide improved habitat for fish (i.e., white sturgeon) by extending adequate DO levels into the upstream end of the transition zone and preventing extreme hypoxic conditions from developing in this area. Several other factors in locating the system were also evaluated: 1) water depth for system efficiency; 2) the need to install the oxygen facility on a concrete pad designed to vendor specifications and applicable safety regulations (CGA G-4.4, NFPA 50); 3) the requirement that liquid oxygen delivery via truck must include a concrete spill apron at the fill-pipe connection; and 4) the need for the facility to be located where it is clear of overhead power lines and provides a suitable turnaround area for delivery trucks. The location was sited based on available flat terrain for a facility approximately 100 ft by 150 ft, and other criteria previously mentioned. Very few siting locations exist in the upper end of the transition zone.

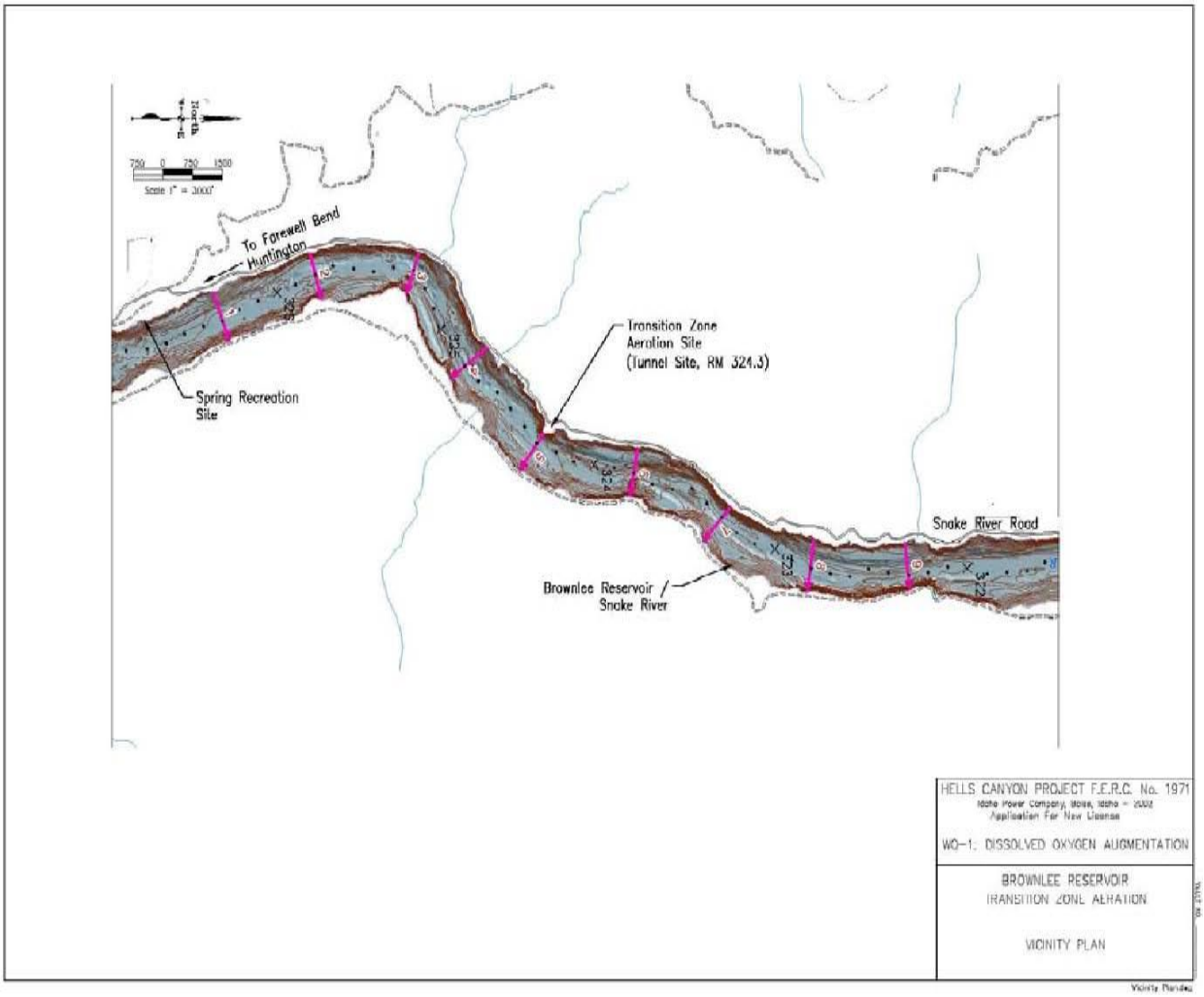


Figure 7.2-5. Vicinity plan for the Brownlee Reservoir transition zone aeration system

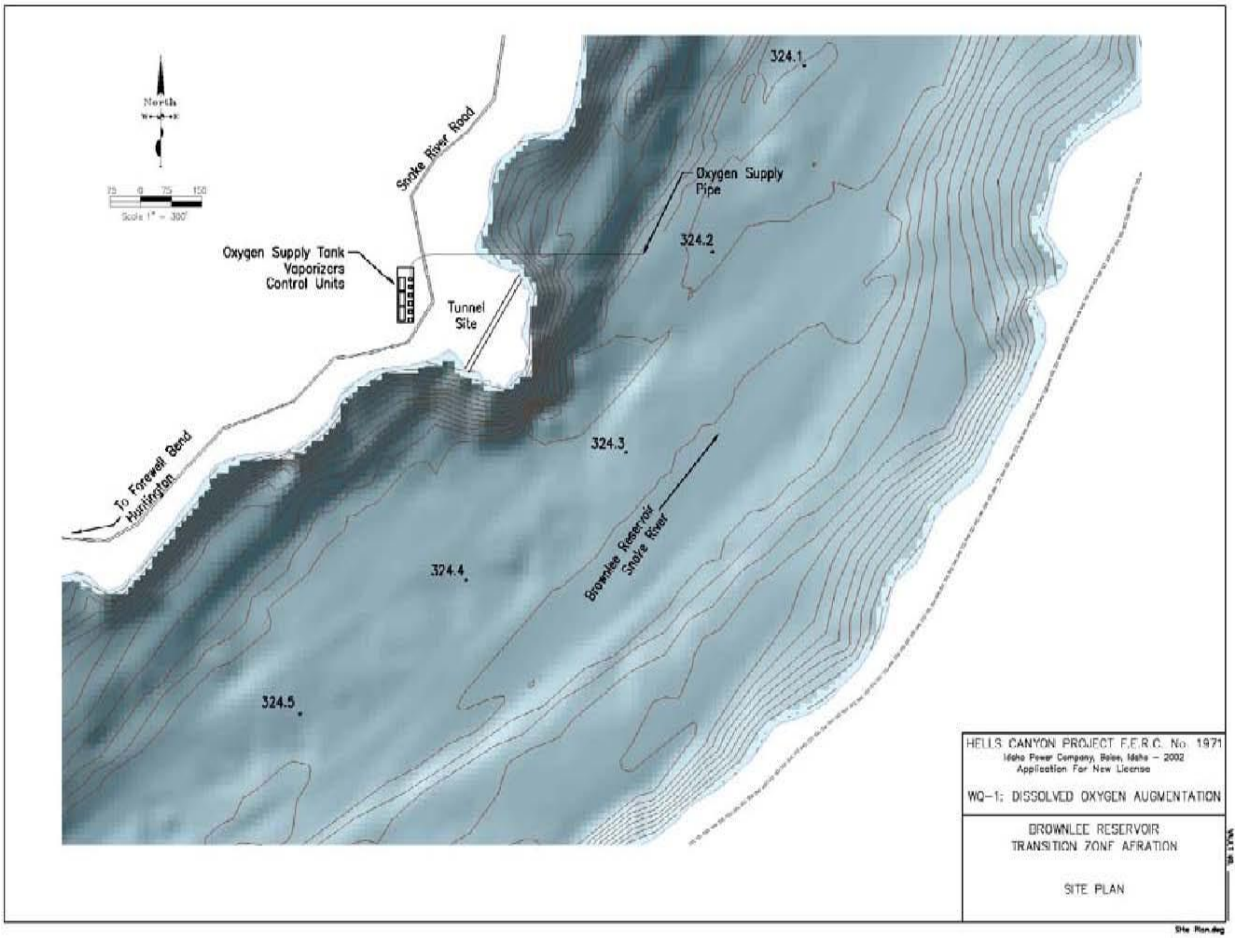


Figure 7.2-6. Site plan for the Brownlee Reservoir transition zone aeration system

Modeling with CE-QUAL-W2 is used to support the design and location of the proposed aeration system. To incorporate reservoir aeration, some additional assumptions to the basic model package are required. The effects of the reservoir aeration system are modeled in CE-QUAL-W2 using customized coding developed for IPC. The coding allows oxygen to be added at a specified rate to a specified number of model cells for a range of days. The desired amount of oxygen per year is converted into a kilogram per day (kg/day) rate (i.e., 1,125 tons/year equals 15,727 kg/day over the 65 days included from Julian days 182 to 247), and that mass is added equally into the specified model segments and layers.

Three model segments are aerated, representing 1.8 miles of diffusers centered near RM 325. Eight layers of these segments are aerated, representing 40 ft (12.2 m) of depth. The layers aerated begin slightly off the bottom, representing the ability to float the diffuser line from anchors (Mobley 1997). The number of layers aerated represents the predicted distribution of oxygen absorption through the water column as bubbles rise. At the anticipated depths and oxygen flow rates, the oxygen is expected to be dissolved within the bottom 40 ft (Exhibit 7.2-1). Modeling indicates that the oxygen will be approximately equally distributed throughout this depth and along the diffuser lines (Exhibit 7.2-1). To represent rising bubbles, the modeling includes an increased rate of vertical mixing between model layers. This factor was set to slightly

increase mixing, since the diffuser design at the oxygen flow rates is anticipated to cause relatively little mixing.

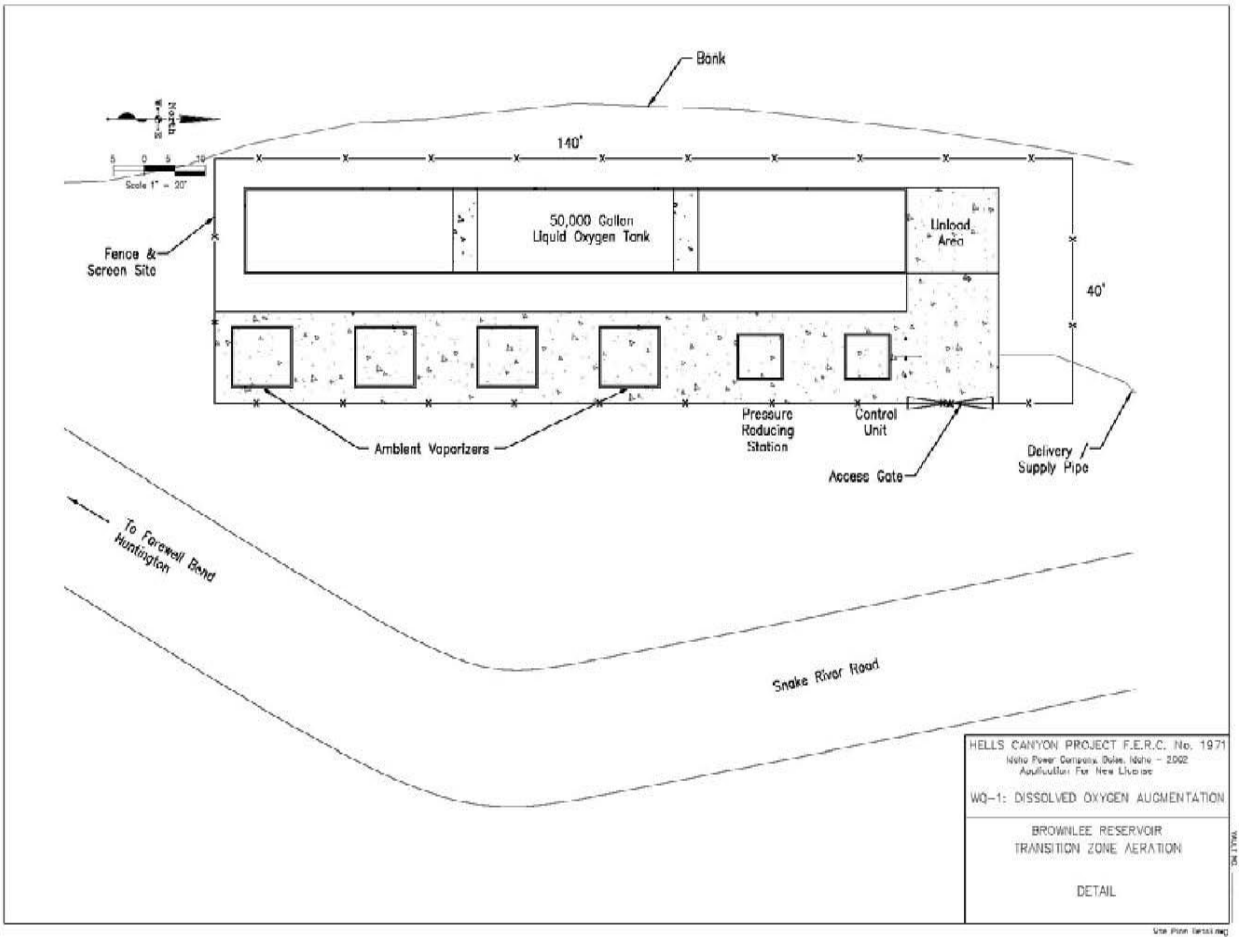


Figure 7.2-7. Site detail for the Brownlee Reservoir transition zone aeration system

Model results showed that, under current conditions, with the 1,125 tons/year applied from Julian days 182 to 247, DO levels are increased in the vicinity of the diffusers with small increases seen downstream (Figures 7.2-8 and 7.2-9). In a low-water year (1992), the model shows that some anoxia can occur upstream of the diffusers. In very extreme cases (i.e., 1990), these conditions could potentially extend to the surface and interrupt continuous habitat, as occurred in 1990. However, moving the system farther upstream of the proposed location was determined to be undesirable because of decreasing oxygen transfer efficiency with shallower water and the very low frequency of extreme hypoxic conditions occurring upstream of the proposed location. Placement of the system farther downstream, under current conditions, has potential to create an area of higher DO near the diffusers that is surrounded by hypoxic water.

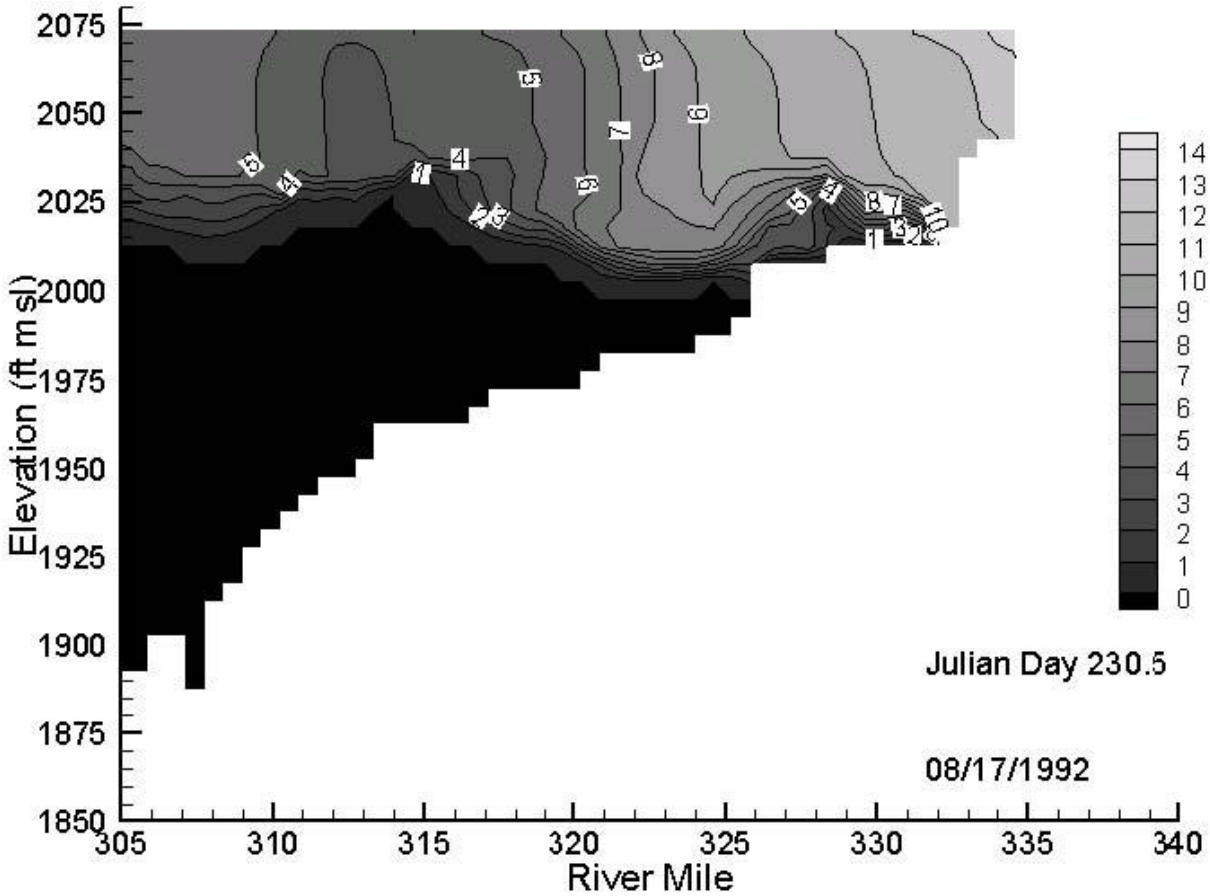


Figure 7.2-8. Simulated 1992 (low-water year) dissolved oxygen (DO) in milligrams per liter (mg/L) isopleth for the Brownlee Reservoir transition zone with no aeration.

In high-water years, the benefits of aerating at this location are less apparent because hypoxia does not develop as strongly (Table 7.2-1, IPC 2005). Measured data indicate that DO problems were common in this area in low-water years, while low DO was generally not measured in medium–high and high-water years (1999 and 1997, respectively).

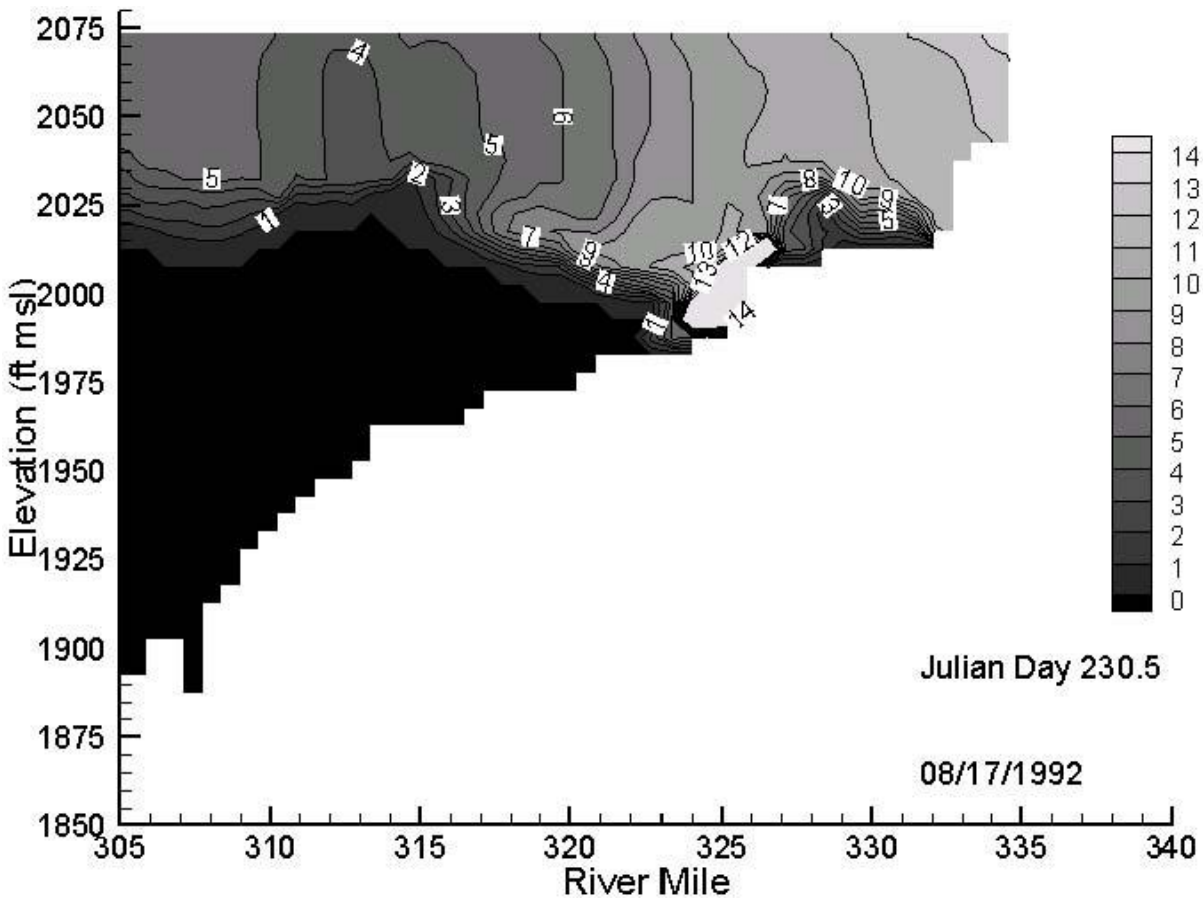


Figure 7.2-9. Simulated 1992 (low-water year) dissolved oxygen (DO) in milligrams per liter (mg/L) isopleth for the Brownlee Reservoir transition zone with 1,125-tons/year aeration at the proposed location.

White sturgeon is considered a species of special concern by the State of Idaho. Lepla et al. (2003) suggested that poor water quality, specifically low DO, is the primary factor contributing to low condition factors for 11 white sturgeon captured in the upstream end of Brownlee Reservoir (approximately RM 335–RM 325) in August 1997. Sturgeon habitat suitability indices (HSI) were developed by Lepla and Chandler (2003) on a scale of 0 to 1 (0 = unsuitable and 1 = most suitable) to evaluate habitat conditions for Snake River white sturgeon based on temperature and DO levels. HSI computed from CE-QUAL-W2 results show that aeration at the proposed location in low water years provides a larger area of benefit than apparent with only DO concentration results. Relatively small increases in DO can translate to large increases in habitat suitability for sturgeon. In August 1992, the relatively small DO increases seen near diffusers and downstream (Figures 7.2-8 and 7.2-9) translated to a relatively large volume in the transition zone that improved from an HSI below 0.5 (without aeration) to above 0.8 (with aeration) (Figures 7.2-10 and 7.2-11). HSI calculations for 1999 and 1997 showed acceptable conditions for sturgeon in the system vicinity without aeration (IPC 2005).

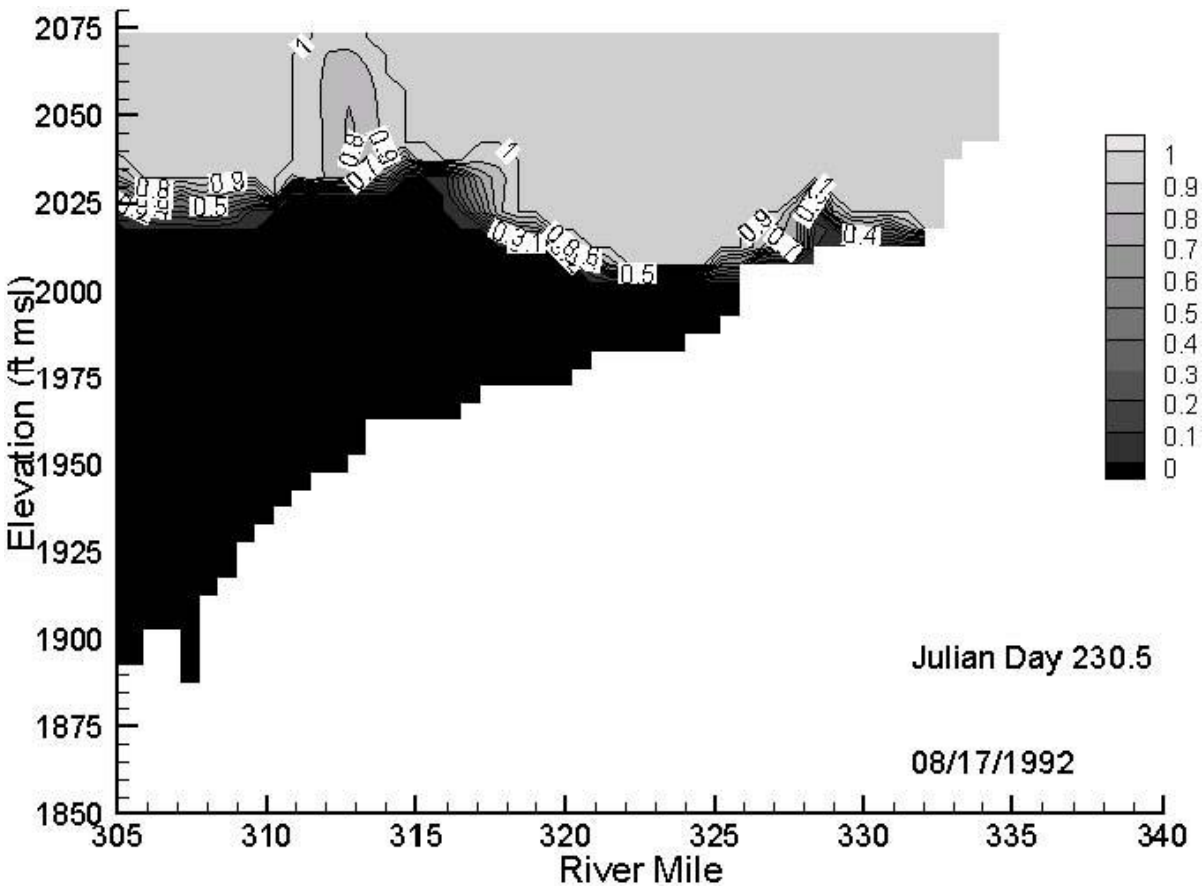


Figure 7.2-10. Simulated 1992 (low-water year) sturgeon habitat suitability index (HSI) isopleth for the Brownlee Reservoir transition zone with no aeration.

The proposed location of the diffuser system provides near-term benefits under current conditions. As upstream water quality improves, the largest DO deficits may occur farther downstream, and benefits may be realized by moving the system to supplement metalimnetic DO. Relocating the system may be considered in the future; however, because of the difficulty in relocating the system components (i.e., liquid oxygen storage tank and distribution, diffuser system anchor weight and line length), relocation would be warranted only if it would result in significant long-term environmental benefits.

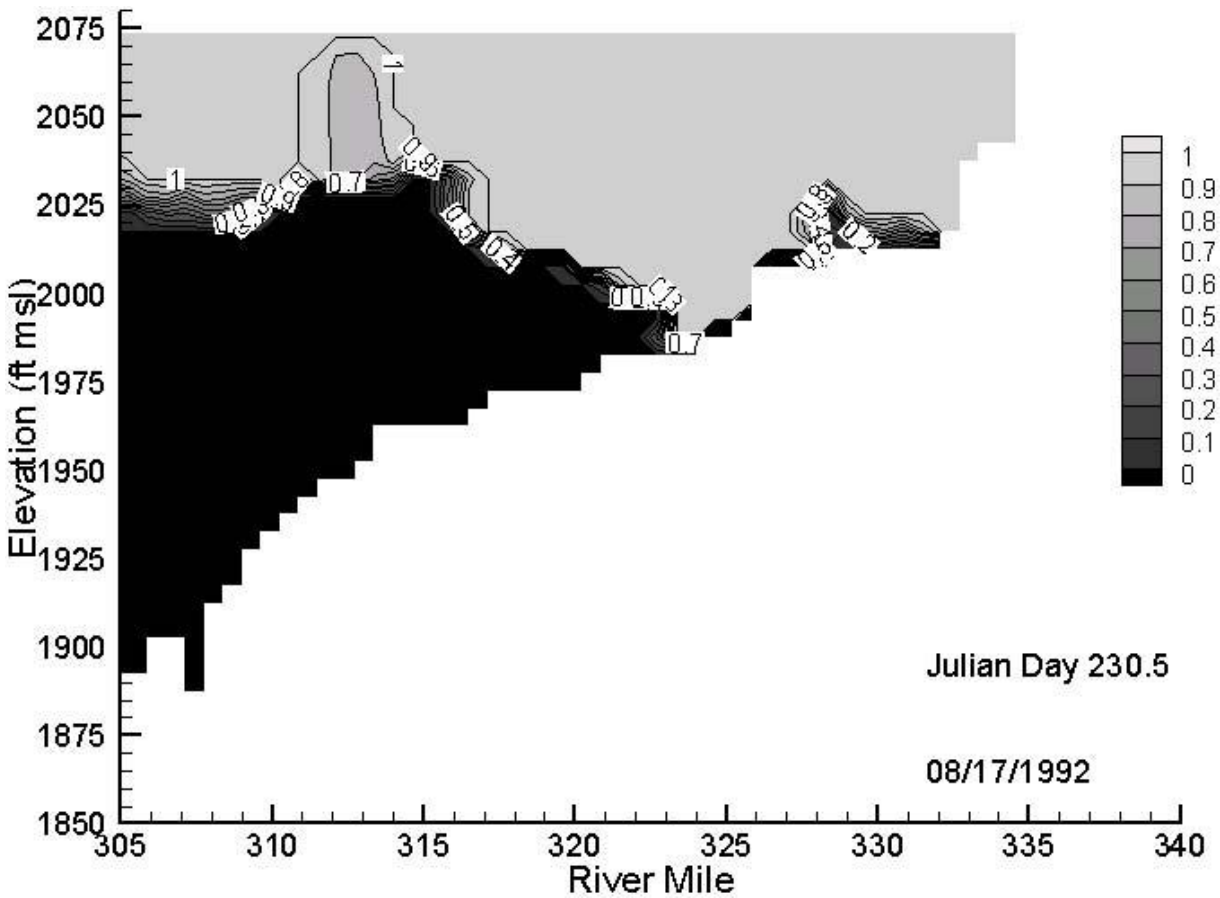


Figure 7.2-11. Simulated 1992 (low-water year) sturgeon habitat suitability index (HSI) isopleth for the Brownlee transition zone with 1,125-tons/year aeration at the proposed location.

7.2.1.1.4. Conceptual Operational Plan

The SR-HC TMDL calculations identified the need for DO augmentation from Julian days 182–247. The SR-HC TMDL provides for flexibility in this timeframe and suggests that aeration should be implemented to coincide with the actual time periods when DO "sags" occur and where it would provide the most benefit to aquatic life (IDEQ and ODEQ 2004). Because of the significant annual variability in Brownlee water-quality conditions, IPC proposes to maximize benefits of the aeration system by varying injection rates and periods depending on conditions. DO dynamics in the transition zone are, in part, determined by water-year conditions. At RM 325 (the center of the proposed diffuser system), anoxic conditions occur in summer during low-water years. Anoxic conditions have not been measured at RM 325 in higher water years (Table 7.2-1). Although water-year conditions appear to be a strong driver, there is some risk that isolated and infrequent hypoxic conditions may develop even in medium–high water years. For example, Table 7.2-1 shows one instance of low DO (2.05 mg/L) measured in a high-water year (1998).

IPC's operational plan for the aeration system allows more oxygen to be injected in years when the problem is likely to occur, and less or none when the problem is unlikely to occur.

Table 7.2-2 shows how the allocation could be applied to meet the allocation on a 10-year average basis. This flexible approach avoids aerating at 17.3 tons/day when DO levels in the vicinity of the aeration system are well above targets. DO and sturgeon HSI results with aeration of 2,250 tons/year in low-water years show that improvements are, as expected, larger in the vicinity of the diffusers and move farther downstream than with aeration at 1,125 tons/year (Figures 7.2-12 and 7.2-13). IPC's approach results in larger benefits in years when there are potential DO problems. IPC's current understanding may anticipate DO problems in low-water years, but the specific time of the year when such problems are likely to occur is much more difficult to predict. Therefore, the initial operational plan includes operation during the dates identified in the SR-HC TMDL (Julian days 182–247); however, moving the aeration dates to start and end earlier may be warranted.

Table 7.2-2. Summary of measured profile transition zone dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) collected in July at or near RM 325, 1991–2003, and an example of the aeration allocation implementation approach using a 10-year average concept.

Year	Water Year Conditions	Mean (Range) DO mg/L	Dates Sampled	Example Aeration Level Tons/Year	10-Year Average Aeration Level
1991	Low	2.8 (0.2–5.1)	7/9, 7/23	2,250	
1992	Low	4.8 (0.2–9.6)	7/7, 7/21	2,250	
1993	Medium	9.3 (5.4–13.6)	7/8, 7/22	1,125	
1994[a]	Low	6.2 (3.5–10.8)	7/11	2,250	
1995	Medium	10.7 (9.1–15.1)	7/5, 7/17	1,125	
1996	High	10.8 (8.4–12.8)	7/2, 7/17	0	
1997	High	10.0 (9.0–12.1)	7/9, 7/22	0	
1998	High	7.2 (2.1–11.3)	7/8, 7/22	0	
1999	Medium–high	10.7 (7.9–13.8)	7/7, 7/28	0	
2000	Medium–low	7.2 (5.6–10.2)	7/6	2,250	1,125
2001	Low	2.3 (0.1–4.6)	7/12, 7/25	2,250	1,125
2002	Low	4.1 (0.2–7.0)	7/1	2,250	1,125
2003	Low	3.8 (0.1–10.0)	7/23	2,250	1,237.5

[a] Data collected at RM 323; none collected at RM 325 in 1994.

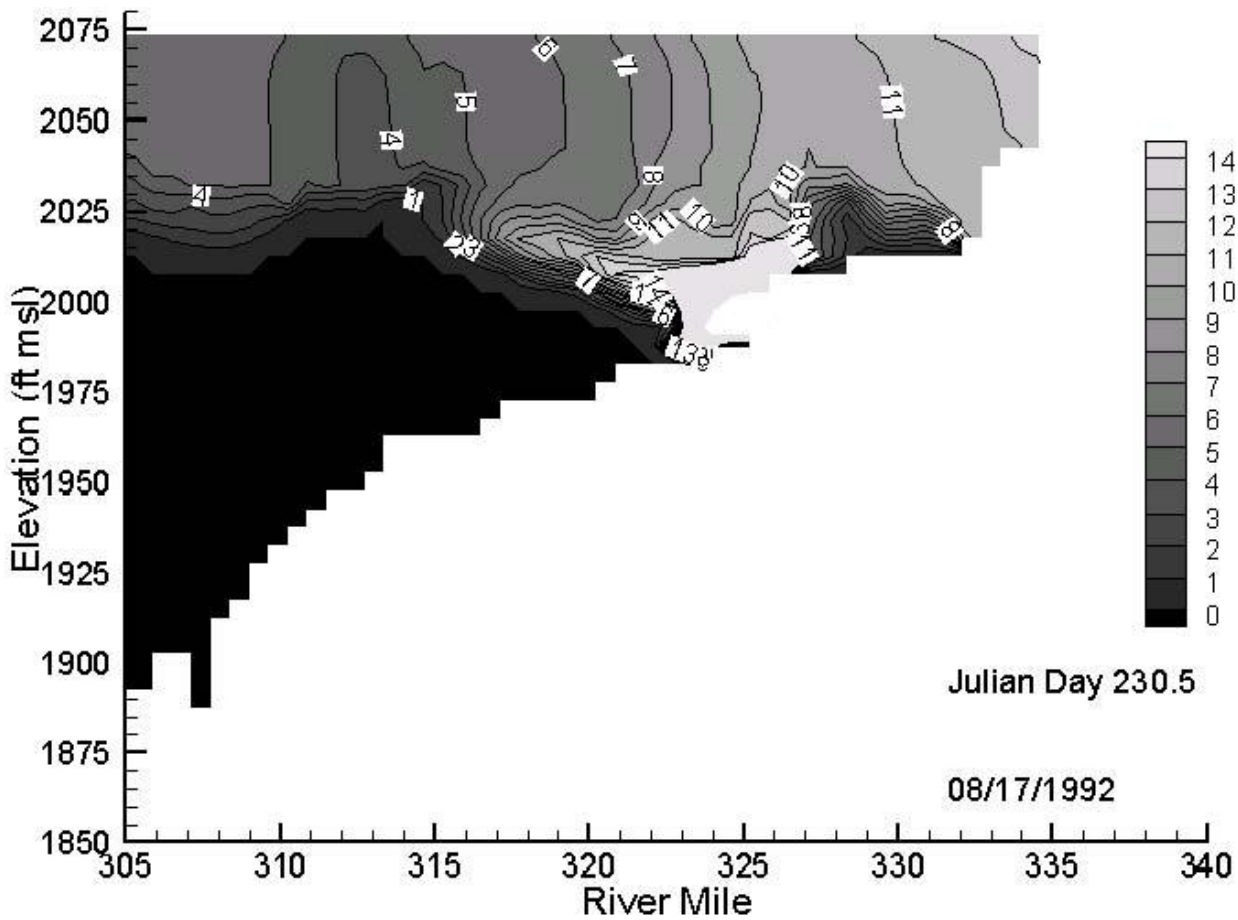


Figure 7.2-12. Simulated 1992 (low-water year) dissolved oxygen (DO) in milligrams per liter (mg/L) isopleth for the Brownlee Reservoir transition zone with 2,250-tons/year aeration at the proposed location.

The DO load allocation for Brownlee Reservoir was developed following extensive analysis of average water conditions in the Snake River (IDEQ and ODEQ 2004). Due to uncertainty in the timing and magnitude of upstream improvements assumed in the SR-HC TMDL analysis, IPC's proposed location and operations for reservoir aeration were developed to provide the most benefit under current conditions. The system design and operation plan is based on professional experience with reservoir conditions and aeration systems and measured data. CE-QUAL-W2 modeling was used to support design and development of operational aspects; however, CE-QUAL-W2 results simulating the resultant DO concentrations from the system should be considered simplistic. CE-QUAL-W2 is a 2-dimensional, laterally averaged model that simulates the effect of fully mixed oxygen mass added to a laterally averaged cell and not the three-dimensional effects associated with a mid-channel diffuser-line source or the localized bubble dynamics and gas transfer processes.

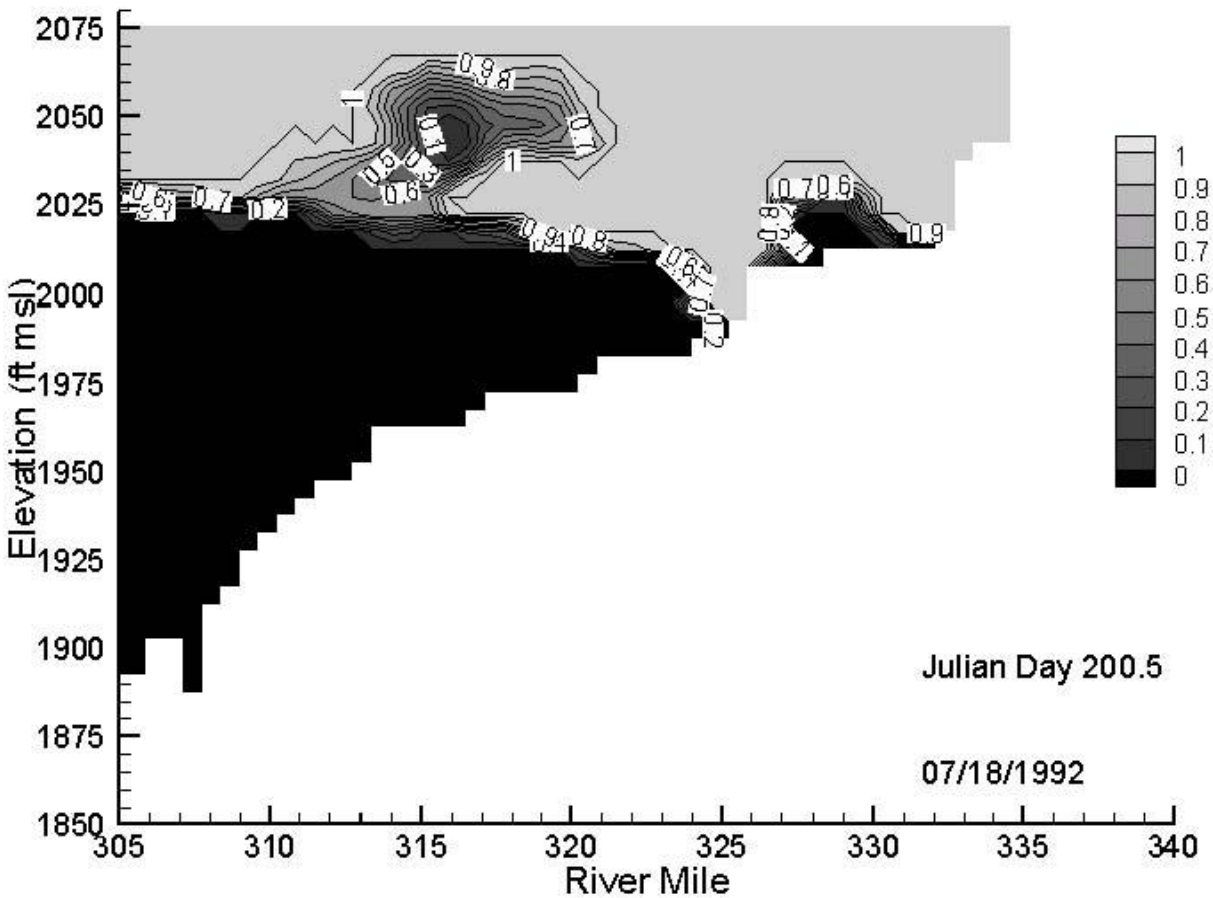


Figure 7.2-13. Simulated 1992 (low-water year) sturgeon habitat suitability index (HSI) isopleth for the Brownlee Reservoir transition zone with 2,250-tons/year aeration at the proposed location.

7.2.1.2. Upstream Watershed Phosphorus Trading

Watershed trading was identified in the SR-HC TMDL (IDEQ and ODEQ 2004) as an approach to address the Brownlee Reservoir DO allocation. Both Oregon and Idaho have developed policies for phosphorus trading. ODEQ will consider trading when it accomplishes one or more objectives including progress toward TMDL reductions, reduced costs on implementation, or achieving greater environmental benefits (ODEQ 2005). Idaho's policy is to allow trading as an approach to meet TMDLs (IDAPA 58.01.02.054.06) and has developed draft guidance focused on lower Boise River nutrient trading (IDEQ 2003).

A primary requirement for any trade will be determining the relationship between the Brownlee Reservoir DO load allocation and TP, referred to in this section as nutrient ratios. Another consideration is the time period of the reservoir's load allocation versus the time period of an upstream phosphorus reduction. The periods can be different, but have comparable environmental benefits. A general linkage between TP and oxygen is established in the SR-HC TMDL (IDEQ and ODEQ 2004). However, exact trading ratios (e.g., conversion from TP to oxygen) and time periods for a trade have not been established.

The following sections provide a summary of proposed nutrient ratios that could be used to implement a trade for a point-source discharge upstream of HCC. The ratios and time periods of a trade are compared to the Brownlee Reservoir DO allocation using an example point-source discharging to the Snake River located a few miles upstream of the HCC. This is then compared with the Brownlee Reservoir DO allocation of 1,125 tons/year with a 65-day allocation period (e.g., beginning July 1 through September 7).

7.2.1.2.1. Nutrient Ratios

The ratio of TP to oxygen (TP/Ox ratio) is related to organic matter stoichiometry, which varies in response to environmental conditions (Sterner and Elser 2002). For example, the classic Redfield ratios for algae organic matter are $C_{106}N_{16}P_1$. Assuming organic matter is 50% carbon, this implies a TP to organic matter (TP/OM) ratio of approximately 0.005. This is a typical value used in CE-QUAL-W2 modeling (Table 7.2-3). However, under eutrophic conditions, algae can store phosphorus, causing the ratio to increase. For example, ratios used in the 1995 Snake River model application (Table 7.2-3—SR ’95) are appropriate for modeling current hypereutrophic conditions with relatively high phosphorus levels. More typical levels, such as the default values given for CE-QUAL-W2 (Table 7.2-3—W2), would be anticipated as phosphorus loads decrease through implementation of the SR-HC TMDL. Lower ratios are also observed in reservoirs in response to settling and organic matter processing (Table 7.2-3—Brwn ’95).

The Brownlee Reservoir DO load allocation required addition of oxygen to break down organic matter and thereby reduce oxygen-demanding materials that contribute to low DO in the reservoir. The oxygen to organic matter (Ox/OM) ratio represents the amount of oxygen needed to break down organic matter. This ratio varies with the type and characteristics of the organic matter. Ratios were discussed during § 401 preparation discussions with IDEQ and ODEQ (Table 7.2-3—Proposed) for initial analysis of upstream measures relative to the Brownlee Reservoir DO allocation. These ratios are proposed as the starting point for evaluating upstream trades. The proposed ratios and various time periods of a trade are compared to the Brownlee Reservoir DO allocation using an example point source discharging 500 kg/day of total phosphorus to the Snake River a few miles upstream of HCC. Assuming an 80% reduction as established SR-HC TMDL for point sources, the example point-source allocation would be:

- 100 kg/day during the SR-HC TMDL critical period of May through September (152 days) and
- 500 kg/day during the non-critical period of October through April (213 days).

The Brownlee Reservoir DO allocation is 1,125 tons of oxygen per year (tons-DO/yr) to be provided over a 65-day critical period (from July 1 through September 7) (IDEQ and ODEQ 2004). Load allocations for point sources are typically given in kilograms of phosphorus per day (kg-TP/day). To compare these load allocations, the example point-source load allocation of 100 kg-TP/day is used and converted to tons-DO/yr to compare with the Brownlee Reservoir DO allocation (Table 7.2-3).

Table 7.2-3. Upstream phosphorus trading ratios and resultant loads over various time periods.

Ratio or Load	W2	Brwn '02	Brwn '95	SR '95	Proposed
Stoichiometry ratios					
TP/OM	0.005	0.01	0.01	0.02	**0.01**
Ox/OM	1.4	1.7	1.4	1.4	**1.5**
TP/Ox ratio					
TP/Ox	0.36%	0.59%	0.71%	1.43%	**0.67%**
Daily point-source loads (kg-TP/day)					
Current load	500	500	500	500	**500**
SR-HC TMDL TP allocation					
During critical period	100	100	100	100	**100**
During non-critical period	500	500	500	500	**500**
TP allocation as oxygen (tons-DO/day)					
During critical period	30.8	18.7	15.4	7.7	**16.5**
During non-critical period	154.0	93.5	77.0	38.5	**82.5**
Point source trade loads (tons-DO/yr)					
During Brownlee allocation period (65 days)	2,002	1,216	1,001	501	**1,073**
During critical period (152 days)	4,682	2,842	2,341	1,170	**2,508**
During non-critical period (213 days)	32,802	19,916	16,401	8,201	**17,573**
Total annual	37,484	22,758	18,742	9,371	**20,081**

Notes: CE-QUAL-W2 stoichiometry are model default values per Cole and Wells 2002.

Brwn '95 stoichiometry are optimized model values used in the 1995 Brownlee model application.

SR '95 stoichiometry are optimized model values used in the 1995 Snake River model application.

Brwn '02 based on data collected in upper end of reservoir.

Brownlee Reservoir SR-HC TMDL oxygen load allocation is 1,125 tons-DO/yr provided over 65 days (July 1 through September 7).

Critical period is 152 days from May–September as defined in the SR-HC TMDL.

Non-critical period is from October–April.

Total annual load is critical plus non-critical period loads.

The comparative point-source trade load changes depending on the time period of the trade. If the trade occurred over the 65-day period given in the SR-HC TMDL, the point-source trade load would be 1,073 tons-DO/yr using the proposed ratio (Table 7.2-3). This is less than the Brownlee Reservoir DO allocation of 1,125 tons-DO/yr. However, extending the trade for the TMDL critical period increases the point-source trade load to 2,508 tons-DO/yr, which is more

than double the Brownlee Reservoir allocation. If the trade occurs over an entire year, the annual point-source trade load would be over 15 times the reservoir allocation.

Use of the critical or annual period for assessing a trade is appropriate because of the cumulative benefits of phosphorus source reductions related to this trade. Over a period of time, the internal cycling of phosphorus will be reduced and add to the overall benefits of source reduction. Overall benefits of a TP trade are considerable because a trade would eliminate phosphorus from the river system, and is cumulative because the reduction addresses one of the primary factors leading to low DO: The production of organic matter. DO aeration is more definable in regard to implementation but treats the symptom and not the source of the problem. The excess TP stays in the river system, accumulating in the reservoirs or moving downstream to contribute to downstream DO problems.

The proposed ratios are appropriate for a point source to address the Brownlee Reservoir DO allocation, considering the reductions in overall phosphorus levels required under the SR-HC TMDL (e.g., as phosphorus levels decrease, the ratios decrease). Furthermore, the overall benefits of trading will increase as the length of the trading period increases.

7.2.2. Turbine Aeration at Hells Canyon Dam

IPC proposes to aerate Hells Canyon outflows using a forced air (blower) system at the Hells Canyon powerhouse to add 1,500 tons/year of DO downstream during summer and fall. This level of downstream DO augmentation is substantially higher than required relative to the maximum appropriate HCC DO responsibility. However, because of the uncertainty of the correct load in the absence of a TMDL, and because the additional DO would provide tangible benefits to downstream aquatic life pending establishment of a TMDL, IPC proposes to provide 1,500 tons/year of DO augmentation.

A blower system at the Hells Canyon powerhouse is proposed. However, turbine aeration measures at the Brownlee powerhouse have been, and continue to be, evaluated (see Section 7.2.3.). Preliminary evaluations indicate that measures at Brownlee Dam are also feasible to meet the proposed 1,500 tons/year below Hells Canyon Dam. Measures at Brownlee Dam also have potential to provide additional benefit in Oxbow and Hells Canyon Reservoirs. However, measures at Brownlee Dam are more complex to evaluate due to DO dynamics in Oxbow and Hells Canyon Reservoirs and due to more complicated turbine operations at Brownlee.

Additional information may be developed related to benefits, feasibility, or cost effectiveness of the proposed measures that indicate installation of a turbine aeration system at Brownlee Dam might be preferable to installation at the Hells Canyon powerhouse. In that case, IPC will evaluate whether turbine aeration at Brownlee Dam would provide reasonable assurance that the targets below Hells Canyon Dam would be met. Pending ODEQ and IDEQ approval, measures at Brownlee Dam would be implemented within a specified timeframe following license issuance (see Section 7.2.7.).

7.2.2.1. Description

Forced air uses compressors or blowers (air compressors are used in high-pressure applications and blowers are used in lower pressure applications) to force air into the draft tube through either passages in the turbine or the draft-tube wall. The blowers are operated when the turbines are running. Oxygen from the air is dissolved into the water and increases DO in the turbine discharges. Oxygen transfer is obtained in the turbulent flow of the draft tube and as the bubbles rise to the surface in the tailrace. However, as air is dissolved into the water, both nitrogen and oxygen are dissolved and TDG pressures are increased.

Blowers are an established technology in the United States. IPC currently uses blowers at the American Falls (FERC Project No. 2736) and Cascade (FERC Project No. 2848) power plants in the summer as a method of increasing the outflow DO. The American Falls plant has 3 250-hp blowers that can provide 6,000 standard cubic feet per minute (scfm) of air each. The Cascade plant has four 150-hp blowers that provide noticeable DO increases when they are in operation.

Forced air is also currently being used at 2 TVA projects: Tims Ford and Nottely. Both TVA projects are unmanned hydro stations. There are 2 blowers at Tims Ford, a 350-hp 4,400 scfm unit and a 200-hp 3,400 scfm unit. Both of these blowers force air into a distribution ring around the draft tube of the single turbine discharging approximately 4,800 cfs. Operation of the blowers is initiated with a single blower, then both as the DO conditions decline. DO uptake is limited by TDG measured in the tailrace. As TDG approaches dangerous limits, the operations of a penstock oxygen system is initiated to provide the desired uptake, generally operating with at least 1 blower (Harshbarger et al. 1995).

Forced-air systems include blowers, electric supply, air piping, and controls. Turbine efficiency is often reduced in proportion to the amount of air forced into the draft tube. The blowers also typically require a significant amount of maintenance. Electric power requirements are large and may require installation of additional station service capacity at the powerhouse.

7.2.2.1.1. Proposed Design

The Hells Canyon powerhouse consists of 3 generating units; each operates on a total head of approximately 213 feet of water and can provide a maximum hydraulic flow rate of 10,200 cfs per unit. The turbine blades at the plant have more submergence (i.e., the depth at which the turbine blades sit below the tailwater elevation) than what is typically considered to be normal. Because of the higher submergence, the operating air pressures for the blower systems will be somewhat increased because of the back-pressure from the tailwater. The high pressures will increase operating costs and initial blower costs.

When the powerhouse was originally constructed, a system was built into each of the 3 units that would allow the plant operators to depress the units (i.e., pump air below the turbine blades, allowing the turbine to spin without a water load). This system consists of a distribution ring that wraps around the circumference of the draft tube below the turbine and pipes leading to the distribution ring that are embedded in the concrete (Figure 7.2-14). Because of operational constraints with tailwater regulation, none of these pipes or the distribution ring has ever been needed, so they have gone unused.

IPC has also investigated other routes to deliver air into the turbine. However, it has been determined that the unused depression system is likely to be the best route to deliver blower air to the draft tube. Introducing air through a distribution ring on the outside of the draft tube is the most-efficient route of dissolving oxygen from the air into the water and will have less impact on operations compared to the other available routes. This route also would have the least disruption to existing systems and operations.

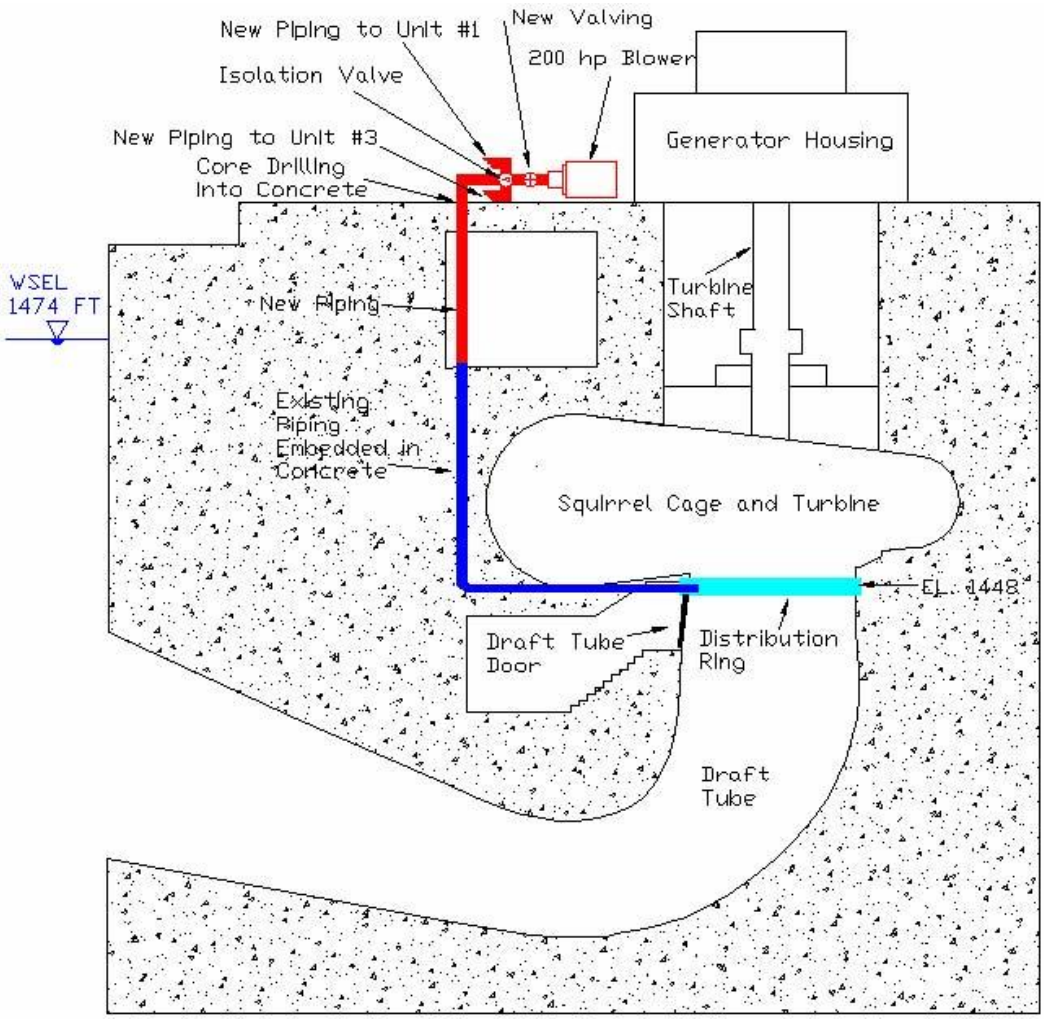


Figure 7.2-14. Conceptual diagram of Hells Canyon powerhouse blower system.

The generator deck on top of the powerhouse and outside the plant is likely to be the best place to locate the blower due to noise and space concerns (Figure 7.2-14). Installing the blower on the generator deck outside the plant will require core drilling into the concrete and new piping to connect the blower to the existing piping (Figure 7.2-14). Additional valving, connector Ts, piping, and automation systems would be needed to connect each of the 3 units to 1 common blower. This configuration would allow the use of 1 blower with any of the 3 units, but could only be used on 1 unit at a time.

7.2.2.1.2. Blower Sizing

The blower must be sized to supply enough air-flow volume into the turbine to provide the required DO benefit. TDG must also be considered because it is possible that the TDG limit of 110% in the outflows could be exceeded if large amounts of air were used. The blower must also overcome energy losses that occur in the piping and distribution ring, as well as overcome water back-pressures in the draft tube.

The distribution ring is submerged below the tailwater elevation; therefore, the blower must overcome the back-pressure from the tailwater onto the distribution ring. During most flow conditions, the tailwater at Hells Canyon varies between 1,464 and 1,486 ft msl. The majority of the time, tailwater is below 1,474 ft msl during the lower flow periods of the late summer and fall. With a tailwater elevation of 1,474 ft msl, the distribution ring is roughly 26 feet submerged, which corresponds to a pressure at the distribution ring of approximately 12pounds per square inch (psi). The pressure losses from the piping are estimated to be approximately 2 psi.

The total pressure that the blower must overcome is approximately 14 psi (submergence plus piping losses). This pressure is at the upper limits of the typical capabilities of blowers. Therefore, a high-volume, screw-type compressor is recommended for this application. This system would consist of a motor (approximately 200 horsepower [hp]) and compressor in a weatherproof housing, variable frequency drive, after-air cooler, servomechanism-actuated isolation valves, pilot operating valve, and silencers. The unit itself would be approximately 8 feet long by 12 feet wide and would reside on the generator housing deck near the existing piping header. Isolation valves would be required to make this system accessible to each of the 3 turbines (Figure 7.2-14). Power is available at the plant for a 200-hp motor, but it would be necessary to make some modifications to the circuit breaker system and add a switchgear.

There are a number of variables that will control the overall DO benefit and corresponding TDG concentrations. These variables include the total plant water-flow rate, individual unit water-flow rates, tailrace elevations, water temperatures, existing DO concentrations, existing TDG concentrations, blower air-flow rates, and the size of air bubbles emitted from the distribution ring. Changes in any of these variables will affect the amount of DO benefit.

IPC has developed a numerical model that incorporates the above variables to estimate a resultant DO benefit and TDG concentration (Table 7.2-4, Exhibit 7.2-2). Blower size (in terms of maximum air-flow rate) needed to provide the 1,500 tons/year was estimated by modeling various air-flow rates. After each run, the results were reviewed and the maximum blower air-flow rate was adjusted until the blower provided the desired 1,500 tons of DO benefit. Through the modeling, it was determined that a blower delivering an air-flow rate of 2,000 scfm could provide the required DO benefit with an additional safety factor of 150 tons (Table 7.2-5). The resultant DO concentration increase averaged 0.4 mg/L, and it was unlikely that the blower system would cause the TDG to exceed the 110% criteria (Figure 7.2-15).

Table 7.2-4. Summary of variables used for modeling Hells Canyon powerhouse blower system.

Variable	Assumption
TOTAL Hells Canyon powerhouse flow rate	Actual measured Hells Canyon outflows for a low-water year (2002).
INDIVIDUAL Hells Canyon unit flow rates	A reference table was included in the model to provide each unit's flow, given the total powerhouse flow rate. The unit flow specified to optimize the overall efficiency of the plant.
Tailwater elevation	Calculated from the total powerhouse flow rate using a known flow–tailwater elevation curve.
Outflowing DO concentrations (before using the blowers)	CE-QUAL-W2 model output for the low-water year.
Inflowing Temperatures (before using the blowers)	CE-QUAL-W2 model output for the low-water year.
Inflowing TDG concentrations (before using the blowers)	The existing TDG concentrations in the summer and fall are somewhat unknown. For this analysis, the TDG in was assumed to be TDGin = 80% + 20% * (DOin/DOsat); these are the partial pressures of nitrogen plus oxygen in the atmosphere. Using this equation assumes that the water is fully saturated with nitrogen.
Saturated DO concentration	DOsat = (Exp(7.7117–1.31403 * (Log(Temperature + 45.93))) * 0.94)
Outflow TDG (output variable)	Estimated using the above assumptions as inputs into the bubble model detailed in Exhibit 7.2-2.
Outflow DO (output variable)	Estimated using the above assumptions as inputs into the bubble model detailed in Exhibit 7.2-2.
Bubble Diameter	Assumed as 5 mm.

Table 7.2-5. Simulated dissolved oxygen (DO) tons added with operation of a 2,000 standard cubic feet per minute (scfm) blower system at the Hells Canyon powerhouse from July through November.

Month	DO Added (Tons)
July	356
August	319
September	305
October	339
November	335
Total	1,654

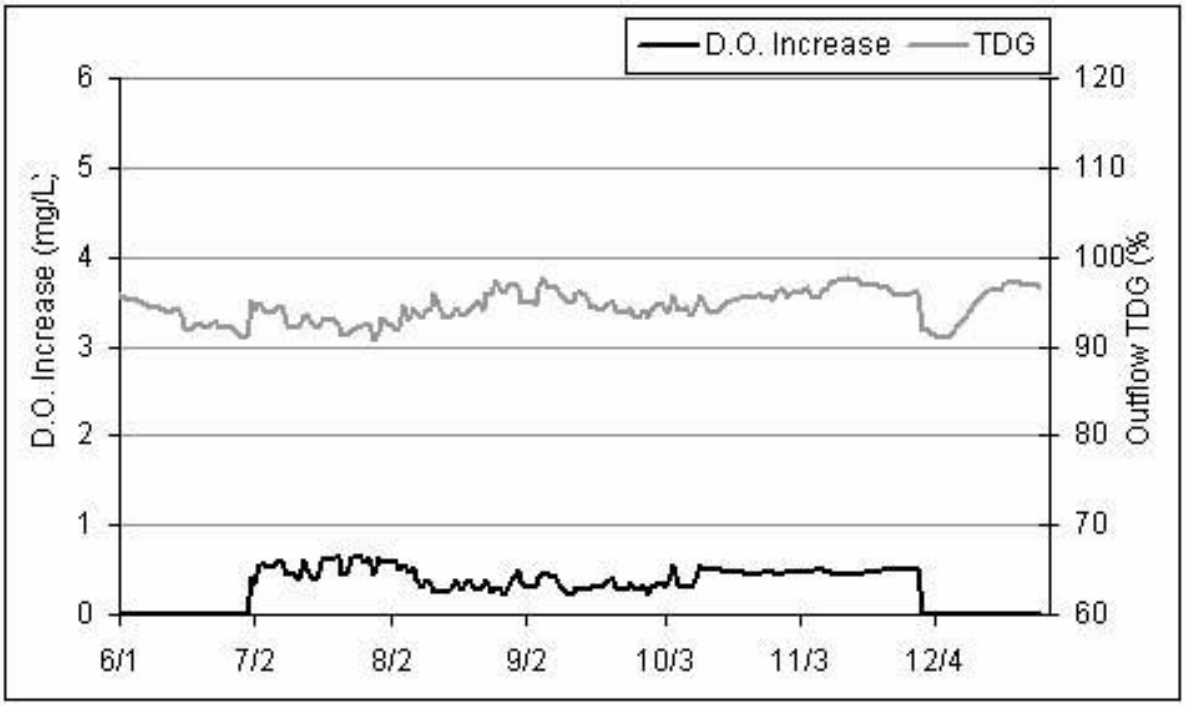


Figure 7.2-15. Simulated dissolved oxygen (DO) increase in milligrams per liter (mg/L) and percent (%) total dissolved gases (TDG) concentrations resulting from proposed Hells Canyon powerhouse blower operation for June through December.

7.2.2.2. Conceptual Operational Plan

A conceptual operational timeframe is proposed to address periods of DO deficits from criteria while optimizing the increase in DO and minimizing TDG increases. The conceptual timeframe for blower operation addresses 4 primary considerations relative to deficits from criteria.

1. The period when deficits from criteria are anticipated to occur following full upstream SR-HC TMDL implementation.

2. The period when IPC's contribution to the deficits occurs. The level of aeration must be sufficient to provide reasonable assurance that the maximum appropriate HCC DO responsibility of 637 tons/year is being addressed.

3. The period when deficits currently occur.

4. Simulated increase in DO concentrations and TDG levels.

Modeling showed that, following full upstream SR-HC TMDL implementation, deficits may begin in August and continue through November (Figure 6.2-19). Modeling also showed that the period when the appropriate HCC responsibility for the deficits may begin is in September and continue through the end of October (Figure 6.2-20). Analysis of measured data in Hells Canyon outflow from 1991 to 2005 showed that daily average DO typically drops below 8 mg/L in June, below 6 mg/L in July, and remained below criteria through the end of the year (Figure 6.2-2).

The longer the timeframe for addition of the 1,500 tons, the smaller the actual DO concentration and TDG increases. Alternatively, the shorter the timeframe, the larger the actual DO and TDG increases. These considerations must be weighed along with the various periods during which deficits occur. Therefore, IPC proposes beginning blower operation on July 1 and continuing operation to the end of November. Although DO levels may be below 8 mg/L on July 1, this start date reserves a portion of the 1,500 tons to provide for larger DO increases through the rest of the year. An example of the tons of DO added with this operation (Table 7.2-5, Figure 7.2-15) shows that the maximum appropriate HCC responsibility (637 tons) would be met during September and October, and the majority of the 1,500 tons would be added during the anticipated SR-HC TMDL deficit period. It is important to note that if the blower operation began strictly when the anticipated SR-HC TMDL deficit period begins (August), DO concentrations may have already decreased to near 4 mg/L (Figure 6.2-2). With this conceptual operational plan, the 1,500 tons would be applied during low DO periods of the downstream salmonid-rearing and salmonid-spawning periods.

7.2.2.3. Additional Study

The blower design and conceptual operational plan developed should be sufficient to supply the proposed DO benefit without exceeding the 110% TDG limit. The numerical model that was used in this analysis is based on both theoretical and analytical equations and is the best method available to estimate the overall DO benefit. However, the model has not been optimized against actual aeration data at the Hells Canyon powerhouse because the aeration system does not yet exist. Therefore, there are some inherent uncertainties in the parameter settings and DO and TDG increases.

There is also some uncertainty as to how the addition of air into the draft tube will affect operation of the turbine. Water-flow patterns in the turbine are changed with the introduction of air. Cavitation is typically reduced with the introduction of air but cavitation damage patterns will likely change and cannot be predicted in advance. It is possible that cavitation damage could increase as a result of using blowers that might be undesirable and affect the limits at which air can be introduced into the turbine.

To address the uncertainties, IPC proposes to implement a pilot testing program where a blower would be rented for a finite period of time and tests would be completed with the blower in operation. This testing would ensure that DO objectives can be met, the 110% TDG limit is not exceeded, and cavitation patterns are acceptable. Also, based on results from the pilot testing, some minor enhancements to the blower design might be required to improve the system's performance. Specific objectives of the pilot testing would include:

- Collecting data needed to optimize the bubble model;
- Monitoring and confirming TDG levels to remain below 110% with blower operation; and
- Using an optimized model to develop final blower design and timeframe to result in adding 1,500 tons/year without exceeding 110% TDG.

7.2.3. Turbine Aeration at Brownlee Dam

A blower system at the Hells Canyon powerhouse is proposed at this time. However, additional information may be developed related to benefits, feasibility, or cost effectiveness of the proposed measures that may indicate installation of a turbine aeration system at Brownlee Dam is preferable to Hells Canyon powerhouse. Potential installation and operation of an HPS for temperature reductions at Brownlee will affect outflow DO and require re-evaluation of preferred measures to address DO concerns. For these reasons, IPC continues to evaluate turbine aeration measures at the Brownlee powerhouse.

7.2.3.1. Description

Forced air and aerating runners are being evaluated to increase Brownlee outflow DO by introducing air into the draft tube. Forced air uses compressors or blowers (air compressors are used in high-pressure applications and blowers are used in lower pressure applications) to force air into the draft tube, either through passages in the turbine or the draft-tube wall. The blowers are operated when the turbines are running. Oxygen from the air is dissolved into the water and increases DO in the turbine discharges. Oxygen transfer is obtained in the turbulent flow of the draft tube and as the bubbles rise to the surface in the tailrace. However, as air is dissolved into the water, both nitrogen and oxygen are dissolved and TDG pressures are increased. The configuration of the Brownlee powerhouse would allow aeration using blowers for Units 1−4 and Unit 5.

Aerating runners are specifically designed to add air into the draft tube using air passages that lead to the trailing edge of the runner. The operating principles are very similar to forced-air injection except that the runners allow for passive-air introduction without the need for blowers. The efficiency losses are smaller than the blowers, and there is no need for a blower motor or associated power usage. Therefore, the operational costs of aerating runners can be much less than forced-air injection. As with blower systems, there is potential to elevate TDG with passive-air introduction using aerating runners. Because of the TDG limitation, blowers and aerating runners will have nearly the same potential to increase DO. The configuration of Units 1–4 at the Brownlee powerhouse would allow aerating runner installation.

Blowers and aerating runners are established technologies in the United States. IPC currently uses blowers at the American Falls and Cascade power plants in the summer as a method of increasing the outflow DO. The American Falls plant has three 250-hp blowers that can provide 6,000 scfm of air each. The Cascade plant has four 150-hp blowers. The blowers provide noticeable DO increases when they are in operation. Forced air is also currently being used at 2 TVA projects: Tims Ford and Nottely. Voith Siemens Hydro’s research and development efforts have successfully developed and evaluated a variety of designs and methods for aeration using aerating runners. Voith Siemens Hydro’s aerating runner designs are currently in operation at TVA’s Norris Dam, Duke Power’s Wateree plant, and the USACE’s J. Strom Thurmond plant, with additional units being installed at TVA’s Boone and Exelon’s Conowingo plants.

7.2.3.2. Preliminary Evaluation

There are a number of variables that will control the overall DO benefit and corresponding TDG levels from turbine aeration at Brownlee. These variables include the total plant

water-flow rate, individual unit water-flow rates, tailrace elevations, water temperatures, existing DO concentrations, existing TDG concentrations, blower air-flow rates, and the size of air bubbles emitted. IPC has developed a numerical model (Exhibit 7.2-2) that incorporates the above variables to evaluate the ability of blower and aerating runner systems at Brownlee to address the DO target of 1,500 tons/year downstream of Hells Canyon Dam. CE-QUAL-W2 model applications were used to simulate DO dynamics in Oxbow and Hells Canyon reservoirs, following Brownlee turbine aeration, and their resulting effect on Hells Canyon outflow DO.

Preliminary evaluations indicate that various combinations of turbine aeration measures at Brownlee are feasible to meet the 1,500 tons/year DO target below Hells Canyon Dam. CE-QUAL-W2 modeling indicates that, to meet the 1,500 tons/year, additional DO may need to be added at Brownlee Dam to account for processes in Oxbow and Hells Canyon Reservoirs. Preliminary evaluations indicate that an addition of 1,500 tons/year is possible with turbine aeration at Brownlee Dam but requires further evaluation.

Measures at Brownlee Dam also have potential to provide additional benefits in Oxbow and Hells Canyon Reservoirs. However, measures at Brownlee are more complex to evaluate due to DO dynamics in Oxbow and Hells Canyon and more complicated turbine operations at Brownlee.

Preliminary modeling indicates that the targets for DO augmentation can be addressed by turbine aeration at Brownlee Dam. These measures have not been investigated to the same level of detail as the blower system at the Hells Canyon powerhouse. Should turbine aeration at Brownlee Dam become the preferred option in the future, IPC will conduct additional studies to evaluate whether such a system at Brownlee Dam would provide reasonable assurance that the targets below Hells Canyon Dam would be met. Pending ODEQ and IDEQ approval, measures at Brownlee would be implemented within a specified timeframe following license issuance.

7.2.4. Destratification Measure for Oxbow Bypass

IPC proposes to install and operate a destratification system in the Oxbow Bypass. This system would be located in the deep pool just upstream of the Indian Creek confluence. Thermal stratification in the deep pool causes anoxic conditions to develop in the deeper water. Mixing to prevent anoxic conditions will provide improved habitat for aquatic life. The goal of this measure is to introduce sufficient mixing using diffused air bubbles to prevent thermal stratification and development of anoxic conditions in the deep pool.

7.2.4.1. Description

Destratification systems are common throughout the United States, and several different manufacturers offer various configurations and models. At least 2 manufacturers offer designs that are all-inclusive, self-contained mixing units (water is mixed using a propeller in the water column) that are powered by wind and/or solar energy. These units are anchored in the water over the location to be mixed. Despite the ease of use with these types of units, IPC has determined that the high flows through the bypass during periodic spill events will likely damage these units if they are not removed from the water. The units are large, heavy, and awkward to move, which makes temporary removal difficult.

Several manufacturers offer systems that use an air compressor stationed on the shore that pumps air through a pipe to bubble diffusers that are anchored on the channel bottom. As the bubbles rise through the water column, they entrain water and lift it to a higher elevation. These types of systems are more suitable for the deep pool because they would be somewhat resistant to high-spill flows. Also, if the piping or diffusers are damaged during spill, replacement effort and expense would be lower.

7.2.4.1.1. Proposed Design

IPC contracted with Mobley, Engineering, Inc., to determine the optimal flow rate needed to keep the pool mixed throughout the summer. Knowing the flow rate helps determine the size of compressor and diffuser required. Based on an estimation of the deep pool volume, a flow rate of approximately 6 cfs is needed to exchange all of the water in the pool once every 8 hours. With this flow rate, all of the water volume within the pool would be exchanged approximately 3 times a day. It is believed that this will be a sufficient flow rate to prevent thermal stratification.

IPC has contacted the manufacturer (Vertex Water Features) to approximately install a destratification system in the deep pool. This manufacturer offers an off-the-shelf compressor, sinking pipe, and diffuser that is suitable to this application (Figure 7.2-16). The compressor is a 1/3-hp piston-type pump that can run continuously without oil. This manufacturer also provides a cabinet for the compressor that will shield the compressor from the elements and help reduce noise. The pipe is 0.55-inch flexible polyvinyl chloride (PVC) composite that sinks in water. The diffuser has 2 self-cleaning, 9-inch-diameter flexible-membrane diffusers that produce millions of 500–3,000 micron bubbles.

7.2.4.1.1.1. Location

The pool is located in a section of the Oxbow Bypass that is not accessible by road (Figure 7.2-17). The compressor will be placed in the provided protective cabinet above the high-water line at the closest location to the deep hole that is accessible from the road (Figure 7.2-18). The diffuser will be anchored to the bottom of the river channel in the deepest part of the pool. Approximately 1,400 feet of pipe will be needed to connect the compressor to the diffuser; the piping will run along the shore for approximately 500 feet and will be angled into the river channel until it reaches the diffuser (Figure 7.2-18).

Vertex Water Features

Lake Aeration Systems & Floating Fountains

With Vertex MicronBubble™ Technology

B O T T O M A E R A T I O N

AIR 2™

The Vertex Air 2™ is a super-efficient, affordable and safe system for circulating up to 8,200 GPM. In a typical lake with 8 foot depths, an Air 2™ can aerate approximately 4 acres depending on dissolved oxygen demand and other factors. A 1/3 hp piston compressor, housed in our rustproof outdoor cabinet, feeds two bottom mounted CoActive AirStations™ each utilizing Vertex's MicronBubble™ technology. The majority of bubbles are only 500 to 1000 microns in diameter. As bubble size decreases, oxygen transfer rates increase dramatically. The rising force of millions of bubbles circulates the entire water column, entraining bottom water up to the surface allowing vital oxygen to be absorbed. Oxygen levels are increased and kept constant throughout the entire lake, preventing drastic O_2 swings that can lead to fish-kills. With no electricity in the water, Vertex's aeration systems are safe for any type of water recreation. Our self-cleaning CoActive AirStations™ allow for years of high performance, reliability, low maintenance and are covered under our five-year warranty.

FEATURES

CoACTIVE AIRSTATION™

- Four 9" flexible membrane discs with MicronBubble™ technology
- Self-cleaning, low maintenance, & five-year warranty
- Rugged EPDM construction
- Two vacuum formed & sonic welded HDPE base units
- Hollow design for sand ballast
- Lipped edge prevents sinking into soft bottom sediments

BROOKWOOD™ COMPRESSOR

- U.L. listed
- 1/3 hp for exceptionally low monthly electrical cost
- Thermal overload protection
- 115 volt operation
- One-year warranty

QUIETAIR™ CABINET

- "Class A" GFCI protection on all circuits
- Powder coated for durable, attractive finish
- Heavy duty cooling fan rated at 290 CFM
- Rustproof aluminum construction
- Easy plug-in connection to waterside electrical service
- Equipped with barrel lock for increased security

BOTTOMLINE™ TUBING

- Self-weighted for easy installation
- Heavy duty wall thickness (0.24") for durability
- Available in 100' increments
- Remains flexible in cold temperatures

BENEFITS TO THE LAKE

- Air2™ systems circulate the entire water column — up to 8,200 gallons per minute depending on diffuser depth
- Increased dissolved oxygen
- Stops oxygen related fish kills by raising entire water column oxygen levels
- Reduces nutrient levels and associated algae growth
- Ends thermal stratification
- Improves fisheries by expanding oxygenated habitat
- Reduces aquatic midge and mosquito insect hatches
- Eliminates foul odors from undesirable dissolved gases
- SAFE — no electricity in the water and full GFCI protection on all circuits

Figure 7.2-16. Description of the compressor, piping, and diffuser system offered by Vertex Water Features.

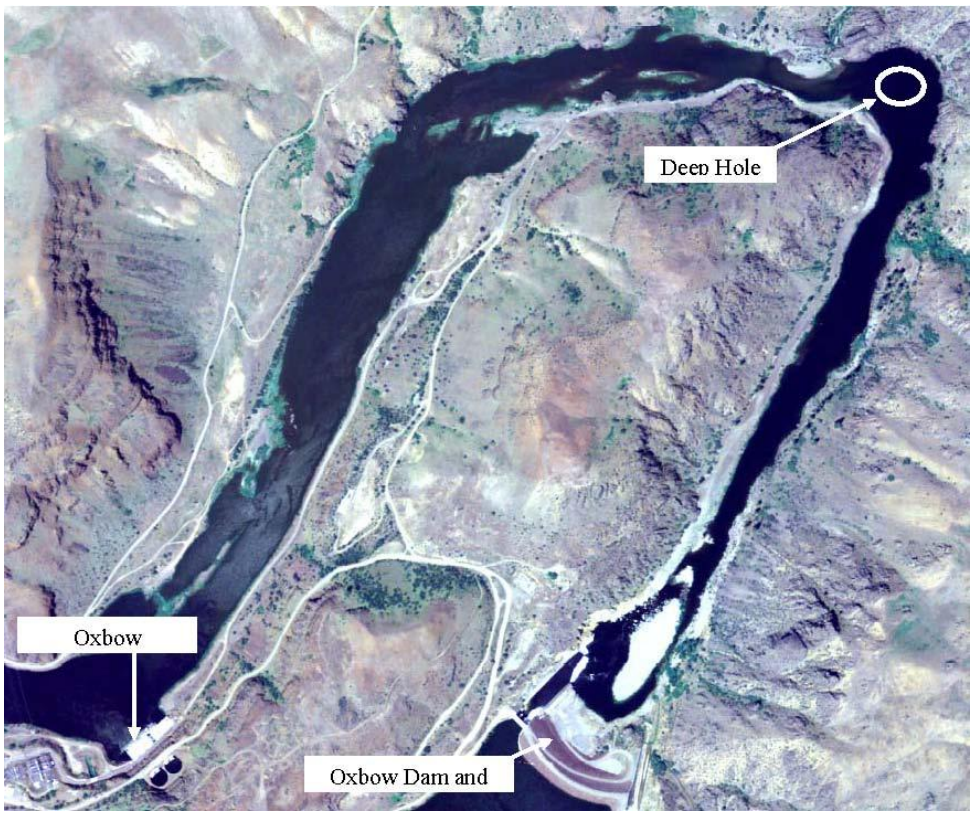


Figure 7.2-17. Aerial photograph and description of the Oxbow Bypass Reach and deep pool.

Figure 7.2-18. Site layout of the compressor, piping, and diffuser system.

7.2.4.1.1.2. Power Source

The compressor site is located approximately 1.2 miles from the nearest electrical power source; therefore, supplying a constant, reliable power source to the compressor is problematic. IPC has considered a number of alternatives to provide power to the compressor, including wind power, solar power, a gas-powered generator, and building a new electrical powerline. Because the Oxbow Bypass is located in the bottom of a steep canyon, it is considered to be sheltered from wind. Therefore, wind was not considered to be a reliable power source. The bypass is also sheltered from the sun much of the day, making solar power less effective. Gas-powered generators can require a great deal of maintenance so they are also considered to be undesirable.

IPC has determined that extending an electrical powerline directly to the site is the best method for providing power to the compressor. IPC will construct a new, 1.2-mile-long, overhead powerline that will be paired off from an existing power line 1.2 miles from the site.

7.2.4.2. Operational Plan

The destratification system would be operated during the summer and fall months when thermal stratification occurs, and flows through the Oxbow Bypass are at the 100 cfs minimum. Specifically, the system would run from May through October when flows are at the minimum 100 cfs.

7.2.5. DO Reasonable Assurance

IPC will implement measures to meet the SR-HC TMDL DO load allocation for Brownlee Reservoir, address the appropriate HCC responsibility for the DO deficit below Hells Canyon Dam, and address IPC's responsibility for low DO in the deep Oxbow Bypass pool. IPC will meet its load allocation established in the SR-HC TMDL for the Brownlee Reservoir through an in-reservoir aeration system or upstream watershed phosphorus trading. Analysis and modeling have been provided to demonstrate that in-reservoir aeration measures can meet the load allocation if watershed phosphorus trading isunfeasible.

Substantial DO improvements downstream of Hells Canyon Dam are anticipated with full implementation of the SR-HC TMDL. However, IPC's analysis showed that the HCC may still contribute to DO deficits relative to salmonid-rearing and salmonid-spawning water column criteria. IPC's analysis (presented in Section 6.2.3.3.) showed the appropriate HCC responsibility for DO below the HCC to be a maximum of 637 tons/year. However, IPC will supply 1,500 tons/year of DO below the Hells Canyon Dam through a turbine aeration system to address the appropriate HCC responsibility and provide additional benefit. For this application, IPC proposes that the blower system be installed at Hells Canyon powerhouse, but may propose relocation to the Brownlee powerhouse if substantial benefits may be realized and if feasible. This application includes a proposed design, conceptual annual operation plan, and an implementation schedule to provide reasonable assurance.

An aeration system is proposed for the Oxbow Bypass pool. This application includes a proposed design, annual operation plan, and an implementation schedule to provide reasonable assurance.

7.2.6. DO Monitoring Plan

Upon acceptance of IPC'sCWA § 401 application, IPC will work with ODEQ and IDEQ to develop a DO monitoring plan. The plan will include a specific methodology, including equipment and location, for determining compliance with IPC's DO load allocation identified in the SR–HC TMDL and 1,500 tons/year of DO downstream of Hells Canyon Dam. The goal of the monitoring plan will be to document that IPC's actions have resulted in injection of 1,125 tons/year of DO to Brownlee Reservoir, or removal of an equivalent phosphorus load upstream and injection of 1,500 tons/year of DO downstream of the HCC. IPC will monitor TDG levels in the releases from Hells Canyon turbines whenever aeration is occurring to ensure that the action is not resulting in TDG levels that exceed the 110% target. IPC will also monitor the deep pool proposed for destratification in the Oxbow Bypass to ensure that DO levels in the water column remain mixed.

7.2.7. DO Implementation Schedule

IPC proposed measures to meet the SR-HC TMDL DO load allocation for Brownlee Reservoir, address IPC's responsibility for low DO in the deep Oxbow Bypass pool, and address the appropriate HCC responsibility for the DO deficit below Hells Canyon Dam. IPC proposes the following schedule for implementation of DO measures to begin following issuance of the new HCC license from FERC.

SR-HC TMDL DO load allocation for Brownlee Reservoir:

- A willing participant for upstream phosphorus trade to meet the SR-HC TMDL allocation will be confirmed within 1 year of new license issuance.

- If a willing participant or participants are confirmed, details of the trade will then be developed and implementation of an upstream phosphorus trade or trades will begin. The upstream phosphorus trade will be implemented within 2–4 years of license issuance.

- If a willing participant for upstream phosphorus trading is not confirmed within 1 year, implementation of in-reservoir aeration to meet the SR-HC TMDL allocation will then begin.

    - Final design for in-reservoir aeration will be completed within 3 years after license issuance.

    - Upon completion of the final design, construction will occur in the fourth year after license issuance. IPC anticipates that reservoir aeration will be installed and fully functional within5 years of license issuance. This schedule assumes that permits to install the reservoir aeration system could be obtained within a 1-year period between final design and installation. Permitting delays could result in installation delays. Inflow conditions and planned reservoir operations may influence the construction schedule. Construction will be coordinated with reservoir operations and forecasted inflow predictions.

- IPC proposes an adaptive management approach to determine the location of the diffuser system. The system will be optimally located under current conditions. As upstream water quality improves, however, the system may need to be relocated further downstream. Because of the practical difficulties, relocation would be warranted only if the evidence is clear that significant environmental benefits would result.

DO in the deep Oxbow Bypass pool:

- Final design and permitting process for the Oxbow Bypass destratification system will begin in the first year following new license issuance.

- Installation of the Oxbow Bypass deep-pool destratification system will be completed and operation will begin within 2 years after new license issuance, provided that the required permits and approvals can be obtained in this time period.

DO augmentation below Hells Canyon Dam:

- Turbine aeration at Brownlee Dam or the blower system at Hells Canyon Dam will be identified as the preferred option for downstream DO augmentation within 120 days of new license issuance.

- If the preferred option is turbine aeration at Brownlee Dam, then the specific timeframe for installation will also be known within 120 days of new license issuance. Pending IDEQ and ODEQ approval of this measure and timeframe, the process of implementing turbine aeration at Brownlee Dam will begin. If turbine aeration at Brownlee Dam is not approved, then implementation of blowers at Hells Canyon Dam will begin.

- If the preferred option for downstream DO augmentation is turbine aeration at Hells Canyon Dam, or Brownlee Dam measures are not approved, then additional study needed for the Hells Canyon blower system (see Section 7.2.2.3.) would be completed within 1 year of the decision and approval process. Installation of the Hells Canyon blower system would be completed and operation would begin within2 years of the decision and approval process.

7.3. TDG Adaptive Management Plan

The TDG adaptive management plan includes PME measures that research shows to be the best available technologies to reduce TDG levels. These include: 1) continued preferential spilling of water through the Brownlee Dam upper spillgates as an early implementation measure, 2) evaluation of TDG reduction structures at Oxbow Dam as an early implementation measure, 3) installation of Hells Canyon Dam sluiceway flow deflectors, 4) installation of Brownlee Dam spillway flow deflectors, and 5) installation of a spillway flow deflector at Oxbow Dam.

IPC will monitor TDG levels at the edge of the aerated zone below spillways and at other locations throughout the HCC and Snake River downstream, as needed, for PME measure

effectiveness and compliance relative to the criterion. In addition, IPC will monitor fish communities to evaluate effects of TDG levels, particularly for evidence of gas-bubble trauma in individual fish. If monitoring indicates that the PME measures fail to meet the TDG criterion or protect aquatic life, IPC will adaptively manage TDG in the HCC through evaluation and implementation of additional PME measures designed to further reduce TDG levels. IPC concurs with the IDEQ and ODEQ (2004) that the TDG criterion is conservative for the protection of aquatic life and, therefore, the load allocation has an implicit margin of safety. Thus, results of fish community monitoring will provide information useful in evaluation and adaptive management of TDG.

7.3.1. TDG Proposed Measures

7.3.1.1. Preferential Brownlee Dam Upper Gate Spill

IPC proposes to continue the current practice of preferentially spilling water from the Brownlee Dam upper spillgates. IPC proposes this PME measure as part of early implementation of § 401 certification.

7.3.1.2. Oxbow Dam Spillway Flow Deflector

IPC has evaluated TDG reduction structures at Oxbow Dam. A report describing the physical model developed by Northwest Hydraulic Consultants (NHC) and the testing conducted to evaluate the feasibility of deflector designs is being provided as supporting documentation to this application (NHC 2007). The evaluation included the construction of a physical model of the spillway and the use of the model to provide a conceptual design optimized to meet the 110% of saturation criterion at the 7Q10 average flood flow.

7.3.1.3. Hells Canyon Dam Sluiceway Flow Deflectors

7.3.1.3.1. Proposed Action

IPC proposes to install Hells Canyon Dam sluiceway flow deflectors to meet the SR-HC TMDL TDG load allocation at Hells Canyon Dam. Final design, quantitatively optimized to the 7Q10 average flood flow, will be completed within 1 year following issuance of the new FERC HCC license. Construction and installation is expected to occur consistent with the schedule in the license. This schedule would incorporate FERC's required design review process and permitting requirements. It is expected these requirements could be completed within 2 years of new license issuance with construction and installation occurring the following year.

7.3.1.3.2. Proposed Design

Iowa Institute of Hydraulic Research[11] (IIHR), under contract with IPC, investigated the applicability of flow deflectors at Hells Canyon Dam to reduce TDG levels. The distinctive geometry of Hells Canyon Dam presents challenges in developing flow deflectors because of the existing upper-nappe deflectors, relatively large head, deep and short stilling basin, and high unit flow (IIHR 2000). Specifically, flows originating from the upper spillway gates are deflected

[11] Iowa Institute of Hydraulic Research recently changed its name. Its current name is Iowa Institute of Hydraulic Research—Hydroscience and Engineering.

away from the concrete spillway surface by the nappe deflectors, and the flow becomes a nearly unattached, free-falling jet. Very large deflectors for the upper spillway gates would be needed because the falling jet would over-shoot smaller deflectors. When large deflectors were tested in a physical model (Figures 7.3-1 and 7.3-2), the deflected flows impacted the riverbed downstream of the stilling basin, which could compromise dam safety during passage of large spillway flows.

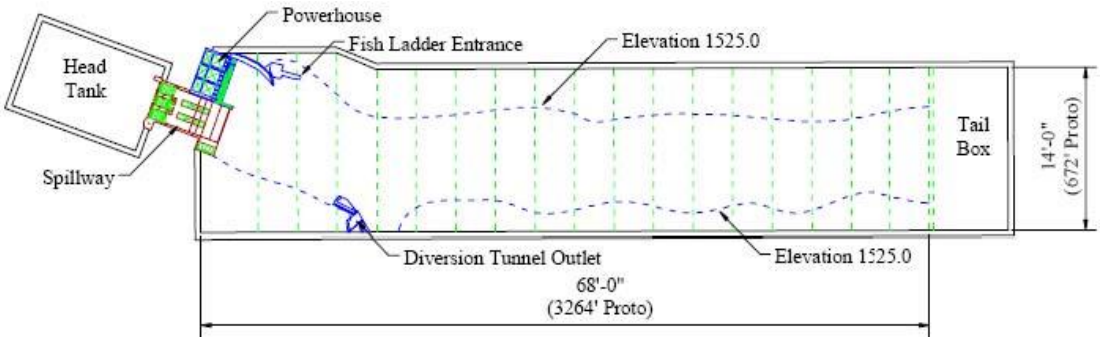


Figure 7.3-1. Plan view of 1:48-scale, 3-dimensional Hells Canyon Dam physical model.

Figure 7.3-2. Photograph of 1:48-scale, 3-dimensional Hells Canyon Dam physical model.

The unique geometry of Hells Canyon Dam favors implementation of flow deflectors in the 2 lower-level sluiceways. The concept of flow-deflector design is to favor a flow regime that minimizes air entrainment at depth (IIHR 2000). As such, flow-deflector elevation is critical. The flow-deflector elevation was determined by analyzing tailwater curves for Snake River flow

at or below 60,000 cfs. This accounts for most of the flows recorded from 1968 through 2003 (Figure 6.3-8). The design must remain below the tailwater elevation to prevent vented surface or plunging flows from occurring, which tend to allow air bubbles to penetrate to depth, while remaining high enough to keep the performance within the surface-jet flow regime (Figure 7.3-3). The flow deflector design was qualitatively optimized using a 1:48-scale, three-dimensional physical model (Figure 7.3-2). The design consists of a 16.0-ft deflector at elevation 1,468.0 ft msl with a 5º lip angle (Figure 7.3-4). This design resulted in a surface jet up to total Snake River flow of 60,000 cfs. More detail on the Hells Canyon Dam sluiceway flow deflectors design is available in Technical Report E.2.2-4, which accompanied the *New License Application: Hells Canyon Hydroelectric Complex*.

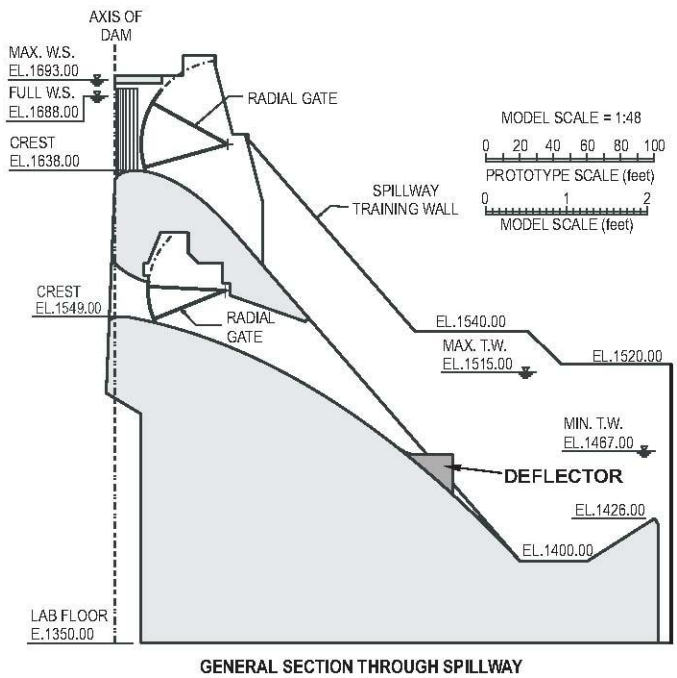


Figure 7.3-3. Sectional view of the Hells Canyon Dam model constructed by the Iowa Institute of Hydraulic Research (2000) showing the general location of sluiceway flow deflectors.

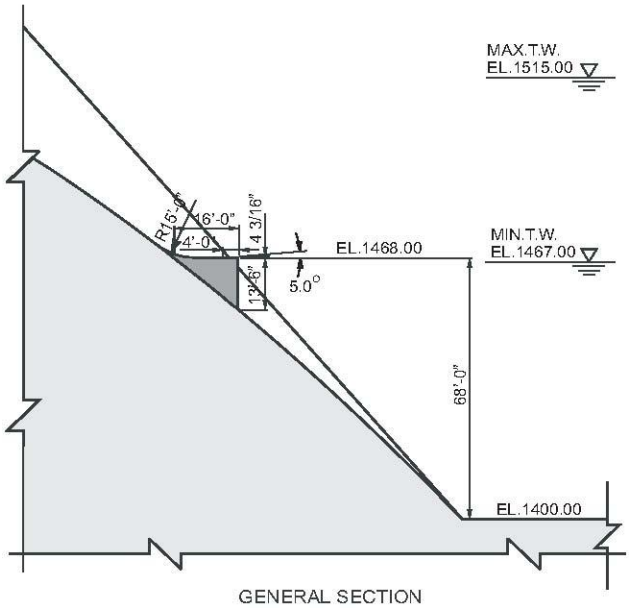


Figure 7.3-4. General view of the Hells Canyon Dam sluiceway flow deflector configuration developed by the Iowa Institute of Hydraulic Research (2000).

This design is qualitatively optimized to be effective at reducing TDG levels at almost all flows. The design was determined based on Snake River flow at or below 60,000 cfs. The 7Q10 average flood flow at Hells Canyon Dam is 71,498 cfs. Approximately 1% of flows are greater than 60,000 cfs and less than the 7Q10 average flood. There remains uncertainty on how sluiceway flow deflectors will perform across these flows. To address this uncertainty, IPC proposes to quantitatively optimize the final Hells Canyon Dam sluiceway flow deflector design to the 7Q10 average flood based on computations using a 3-dimensional finite element computational fluid dynamics (CFD) model. The model quantitatively evaluates TDG levels based on dam geometry, bathymetry, gas-bubble diffusivity, and fluid dynamics. Currently, IIHR has applied a CFD model to Wanapum Dam in Grant County, Washington. The model reasonably predicted TDG levels within 800 m of the spillway flow (Weber 2005). Application of a CFD model for the Hells Canyon Dam tailwater will provide additional reasonable assurance that the deflector design will perform optimally up to the 7Q10 average flood, as well as demonstrate its applicability to projects in the HCC.

7.3.1.4. Brownlee Dam Spillway Flow Deflectors

7.3.1.4.1. Proposed Action

IPC proposes Brownlee Dam spillway flow deflectors to meet the SR-HC TMDL TDG load allocation at Brownlee Dam. Final design will be completed following construction and installation of the Hells Canyon Dam sluiceway flow deflectors. Construction and installation is expected to occur consistent with the schedule in the HCC FERC license. This schedule would incorporate FERC's required design review process and permitting requirements. It is expected these requirements could be completed within 1 year of final design, with construction and installation occurring the following year. It may be necessary to monitor effectiveness of the optimized Hells Canyon Dam sluiceway flow deflectors before developing a CFD model

to optimize the Brownlee Dam spillway flow defector final design. Until the deflectors are installed, IPC will preferentially spill from the Brownlee Dam upper gates as an early implementation PME measure.

7.3.1.4.2. Proposed Design

Similar to the Hells Canyon Dam deflectors, IIHR, under contract with IPC, investigated the applicability of flow deflectors at Brownlee Dam to reduce TDG levels (Exhibits 7.3-1 and 7.3-2). IPC identified, prior to physical modeling, a concern relative to downstream scour following installation of deflectors. This concern was not only for dam safety, but was also identified as having the potential to disrupt power distribution and public transportation. As such, the Brownlee Dam 1:48-scale, 3-dimensional model (Figures 7.3-5 and 7.3-6) included not only the spillway section of the dam but also the powerhouse units, training walls, earthen embankments, and 2,900 prototype feet of downstream tailrace bathymetry. The latter 2 elements were included to evaluate scour resulting from a geometric spillway change. While scaled laboratory model tests do not necessarily replicate field results, the comparison was useful in evaluating either a worsening or lessening of scour effects.

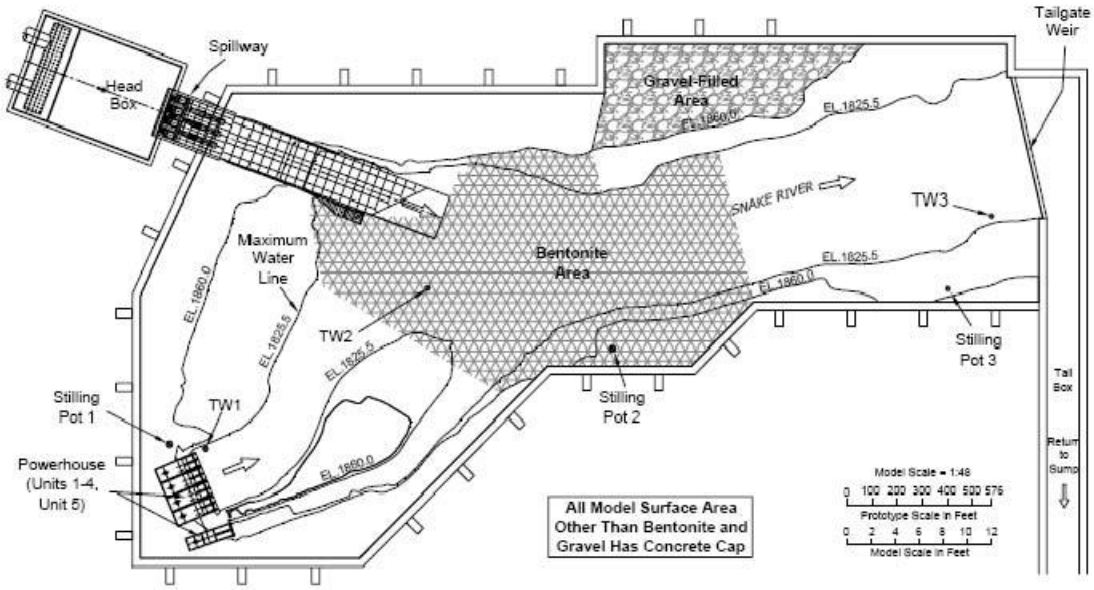


Figure 7.3-5. Plan view of 1:48-scale, 3-dimensional Brownlee Dam physical model (reproduced from Exhibit 7.3-2).

Figure 7.3-6. Photograph of 1:48-scale, 3-dimensional Brownlee Dam physical model.

Flow deflector elevation is also critical to the Brownlee Dam deflector design. The Brownlee Dam spillway flow-deflector elevation was determined by analyzing tailwater curves for the Snake River. The elevation was determined based on tailwater flow up to the 7Q10 average flood of 67,898 cfs. The qualitatively optimized Brownlee Dam spillway flow deflectors resulted in an observed skimming surface-jet flow regime. The flow-deflector design consists of an 18.0-ft-long deflector at elevation 1,800.0 ft msl (Figure 7.3-7). More detail on the design of Brownlee Dam spillway flow deflectors is available in Exhibit 7.3-1. Erosion tests were performed with and without the proposed deflector design affixed to the 3-dimensional model. Each test was run with 48 hours of continuous model operation at both the 7Q10 average flood and the probable maximum flood (PMF). No scour occurred anywhere in the erodible materials at the 7Q10 average flood (Exhibit 7.3-1). Significant scour was observed in the erodible materials downstream of the spillway, as well as the formation of gravel bars in the tailrace at the PMF, both with and without the proposed deflector design affixed to the model. The model indicates that erosion due to sustained PMF causes tremendous erosion downstream of the Brownlee Dam spillway with or without deflectors. During the PMF, the deflectors are overridden and the spillway jet resubmerges, dissipating energy in the stilling basin.
The deflector appeared to cause no significant difference in tailrace erosion and does not significantly affect scour downstream of the spillway at the PMF. More detail on erosion potential of Brownlee Dam spillway flow deflectors is available in Exhibit 7.3-2.

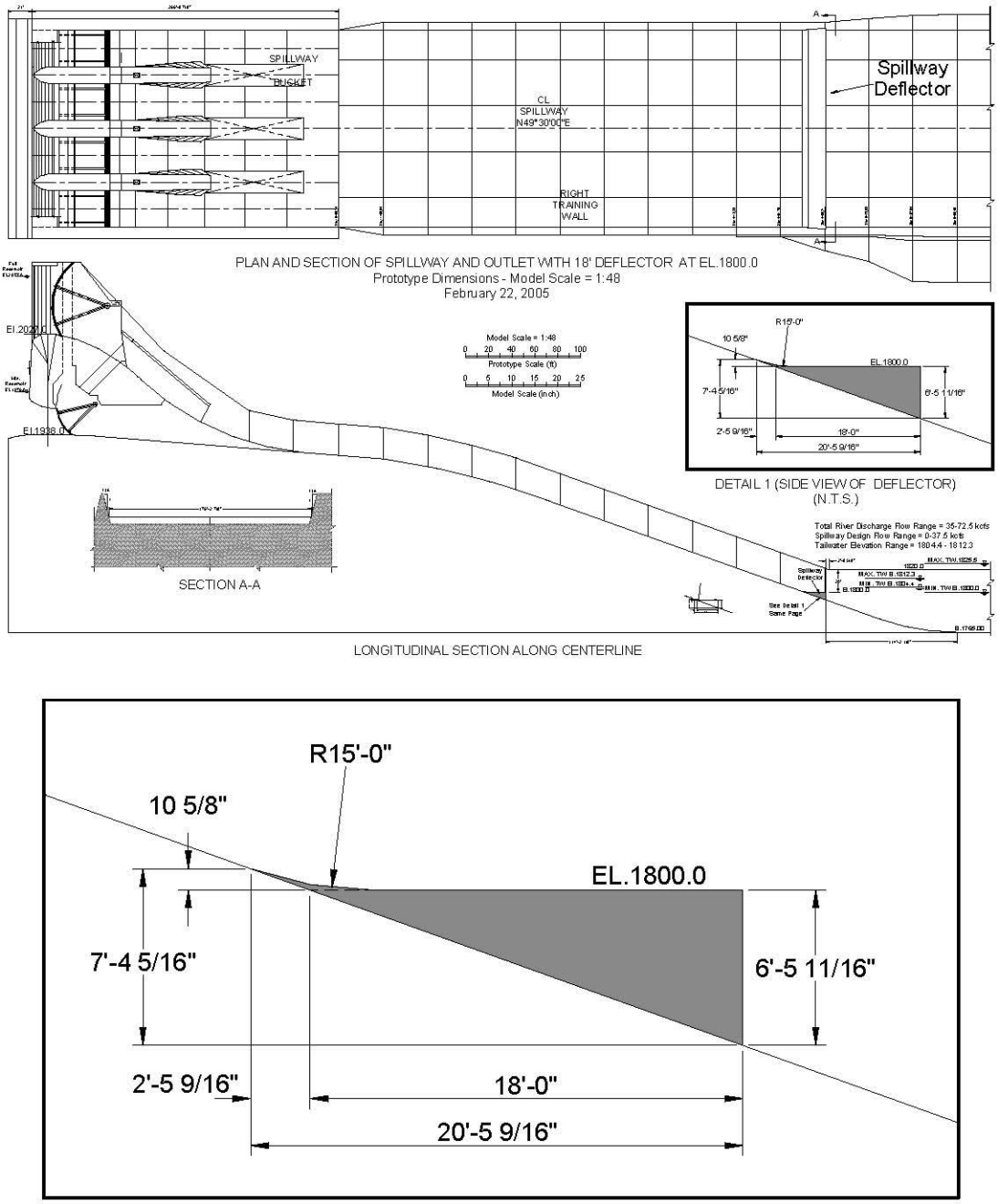


Figure 7.3-7. Plan and sectional view showing the general location of the Brownlee Dam spillway flow deflectors and a detailed sectional view drawing of the proposed design (reproduced from Exhibit 7.3-1).

This design was qualitatively optimized to be effective at reducing TDG levels at the 7Q10 average flood. IPC proposes the final Brownlee Dam spillway flow deflector design to be quantitatively optimized to the 7Q10 average flood, based on computations using a CFD model and information gained from applying a similar model to optimize deflector design at Hells Canyon Dam. Application of a CFD model to the Brownlee Dam spillway flow deflectors

design will provide additional reasonable assurance that the deflector design will perform optimally up to the 7Q10 average flood.

7.3.1.5. Oxbow Dam TDG Reduction Structures

The SR-HC TMDL identified Brownlee and Hells Canyon dams as the sources of elevated TDG in the HCC (IDEQ and ODEQ 2004). Since approval of the SR-HC TMDL, IPC has had the opportunity to collect new information that allowed evaluation of spill at Oxbow Dam independent of Brownlee Dam spill; that is, when Oxbow Reservoir forebay TDG levels were less than 110% of saturation. These data showed that when Oxbow Reservoir forebay was below 110% of saturation, spill at Oxbow Dam increased TDG levels above the criterion in the bypassed reach (Figure 6.3-4).

IPC evaluated TDG reduction structures at Oxbow Dam relative to the potential for meeting the SR-HC TMDL TDG load allocation at Oxbow Dam. Conceptual design for a spillway flow deflector was developed based on a physical model (NHC 2007). IPC proposes the final Oxbow Dam spillway flow deflector design will be quantitatively optimized to the 7Q10 average flood, based on computations using a CFD model and information gained from applying a similar model to optimize deflector design at Hells Canyon Dam. Application of a CFD model to the Oxbow Dam spillway flow deflector design will provide additional reasonable assurance that the deflector design will perform optimally up to the 7Q10 average flood. Final design can not be completed until Brownlee Dam spillway flow deflectors are installed and TDG levels downstream are monitored in order to more accurately understand the dynamics of the effects of Brownlee Dam on Oxbow Dam TDG levels. Construction and installation is expected to occur consistent with the schedule in the HCC FERC license. This schedule would incorporate FERC's required design-review process and permitting requirements.

7.3.2. TDG Adaptive Measures

IPC proposes preferential Brownlee Dam upper gate spill, Hells Canyon Dam sluiceway flow deflectors, Brownlee Dam spillway flow deflectors, and an Oxbow Dam spillway flow deflector as PME measures to address the SR-HC TMDL TDG load allocation. These are the best available technologies, but their performance cannot be definitively evaluated using models alone. Because performance of these measures must be predicted either qualitatively or quantitatively, IPC proposes monitoring their effectiveness, and an adaptive management approach to address any potential uncertainties.

IPC concurs with the IDEQ and ODEQ (2004) that the TDG criterion is conservative for the protection of aquatic life and, therefore, the load allocation has an implicit margin of safety. If monitoring during spill indicates that these PME measures fail to meet the TDG criterion or protect aquatic life, then IPC will adaptively manage TDG in the HCC through evaluation and implementation of additional PME measures designed to further reduce TDG levels. Biological monitoring of fish communities during spill will also be conducted to provide information for evaluation and adaptive management of TDG.

Several additional PME measures are available for investigation if the proposed PME measures fail to meet the TDG criterion or protect aquatic life. These include, but are not limited to,

the following. Any PME measure may not necessarily be a viable measure at a particular project due to site-specific characteristics.

- Modify the shape or location of the flow deflectors after installation to further optimize performance. A priori knowledge of deflector performance to attain the 110% of saturation criterion is difficult with exact certainty using modeling alone. Once the deflectors are installed, it may be feasible to further investigate their performance and determine if field modifications can be made toward improvement. Some possible modifications would include changing the angle of the deflector, increasing the deflector length, or slightly changing the deflector's elevation.

- Modify or extend the training walls. It may be feasible to extend training walls to better separate turbine and spill flows, thus reducing the volume of turbine flow that is entrained into the spill flow. This would reduce the overall volume of water that has elevated TDG levels.

    - Physical modeling of Brownlee Dam indicated that turbine flow overtopped the existing training wall and becomes entrained into the spillway during high spill flows (Exhibit 7.3-2). It would be possible to increase the height of this wall to preclude turbine flows from becoming entrained with the spill flows, thus improving the deflectors' effectiveness.

- Refurbish or add 1 or more units to allow for increased hydraulic capacity. Increasing the capacity would allow more flow to travel through the powerhouse instead of over the spillway, thus potentially reducing TDG levels but definitely reducing the volume of water with elevated TDG levels.

- Modify the stilling basin or spillway apron to reduce the depth bubbles plunge. It may be possible to modify the depth or shape of the stilling basin to reduce the depth that bubbles can plunge, thus reducing TDG levels. Some of the possible modifications may include adding concrete to the stilling basin to reduce the bottom depth, adding some type of underwater wig-walls or floors, or changing the shape of the apron lip to deflect flow upward.

- Build an off-gassing structure downstream of the spillway. Off-gassing structures typically are small weirs allowing for a short free-fall of water and are typically constructed across the width of the river channel. These structures create conditions for the turbulent exchange of gas between the water and the atmosphere. This allows supersaturated water with high TDG levels to off-gas.

- Construct a bypass conveyance to pass spill flows. Water could be passed through the conveyance instead of over the spillway, and TDG levels would be reduced or the volume of elevated TDG level water would be reduced.

7.3.3. TDG Reasonable Assurance

7.3.3.1. Preferential Brownlee Dam Upper Gate Spill

Spill test data were collected at Brownlee Dam during a single test conducted on June 4, 1998. The test was conducted while spilling water at 39,000 cfs, an amount that is greater than the 7Q10 average flood of 67,898 cfs when combined with the powerhouse flows. Analysis of these data indicated that TDG levels from Brownlee Dam upper gate spill were statistically lower (P = <0.001) when compared to TDG levels from lower gate spill. Figure 7.3-8 shows TDG levels downstream of Brownlee Dam averaged 114% of saturation while spilling from the upper gates, and increased during transition to spilling through the lower gates, resulting in an average TDG level of approximately 128% of saturation (Myers and Parkinson 2003).

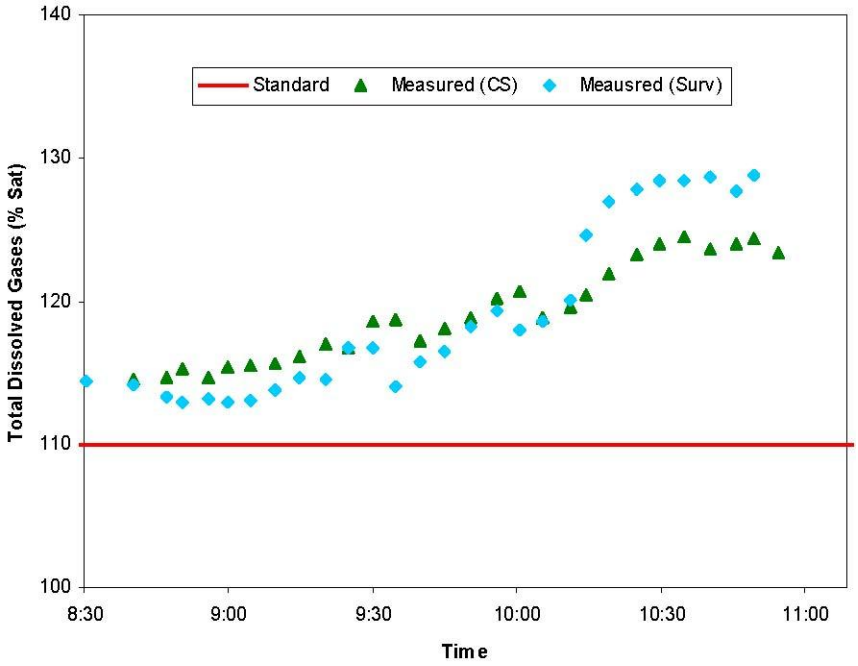


Figure 7.3-8. Measured total dissolved gases (TDG) percent saturation (% Sat) below Brownlee Dam during operation of upper and lower spillgates at 39,000 cubic feet per second (cfs). (Note: Add 35,000 cfs to spill to estimate total Snake River flow.) Data were collected concurrently with 2 probes: Common Sensing (CS) and Hydrolab (Surv).

IPC's evaluation of Brownlee Dam spill test data indicated that upper gate spill resulted in lower TDG levels. IPC does not contend that this preferential spill alone will attain the SR-HC TMDL load allocation; however, this measure will minimize TDG levels to the extent possible until spillway flow deflectors are installed at Brownlee Dam. Further, IPC contends that TDG levels of 114% of saturation, as measured from upper gate spill greater than the 7Q10 average flood flow, will not have a discernable effect on aquatic life. This is supported by IPC's recent monitoring of resident fish in the HCC (Exhibit 6.3-1) and corroborated by McGrath et al. (2006). Both reported the conclusion that short-term exposure up to 120% of saturation does

not produce significant effects on resident and migratory fish when compensating depths are available.

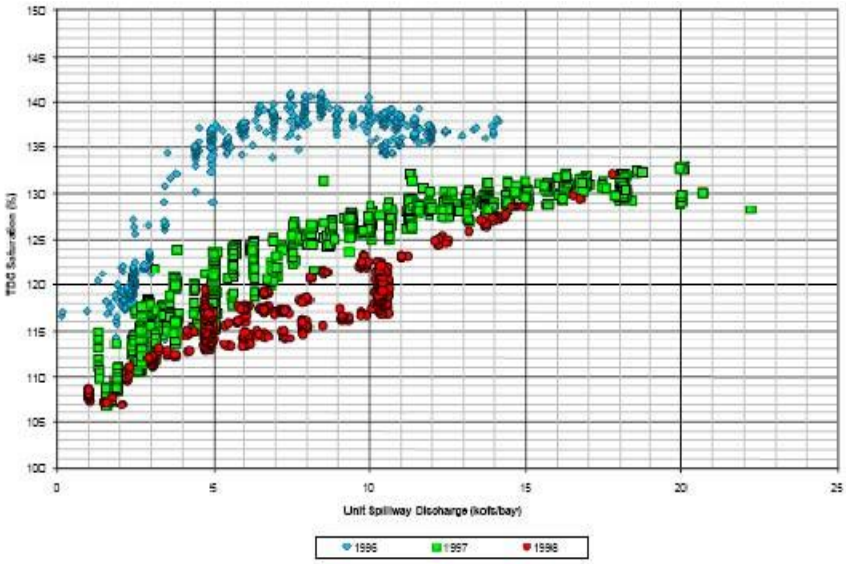
7.3.3.2. HCC Flow Deflectors

Flow deflectors are the best available technology for reducing elevated TDG levels at hydroelectric projects in the Northwest. USACE has performed most of the research relevant to flow-deflector design, physical model studies, and initial prototype testing. USACE evaluated numerous alternatives and concluded that the best options to reduce TDG levels are to structurally modify the dam to either reduce the volume of air entrained into the water column or reduce the hydrostatic pressures that act upon entrained air by keeping entrained air near the surface (USACE 1999; as cited in Weber et al. 2000).

USACE evaluated several alternatives for reducing the volume of air entrained into the water column, including creating submerged spillway conduits, constructing powerhouse and spillway separation walls (training walls), converting turbines to sluices, modifying existing powerhouses to act as hydro-combine powerhouses, using submerged pressure conduits with slots, using flow through existing skeleton bays, and constructing additional powerhouse units. Each of these alternatives reduces TDG levels by preventing spilled water from contacting air. With the exception of submerged spillway conduits, each alternative adds increased structural and fish safety concerns and has significant construction costs.

USACE also evaluated alternatives to reduce the maximum hydrostatic pressures that act upon entrained air including raising the tailrace channel and raising the stilling basin to develop surface-oriented flow. Generally, altering the tailrace channel or stilling basin involves significantly more effort and cost than implementing flow deflectors to reduce hydrostatic pressures on entrained air. Alternatives that combine the principles of reducing air volume and hydrostatic pressures include spillway deflectors, baffled-chute spillways, side-channel spillways, pool and weir channels, additional spillway bays, new spillway-gate types or openings, and v-shaped spillways. USACE concluded that the 3 most feasible alternatives for most large river dams are 1) submerged spillway conduits, 2) spillway deflectors, and 3) new spillway-gate types or openings. Of these alternatives, the installation of spillway deflectors appears to be the best available technology for most dams.

As a result of this type of analysis, USACE has installed flow deflectors on many of the Lower Snake and Columbia rivers projects. USACE designs deflectors for a dual purpose: to reduce TDG levels while balancing anadromous smolt passage survival rates. Because of this dual purpose, USACE often receives waivers to exceed the 110% of saturation criterion for voluntary spill up to 120% of saturation. Likewise, TDG levels measured after installation of flow deflectors may not represent the optimized effectiveness if only reduction of TDG levels is the goal. At Ice Harbor Dam on the Lower Snake River, USACE has measured TDG levels of 140% of saturation prior to installation of flow deflectors and 130% of saturation after installation (Figure 7.3-9).



Note: No deflectors in 1996, 4 of 10 installed in 1997, 8 of 10 installed in 1998.

Figure 7.3-9. Measured total dissolved gases (TDG) percent (%) saturation below Ice Harbor Dam, 1996–1998, with and without flow deflectors (USACE 2002).

The IIHR has evaluated flow deflectors for Rock Island Dam and Wanapum Dam, located in Grant County, Washington. Wanapum Dam, a Grant County (Washington) Public Utility District project, has had several prototype spillway deflectors installed. These data provide reasonable assurance that the 110% of saturation criterion can be met using a deflector design that results in a surface jet. The first 2 designs, a deep horizontal deflector and a deep sloping deflector, did not function optimally to meet objectives of reducing TDG levels (Table 7.3-1). The deep sloping design appears to have no observable effect on reducing TDG levels. The next iteration in Wanapum Dam deflector design was a shallow horizontal deflector. This design functioned optimally to meet objectives of reducing TDG levels (Table 7.3-2). TDG levels measured in spill from bays without deflectors reached nearly 130% of saturation (Figure 7.3-10). These levels are comparable to TDG levels measured below projects in the HCC. The shallow horizontal deflector design reduced TDG levels to the criterion of 110% of saturation or less. The proposed Hells Canyon Dam design is comparable to the Wanapum Dam shallow horizontal design.

Table 7.3-1. Total dissolved gases (TDG) percent (%) saturation levels at Wanapum Dam, Grant County, Washington, in 1998 (Weitkamp and Hagen 1999a). Ten-year, 7-day (7Q10) average flood flow is 12,916 cubic feet per second (cfs) per spillway (Jeske 1999). The Wanapum Dam powerhouse has the ability to increase flow passage, which would decrease the 7Q10 average flood flow to 8,333 cfs per bay.

Spillbay	Deflector Design	Flow (cfs)	TDG (%)
2	Deep horizontal	2,800	108–109
		6,000	109
		11,300	114–116
3	None	2,800	123–125
		6,000	128–129
		11,300	123–124
4	Deep sloping	2,800	121–122
		6,000	127–128
		11,300	122–123
5	None	6,000	123–124
		6,000	123–125

Table 7.3-2. Total dissolved gases (TDG) percent (%) saturation levels at Wanapum Dam, Grant County, Washington, in 1999 (Weitkamp and Hagen 1999b). Ten-year, 7-day (7Q10) average flood flow is 12,916 cubic feet per second (cfs) per spillway (Jeske 1999). The Wanapum Dam powerhouse has the ability to increase flow passage, which would decrease the 7Q10 average flood flow to 8,333 cfs per bay.

Spillbay	Deflector Design	Flow (cfs)	TDG (%)
2	Deep horizontal	2,800	—
		6,000	107–108
		7,500	108–110
3	None	2,800	121–122
		6,000	127–128
		7,500	—
5	Shallow horizontal	2,800	103–105
		2,800	105–106
		6,000	108–109
		6,000	108–109
		6,000	107
		7,500	109–110
		7,500	109–110

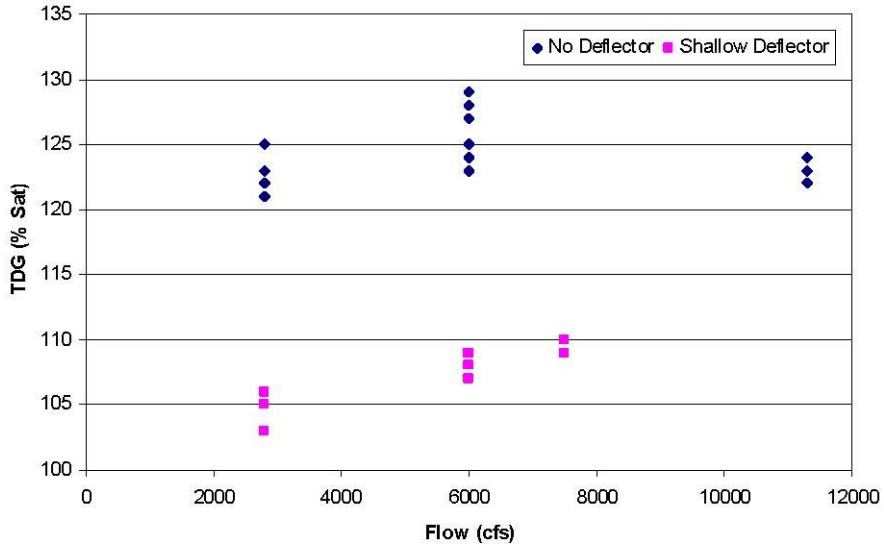


Figure 7.3-10. Total dissolved gases (TDG) percent saturation (% Sat) at Wanapum Dam, Grant County, Washington, with no spillway deflector and a shallow horizontal design deflector (Weitkamp and Hagen 1999a, 1999b).

The IIHR 3-dimensional models for both Hells Canyon Dam and Brownlee Dam were developed to qualitatively optimize flow-deflector designs to minimize air bubbles at depth (Figure 7.3-11). Currently, physical or mathematical models do not exist to conclusively predict TDG levels prior to installation of flow deflectors. Analytical tools have recently been developed and are continually being improved to better model potential future TDG levels, but these tools have had limited field application. One such model is the IIHR CFD model, which has only been applied to Wanapum Dam but with promising results. While a CFD model will be used to optimize the final design at both the Hells Canyon and Brownlee projects to meet the TDG criterion, the only definitive way to demonstrate compliance with the 110% of saturation criterion is to implement the PME measures and monitor TDG levels during spill.

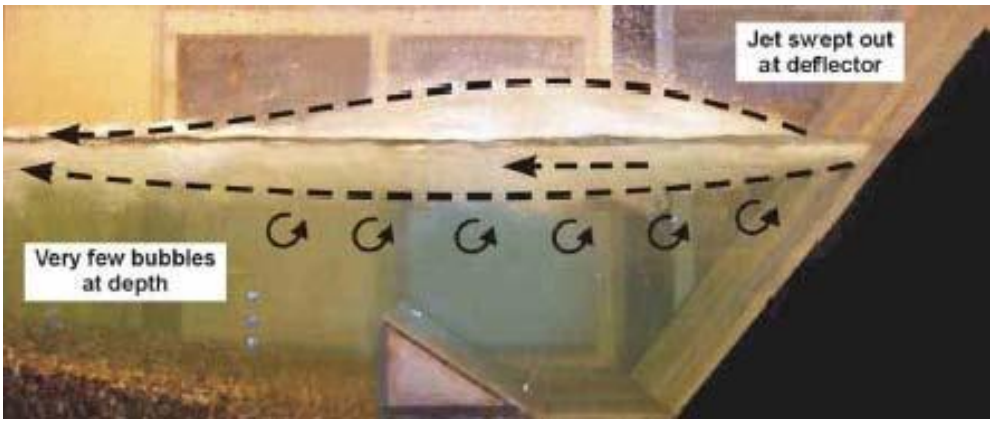


Figure 7.3-11. Sectional view photograph of a surface jet flow regime expected from both the Hells Canyon Dam sluiceway and Brownlee Dam spillway

flow-deflector designs (Weber 2005). Note the lack of observed air bubbles at depth, either in the stilling basin or downstream.

7.3.4. TDG Monitoring

As described in the SR-HC TMDL, IPC will work with both the ODEQ and IDEQ as part of the HCC § 401 certification to develop a TDG monitoring plan with specific compliance locations and protocol for monitoring (IDEQ and ODEQ 2004). The plan will include specific locations to define the edge of the aerated zone below each project for determining compliance with IPC's SR-HC TMDL TDG load allocation, a specific methodology for monitoring during spill, including equipment and the need to evaluate adaptive PME measures. (This may include monitoring effects of TDG levels on aquatic life.) Additional monitoring may be needed to collect data necessary to run a CFD model to finalize flow-deflector designs. IPC will coordinate with the ODEQ and IDEQ, as much as practicable, to develop these methods.

7.3.5. TDG Adaptive Management Schedule

Spilling at the HCC projects is almost exclusively involuntary, occurring usually as a result of flood-control constraints or high-runoff events (IDEQ and ODEQ 2004). Spilling typically occurs for short periods in higher water years when Snake River flows exceed the project's flood storage capacity, as mandated byUSACE, or the hydraulic capacity of generation turbines. Other unusual situations, including emergencies or unexpected unit outages, can induce a spill episode at any of the projects. As such, IPC is compliant with the TDG criterion and, therefore, the load allocation, in all but higher water years when spill occurs. In addition, IDEQ and ODEQ (2004) concluded the TDG criterion is conservative for the protection of aquatic life; thus, the load allocation has an implicit margin of safety.

IPC proposes the following schedule for implementation of proposed PME measures. This schedule allows IPC to be compliant with the criterion as soon as practicable based on water years that IPC has responsibility associated with spill. There may be a need to monitor effectiveness of PME measures prior to final design and, therefore, implementation of successive PME measures. Monitoring must occur during higher water years when spill occurs. Monitoring will be limited to no more than 1 year before the next step is initiated.

- Continue preferential spill from Brownlee Dam upper spillgates. This PME measure is currently in practice and will continue as part of early implementation of § 401 certification.

- Continue monitoring during spill events to provide data for CFD model development and use in final design of PME measures as part of early implementation of § 401 certification.

- Continue monitoring during spill events to provide data relative to TDG effects on aquatic life as part of early implementation of § 401 certification.

- Complete final design of the Hells Canyon Dam sluiceway flow deflectors, based on a CFD model optimized to the 7Q10 average flood flow within 1 year following issuance of the new HCC FERC license.

- Construct and install the Hells Canyon Dam sluiceway flow deflectors consistent with the schedule in the new license that incorporates FERC's required design-review process and permitting requirements. It is expected these requirements could be completed within 1 year of final design, with construction and installation occurring the following year. This tentatively schedules construction following the third year after new license issuance.

- Complete final design of the Brownlee Dam spillway flow deflectors, based on a CFD model optimized to the 7Q10 average flood flow, following construction and installation of the Hells Canyon Dam sluiceway flow deflectors. It may be necessary to monitor effectiveness of the optimized Hells Canyon Dam sluiceway flow deflectors before developing a CFD model to optimize the Brownlee Dam spillway flow-deflector final design.

- Construct and install the Brownlee Dam spillway flow deflectors consistent with the schedule in the FERC license that incorporates FERC's required design-review process. It is expected these requirements could be completed within1 year of final design, with construction and installation occurring the following year. Until the deflectors are installed, IPC will preferentially spill from the Brownlee Dam upper gates as an early implementation PME measure.

- Complete final design of the Oxbow Dam spillway flow deflector, based on a CFD model optimized to the 7Q10 average flood flow, following construction and installation of the Brownlee Dam flow deflectors. It may be necessary to monitor effectiveness of the Brownlee Dam flow deflectors before developing a CFD model to optimize the Oxbow Dam spillway flow-deflector final design.

- Construct and install the Oxbow Dam spillway flow deflector consistent with the schedule in the FERC license that incorporates FERC's required design-review process. It is expected these requirements could be completed within1 year of final design, with construction and installation occurring the following year. Since Brownlee Dam TDG levels influence Oxbow Dam TDG levels, final design cannot be completed until Brownlee Dam spillway flow deflectors are installed and TDG levels downstream are monitored in order to more accurately understand the dynamics of the effects of Brownlee Dam on Oxbow Dam TDG levels.

- Conduct monitoring to determine if the TDG criterion is met at the edge of the aerated zone below each project. If monitoring indicates the TDG criterion is exceeded with the above measures implemented, adaptive steps (as described in Section 7.3.2.) will be taken.

8. LITERATURE CITED

Alderice, D. F., W. P. Wickett, and J. R. Bret. 1958. Some effects of temporary exposure to low dissolved oxygen levels on Pacific salmon eggs. Journal of the Fisheries Research Board of Canada 35:69–75.

Allan, J. D. 1995. Stream ecology: Structure and function of running waters. London, UK: Chapman & Hall. 388 p.

American Public Health Association (APHA). 1999. Standard methods for the examination of water and wastewater. 20th edition. Washington, D.C.: APHA.

Arntzen, E. V., D. R. Geist, and T. P. Hanrahan. 2001. Substrate quality of fall Chinook salmon spawning habitat, Hells Canyon Reach, Snake River, Idaho. Prepared for Idaho Power Company, Boise, ID, by Battelle Memorial Institute, Richland, WA. 40 p.

Battin, T. J., and D. Sengschmitt. 1999. Linking sediment biofilms, hydrodynamics, and river bed clogging: Evidence from a large river. Microbial Ecology 37:185–196.

Bechard, M., G. S. Kaltenecker, and D. N. Perkins. 2005. Organochlorine pesticide and heavy metal contamination in the blood and feathers of bald eagles in Southern Idaho. Boise, ID: Raptor Research Center, Boise State University. 35 p.

Bell, W. H., and E. Sakshaug. 1980. Bacterial utilization of algal extracellular products. Limnology and Oceanography 25:1021−1033.

Bertilsson, S., and J. B. Jones. 2003. Supply of dissolved organic matter to aquatic ecosystems: Autochthonous sources. In: E. G. Findlay and R. L. Sinsabaugh, editors. Aquatic ecosystems: Interactivity of dissolved organic matter. San Diego, CA: Academic Press.

Boyd, M. S., and B. Casper. 2003. Analytical methods for dynamic open-channel heat and mass transfer: Methodology for heat source model version 7.0. 204 p.

Brennan, T., A. Campbell, A. Lehmann, and I. O'Dell. 2000. Water resources data—Idaho, water year 1999. Volume 2. Upper Columbia River Basin and Snake River Basin below King Hill. U.S. Geological Survey, Water Resources Division, Idaho District, Boise. Water Data Report ID-99-2. 440 p.

Brown, G. W. 1970. Predicting the effects of clearcutting on stream temperature. Journal of Soil and Water Conservation 25:11–13.

Burton, T. A., G. W. Harvey, and M. McHenry. 1990. Monitoring the effects of nonpoint sources of sediment pollution on salmonid incubation and eggs to alevins survival. In: Proceedings of the annual conference of the Western Association Fish and Wildlife Agencies 70:104–113.

Chandler, J. A., R. A. Wilkison, and T. J. Richter. 2003. Distribution, status, life history, and limiting factors of redband trout and bull trout associated with the Hells Canyon Complex. In: Technical appendices for new license application: Hells Canyon Hydroelectric Complex. Boise, ID: Idaho Power Company. Technical Report E.3.1-7; Chapter 4. 168 p.

Chapman, D. W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society 117:1–21.

Chapman, D. W., D. E. Weitkamp, T. L. Welsh, M. B. Dell, and T. H. Schadt. 1986. Effects of river flow on the distribution of Chinook salmon redds. Transactions of the American Fisheries Society 115:537–547.

Chapra, S. C. 1997. Surface water-quality modeling. New York, NY: McGraw-Hill. 844 p.

Clark, G., and T. Maret. 1998. Organochlorine compounds and trace elements in fish tissue and bed sediments in the lower Snake River Basin, Idaho and Oregon. U.S. Geological Survey Water Resources Investigations Report 98-4103. 35 p.

Clark, G. M., T. R. Maret, M. G. Rupert, M. A. Maupin, W. H. Low, and D. S. Ott. 1998. Water Quality in the Upper Snake River Basin, Idaho and Wyoming, 1992–1995. U.S. Geological Survey Circular 1160. 35 p.

Clayton, J. L., J. G. King, and R. F. Thurow. 1996. Evaluation of an ion adsorption method to estimate intragravel flow velocity in salmonid spawning gravel. North American Journal of Fisheries Management 16:167–174.

Cobel, D. W. 1961. Influence of water exchange and dissolved oxygen in redds on survival of steelhead trout embryos. Transactions of the American Fisheries Society 90:469–474.

Cole, T. M., and S. A. Wells. 2002. CE-QUAL-W2: A two-dimensional, laterally averaged, hydrodynamic and water quality model. Version 3.1 draft user manual. Instruction Report EL-02-1. U.S. Army Corps of Engineers.

Connor, W. P., H. L. Burge, J. R. Yearsley, and T. C. Bjornn. 2003. Influence of flow and temperature on survival of wild subyearling fall Chinook salmon in the Snake River. North American Journal of Fisheries Management 23:362–375.

Dauble, D. D., and D. R. Geist. 2000. Comparison of mainstem spawning habitats for two populations of fall Chinook salmon in the Columbia River Basin. Regulated Rivers: Research and Management 16:345–361.

Dauble, D. D., T. P. Hanrahan, D. R. Geist, and M. J. Parsley. 2003. Impacts of the Columbia River Hydroelectric System on main-stem habitats of fall Chinook salmon. North American Journal of Fisheries Management 23:641-659.

Driscoll, C. T., C. Yan, C. L. Schofield, R. Munson, and J. Holsapple. 1994. The mercury cycle and fish in the Adirondack lakes. Environmental Science and Technology 28:136–143.

Essington, T. E., and S. R. Carpenter. 2002. Nutrient cycling in lakes and streams: Insights from a comparative analysis. Ecosystems 3:131–143.

Evermann, B. 1896. A preliminary report upon salmon investigations in Idaho in 1894. Bulletin of the U.S. Fish Commission. Volume XV for 1895, p. 253−284. Washington, D.C.: U.S. Government Printing Office.

Falter, C. M., and C. Burris. 1996. Middle Snake River productivity and nutrient assessment 1994. Report to Idaho Department of Health and Welfare, Division of Environmental Quality, Twin Falls, ID.

Federal Energy Regulatory Commission (FERC). 2006. Draft environmental impact statement for hydropower license. Hells Canyon Hydroelectric Project, FERC Project No. 1971-079. Washington, D.C.: Federal Energy Regulatory Commission, Office of Energy Projects, Division of Hydropower Licensing. 688 p.

Findlay, S. 1995. Importance of surface–subsurface exchange in stream ecosystems: the hyporheic zone. Limnology and Oceanography 40:159–164.

Findlay, S., D. Strayer, C. Goumbala, and K. Gould. 1993. Metabolism of stream water dissolved organic carbon in the shallow hyporheic zone. Limnology and Oceanography 38:1493–1499.

Geist, D. R., C. S. Abernathy, K. D. Hand, V. I. Cullinan, J. A. Chandler, and P. A. Groves. 2006. Survival, development, and growth of fall Chinook salmon embryos, alevin, and fry exposed to variable thermal and dissolved oxygen regimes. Transactions of the American Fisheries Society 135:1462–1477.

Gilbert, C., and B. Evermann. 1894. A report on investigations in the Columbia River basin, with descriptions of four new species of fishes. In: Report of the Commissioner of Fish and Fisheries on investigations in the Columbia River Basin in regard to the salmon fisheries. Washington, D.C.: U.S. Senate Miscellaneous Documents, No. 200, Serial No. 3174. P. 19−57.

Goodell, S. A. 1988. Water use on the Snake River Plain, Idaho, and Eastern Oregon. U.S. Geological Survey Professional Paper 1408-E. 51 p.

Groves, P. A., and J. A. Chandler. 1999. Spawning habitat used by fall Chinook salmon in the Snake River. North American Journal of Fisheries Management 19:912–922.

Groves, P. A., and J. A. Chandler. 2005. Habitat quality of historic Snake River fall Chinook salmon spawning locations and implications for incubation survival. Part 2: Intra-gravel water quality. River Research and Applications 21:469–483.

Groves, P. A., J. A. Chandler, and R. Myers. 2007. White Paper: The effects of the Hells Canyon Complex relative to water temperature and fall Chinook salmon. Boise, ID: Idaho Power Company.

Hanrahan, T. P., D. R. Geist, and E. V. Arntzen. 2005. Habitat quality of historic Snake River fall Chinook salmon spawning locations and implications for incubation survival. Part 1: Substrate quality. River Research and Applications 21:455–467.

Hanrahan, T. P., E. V. Arntzen, F. Khan, J. R. Stephenson, P. S. Titzler, and C. Tunnicliffe. 2007. Hyporheic exchange characteristics in Snake River fall Chinook salmon spawning areas. PNWD-3847. Prepared for Idaho Power Company, Boise, ID, by Battelle Pacific Northwest Division, Richland, WA. 50 p.

Harrison, J. R. 2005. Partitioning Snake River organic matter and modeling aerobic oxidation in Brownlee Reservoir, Idaho. Ph. D. dissertation. 260 p. Moscow, ID: College of Graduate Studies, University of Idaho.

Harrison, J., S. Wells, R. Myers, S. Parkinson, and M. Kasch. 1999. 1999 status report on Brownlee Reservoir water quality and model development. Draft technical report. Boise, ID: Idaho Power Company.

Harshbarger, E. D., M. H. Mobley, and W. G. Brock, 1995. Aeration of Hydroturbine Discharges at Tims Ford Dam using Penstock Oxygen Injection and Turbine Air Injection. ASCE 1st International Conference on Water Resources Engineering, August 1995. San Antonio, TX.

Hoelscher, B. 2002. Evaluation of chlorophyll *a* nuisance thresholds and targets for the southwest Snake River and Brownlee Reservoir. Draft report. Boise, ID: Idaho Power Company. 16 p.

Hoelscher, B., and R. Myers. 2003. Tributary pollutant sources to the Hells Canyon Complex. Final report. In: Technical appendices for new license application: Hells Canyon Hydroelectric Complex. Boise, ID: Idaho Power Company. Technical Report E.2.2-1. 104 p.

Idaho Administrative Procedures Act (IDAPA) 58.01.02. No date. Water quality standards and wastewater treatment requirements. Boise, ID: Idaho Department of Environmental Quality, Idaho State Office. 190 p.

Idaho Department of Environmental Quality (IDEQ). No date. Idaho 401 guidance. <http://www.deq.state.id.us/water/data_reports/surface_water/monitoring/401_npdes_guidance.pdf>. Accessed on: December 29, 2006.

Idaho Department of Environmental Quality (IDEQ). 2003 Draft Pollutant Trading Guidance document. DEQ Publication. http://deq.idaho.gov/water/prog_issues/waste_water/pollutant_trading/pollutant_trading_guidance_entire.pdf. Accessed on: January 8, 2007.

Idaho Department of Environmental Quality (IDEQ). 2005. Principles and policies for the 2002 integrated (303(d)/305(b)) report–section 5: impaired waters: rivers (listed by basin). http://www.deq.state.id.us/water/data_reports/surface_water/monitoring/integrated_report_2002_final_sec5.pdf. Accessed on: October 13, 2006.

Idaho Department of Environmental Quality (IDEQ). 2008. Department of Environmental Quality working principles and policies for the 2008 integrated 9303[d]/305[b]) report. http://www.deq.state.id.us/water/data_reports/surface_water/monitoring/integrated_report_2008_entire.pdf. Accessed on: May 20, 2009.

Idaho Department of Environmental Quality (IDEQ) and Oregon Department of Environmental Quality (ODEQ). 2004. Snake River–Hells Canyon total maximum daily load (TMDL). IDEQ, Boise Regional Office, Boise, ID, and ODEQ, Pendleton Office, Pendleton, OR. 710 p., plus appendices.

Idaho Department of Health and Welfare (IDHW). 2005. Idaho fish consumption advisory for selected waters: safe fish eating guidelines. http://healthandwelfare.idaho.gov/_Rainbow/Documents/Health/safe_fish_eating_guidelines.pdf. Accessed on: March 28, 2005.

Idaho Department of Water Resources (IDWR). 1971. Inventory of dams in the State of Idaho. Boise, ID: Idaho Department of Water Administration, Idaho State Office. 97 p.

Idaho Power Company (IPC). 1991. Fall Chinook interim recovery plan and study. Boise, ID: Idaho Power Company. 28 p.

Idaho Power Company (IPC). 2002. Letter to T. Dombrowski regarding the December 2001 draft Snake River-Hells Canyon Total Maximum Daily Load (TMDL). Prepared by James Tucker, Senior Attorney. Boise, ID: Idaho Power Company. 7 p.

Idaho Power Company (IPC). 2003. Idaho Power Company comments on the June 10, 2003, draft Mid-Snake River/Succor Creek Subbasin Assessment and Total Maximum Daily Load. Prepared by B. Hoelscher. 5 p.

Idaho Power Company (IPC). 2005. Response to FERC additional information request (AIR) WQ-1. Final report. AIR WQ-1 for new license application: Hells Canyon Hydroelectric Complex. Boise, ID: Idaho Power Company. 192 p.

Idaho Power Company (IPC). 2006. Comments to the draft environmental impact statement, Hells Canyon Project, FERC No. 1971. Boise, ID: Idaho Power Company. 119 p.

Idaho Power Company (IPC). 2007a. Upper Snake River/Rock Creek temperature total maximum daily loads: addendum to the Upper Snake/Rock Creek watershed management plan. Letter to Dr. Buhidar from Brian Hoelscher and Chris Randolph. Dated October 17, 2007.

Iowa Institute of Hydraulic Research (IIHR). 2000. Hells Canyon Dam deflector design. In: Technical appendices for new license application: Hells Canyon Hydroelectric Complex. Boise, ID: Idaho Power Company. Technical Report E.2.2-4. 26 p.

Irving, R. B., and P. E. Cuplin. 1956. The effects of hydroelectric developments on the fishery resources of the Snake River. Boise, ID: Idaho Department of Fish and Game. 168 p.

Jager, H., K. Lepla, J. A. Chandler, W. Van Winkle, A. Sullivan, R. Myers, and M. Bevelhimer. 2003. Population viability model for Snake River white sturgeon. Final report. In: K. Lepla, editor. Chapter 3, Status and habitat use of Snake River white sturgeon associated with the Hells Canyon Complex. Technical appendices for new license application: Hells Canyon Hydroelectric Project. Boise, ID: Idaho Power Company. Technical Report E.3.1-6.

Jeske, D. 1999. December 13 e-mail to Larry Weber, IIHR-Hydroscience & Engineering, University of Iowa, Iowa City, IA.

Kaplan, L. A., and J. D. Newbold. 2000. Surface and subsurface dissolved organic carbon. In: J. B. Jones and P. J. Mulholland, editors. Streams and ground waters. San Diego, CA: Academic Press.

Lancaster, S., R. Haggerty, and S. Gregory. 2005. Investigation of the temperature impact of hyporheic flow: Using groundwater and heat flow modeling and GIS analyses to evaluate temperature mitigation strategies on the Willamette River, Oregon. Final Report. Corvallis, OR: Oregon State University. 104 p.

Lepla, K., and J. A. Chandler. 2003. Physical habitat use and water quality criteria for Snake River white sturgeon. In: K. Lepla, editor. Chapter 2, Status and habitat use of Snake River white sturgeon associated with the Hells Canyon Complex. Technical appendices for new license application: Hells Canyon Hydroelectric Project. Boise, ID: Idaho Power Company. Technical Report E.3.1-6.

Lepla, K., J. A. Chandler, and P. Bates. 2003. Status and habitat use of Snake River white sturgeon associated with the Hells Canyon Complex. In: K. Lepla, editor. Chapter 1, Status and habitat use of Snake River white sturgeon associated with the Hells Canyon Complex. Technical appendices for new license application: Hells Canyon Hydroelectric Project. Boise, ID: Idaho Power Company. Technical Report E.3.1-6.

Maier, R. M., I. L. Pepper, and C. P. Gerba. 2000. Environmental microbiology. San Diego, CA: Academic Press. 585 p.

Maret, T. R., T. A. Burton, G. W. Harvey, and W. H. Clark. 1993. Field testing of new monitoring protocols to assess brown trout spawning habitats in an Idaho stream. North American Journal of Fisheries Management 13:567−580.

Marshall, K. C. 1997. Colonization, adhesion, and biofilms. In: C. J. Hurst, G. R. Knudsen, M. J. McInerney, L. D. Stetzenbach, and M. V. Walter, editors. Manual of environmental microbiology. Washington, D.C.: American Society for Microbiology Press. P. 358–365.

McGrath, K. E., E. Dawley, and D. R. Geist. 2006. Total dissolved gas effects on fishes of the Lower Columbia River. Prepared for the U.S. Army Corps of Engineers (USACE), Contract No. MIPR W66QKZ52991442. 15 p., plus appendix.

McHenry, M. L., D. C. Morrill, and E. Currence. 1994. Spawning gravel quality, watershed characteristics, and early life history survival of coho salmon and steelhead in

five North Olympic peninsula watersheds. Report funded by the Department of Ecology, Centennial Clean Water Act, Section 205J Clean Water Act.

Meili, M. 1997. Mercury in lakes and rivers. Pages 21–52 in: A. Sigel and H. Sigel, editors. Metal ions in biological systems. Volume 34, Mercury and its effect on environment and biology. New York, NY: Marcel Dekker. 603 p.

Miskimmin, B. M., J. W. Rudd, and C. A. Kelly. 1992. Influence of dissolved organic carbon, pH, and microbial respiration rates on mercury methylation and demethylation in lake water. Canadian Journal of Fisheries and Aquatic Sciences 49:17–22.

Mobley, M. H. 1997. TVA reservoir aeration diffuser system. In: Proceedings of the conference Waterpower 1997; Atlanta, GA. Waterpower. Technical paper 97-3. 10 p. Available at: www.loginetics.com/pubsm/Aeration.html. Accessed on: November 1, 2004.

Mobley, M. H., and W. G. Brock. 1995. Widespread oxygen bubbles to improve reservoir releases. Lake and Reservoir Management 11:231–234.

Mobley, M. H., and W. G. Brock. 1996. Aeration of reservoirs and releases using TVA porous hose line diffuser. Available at: www.tva.gov/environment/water/rri_papers.html. Accessed on: November 1, 2004.

Mobley, M. H., R. J. Ruane, and E. D. Harshbarger. No date. "And then it sank …" the development of an oxygen diffuser for hydropower. 12 p. Available at: www.loginetics.com/pubsm/Aeration.html. Accessed on: November 1, 2004.

Mulholland, P. J., and D. L. DeAngelis. 2000. Surface–subsurface exchange and nutrient spiraling. In: J. B. Jones and P. J. Mulholland, editors. Streams and ground waters. San Diego, CA: Academic Press.

Myers, R., S. Parkinson, and J. Harrison. 1998. Tributary nutrient loadings to the Snake River, Swan Falls to Farewell Bend, March through October 1995. Boise, ID: Idaho Power Company.

Myers, R., J. Harrison, S. K. Parkinson, B. Hoelscher, J. Naymik, and S. E. Parkinson. 2003. Pollutant transport and processing in the Hells Canyon Complex. Final report. In: Technical appendices for new license application: Hells Canyon Hydroelectric Complex. Boise, ID: Idaho Power Company. Technical Report E.2.2-2. 201 p.

Myers, R., and J. A. Chandler. 2003. Oxbow Bypass minimum flow evaluation. Revised version. In: Technical appendices for new license application: Hells Canyon Hydroelectric Complex. Boise, ID: Idaho Power Company. Technical Report E.2.3-1. 244 p.

Myers, R., and S. E. Parkinson. 2003. Hells Canyon Complex total dissolved gas study. Final report. In: Technical appendices for new license application: Hells Canyon Hydroelectric Project. Boise, ID: Idaho Power Company. Technical Report E.2.2-4.

Nauen, C. E. 1983. Compilation of legal limits for hazardous substances in fish and fishery products. Food and Agriculture Organization of the United Nations, Rome, Italy. Circular No. 764.

Northwest Hydraulic Consultants (NHC). 2007. Oxbow Spillway TRS Hydraulic Model Study Final Report. Prepared for Idaho Power Company, Boise, ID.

Nowell, L. H., and E. A. Resek. 1994. Summary of national standards and guidelines for pesticides in water, bed sediment, and aquatic organisms and their application to water-quality assessments: U.S. Geological Survey Open-File Report 94-44. 115 p.

Oregon Administrative Rules (OAR) 340-041. No date. Water quality standards: beneficial uses, policies, and criteria for Oregon. Portland, OR: Oregon Department of Environmental Quality (ODEQ). 87 p., plus tables and figures.

Oregon Department of Environmental Quality (ODEQ). 2005. Water Quality Trading Internal Management Directive. http://www.deq.state.or.us/wq/wqpolicy/WQIMDTrading.pdf. Accessed on: November 2006.

Oregon Department of Environmental Quality (ODEQ). 2007a. Oregon's 2004/2006 Integrated Report: Snake River. http://www.deq.state.or.us/wq/assessment/rpt0406/ results.asp. Accessed on: October 13, 2006.

Oregon Department of Environmental Quality (ODEQ). 2008. Temperature water quality standard implementation. A DEQ internal management directive. Oregon Department of Environmental Quality. Available at http://www.deq.state.or.us/wq/pubs/imds/ Temperature.pdf.

Oregon Department of Environmental Quality (ODEQ). 2009. Oregon's 2004/2006 integrated report. http://www.deq.state.or.us/wq/assessment/rpt0406/search.asp#db. Accessed on: May 20, 2009.

Oregon Department of Human Services (ODHS). 2005. Fish advisories: consumption guidelines. http://oregon.gov/DHS/ph/envtox/fishconsumption.shtm#Brownlee. Accessed on: March 28, 2005.

Park, R. A., and J. S. Clough. 2004. AQUATOX (release 2): Modeling environmental fate and ecological effects in aquatic ecosystems. Volume 2, Technical documentation. Washington, D.C.: U.S. Environmental Protection Agency.

Parkhurst, Z. 1950. Survey of the Columbia River and its tributaries. Part VII. U.S. Fish and Wildlife Service. Special Scientific Report, Fisheries No. 57. 19 p.

Peterson, S. A., A. T. Herlihy, R. M. Hughes, and J. Van Sickle. 2006. Mercury concentration in fish from streams and rivers throughout the western United States. Northwest Biological Assessment Workgroup, 17th Annual Meeting. November 1, 2006, Post Falls, ID.

Pirtle, R. B. 1956. The size and timing of the runs of anadromous species of fish in the Columbia and Snake rivers and their tributaries above the confluence of the Snake River—1955. A report prepared for the U.S. Army Corps of Engineers, Idaho Department of Fish and Game. Contract DA35-026-eng-20608. Boise, ID. 14 p.

Pirtle, R. B., and J. Keating. 1955. The size and timing of the runs of anadromous species of fish in the Columbia and Snake rivers and their tributaries above the confluence of the Snake River - 1954. A report prepared for the U.S. Army Corps of Engineers, Idaho Department of Fish and Game. Contract DA35-026-eng-20608. Boise, ID. 30 p.

Poole, G. C., and C. H. Berman. 2001. An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation. Environmental Management 2001 Jun; 27(6):787–802.

Reynolds, C. S. 1984. The ecology of freshwater phytoplankton. 1990 reprint. Cambridge, United Kingdom: Cambridge University Press. 384 p.

Richards, M. 1957. Snake River fall chinook spawning ground survey, 1957. Idaho Department of Fish and Game, Boise. 12 p.

Richards, M. 1959. Snake River fall chinook spawning ground survey, 1959. Idaho Department of Fish and Game, Boise. 15 p.

Richards, M. 1960. Snake River fall chinook spawning ground survey, 1960. Idaho Department of Fish and Game, Boise. 17 p.

Richards, M. 1961. Snake River fall chinook spawning ground survey, 1961. Idaho Department of Fish and Game, Boise. 15 p.

Richards, M. 1962. Snake River fall chinook spawning ground survey, 1962. Idaho Department of Fish and Game, Boise. 10 p.

Richter, T. J., and J. A. Chandler. 2003. Status of fish community 1991–2000. Final Report. In: Technical appendices for new license application: Hells Canyon Hydroelectric Complex. Boise, ID: Idaho Power Company. Technical Report E.3.1-5. 256 p.

Romani, A. M., H. Guasch, I. Muñoz, J. Ruana, E. Vilalta, T. Schwartz, F. Emtiazi, and S. Sabater. 2004. Biofilm structure and function and possible implications for riverine DOC dynamics. Microbial Ecology 47:316–328.

Seattle Marine Laboratories. 1972. Final report: 1972 nitrogen monitoring studies. Report to Idaho Power Company, Boise, ID. 74 p.

Shumar, M., and J. de Varona. 2009. The potential natural vegetation (PNV) temperature total maximum daily load (TMDL) procedures manual. Boise, ID: Idaho Department of Environmental Quality, State Technical Services Office. 308 p.

Smith, S. G., W. D. Muir, E. E. Hockersmith, R. W. Zabel, R. J. Graves, C. V. Ross, W. P. Connor, and B. D. Arnsberg. 2003. Influence of river conditions on survival and travel time of Snake River sub-yearling fall Chinook salmon. North American Journal of Fisheries Management 23:939–961.

Soulsby, C., I. A. Malcolm, and A. F. Youngson. 2001a. Hydrochemistry of the hyporheic zone in salmon spawning gravels: A preliminary assessment in a degraded agricultural stream. Regulated Rivers: Research and Management 17:651−665.

Soulsby, C., A. F. Youngson, H. J. Moir, and I. A. Malcolm. 2001b. Fine sediment influence on salmonid spawning habitat in a lowland agricultural stream: A preliminary assessment. The Science of the Total Environment 265:295–307.

Stearns, H. T. 1936. Origin of the large springs and their alcoves along the Snake River in southern Idaho. The Journal of Geology 44:429-450.

Sterner, R. W., and J. J. Elser. 2002. Ecological Stoichiometry. Princeton, NJ: Princeton University Press. 439 p.

Stumm, W., and J. J. Morgan. 1995. Aquatic chemistry: Chemical equilibria and rates in natural waters. 3rd edition. New York, NY: John Wiley and Sons. 1,022 p.

Urban, S. M. 2004. Water budget for the Treasure Valley aquifer system for the years 1996 and 2000. Idaho Department of Water Resources. Treasure Valley hydrologic project research report. 57 p.

U.S. Army Corps of Engineers (USACE). 1999. Dissolved gas abatement study—phase II. Draft report. USACE, Walla Walla District, Walla Walla, WA. CD-ROM.

U.S. Army Corps of Engineers (USACE). 2002. Improving salmon passage: the Lower Snake River juvenile salmon migration feasibility report/environmental impact statement. Final report. USACE, Walla Walla District, Walla Walla, WA. CD ROM.

U.S. Army Corp of Engineers (USACE). 2005. Personal communication with Rick Delaney regarding transmittal of unregulated Snake River flow. October 6, 2005.

U.S. Bureau of Reclamation (USBR). 1999. Lower Snake River juvenile salmon migration feasibility study and environmental impact statement. Boise, ID: U.S. Department of Interior, Bureau of Reclamation, Pacific Northwest Region.

U.S. Environmental Protection Agency (USEPA). 2000a. Nutrient criteria technical guidance manual: Lakes and reservoirs. 1st edition. Washington, D.C.: U.S. Environmental Protection Agency, Office of Water. EPA 822-B-00-001. 137 p.

U.S. Environmental Protection Agency (USEPA). 2000b. Nutrient criteria technical guidance manual: Rivers and streams. Washington, D.C.: U.S. Environmental Protection Agency, Office of Water. EPA 822-B-00-002. 152 p.

U.S. Environmental Protection Agency (USEPA). 2000c. Ambient water quality criteria recommendations: Information supporting the development of state and tribal nutrient criteria for rivers and streams in nutrient Ecoregion III. Washington, D.C.: U.S. Environmental Protection Agency, Office of Water. EPA 822-B-00-016.

U.S. Environmental Protection Agency (USEPA). 2001a. USEPA's additions to the 1998 Idaho § 303(d) list. Seattle, WA: U.S. Environmental Protection Agency, Region X. 3 p.

U.S. Environmental Protection Agency (USEPA). 2001b. Ambient water quality criteria recommendations: Information supporting the development of state and tribal nutrient criteria for lakes and reservoirs in nutrient Ecoregion III. Washington, D.C.: U.S. Environmental Protection Agency, Office of Water. EPA 822-B-00-008.

U.S. Environmental Protection Agency (USEPA). 2001c. Methylmercury: human health fact sheet. http://www.epa.gov/waterscience/criteria/methylmercury/factsheet.html. Accessed on: July 3, 2003.

U.S. Environmental Protection Agency (USEPA). 2003. EPA Region 10 guidance for Pacific Northwest state and tribal temperature water quality standards. Seattle, WA: U.S. Environmental Protection Agency, Region X, Office of Water. EPA 910-B-03-002. 49 p., plus attachments.

U.S. Fish and Wildlife Service (FWS). 1957. A preliminary progress report on air and water temperature studies, middle Snake River drainage, 1954–1956. Portland, OR: U.S. Fish and Wildlife Service, River Basin Studies.

U.S. Fish and Wildlife Service (FWS). 1958. A preliminary progress report on air and water temperature studies for 1957, middle Snake River drainage. Portland, OR: U.S. Fish and Wildlife Service, River Basin Studies.

U.S. Geological Survey (USGS). 2003. Water-quality data Web page. http://waterdata.usgs.gov/nwis/qw. Accessed on: October 28, 2003.

U.S. Geological Survey (USGS). 2005. Water-quality data Web page. http://waterdata.usgs.gov/nwis/qw. Accessed on: March 2005.

Webb, W. E. 1964. General investigations in water quality. Federal aid to fish restoration job completion report. Project F-34-R-5. Boise, ID: Idaho Department of Fish and Game.

Weber, L. J. 2005. IIHR Hydroscience and Engineering. Iowa Institute of Hydraulic Research relative to the Hells Canyon Complex with reference to other Northwest hydroelectric projects presented to the Hells Canyon Complex Settlement Working Group. 41 p.

Weber, L., P. Haug, and P. Dierking. 2000. Literature review of total dissolved gas modeling. Draft report. Iowa City, IA: Iowa Institute of Hydraulic Research, University of Iowa. 30 p.

Weitkamp, D. E. 1974. Dissolved gas supersaturation in the Columbia River system: Salmonid bioassay and depth distribution studies, 1973 and 1974. Prepared by Parametrix, Inc., for Utility Cooperative, in care of Idaho Power Company, Boise, ID.

Weitkamp, D. E., and M. Katz. 1980. A review of dissolved gas supersaturation literature. Transactions of the American Fisheries Society 109:659–702.

Weitkamp, D. E., and J. E. Hagen. 1999a. Wanapum Dam spillway deflector total dissolved gas evaluation, 1998. Kirkland, WA: Parametrix.

Weitkamp, D. E., and J. E. Hagen. 1999b. Wanapum Dam spillway deflector total dissolved gas evaluation, 1999. Kirkland, WA: Parametrix.

Welch, E. B., and T. Lindell. 1996. Ecological effects of wastewater, applied limnology, and pollutant effects. 2nd edition. London, UK: Chapman & Hall.

Wells, S. A., and T. M. Cole. 2000. Theoretical Basis for the CE-QUAL-W2 River Basin Model. ERDC/EL TR-00-7. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Wetzel, R. G. 2001. Limnology: lake and reservoir ecosystems. 3rd edition. San Diego, CA: Academic Press. 1,006 p.

Worth, D. 1994. Gradient changes in water quality during low flows in run-of-the-river and reservoir impoundments, lower Snake River, Idaho. Lake and Reservoir Management 11(3):217–224.

Yang, C. T. 1996. Sediment transport. New York, NY: McGraw–Hill. 395 p.

Zimmer, P. D. 1950. A three-year study of fall Chinook salmon spawning areas in Snake River above Hells Canyon Dam site. Report of Fish and Wildlife Service, Region 1. Portland, OR.

This page left blank intentionally.

List of Exhibits

Exhibit 4.3-1	Names and addresses of contiguous property owners to the Hells Canyon Complex Project Boundary
Exhibit 4.3-2	Idaho Power Company's Hells Canyon Complex relicensing policies and activities in relation to Baker, Malheur, and Wallowa County plans
Exhibit 6.3-1	HCC gas-bubble trauma monitoring study
Exhibit 7.2-1	Dissolved Oxygen Augmentation in the Transition Zone (report by Mobley Engineering dated November 2004)
Exhibit 7.2-2	Discreet Bubble Model Overview (documentation prepared by Mobley Engineering)
Exhibit 7.3-1	Iowa Institute of Hydraulic Research Brownlee Dam spillway deflector design: Phase I two-dimensional model report
Exhibit 7.3-2	Iowa Institute of Hydraulic Research Brownlee Dam spillway deflector design: Phase II three-dimensional model report

This page left blank intentionally.