Appendix C
Water Quality Standards and Designated Use Classification

Water Quality Standards

The Savannah River Basin is located in North Carolina, South Carolina, and Georgia. Both North Carolina and South Carolina have assigned state water quality standards commensurate with the designated use of a waterbody. Georgia classifies the waters of the state by designated use and has assigned water quality standards to each use classification.

North Carolina, South Carolina, and Georgia all have similar categories of designated use; however, variations or sub-sets of general classifications differ between the states. Even though specific designations differ between the states, the states have distinguished between general use to maintain and support aquatic life and general contact recreation, trout habitats, and high value resource areas. Water use classifications for all three states are described in Tables C-1 through C-3.

Water quality standards for North Carolina, South Carolina, and Georgia are listed in Tables C-4 and C-5.

Table C-1 Water Use Classifications of Waterbodies within the Jocassee Watershed, North and South Carolina

Watershed	Name	Description	Water Use Classification
Lake Jocassee	Horsepasture River (NC)	From dam at Sapphire Lake to NC 281	C, Tr
	Thompson River (NC)	From source to North Carolina-South Carolina State Line	C, Tr
	Thompson River (SC)	From North Carolina-South Carolina State Line to Lake Jocassee	TN
	Toxaway River (NC)	From Dam at Lake Toxaway Estates, Inc. to North Carolina-South Carolina State Line	C
	Rock Creek	That portion within South Carolina (Toxaway River)	TN
	Whitewater River (NC)	From Little Whitewater Creek to North Carolina-South Carolina State Line	C, Tr, HQW
	Whitewater River (SC)	From North Carolina-South Carolina State Line to Lake Jocassee	ORW
	Bear Creek (SC)	From North Carolina-South Carolina State Line to Lake Jocassee	TN
	Bearcamp Creek (SC)	From North Carolina-South Carolina State Line to Lake Jocassee	TN
	Corbin Creek (SC)	Entire tributary to Devils Fork Creek	ORW
	Limber Pole Creek (SC)	Entire tributary to Devils Fork Creek	TN
	Howard Creek (SC)	From headwaters to 0.3 miles below Hwy 130 above flow augmentation system at the Bad Creek Pumped Storage Station Dam	ORW
	Howard Creek (SC)	From just above the flow augmentation system at the Bad Creek Pumped Storage Station Dam to Devils Fork Creek	TN
	Devils Fork Creek (SC)	From the confluence of Corbin Creek and Howard Creek to Lake Jocassee	TN
	Laurel Fork Creek (SC)	The entire tributary to Lake Jocassee	TN
	Wright Creek (SC)	The entire tributary to Lake Jocassee	ORW
	Lake Jocassee (SC)	Entire lake	TPGT
NC (NCDENR 2007)	**C** = Freshwaters protected for secondary recreation, fishing aquatic life including propagation and survival, and wildlife. All freshwaters shall be classified to protect these uses at a minimum.		
	Tr = Trout waters: freshwaters protected for natural trout propagation and survival of stocked trout.		
	HQW = High Quality Waters: waters which are rated as excellent based on biological and physical/chemical characteristics through Division monitoring or special studies, native and special native trout waters (and their tributaries) designated by the Wildlife Resources Commission,		
SC (SCDHEC 2012)	**ORW** = Outstanding Resource Waters		
	TN = Trout-Natural		
	TPGT = Trout-Put, Grow, and Take		
	FW = Freshwaters		

Table C-2 Water Use Classifications of Waterbodies within the Keowee Watershed, South Carolina

Watershed	Name	Description	Water Use Classification
Lake Keowee	Mill Creek (SC)	Entire tributary to Eastatoe Creek	TPGT
	Eastatoe Creek (SC)	From its confluence with Laurel Creek to Lake Keowee	TPGT
	Cane Creek (SC)	Entire stream tributary to Lake Keowee	TN
	Little River (SC)	Entire stream tributary to Hartwell Lake	FW
	Martin Creek (SC)	The entire stream tributary to Hartwell Lake	FW
	Lake Keowee (SC)	Entire lake	FW
SC (SCDHEC 2012)	**TN** = Trout-Natural		
	TPGT = Trout-Put, Grow, and Take		
	FW = Freshwaters		

Table C-3 Water Use Classifications of Major Waterbodies within the Savannah River Watershed, South Carolina and Georgia

Watershed	Name	Description	Water Use Classification
Savannah River	Chattooga River (SC)	That portion of the river from its confluence with Opossum Creek to Tugaloo River	FW
	Chattooga River (SC)	That portion of the river from the North Carolina line to its confluence with Opossum Creek	ORW(FW)
	Tugaloo River (SC)	That portion of the river from Tugaloo Dam to Hartwell Lake	FW
	Twelve Mile Creek (SC)	The entire creek tributary to Hartwell Lake	FW
	Rocky River (SC)	The entire river tributary to Savannah River	FW
	Little River (SC)	The entire river tributary to Hartwell Lake	FW
		The entire river tributary to JST Lake	FW
	Little River Inlet (SC)	The entire inlet from its confluence with the Atlantic Intracoastal Waterway to its confluence with the Atlantic Ocean	SFH
	Stevens Creek (SC)	The entire creek tributary to Savannah River	FW
	Horse Creek (SC)	The entire creek tributary to Savannah River	FW
	Savannah River (SC)	That portion of the river from Hartwell Lake Dam to the headwaters of Richard B Russell Lake	TPGT
		That portion of the river from the headwaters of Richard B. Russell Lake to Seaboard Coastline RR	FW
		That portion of the river from Seaboard Coastline RR to Ft. Pulaski (D.O. not less than daily average of 5 mg/l and minimum 4 mg/l)	SB sp
		That portion of the river from Ft. Pulaski to the Atlantic Ocean	SA
	Chattooga River (GA)	Georgia-North Carolina State Line to Tugaloo Reservoir	WS
	West Fork Chattooga	Confluence of Overflow Creek and Clear	WS

Watershed	Name	Description	Water Use Classification
	(GA)	Creek to confluence with Chattooga River (7.3 miles)	
	Tallulah River (GA)	Headwaters of Lake Burton to confluence with Chattooga River	R
	Tugaloo River (GA)	Confluence of Tallulah and Chattooga Rivers to Yonah Lake Dam	R & DW
	Savannah River (GA)	Highway 184 to JST Dam (Mile 238)	R
		JST Dam to Augusta 13th Street Bridge	DW
		US Hwy. 301 Bridge (Mile 129) to Seaboard Coastline RR Bridge (Mile 27.4)	DW
		Seaboard Coastline RR Bridge to Fort Pulaski	CF
		Fort Pulaski to Open Sea and all littoral waters of Tybee Island	R
SC (SCDHEC 2012)	**ORW** = Outstanding Resource Waters		
	TPGT = Trout-Put, Grow, and Take		
	FW = Freshwaters		
	SB = Class SB (saltwater)		
	SA = Class SA (saltwater)		
	SFH = Shellfish Harvesting Waters		
	sp = the SCDHEC has established site-specific standards for certain parameters for that waterbody. The site-specific standards are listed in parentheses after the waterbody description.		
	For ORW waterbodies, the previous classification for the specific waterbody is given in parenthesis after the Class listing.		
GA (GAEPD 2012)	**WS =** Wild and Scenic **R =** Recreation **DW =** Drinking Water **CF =** Coastal Fishing		

Table C-4 North and South Carolina Numeric State Water Quality Standards Pertinent to Lake Jocassee and Lake Keowee

Parameter	North Carolina Water Quality Standard	South Carolina Water Quality Standard
Temperature (applies to heated effluents only)	Not to exceed 2.8°C (5.04°F) above the natural water temperature. Not to exceed 29°C (84.2°F) for mountain and upper piedmont waters. Not to exceed 32°C (89.6°F) for lower piedmont and coastal plain waters. Trout waters: not to be increased by more than 0.5°C (0.9°F) and in no case exceed 20°C (68°F).	Not to exceed 2.8°C (5°F) above natural temperatures up to 32.2°C (90°F). Trout Waters: Not to vary from levels existing under natural conditions, unless determined that some other temperature shall protect the classified uses.
Dissolved Oxygen (DO)	Not less than 5.0 mg/L daily average. Instantaneous value of not less then 4.0 mg/L. Trout Waters: Not less than 6.0 mg/L daily.	Daily average not less than 5.0 mg/L Low of 4.0 mg/L Trout Waters: Not less than 6.0 mg/L
pH	6.0 - 9.0	Between 6.0 and 8.5. Trout Waters: Between 6.0 and 8.0.
Turbidity	Not to exceed 50 NTUs.	FW Except for lakes: Not to exceed 50 NTUs provided existing uses are maintained. FW Lakes Only: Not to exceed 25 NTUs provided existing uses are maintained. Trout Waters: Not to exceed 10 NTUs or 10% above natural conditions, provided existing uses are maintained.
Phosphorus	N/A	Blue Ridge - Shall not exceed 0.02 mg/L. Piedmont - Shall not exceed 0.06 mg/L.
Nitrogen	N/A	Blue Ridge - Shall not exceed 0.35 mg/L. Piedmont - Shall not exceed 1.5 mg/L.
Chlorophyll a	Not greater than 40 ug/L.	Blue Ridge - Shall not exceed 10 µg/L. Piedmont - Shall not exceed 40 µg/L.

Source: SCDHEC 2012. NCDWQ 2007.

Table C-5 General Criteria for All Waters in the State of Georgia

Use Classification	Bacteria (fecal coliform)	Dissolved Oxygen		pH		Temperature	
	30-Day Geometric Mean (no./100 ml)	Daily Avg (mg/L)	Minimum (mg/L)	Minimum	Maximum	Maximum Rise (°F)	Maximum(°F)
Drinking Water	200 (May-Oct) 300 (lakes and reservoirs) 500 (free flowing streams) 1,000 (Nov-Apr) 4,000 (max. Nov-Apr)	5.0	4.0	6.0	8.5	5	90
Fishing	200 (May-Oct) 300 (lakes and reservoirs) 500 (free flowing streams) 1,000 (Nov-Apr) 4,000 (max. Nov-Apr)	6.0 (trout streams) 5.0 (others)	5.0 (trout streams) 4.0 (others)	6.0	8.5	5 1.5 (estuarine) 0 (trout and bass) 2 (secondary trout stream)	90
Recreation	100 (Coastal) 200 (all other)	5.0	4.0	6.0	8.5	5	90
Coastal Fishing		5.0	4.0			5	90
Wild and Scenic	No alteration of natural water quality from any source						

Source: GAEPD 2012

Water Quality Data

Lakes Jocassee and Keowee

Duke Energy initiated water quality monitoring following the impoundment of Lakes Jocassee and Keowee. Duke Energy water quality sampling on Lakes Jocassee and Keowee generally consisted of monthly[1] in situ temperature, DO, conductivity, and pH at several locations (Figures C-1 and C-2). Nutrients, chlorophyll a, and primary anions and cations as well as various metals were sampled at least semi-annually over the years.

[1] Quarterly sampling occurred from 1984–1987.

Figure C-1 Water Quality Monitoring Sites – Jocassee Watershed

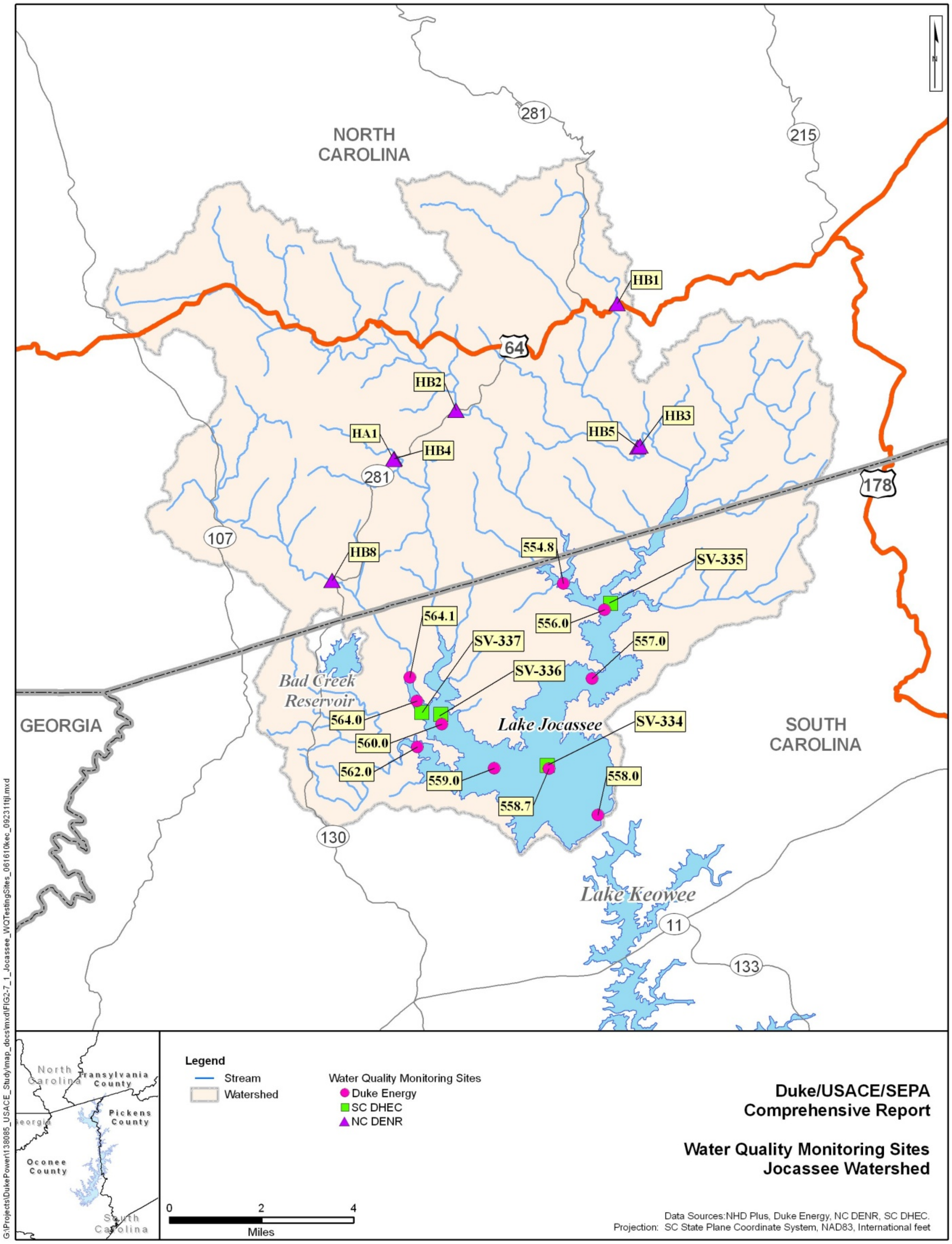
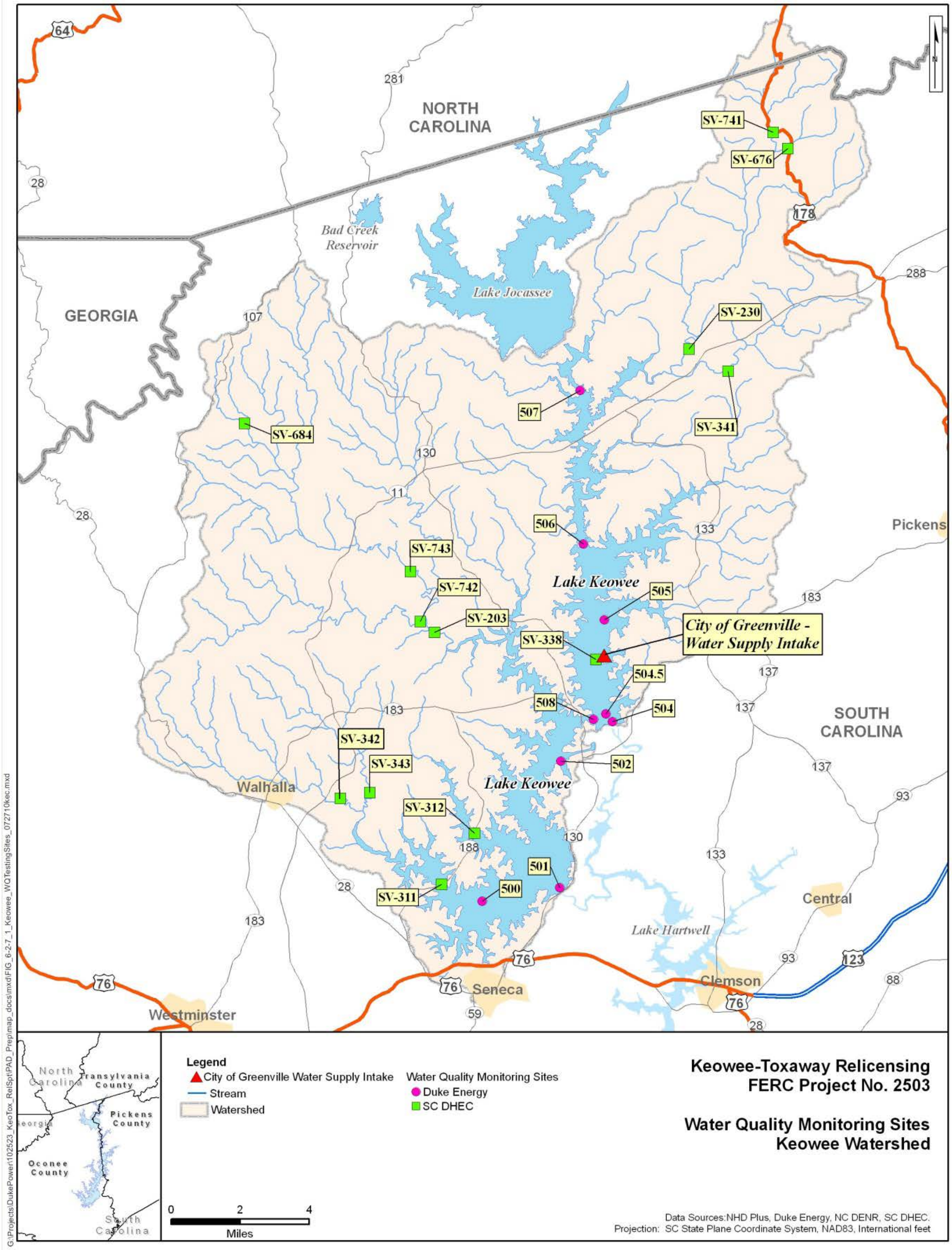


Figure C-2 Water Quality Monitoring Sites – Keowee Watershed



Prior to 1981, ONS's thermal discharge was permitted under the authority of the NRC. Since that time, the ONS thermal discharge has been permitted under the National Pollutant Discharge Elimination System (NPDES) as authorized by SCDHEC. Two 316a demonstrations have been successfully submitted to SCDHEC (Duke Energy 1995 and 2007). The majority of the data collected by Duke Energy on Lake Keowee was in support of ONS permitting. Details of Lake Keowee water quality sampling, water quality data analysis, and impact of once-through-cooling water in Lake Keowee is presented in the two 316a demonstrations.

Various governmental agencies have also conducted water quality assessments of Lakes Jocassee and Keowee. The U.S. Environmental Protection Agency (USEPA) conducted water quality surveys on Lake Keowee as part of the National Eutrophication Survey. USEPA found Lake Keowee was mesotrophic and ranked it first in overall water quality compared to other South Carolina lakes (USEPA 1975).

The USFWS (Oliver and Hudson 1987) conducted monthly temperature and oxygen profiling at 13 locations in Lake Keowee from 1971 to December 1982. The depression of the thermocline, expansion of the epilimnion, and increased vertical mixing DO throughout the lake was the result of ONS pumping deep, cool water for condenser cooling from under a 67 ft deep skimmer wall. In addition, they noted a cold water plume in the northern portion of Lake Keowee as a result of Jocassee operation.

SCDHEC (1982) reported 95% of the lakes in South Carolina including both Lakes Jocassee and Keowee were eutrophic, based upon the Carlson Trophic Index (Carlson 1977). This index used chlorophyll a, secchi disk depth, and total phosphorus as the key parameters. Even though Keowee and Jocassee were classified as eutrophic, Keowee and Jocassee were considered the least eutrophic of these South Carolina lakes. By 1991, the SCDHEC revised its index to reflect the observation "Southeastern lakes tend to be more turbid and nutrient rich than northeastern and north-central lakes" (SCDHEC 1991). This revised index, recalculated using the 1980-81, 1985-86, and 1989-90 data, consistently placed Lakes Keowee and Jocassee as among the cleanest South Carolina lakes. SCDHEC placed those lakes in the highest water quality classification and recommended preservation of existing conditions. Water quality in Lake Keowee is second only to Lake Jocassee, which is considered excellent.

The most recent assessments in the Lake Jocassee and Keowee watersheds by both North Carolina and South Carolina (SCDHEC 2006a and 2006b) show, with rare exception, the waters are fully supporting their designated use (Table C-6). Exceptions included impaired recreational use in some areas due to high coliform levels. In addition, the 2012 South Carolina Section 303(d) list of impaired waters indicates several coves in Lake Jocassee are not meeting fish and aquatic life criteria due to mercury and zinc concentrations (SCDHEC 2012).

Table C-6 Summary of Current Designated Use and Assessment of Waters in the Keowee-Jocassee Watershed

State	Name	State Sampling Name	Sampling Type	Water Use Class	Designated Use Assessment		SCDHEC Data - Percentage of Total Samples NOT meeting State Water Quality Standards										
							DO		pH		Bacteria		Turb	TP	TN	Chl	NH_3
					Aquatic Life	Rec	1997	2003	1997	2003	1997	2003	2003	2003	2003	2003	2003
NC	Horsepasture River	HA1, HB2	P/Bio[1]	C, Tr[2]	S[3]	S	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NC	Thompson River	HB4	Bio	C, Tr	S	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NC	Toxaway River	HB3	Bio	C	S	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NC	Bearwallow Creek	HB5	Bio	C, Tr, HQW	S	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NC	Indian Creek	HB1	Bio	C, Tr	S	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NC	Whitewater River	HB8	Bio	C, Tr, HQW	S	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	**Keowee River Basin**																
SC	Lake Jocassee (Main Lake)	SV-334	P[4]	TPGT[5]	FS[6]	FS	ns	0	3	3	4	0	0	4	4	0	0
SC	Lake Jocassee (Toxaway Arm)	SV-335	P	TPGT	FS[7]	FS	ns	0	3	3	0	0	0	0	4	0	0
SC	Lake Jocassee (Outside Weir)	SV-336	P	TPGT	FS	FS	ns	0	8	8	5	0	2	5	2	0	0
SC	Lake Jocassee (Whitewater)	SV-337	P	TPGT	FS	FS	ns	1	8	8	5	0	2	5	2	0	0
SC	Eastatoe Creek	SV-741	Bio	ORW	FS	FS	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SC	Rocky Bottom Creek	SV-676	Bio	ORW	FS	ND	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SC	Eastatoe Creek	SV-230	P/Bio	TPGT	FS	FS	0	0	0	2	19	6	13	ns	ns	ns	0
SC	Little Eastatoe Creek	SV-341	W/Bio	TPGT	FS	PS	ns	0	ns	0	ns	22[8]	13	ns	ns	ns	0
SC	Lake Keowee (Keowee Arm)	SV-338	P	FW	FS	FS	0	0	0	3	0	0	0	ns	0	0	0
SC	**Little River Basin**																
SC	Crane Creek	SV-684	Bio	FW	FS	ND	ns	0	ns	ns	ns	ns	ns	ns	ns	ns	ns
SC	Flat Shoals River	SC-743	Bio	FW	FS	ND	ns	0	ns	ns	ns	ns	ns	ns	ns	ns	ns
SC	Oconee Creek	SV-742	Bio	FW	FS	ND	ns	0	ns	ns	ns	ns	ns	ns	ns	ns	ns

State	Name	State Sampling Name	Sampling Type	Water Use Class	Designated Use Assessment		SCDHEC Data - Percentage of Total Samples NOT meeting State Water Quality Standards										
							DO		pH		Bacteria		Turb	TP	TN	Chl	NH_3
					Aquatic Life	Rec	1997	2003	1997	2003	1997	2003	2003	2003	2003	2003	2003
	Little River	SV-203	S	FW	FS	FS	0	2	0	2	10	2	0	ns	ns	ns	0
	Little Cane Creek	SV-343	W/Bio	FW	FS	NS	ns	0	ns	0	ns	61[8]	4	ns	ns	ns	0
	Cane Creek at S-37-133	SV-342	W/Bio	FW	FS	NS	ns	0	ns	0	ns	58[8]	8	ns	ns	ns	0
	Lake Keowee (Cane Ck Arm)	SV-311	P	FW	FS	FS	0	0	0	0	0	0	0	0	0	0	0
	Lake Keowee (Crooked Ck arm)	SV-312	P	FW	FS	FS	0	0	0	0	0	0	0	0	0	0	0

[1] North Carolina uses Ambient Monitoring (Physical and Chemical Data), for consistency with South Carolina; P = Ambient Monitoring and Bio = Benthic Organism as Monitoring Indicators

[2] In North Carolina, Class C waters = freshwater used for secondary recreation and support for aquatic life, Tr = Trout waters, HQW = Freshwater with High Quality Water designation

[3] In North Carolina, S = Supporting Designated Use (equivalent to FS in South Carolina), North Carolina does not present data equivalent to South Carolina, NA = Not Applicable

[4] In South Carolina P = Primary (monthly throughout the year) of physical and chemical data, similar to North Carolina's Ambient Monitoring, S= Secondary (same as P, but monthly from May - October), W = Watershed where sites are sampled monthly only during the target year, Bio = similar to North Carolina's Benthic sampling

[5] In South Carolina, FW = freshwater used for secondary recreation and support for aquatic life TPGT = Trout waters, where the fishery is a put, grow, and take strategy, ORW = Freshwater with Outstanding Resource Water designation (similar to NC's HQW), if parameter was not measured, ns = not sampled

[6] In South Carolina, FS = Fully Supporting Designated Use (equivalent to S in North Carolina), PS = Partially supporting designated use, NS = not supporting designated use, ND = data was not collected to make assessment

[7] South Carolina has found elevated Mercury (Hg) in fish tissue and has issued a fish consumption advisory from fish caught in the Toxaway Arm of Lake Jocassee, this is the basis of the 'impairment' classification

[8] Shaded areas represent criteria used for classifying the site as not supporting its designated use

Chemical Characteristics

The chemical characteristics of natural waters is directly linked to the mineral content and weathering rates of underlying rock and soil formations (Stumm and Morgan 1988). The predominant bedrock extending across the Blue Ridge escarpment and upper Piedmont consists primarily of ancient metamorphic granitic gneiss formed over 300 million years ago. Even with the abundant rainfall associated with the Jocassee headwater streams, these rocks chemically weather extremely slowly and dissolve into very dilute solutions of sodium, calcium, chloride, potassium, and magnesium (Drever 1982 and Johnson et al. 1968).

The chemical composition of the water (ranked in order of meq/l concentration) in the Lake Jocassee and Lake Keowee area reflects the chemical composition and weathering sequence of the parent rock material (Table C-7). Not only does the ionic composition mimic the consistency of the solutes from the chemical weathering of the parent rock material, but the very low concentrations reflect the extremely slow rates of chemical weathering of the underlying rock formations. The ionic strength, i.e. low conductivity, was similar to other systems draining the Blue Ridge escarpment (USGS 1982). The bicarbonate concentration dominated the anionic composition as HCO_3 originated from the dissolution of CO_2 in the water with bicarbonate maintaining an ionic equilibrium with other dissolved material. Some differences were noted in the chemical composition of the waters in Lake Jocassee and Keowee and may reflect slight differences in the underlying rock. Downstream from Jocassee, the Keowee system gained approximately 30% more dissolved material from its watershed than observed from the Jocassee Watershed. Again, the ratios of the ions reflect similar underlying geology.

Even though the soil in the area had a relatively high erosion, the total suspended solids in the both lakes were very low, indicating either low loading rates of suspended sediment or high settling rates in the lakes. Inorganic solids (measured by the ash on ignition) represented about 70% of the solids in Jocassee and 60% in Lake Keowee. Even though, on the average, Lake Keowee may be receiving more solids and relatively higher organics than Jocassee (TSS and Inorganic Solids, Table C-7), these values were extremely low compared to other South Carolina lakes (SCDHEC 1982 and 1991).

These primary minerals and the ratios of those compounds have remained essentially unchanged since the impoundments were first constructed. Even with increased development in the watershed, the consistency of these values indicate little, if any, impact from those developments on the overall chemistry of the lakes.

Other general characteristics which reflect the water quality of Lakes Jocassee and Keowee include morphometric (lake basin topography) and chemical relationships (Table C-8). The relatively large volume to surface area ratio (mean depth) indicates both lakes have a limited littoral area suggesting a planktonic-based ecosystem. Especially notable is the large relative depth of Lake Jocassee which greatly influences the water quality by limiting winter mixing.

Table C-7 Mean Chemical Composition of Lake Jocassee and Lake Keowee Water

Ion	Lake Jocassee Concentration		Lake Keowee Concentration	
	(mg/l)	(meq/l)	(mg/l)	(meq/l)
Sodium	1.39	0.060	2.43	0.106
Calcium	1.22	0.061	1.48	0.074
Potassium	0.67	0.017	0.78	0.020
Magnesium	0.41	0.034	0.59	0.049
Σ Cations		**0.172**		**0.248**
Bicarbonate	5.06	0.083	8.68	0.142
Chloride	1.16	0.033	1.50	0.042
Sulfate	1.92	0.040	1.57	0.033
Σ Anions		**0.156**		**0.217**
Total Dissolved Solids (TDS)	10.4		14.6	
Conductivity(units)	17		23	
Ratio TDS/Conductivity	0.60		0.64	
Total Suspended Solids (TSS)	0.84		1.64	
Inorganic Solids	0.60		1.00	

Table C-8 Morphometric Metrics and Indices of Lakes Jocassee and Keowee

Metric	Jocassee	Keowee
Gross Storage Volume (ac-ft)	1,160,298	955,586
Surface Area (ac)	7,980	17,660
Maximum Depth (ft)	340	150
Mean Depth (ft)	145	54
Relative Depth[1] (%)	1.62	0.48
Mean Retention Time (days)	135	465
Hydraulic Loading Rate (m/year)	119.8	12.9
MEI (TDS/mean depth)	0.24	0.89
Chemical Class (Na > Ca : HCO_3 > SO_4)	Type 2-3	Type 2-3

[1] relative depth is defined as the ratio of the maximum depth to the mean diameter of the lake, Hakanson, 1981.

The relatively long retention time of the water in each lake suggests plankton populations would have ample time to grow and provide a food base for the system. However, the high hydraulic loading rate (Vollenweider 1968) suggests Lake Jocassee and Lake Keowee could receive significant loadings of phosphorus and still remain oligotrophic.

The Morphoedaphic Index (MEI) (Oglesby and Jenkins 1982) values for both lakes were extremely low suggesting very poor biological productivity, especially fish. Jenkins (1967) also points out those systems with type 2 and 3 water chemistry are not as biologically productive as systems with a Ca-Mg:HCO3 based chemistry. All of these indicators - high mean depth, higher than normal relative depths, high hydraulic loading, very low MEI, and a chemical class of type 2-3 - reinforce SCDHEC's oligotrophic classification of high quality water in both lakes and the goal of preserving existing water quality.

Temperature and Dissolved Oxygen

Lake Jocassee (Seasonal and Yearly Trends)

Southeastern lakes are generally classified as monomictic, namely the lakes thermally stratify during the summer and, as cooling occurs during the fall-winter period, complete mixing of the water column progresses until vernal warming (Hutchinson 1957). Lake Jocassee, on the other hand, due to its high relative depth (i.e. the ratio of the maximum depth of a waterbody compared to its surface area) of 1.7%, may be characterized as an oligomictic lake, i.e. incomplete mixing during the fall-winter cooling period. During mild winters, the lake may not exchange enough heat through its surface with the atmosphere to cool the deeper reaches of the lake, hence incomplete mixing. However, during more severe winters, the lake may lose enough heat to cool even the bottom waters setting up convective mixing all the way to the bottom.

The years 1990-91 and 1992-93 represent examples of the inter-year variability of temperature and oxygen in Lake Jocassee. The 1990-1991 winter cooling period was an example of the seasonal cooling characteristic of most Southeastern lakes (Figure C-3) namely that the lake looses heat from the surface to the atmosphere after the height of summer stratification (17 Sept 1990). The heat loss, and subsequent temperature decline of the upper water, gradually mixed the upper water to lower depths. However, during the mild 1990-1991 winter, the downward convective cooling was not sufficient to cool Jocassee's bottom waters, i.e. the bottom water did cool beyond the temperature that existed the previous September. The consequence of this incomplete thermal mixing was the oxygen concentrations remained very low in the deep waters (Figure C-4) since the convective mixing process did not distribute the atmospherically derived oxygen deeper. By contrast, the winter of 1992-1993 was cold enough to completely mix the lake (Figure C-3), as evidenced by the temperatures cooling more than the temperatures exhibited the previous September, in this case, the bottom waters were two degrees colder on 15 March 1993 compared to September, 1992. During the mixing process, DO equilibrated with the atmosphere as cooling progressed and eventually re-aerated the entire water column (Figure C-4).

Also notable in March 1991 and February 1993 was the DO increase in the extreme depths of Jocassee. Since the DO was still depressed at the 910 ft level, the increase in DO at the deeper depths could not have originated from the atmospheric exchange of DO. Rather, at this time of year, surface streams and rivers entering Lake Jocassee would be colder than the lake surface since streams and rivers equilibrate with the atmospheric temperatures much faster than a lake; consequently, upon entering the lake the stream or river water would plunge to the depth of equal water density. As this water plunges, it would carry the high DO with it, in these cases, to the bottom of the lake thereby increasing the DO in the deep waters.

The degree of winter mixing sets the initial temperature and oxygen levels throughout the lake at the onset of spring warming and the beginning of stratification. With the beginning of thermal stratification (Figure C-5), both summers showed the same pattern of surface water warming gradually strengthening a thermal gradient (thermocline) which limited the amount of heat transport to the deeper waters. Neither summer had any significant heating of the hypolimnion, and at the end of stratification, the deep water temperatures were essentially the same as at the end of the winter mixing period.

DO showed very substantial differences between the two summer periods (Figure C-6). After the winter of incomplete mixing (1990-91), DO concentrations were low after the winter mixing period and continued to decline as chemical and biological consumption of oxygen progressed throughout the summer. The amount of oxygen remaining at the end of the stratified period (17 September 1991) was very low throughout lower half of the water column. The summer after the complete winter mixing (1993) exhibited a completely different pattern with plenty of oxygen distributed throughout the water column. Oxygen gradually decreased in the lower depths but essentially remained above 5 mg/L throughout the water column. The amount of oxidation between the two years was essentially the same, the only difference was the amount of oxygen in the lake at the time of initiation of stratification, which was a function of the winter mixing.

The combination of the degree of heating at the surface during the summer months and the oxygen concentrations at depth varied significantly between the years. The year-to-year variability of temperature, and especially DO, prompted a request by South Carolina state fisheries biologists for an investigation by Duke Energy on the availability of trout habitat.

Jocassee Reservoir Pelagic Trout Habitat Study (1974–2008)

Lake Jocassee is one of only a handful of reservoirs in South Carolina possessing the necessary combination of water temperatures and DO levels to assure the survival of salmonid (trout) species year-round. Following impoundment of Lake Jocassee in the early 1970s, state fishery biologists from South Carolina introduced both rainbow and brown trout into the reservoir to diversify its fishery. The stocking of rainbow and brown trout has continued annually to present day, and has resulted in a productive combination of various game fish for the avid fishery sportsman. Part of the continued success of the trout fishery is dependent upon the year-round availability of suitable pelagic habitat, as defined by specific thermal and DO limits.

Measurements of temperature and DO have been performed in Lake Jocassee since 1974. Measurements typically were taken at multiple locations (Figure C-3) starting at the water surface (0.3 m) and proceeding downward at 2 m intervals to the reservoir bottom (Foris 2008). This approach provided a continuous recording (i.e., a profile) for both temperature and DO throughout the water column at each location. Locations were selected to assure an adequate

Figure C-3 Lake Jocassee Seasonal Cooling Contrasting a Winter of Incomplete Mixing (1990–1991) with a Winter of Complete Mixing (1992–1993)

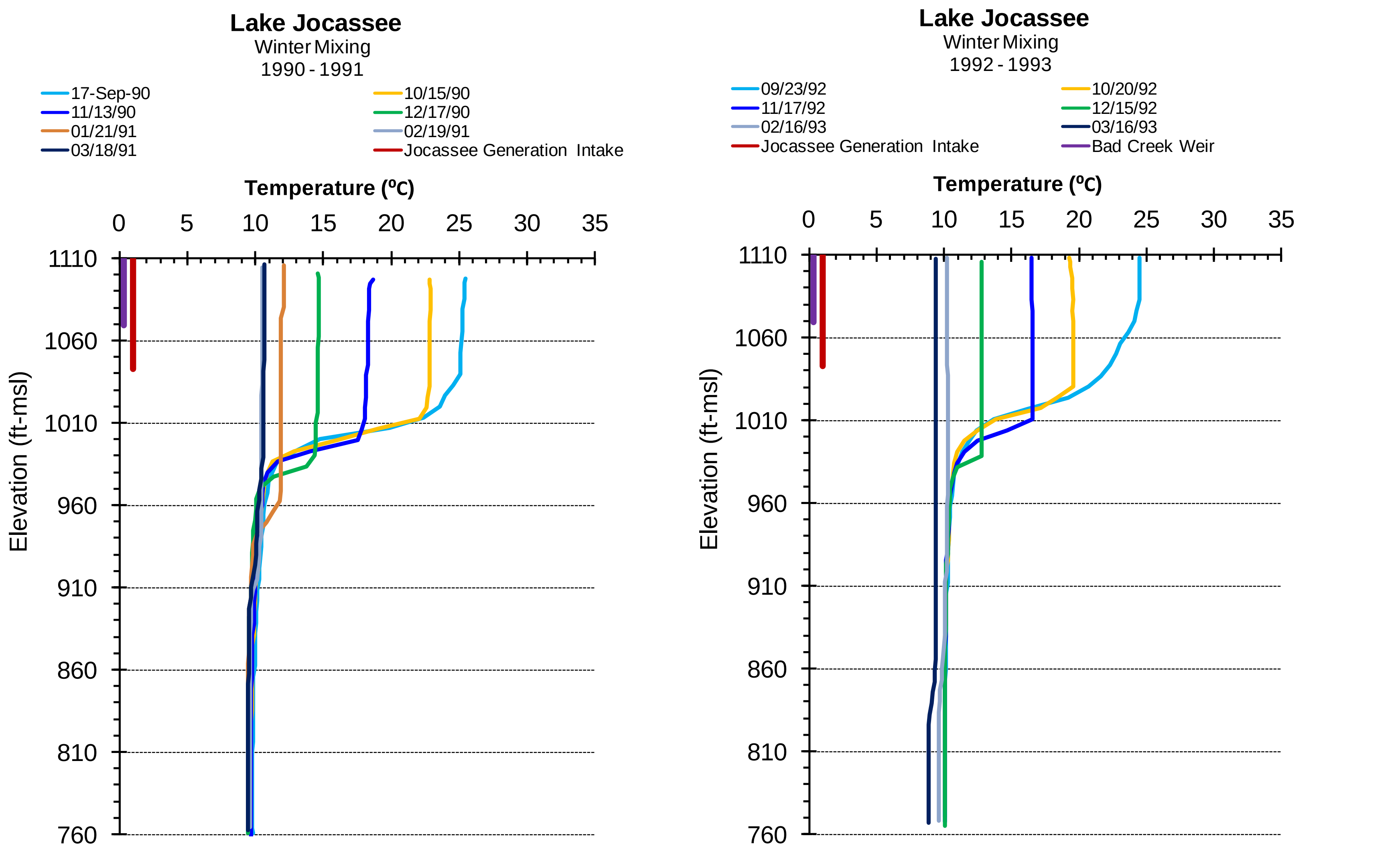


Figure C-4 Lake Jocassee Seasonal DO Contrasting a Winter of Incomplete Mixing (1990–1991) with a Winter of Complete Mixing (1992–1993)

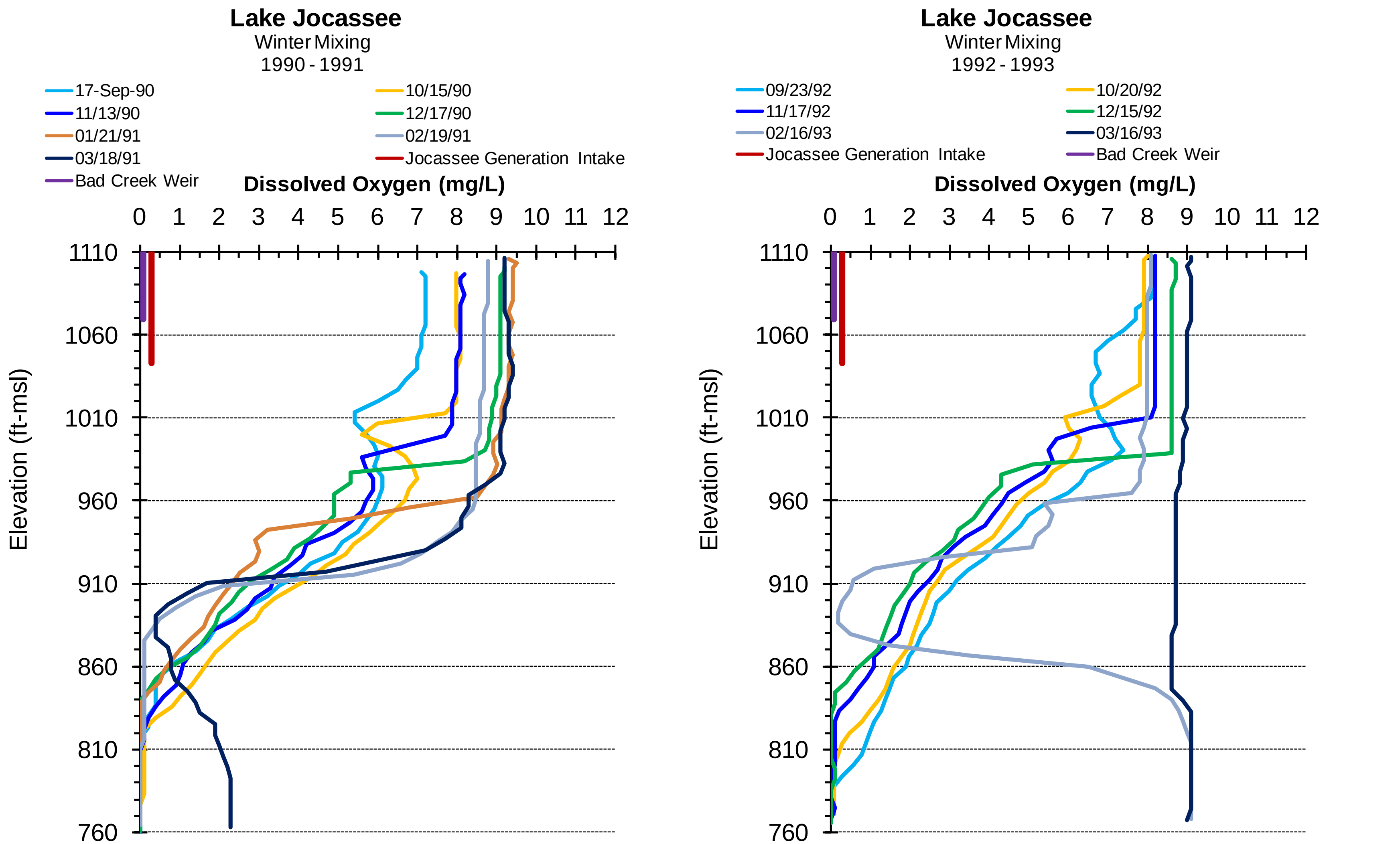
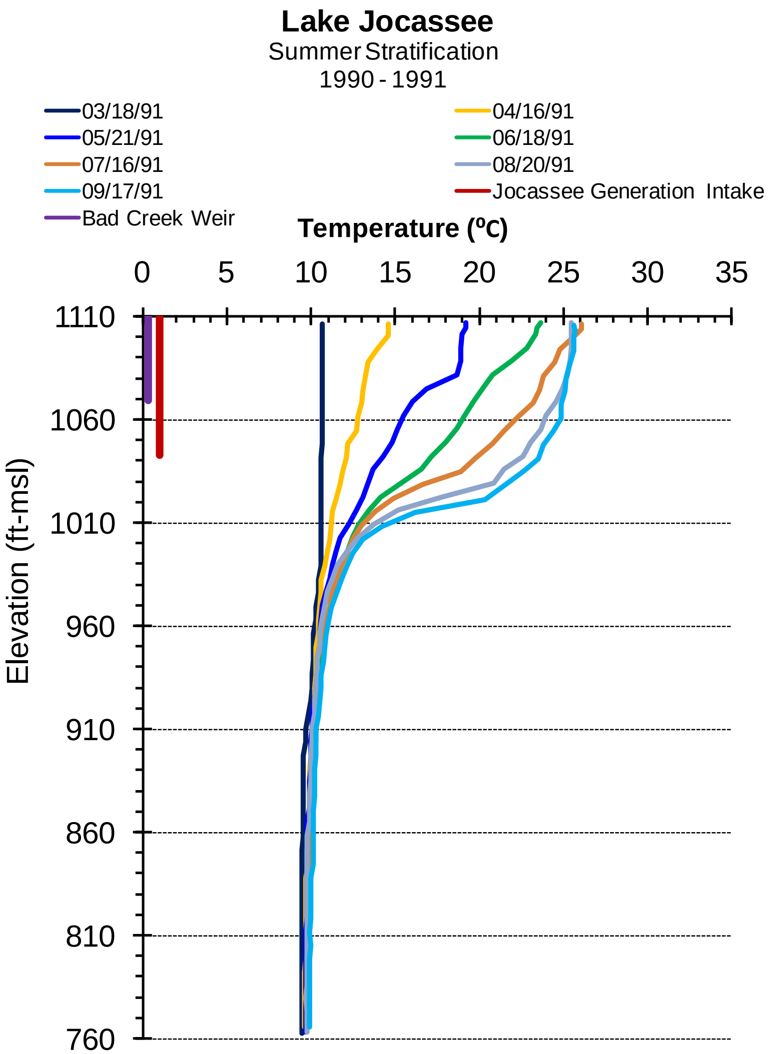


Figure C-5 Lake Jocassee Temperature Stratification Contrasting Two Years with Different Winter Mixing Patterns



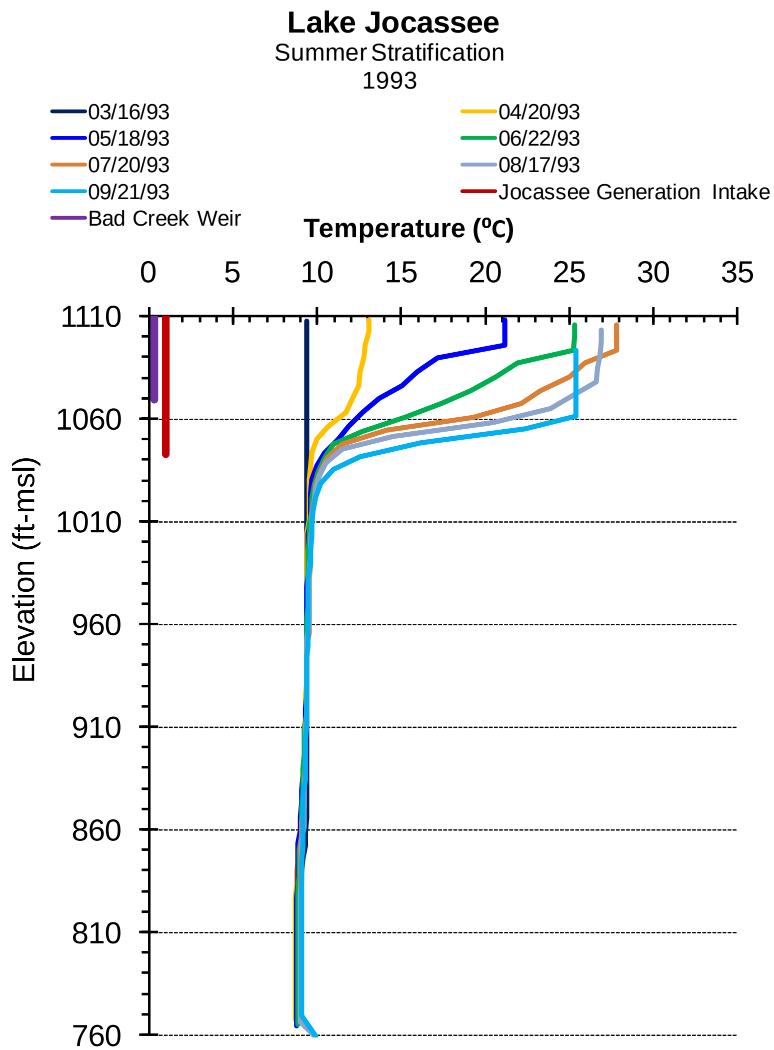
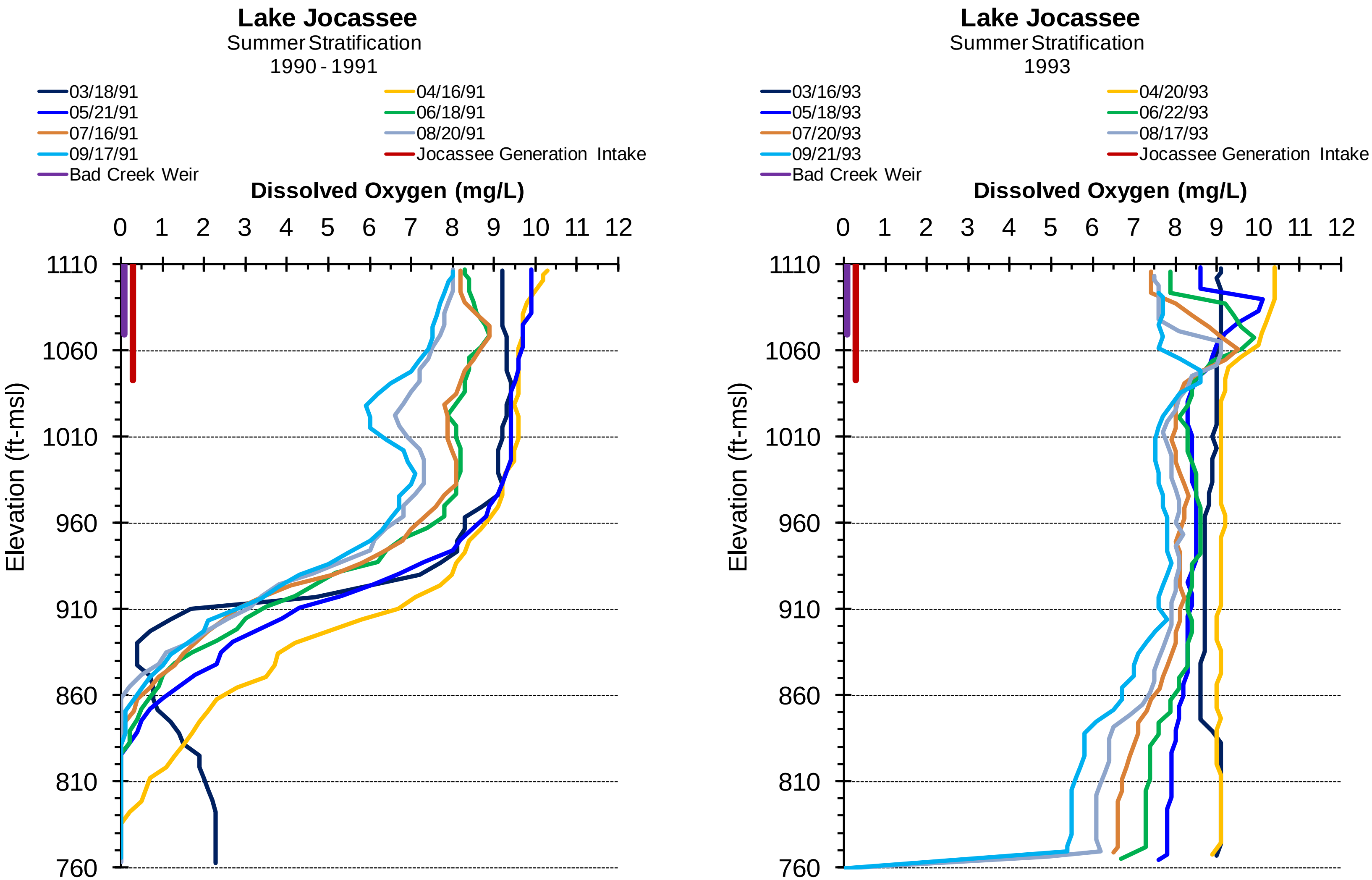


Figure C-6 Lake Jocassee DO during Stratification Contrasting Two Years with Different Winter Mixing Patterns



characterization of the spatial aspects of pelagic trout habitat throughout the reservoir and included uplake, midlake, and downlake sampling stations. The definition used to delineate pelagic trout habitat in Lake Jocassee was the volume of water which exhibited temperatures 20°C and DO concentrations 5.0 mg/L, and followed the definition given by Oliver, et. al. (1978).

The temporal and spatial distribution of trout habitat in Lake Jocassee over the 1974-2008 period was found to parallel patterns exhibited in the temperature and DO regimes. Seasonally, habitat was greatest during the winter cooling period when temperatures were well below 20*C due to atmospheric cooling, and DO levels generally exceeded 5.0 mg/L due to reaeration of the water column as the reservoir cooled and mixed. As the seasons progressed and air temperatures increased, habitat gradually declined both horizontally and vertically within the reservoir due to warming of the upper water layers and depletion of DO in the middle and lower portions of the water column. Habitat was consistently at a minimum (most restrictive) in late summer (September) just prior to fall cooling, coinciding with the height of thermal stratification in the reservoir. In most years, September habitat was restricted to the mainbody of the reservoir where water depths exceeded 70 m.

The annual minimum measurement of habitat, expressed either in thickness (m) measured in September in the mainbody or total volume (m3), varied considerably over the 1974-2008 period with no discernable increasing or decreasing long-term trends (Figures C-8 and C-9). September habitat measured in thickness ranged from a minimum of 9 m in 1976 to maximum of 88 m in 1993. September habitat measured in volume exhibited the same pattern as observed in thickness and ranged from a minimum of 9.9 x 107 m3 in 1976 to a maximum of 88.9 x 107 m3 in 1993. The magnitude of winter cooling and reaeration of the water column, as influenced by the severity of winter meteorology, was found to be the most dominant factor explaining the inter-annual variations in the thickness and volume of September habitat in the reservoir. Inter-annual variations in operations of the Jocassee Pumped Storage Station (JPSS) were found to be of secondary importance in influencing trout habitat, primarily through deepening of the 20°C isotherm. No impacts on seasonal or inter-annual variability in trout habitat, in association with operations of the Bad Creek Project were identified in the statistical analyses.

Foris (1987) developed an empirical model to predict the September thickness of pelagic trout habitat in the mainpool of the reservoir based on two independent variables, operations at the JPSS and winter cooling and reaeration. This model has been employed successfully to "predict" September trout habitat conditions in Lake Jocassee for 20 years, 1989-2008 (Foris 2009). Predictions of the September 20°C isotherm and 5.0 mg/L isopleth elevations have been accurate over the period 1989-2009, generally within 1-3 m of the measured 20°C isotherm and 1-11 m of the measured 5.0 mg/L isopleth (Table C-9).

Table C-9 Measured vs. Predicted Trout Habitat - Jocassee Reservoir

Year	Measured Trout Habitat			Predicted Trout Habitat		
	Elevation 20°C	Elevation 5.0 mg/L	STH[b] (m)	Elevation 20°C	Elevation 5.0 mg/L	STH[b] (m)
1989	307	283	24	305	282	23
1990	307	284	23	310	282	26
1991	312	285	27	314	284	30
1992	313	290	23	316	287	29
1993	323	235	88	323	244	79
1994	314	234	80	316	243	73
1995	312	286	26	317	294	23
1996	313	235	78	316	246	70
1997	311	286	26	314	290	24
1998	311	290	21	312	285	27
1999[a]	313	294	19	312	293	19
2000	313	298	15	316	298	18
2001	310	239	71	311	249	62
2002	309	292	17	310	289	21
2003	311	234	77	312	243	69
2004	310	236	75	311	243	69
2005	309	282	27	309	281	28
2006	308	286	22	310	243	27
2007	311	250	61	312	249	63
2008	307	259	48	312	284	28
2009	308	236	72	312	247	65

a- Represents early October data

b- September Trout Habitat

Figure C-7 Lake Jocassee Pelagic Trout Habitat Monitoring and Submerged Weir Locations

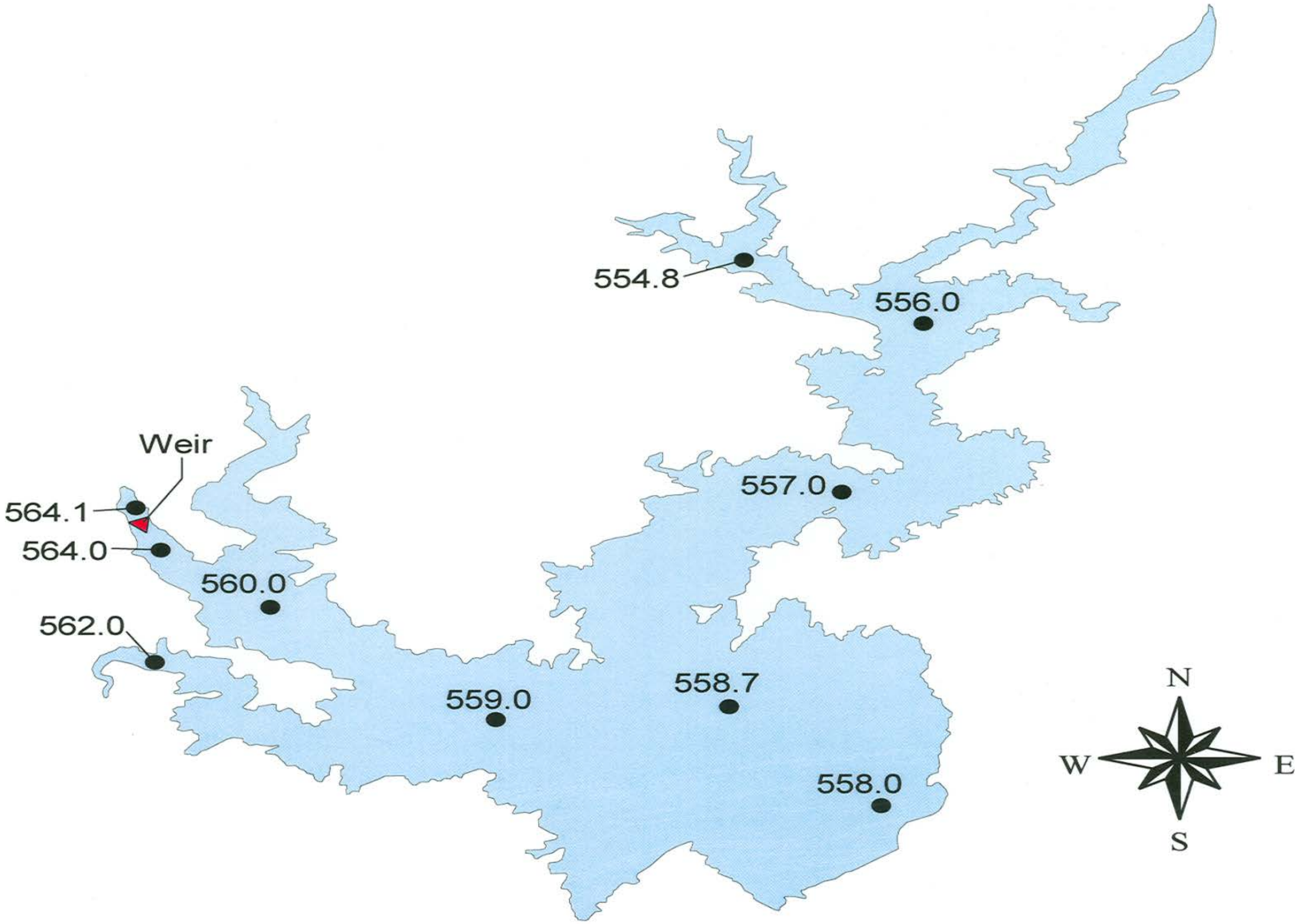
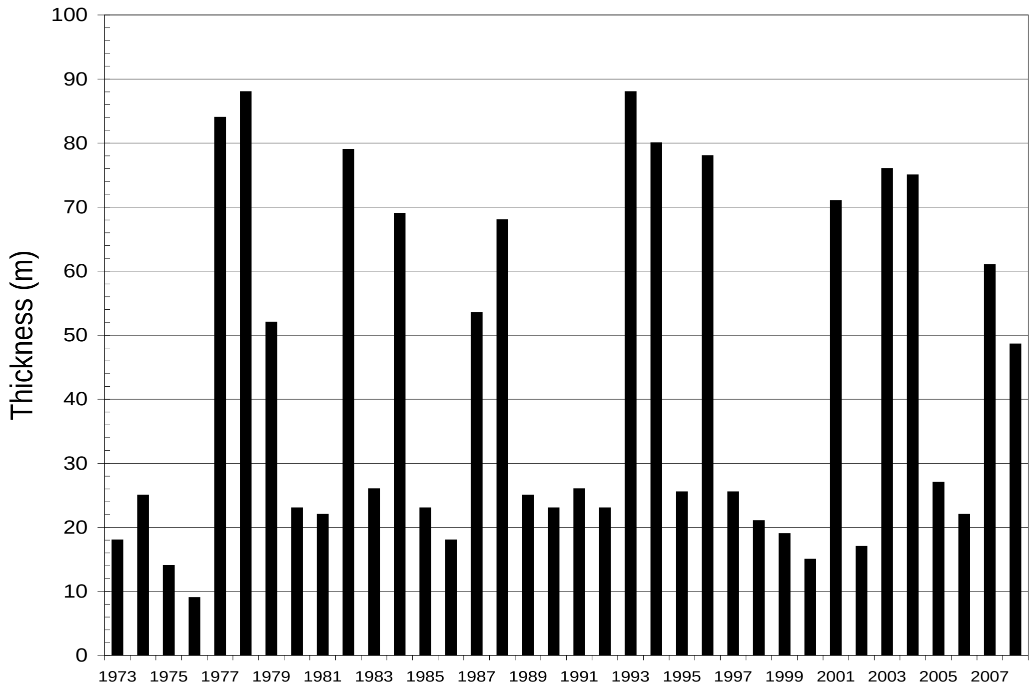
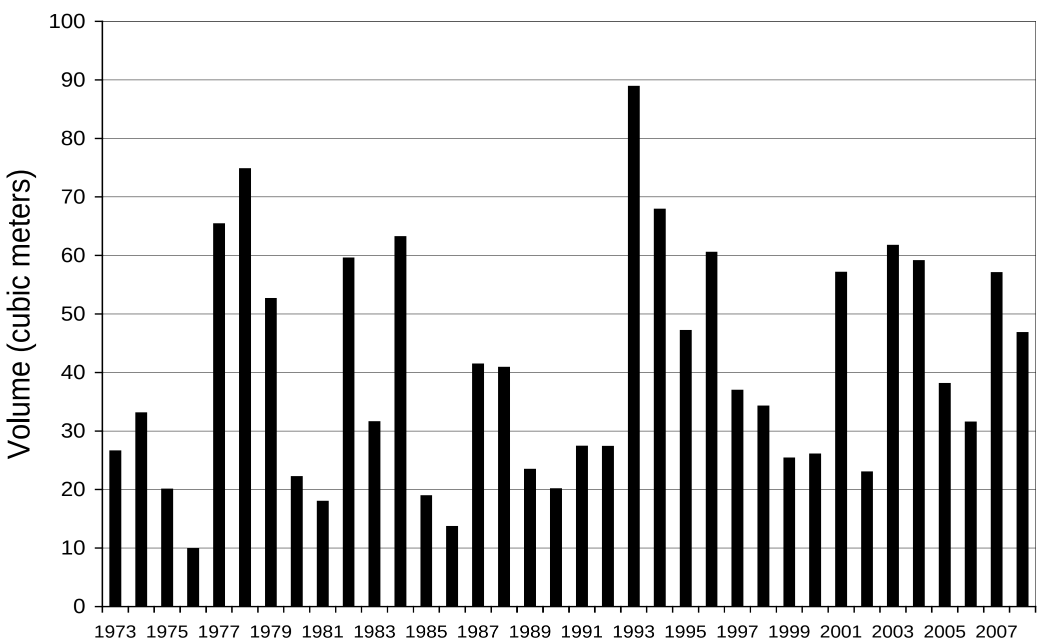


Figure C-8 September Thickness (Meters) of Pelagic Trout Habitat in the Main Pool of Lake Jocassee for the Period 1973-2008



Note: Values for 1999 represent early October data.

Figure C-9 September Volume (107 m^3) of Pelagic Trout Habitat in the Main Pool of Jocassee Reservoir for the Period 1973-2008



Note: Values for 1999 represent early October data.

Lake Jocassee (Impact of Lake Drawdown)

Over the history of JPSS operations, the lake has experienced a few significant reductions in lake level. Temperature and DO distributions within the lake during a significant drawdown were compared to levels at a relatively high lake levels and an intermediate level (Figure C-10). September profiles were chosen since this month typically represents the height of thermal stratification and the time of year when trout habitat is at a minimum, i.e. warmest temperatures and lowest DO. Comparative September data were selected having a similar winter mixing pattern as observed in 1988 and 2008, the years of lowest lake levels where data was available.

The temperatures in the lower depths represented the temperatures at those depths after the winter mixing period. Most notable was the depressed thermal gradient during the times of low lake levels. Both low water years exhibited a deeper and stronger thermocline. This suggests JPSS and/or the Bad Creek Project operations had a tendency to shift the thermocline deeper with less water in the lake. However, this shift of the thermocline was not consistently a function of lake level since the thermocline was at the minimum depth during the intermediate lake level with a deeper epilimnion at relatively high lake level. Whether the deeper thermocline was a function of the drawdown, the amount of water used by JPSS and/or the Bad Creek Project, or both, the overall thermal structure of the lake was maintained in either case.

DO concentrations throughout the water column were not impacted by the reduction of lake level. As mentioned previously, DO concentrations in September were primarily a function of the degree of the previous winter mixing.

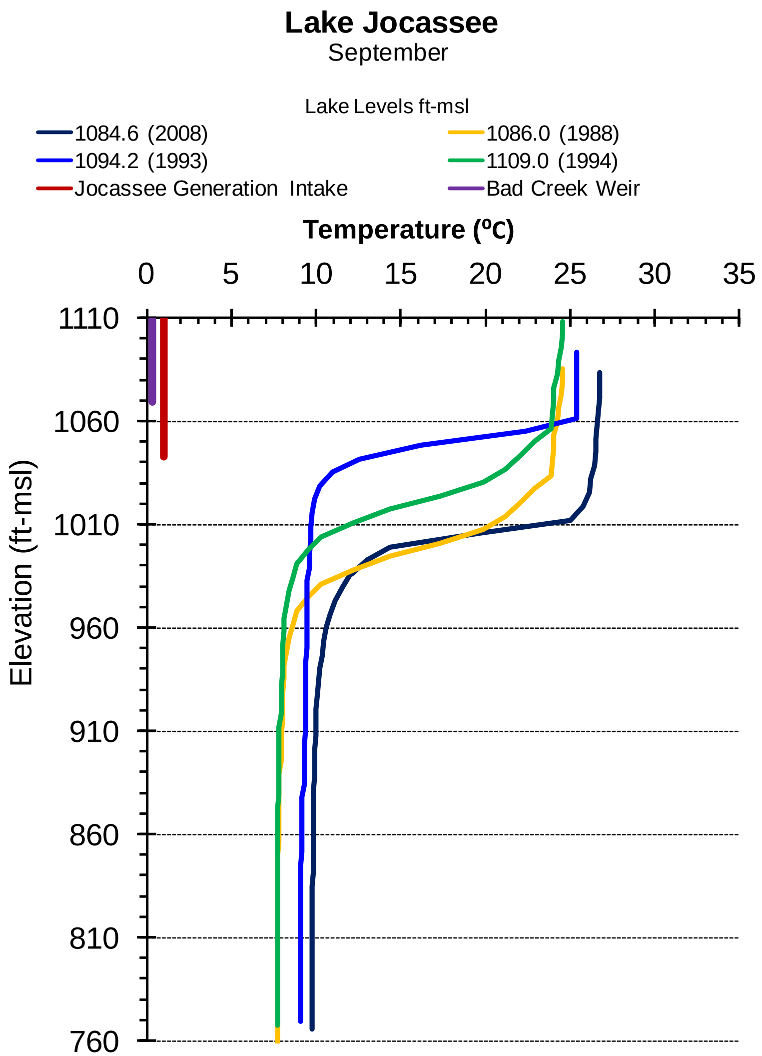
Lake Keowee (Seasonal and Yearly Trends)

Unlike Lake Jocassee, Lake Keowee is a typical Southeastern monomictic lake, with one stratified period and a long, fall-winter mixing period. Rather than having a single basin as Lake Jocassee, Lake Keowee has two basins connected by a man-made canal. Although connected, each basin exhibited slightly different patterns of temperature and oxygen stratification.

Seasonal patterns of temperature and DO in the two basins of Lake Keowee (Figures C-11 through C-14) reflect similar heating and cooling patterns in meteorology, namely as the weather cools in the fall-winter period, heat is continually lost from the lake resulting in the coolest lake temperatures being observed in February and March. Unlike Lake Jocassee, both basins of Lake Keowee mixed completely every year due to its low relative depth and consequently, re-aerated every winter (Figures C-11 and C-12).

With the beginning of stratification, the Little River Basin exhibited a rapid warming of the upper water eventually forming an isothermal epilimnion extending to 80 to 85 ft depth (Figure C-13). DO was relatively high in the upper waters but progressively decreased in the deeper waters. The rate of oxygen loss was greater than at Lake Jocassee indicating a higher organic content of the deeper water.

Figure C-10 Comparison of Temperature and DO in Lake Jocassee at Various Lake Levels



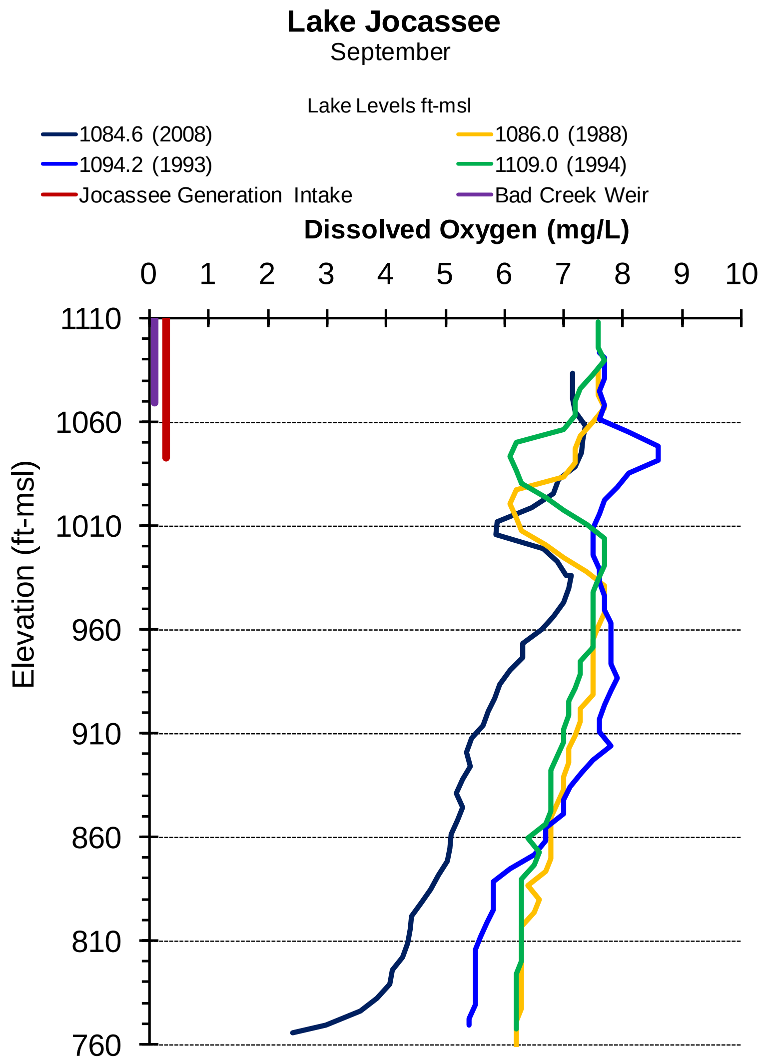
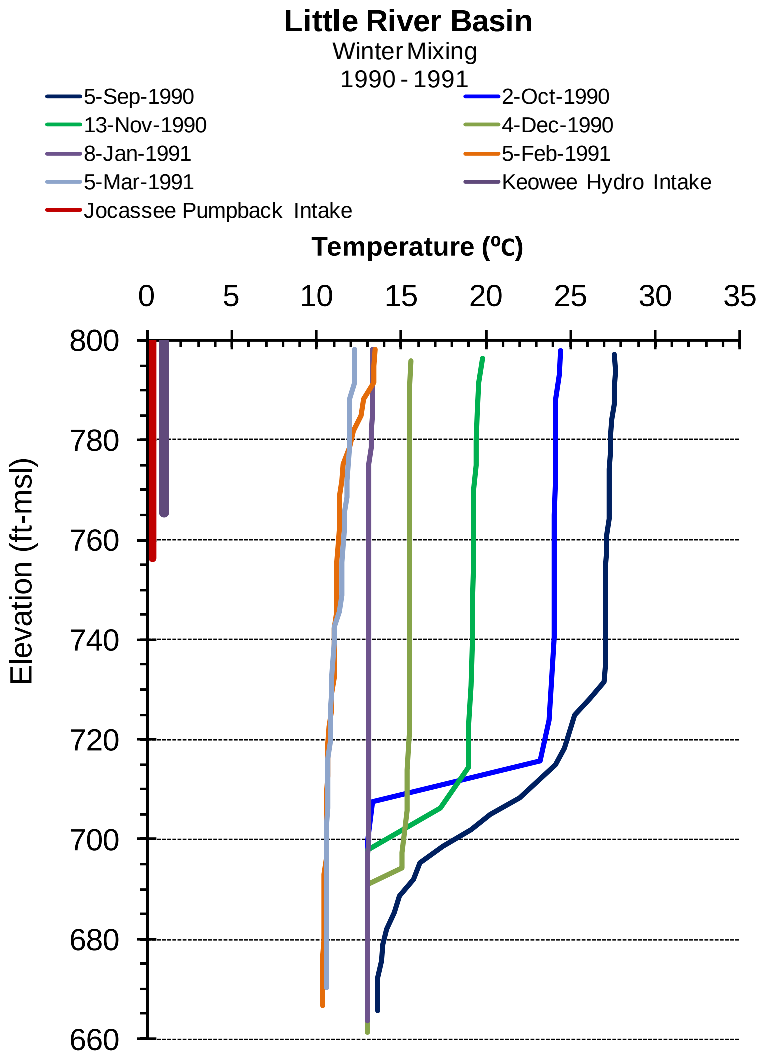


Figure C-11 Lake Keowee Temperature and DO during the Fall-Winter Mixing Period, Little River Basin



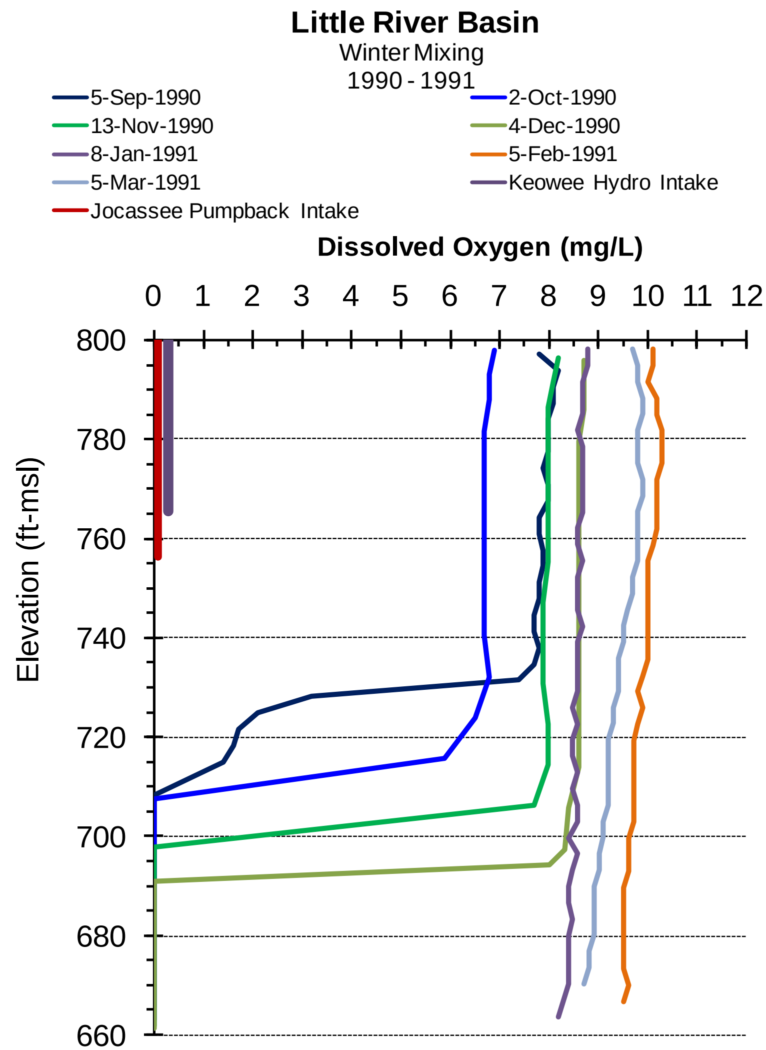
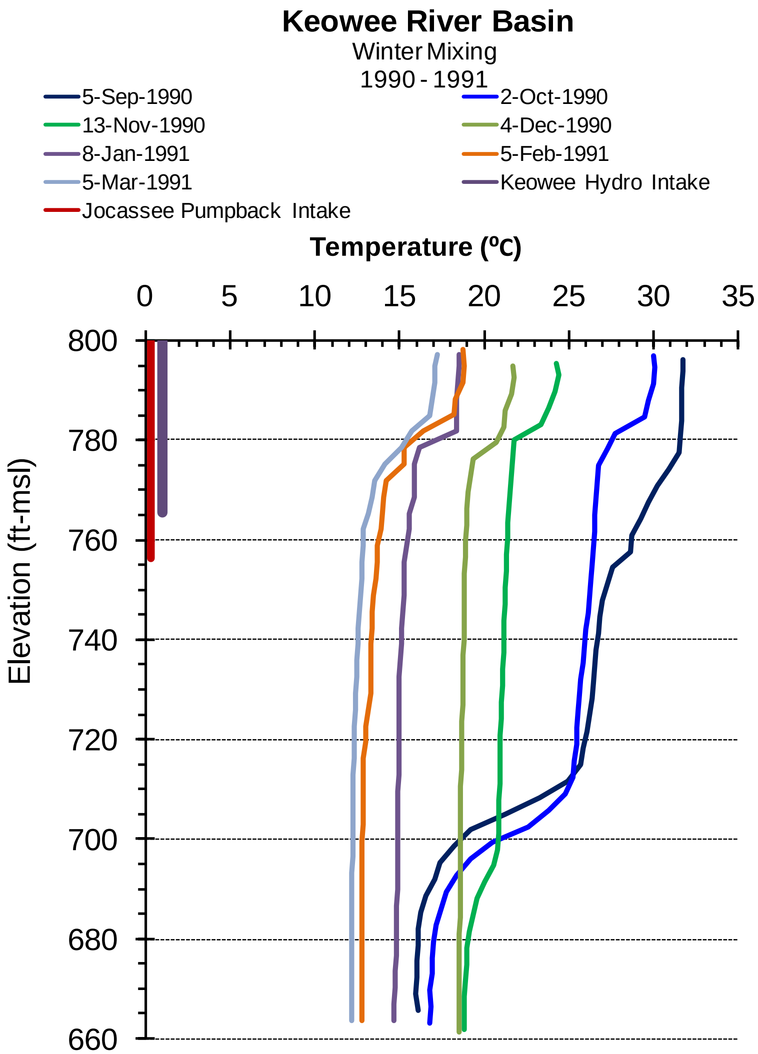


Figure C-12 Lake Keowee Temperature and DO during the Fall-Winter Mixing Period, Keowee River Basin



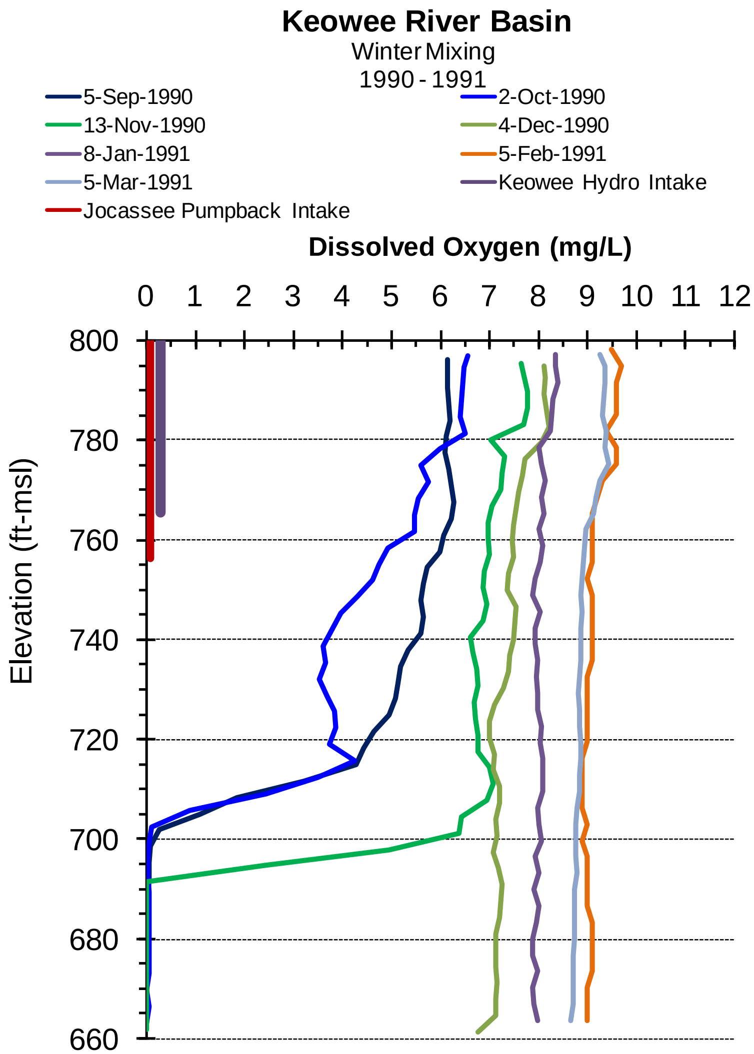
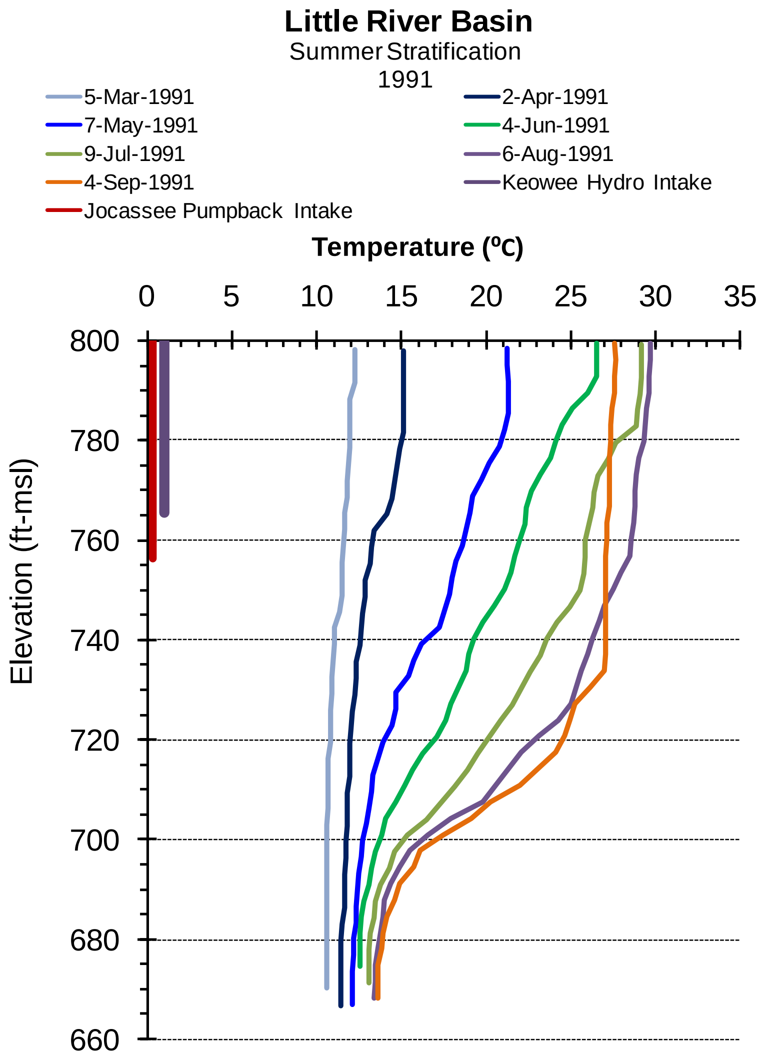


Figure C-13 Lake Keowee Temperature and DO during the Summer Stratified Period, Little River Basin



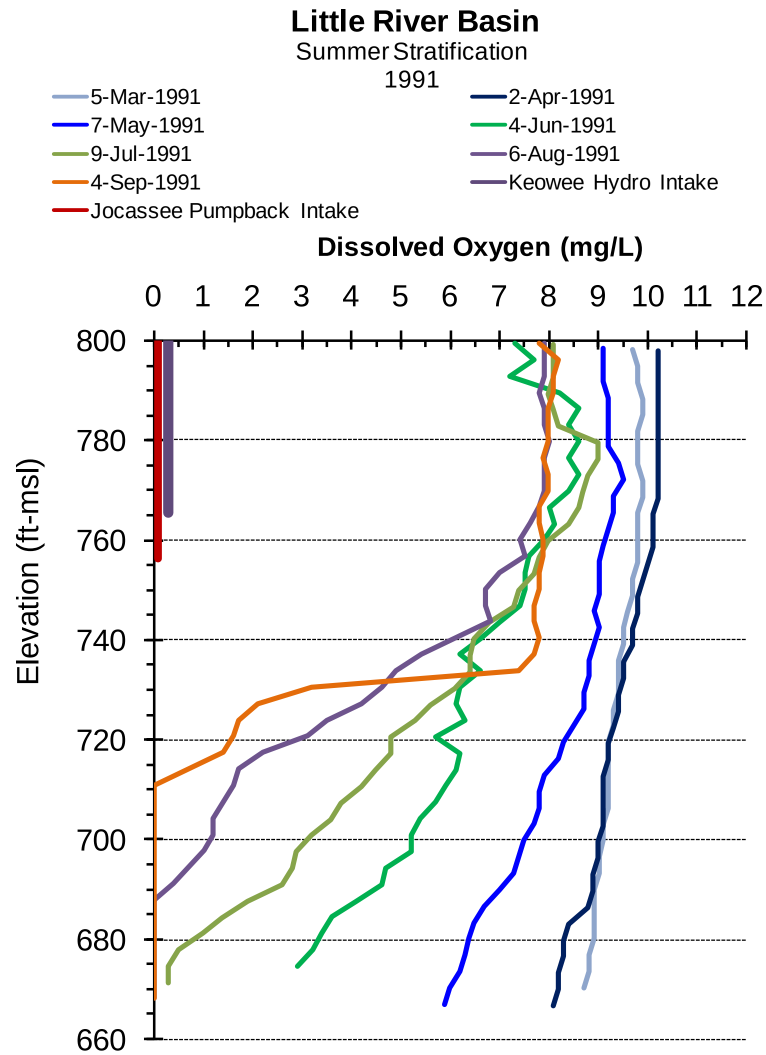
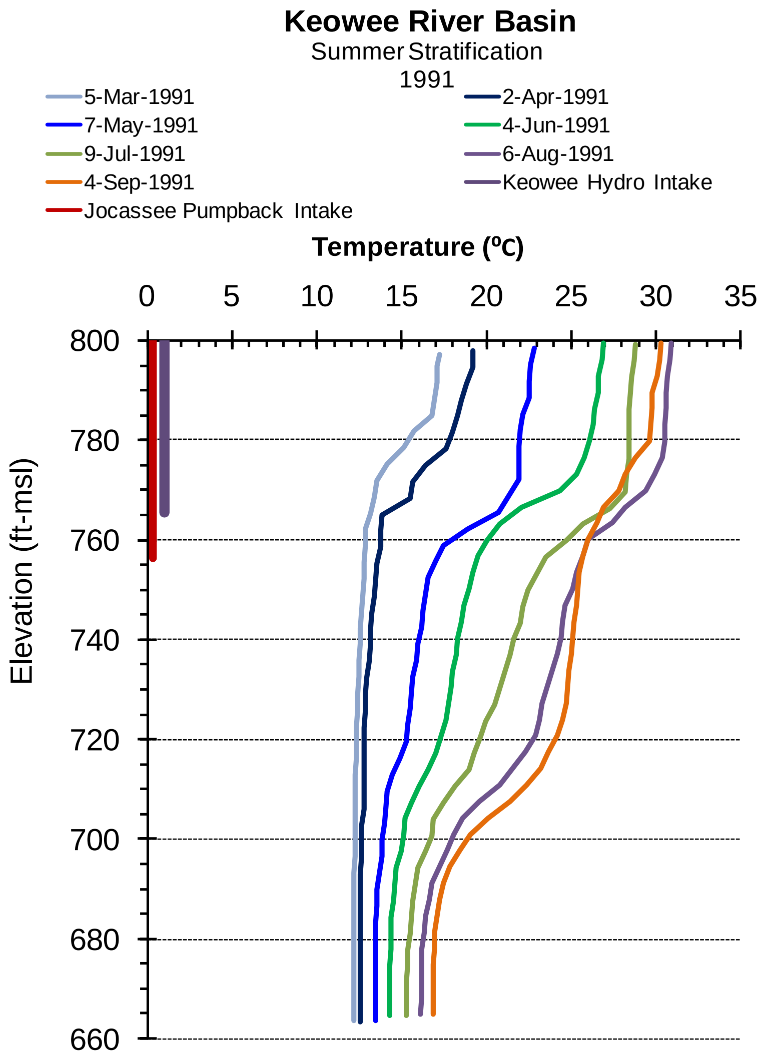
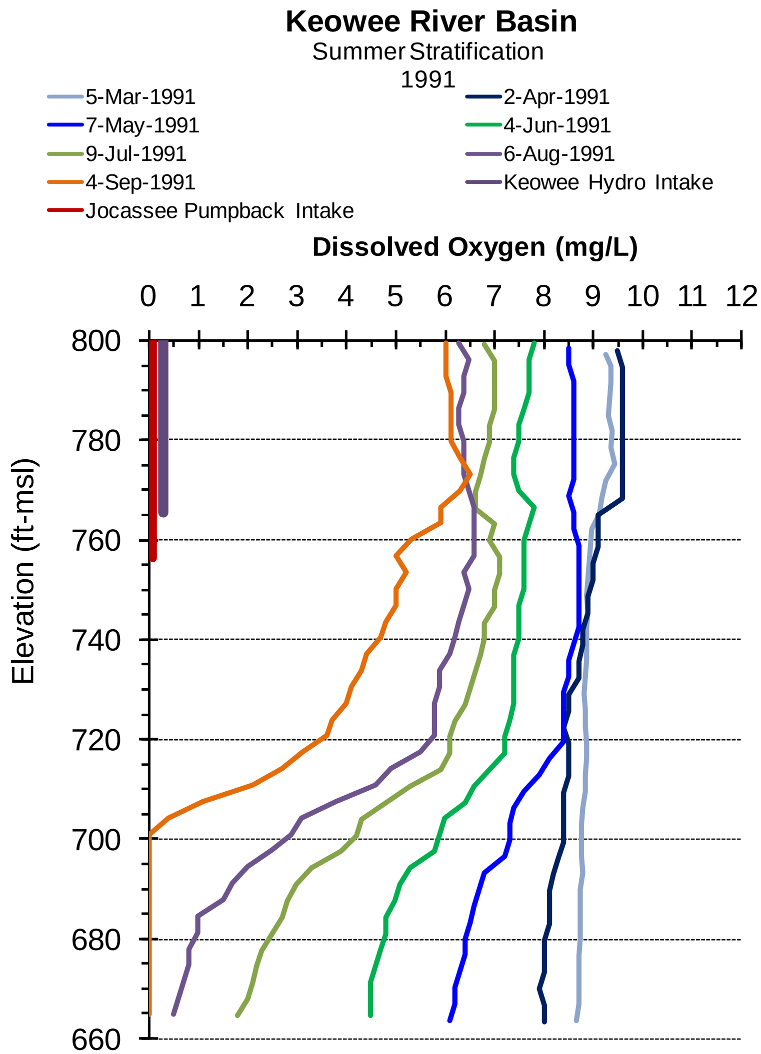


Figure C-14 Lake Keowee Temperature and DO during the Summer Stratified Period, Keowee River Basin





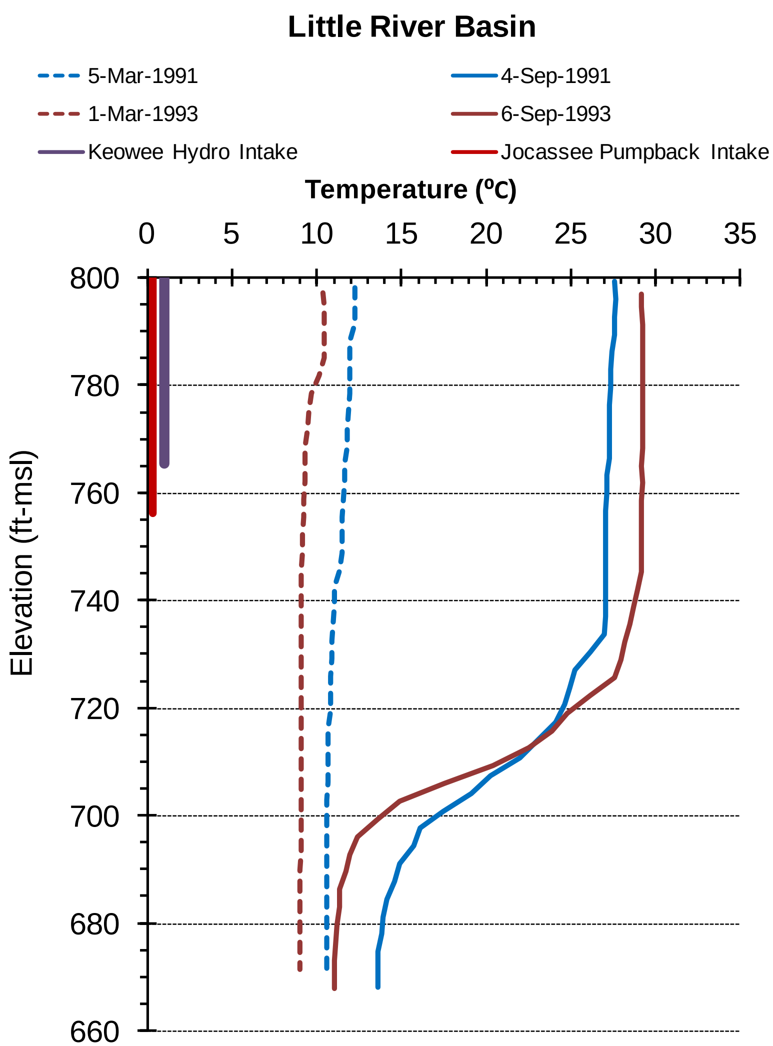
The Keowee Basin exhibited a similar seasonal trend of temperature and DO changes as the Little River. However, rather than developing one thermocline, two temperature gradients were observed, one at the elevation of the JPSS intake and the other at the same elevation as observed in the Little River basin. This vertical pattern of stratification suggests as JPSS generated power and released water into the Keowee basin, the cooler water (relative to the surface of Lake Keowee) from Lake Jocassee ‘plunged’ to a depth commensurate with the water density of cool water in the Keowee basin. Conversely, during times of JPSS pumpback, warmer surface water from Lake Keowee was withdrawn and pumped into Lake Jocassee, thereby strengthening the temperature gradient observed in Lake Jocassee.

The pattern of DO loss during the stratified period in the Keowee basin was similar to that observed in the Little River basin, however, the Little River basin exhibited lower concentrations in the mid to deeper depths suggesting slightly greater organic loading rates in the Little River basin.

Comparisons of the temperature and DO between 1991 and 1993 represented the near extremes of winter mixing (Figures C-15 and C-16). Typical of monomictic lakes, a colder winter (1992 – 1993) produced colder temperatures and higher DO throughout the water column in both basins at the end of the mixing period (March). However, unlike Lake Jocassee, the spring time conditions were not reflected by the end of the stratified period (September) in Lake Keowee (Figures C-15 and C-16). Both basins exhibited warmer temperatures in the upper water in September of the year with the coldest winter. In the Little River Basin, at a depth of 710 ft-AMSL, temperatures were colder in the September 1993, the year with the coldest winter. In the Keowee River Basin, temperatures were colder in September 1993 below a depth of 720 ft-AMSL. As discussed by Oliver and Hudson (1987) and Duke Power (1995 and 2007), the ONS skimmer wall allowed ONS access to water above the 710 ft-AMSL level which corresponded to the thermocline depths in both basins. During the stratified period, along with local meteorology, ONS influenced the temperatures of the upper water, whereby, winter cooling influenced the deep water temperatures in both basins. The mid-depth temperatures of the Keowee Basin were also heavily influenced by the JPSS operation.

DO patterns between years and between basins reflected the same influences as did temperature. Namely, DO concentrations in the upper water were influenced primarily by ONS operations, not the winter mixing conditions. DO in the bottom water was, in part, influenced by the degree of winter mixing of oxygen, but also the organic decomposition processes. In September 1993, the summer preceded by a cold winter, both basins exhibited higher DO and colder temperatures in the bottom water, whereas the year with the mild winter, the DO was depleted in the bottom water of both basins, indicating the rate of organic decomposition was greater at increased temperatures.

Figure C-15 Lake Keowee Temperature and DO Contrasting Two Years with Different Winter Mixing Extremes, Little River Basin



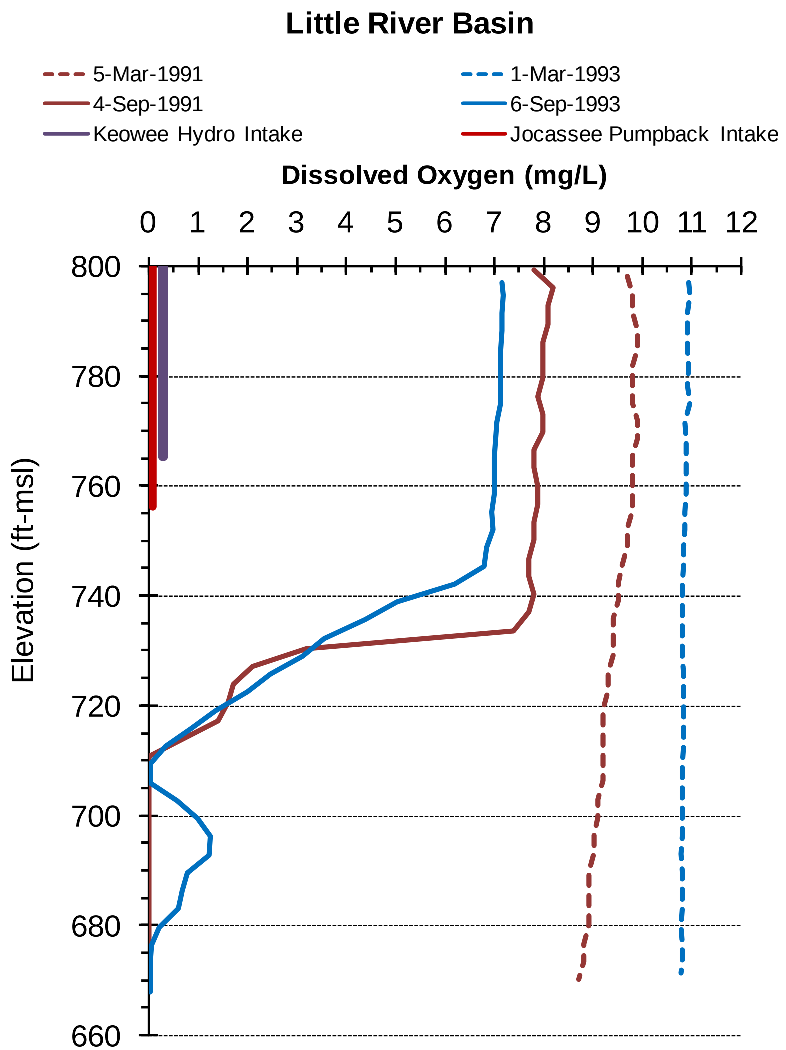
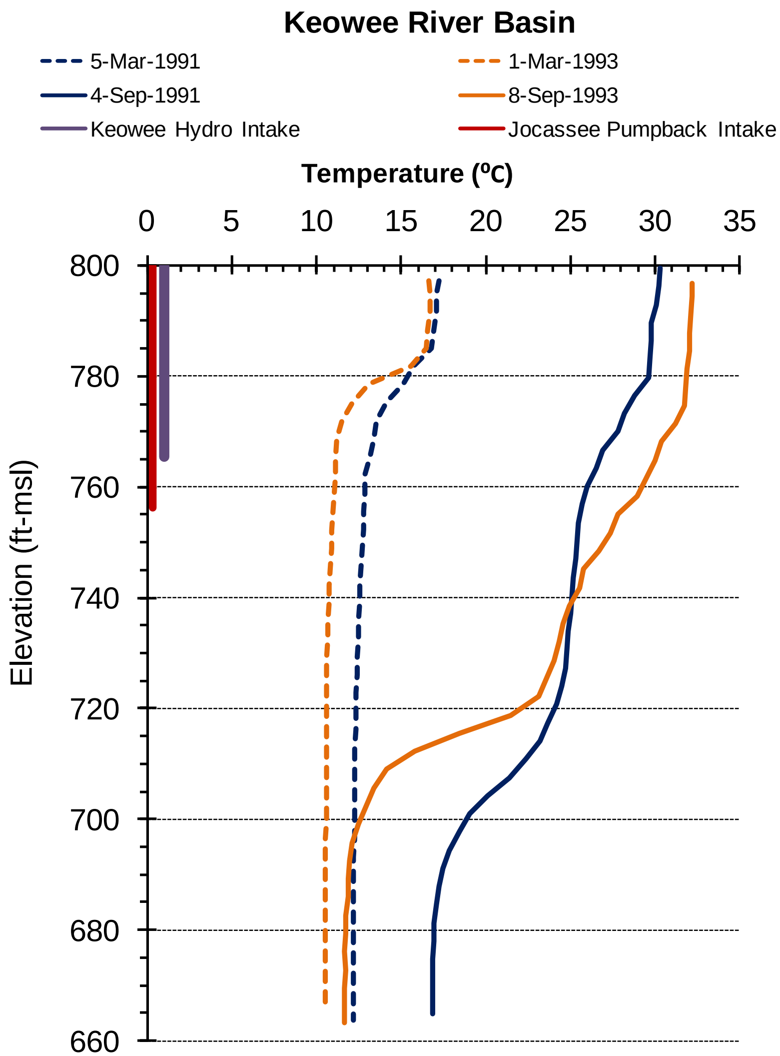
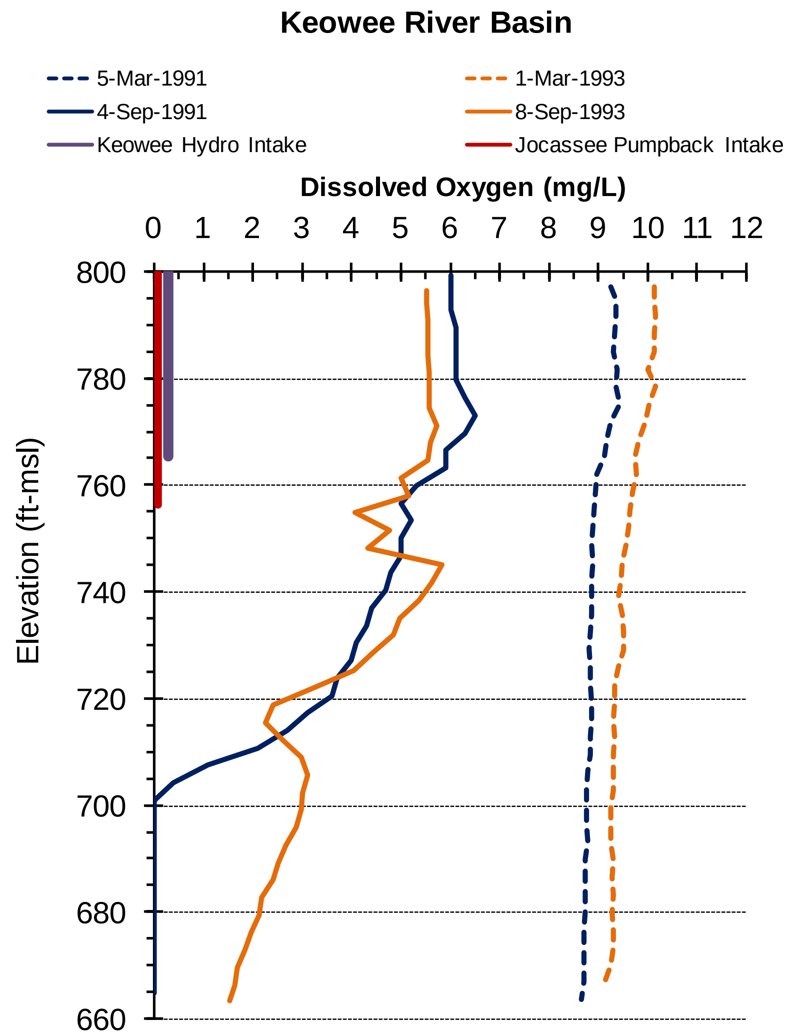


Figure C-16 Lake Keowee Temperature and DO Contrasting Two Years with Different Winter Mixing Extremes, Keowee River Basin





A direct comparison of the two basins at the time of maximum stratification (Figure C-17) revealed each basin exhibiting the same temperature and DO patterns between years. The magnitude of the differences was a combination of meteorology, ONS operations, and JPSS. The Little River basin had a very pronounced epilimnion resulting from ONS water withdrawal and re-circulation (Duke Power, 1995 and 2007). The Keowee Basin received the ONS cooling water discharge warming the surface waters slightly greater than in the Little River basin, but also lowering the DO since ONS pumped cool, lower DO water from the Little River and discharged it to the surface of the Keowee basin. JPSS operations cooled the middle depths and added varying amounts of oxygen.

Lake Keowee (Impact of Lake Drawdown)

The approach employed to investigate the influence of lake drawdown on water quality in Lake Keowee was similar to that used for Lake Jocassee. In August 1986, the lake was 13.8 ft below normal full pond elevation, August 2001 lake level was lowered to 5.9 ft, and August 1991 the lake was almost full at only 0.7 ft lower than the normal full pond elevation. These data chosen were based available data for summer-time conditions, which represented the warmest temperatures and lowest DO concentrations.

The Little River basin and the Keowee River basin temperature and oxygen distributions in the water column exhibited very similar patterns and values at the different lake levels (Figures C-18 and C-19). The slight differences between years within each basin were probably the result of the differences between meteorological variability or JPSS and ONS operations rather than lake level (see previous section).

Keowee and Jocassee Tailrace Temperature and DO

Duke Energy has monitored temperatures in the Keowee Hydro Station forebay and tailrace daily since 2000. In addition, Greenville Water (GW) has been monitoring daily temperatures at its Lake Keowee water intake (Figure C-20). In 2008, Duke Energy installed water quality monitors (temperature, DO, conductivity, and water level) in the tailraces of both Jocassee and Keowee hydroelectric stations. These monitors were equipped with Hach LDO® oxygen sensors and were serviced at 2-3 week intervals according to the protocol established by the Quality Assurance Project Plan (QAPP) for the Catawba-Wateree Hydroelectric Project (Duke Energy 2009).

The long-term, daily temperatures recorded in the Keowee Hydro Station forebay and tailrace show a constant pattern among years with very little difference. The GW water intake temperatures showed similar temperatures as the Keowee Hydro Station forebay or tailrace temperatures, but GW temperatures were generally a little warmer in the winter and slightly cooler during the summer than the temperatures at Keowee Hydro Station. There were only 4 days during the 10-year-period where the Keowee Hydro Station forebay temperatures were greater than the 90ºF reference temperature. The Keowee Hydro Station tailrace temperatures never exceeded the 90ºF reference temperature. (Figure C-20)

Figure C-17 Lake Keowee Basin Comparisons of September Temperature and DO with a Mild and Severe Winter

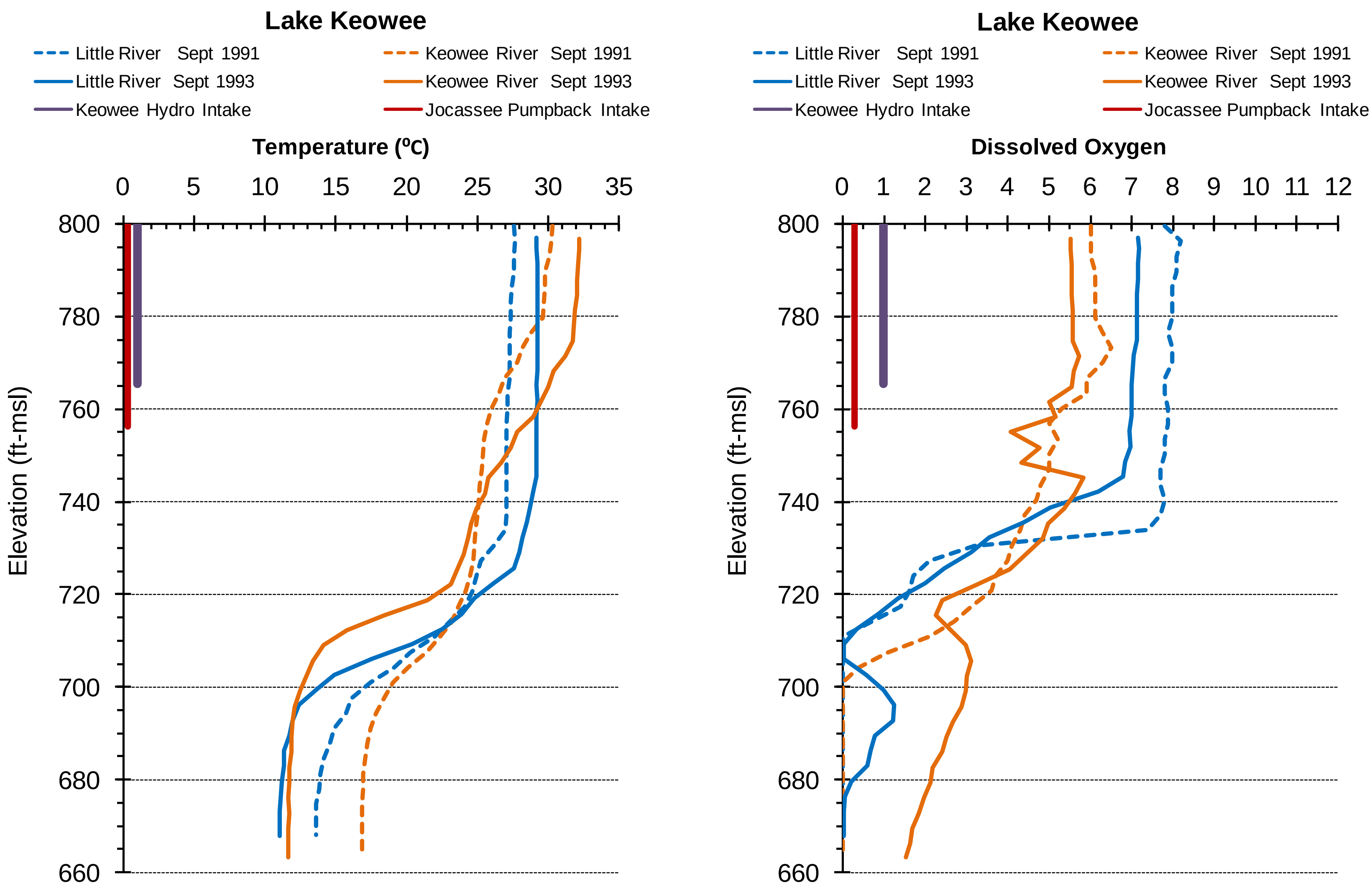
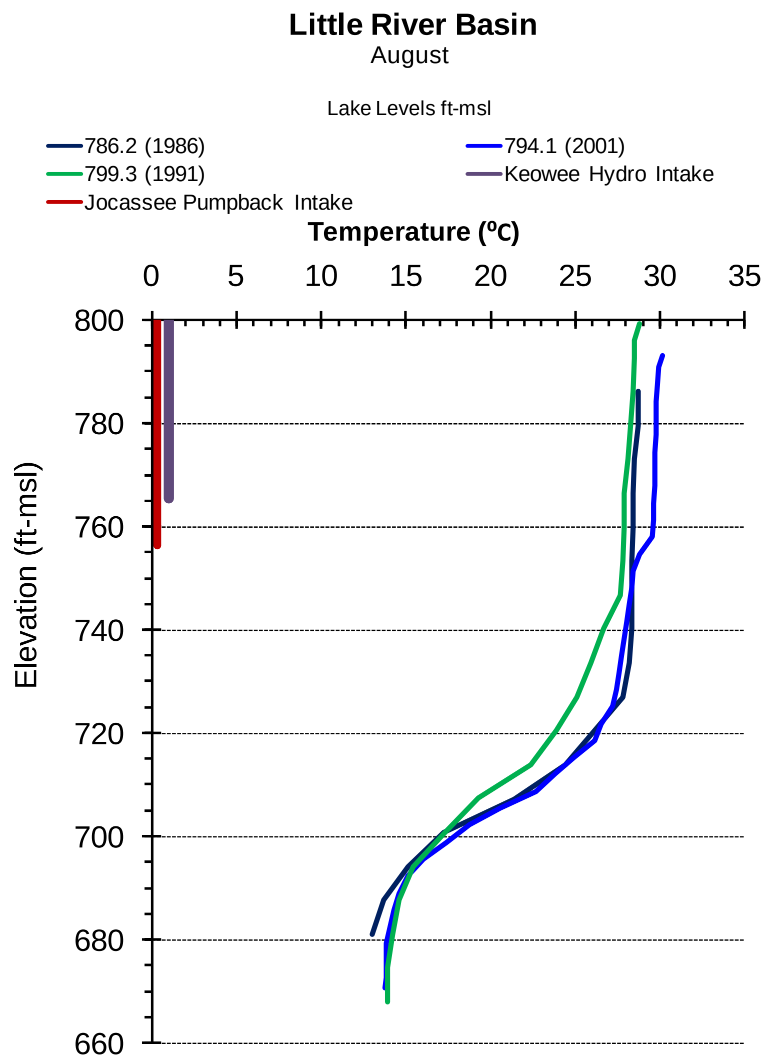


Figure C-18 Comparison of Temperature and DO in Lake Keowee, Little River Basin, at Various Lake Levels



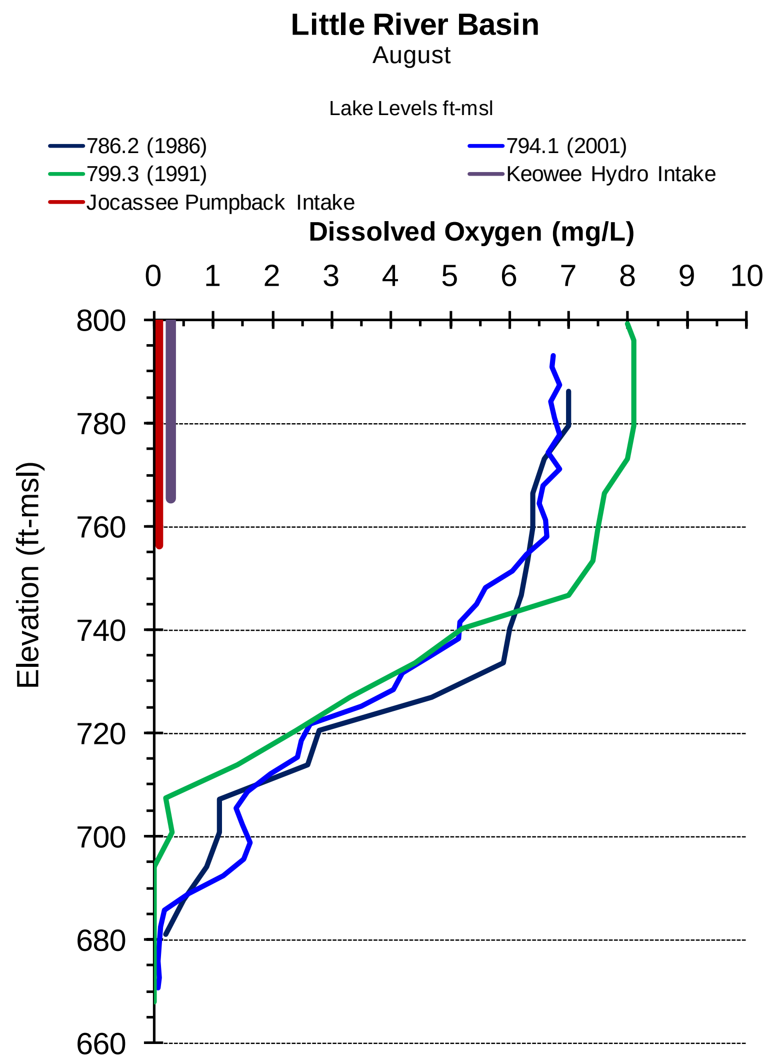
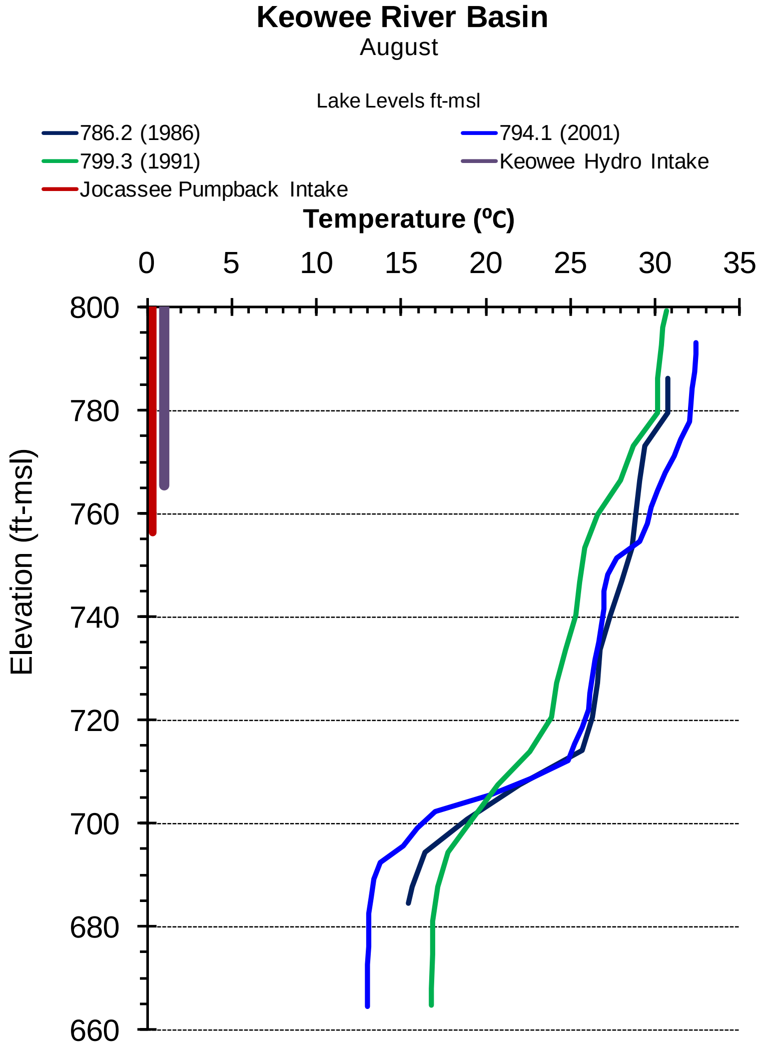


Figure C-19 Comparison of Temperature and DO in Lake Keowee, Keowee River Basin, at Various Lake Levels



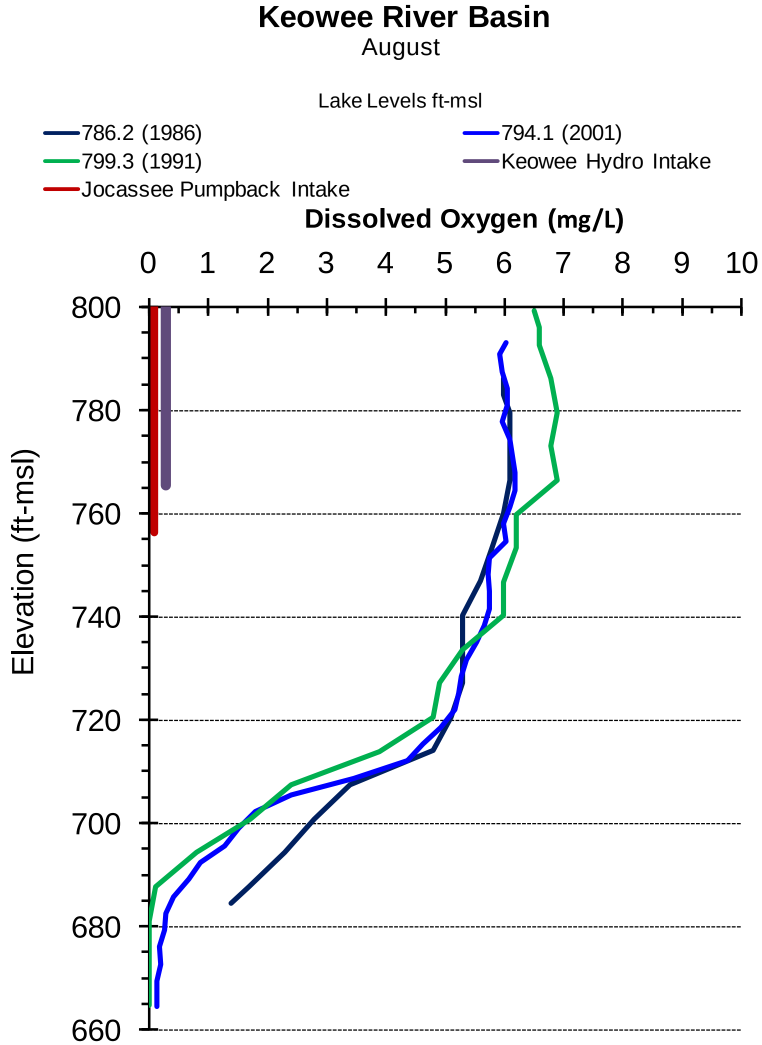
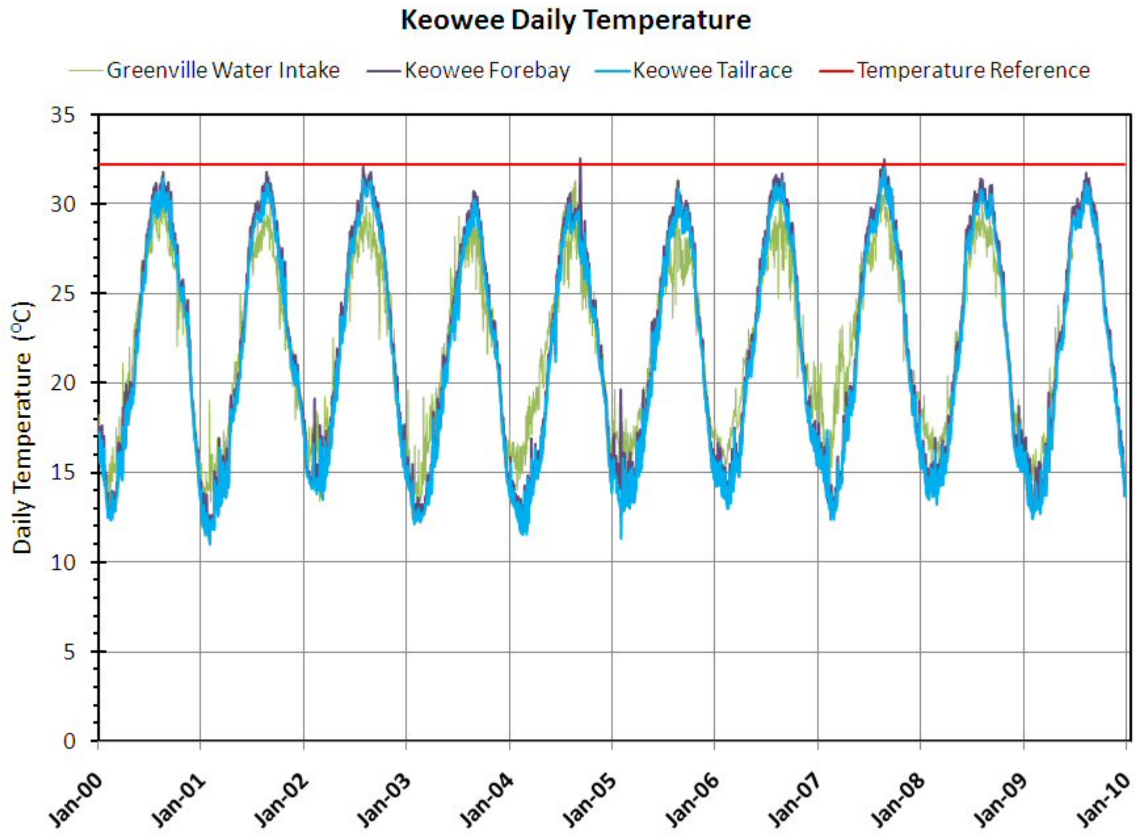


Figure C-20 Daily Temperature in Keowee Hydro Station Forebay and Tailrace, 2000-2009



More recent data collected with the temperature and DO monitors installed in 2008 revealed a similar yearly cycle of meteorologically controlled temperatures (Figure C-21). The differences between the JPSS and the Keowee Hydro Station tailrace temperature data resulted from the different withdrawal depths. Lake Jocassee releases cooler water from deeper in the lake than the surface water withdrawal at the Keowee Hydro Station.

DO concentrations in the tailraces again reflect the oxygen concentrations at the withdrawal depths with Lake Jocassee exhibiting less variability than the Keowee release (Figure C-22). The more consistent DO values in the Jocassee tailrace were the result of high exchange rates of similar water in the tailrace during the Jocassee generating and pumping cycle. Whereas the Keowee Hydro Station released water at infrequent intervals, greater temperature and DO variability was observed due to the differences between the released water and the water remaining in the tailrace for longer periods. The DO concentrations in the water released from both Jocassee hydro and Keowee hydro were well above state water quality standards at all times.

Figure C-21 Daily Average Temperatures Recorded in the Jocassee and Keowee Tailraces, 2008-2009

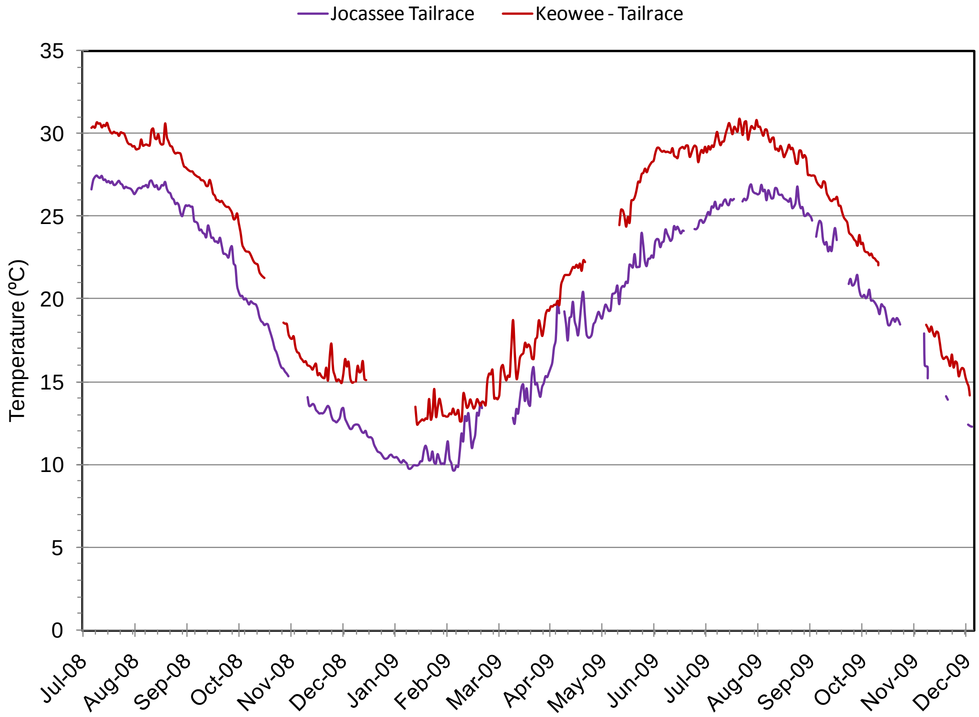
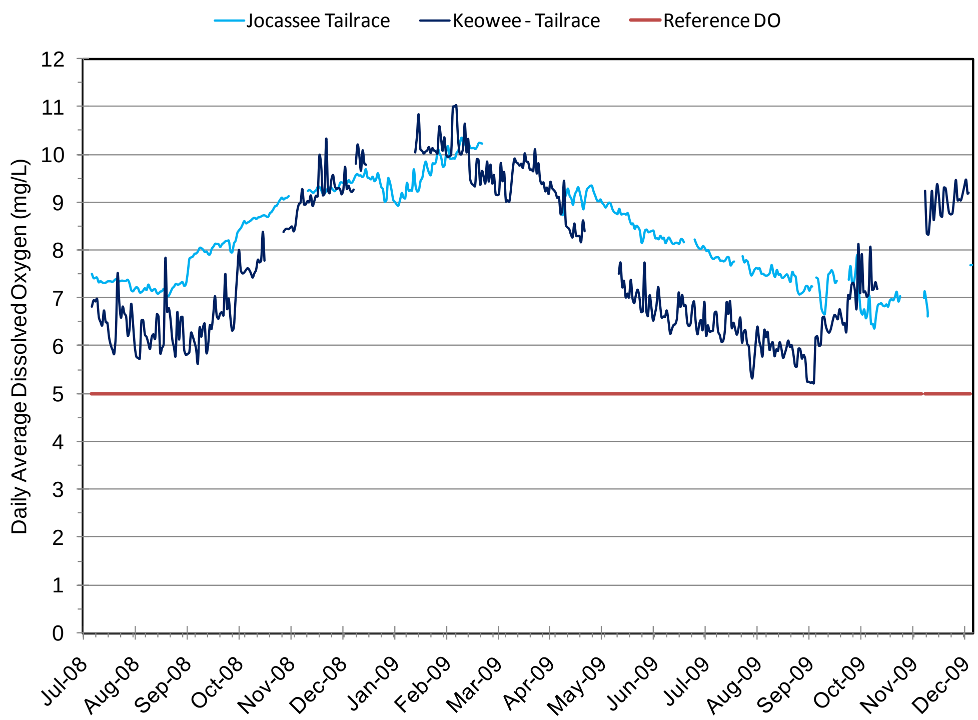


Figure C-22 Daily Average DO Recorded in the Jocassee and Keowee Tailraces, 2008-2009



Analysis of February and September 2009 JPSS tailrace temperature and DO data (Figures C-23 and C-25) showed slight increases in temperature corresponded to small increases in DO in February, when Lake Jocassee was coldest. This indicates water pumped from Lake Keowee into Lake Jocassee was somewhat warmer and had slightly higher DO levels than ambient conditions in Lake Jocassee. (Figures C-23 and C-24). The slightly warmer water pumped into Lake Jocassee also probably enhanced the onset of stratification in Lake Jocassee.

By September when both lakes were at the height of stratification, the correlation between temperature and DO had reversed in the JPSS tailrace (Figure C-24). During generation at JPSS, the temperature was lower and the DO higher, again reflecting the water characteristics at the deeper withdrawal depth. These data support the conclusion that the middle layer water in the Keowee basin was primarily derived from the JPSS releases. Conversely, the water pumped back into Lake Jocassee was Lake Keowee surface water indicated by the warmer temperatures and lower DO.

The JPSS tailwater area water levels were a more of a function of Lake Keowee's lake level rather than JPSS's operation since the Jocassee tailwater area is a very wide channel. By contrast, the tailrace water level measurements in the Keowee tailrace definitely reflected the operations of the hydro station (Figures C-25 and C-26). The Keowee tailrace is a narrow channel which exhibited a pronounced water level rise during generation, but the rise was quickly dissipated as the water in the narrow channel drained into Hartwell Lake.

The Keowee Hydro Station tailrace showed the same correlation with temperature and oxygen in March (the time when Lake Keowee was coldest) as the JPSS tailwater area, but both parameters showed a much more dramatic change in the tailrace during generation than did the JPSS operations (Figure C-25). The temperature difference in the tailrace before and after generation compared to the water released during generation was 2-3º C higher during generation, reflecting Lake Keowee's warmer surface temperature compared to the temperature in the Keowee Hydro Station's tailrace after a prolonged period. Likewise, DO concentrations increased by 1-2 mg/L during generation (Figure C-25). The amount of increase in oxygen is probably related to the turbulence created by the Keowee Hydro Station release in a narrow channel. Both temperature and oxygen levels returned to pre-generation conditions as the water drained into Hartwell Lake.

The Keowee Hydro Station tailrace data showed both temperatures and DO increased during generation (Figure C-26). The temperatures reflected the forebay surface water temperatures but the DO was similar to or higher than the forebay concentrations (compare Figure C-26 with Figure C-20). This difference probably indicated water was undersaturated more than in February and aerated to some extent as turbulence increased as the water was released through the turbines.

Figure C-23 Hourly Temperature, DO, and Tailrace Water Level in the Jocassee Tailrace, February 2009

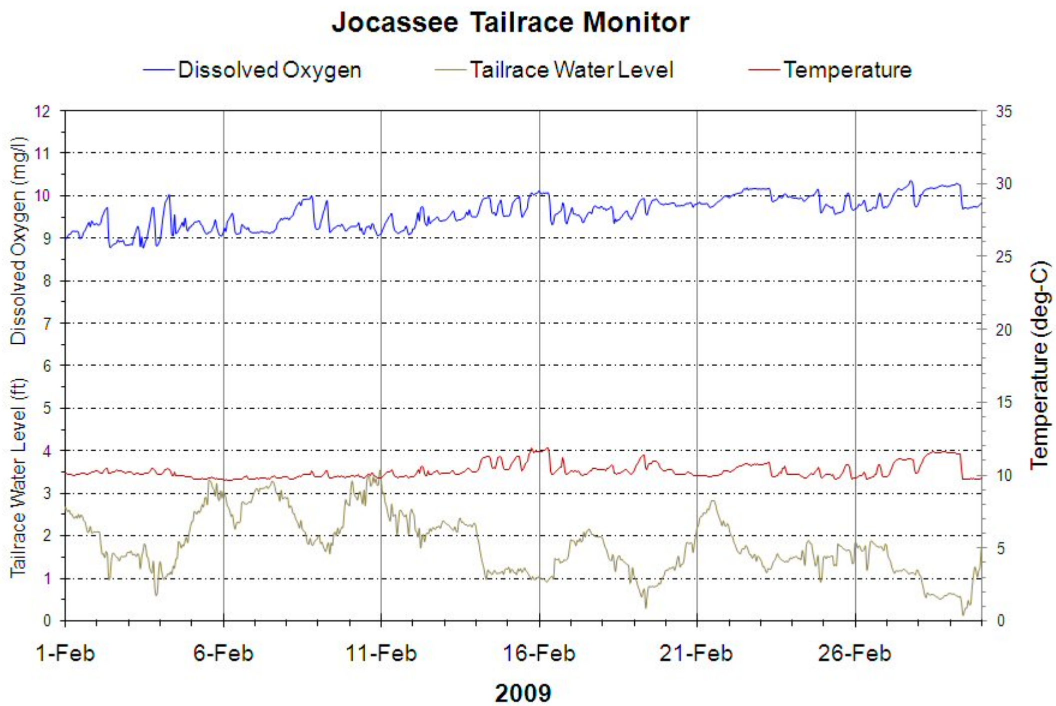


Figure C-24 Hourly Temperature, DO, and Tailrace Water Level in the Jocassee Tailrace, September 2009

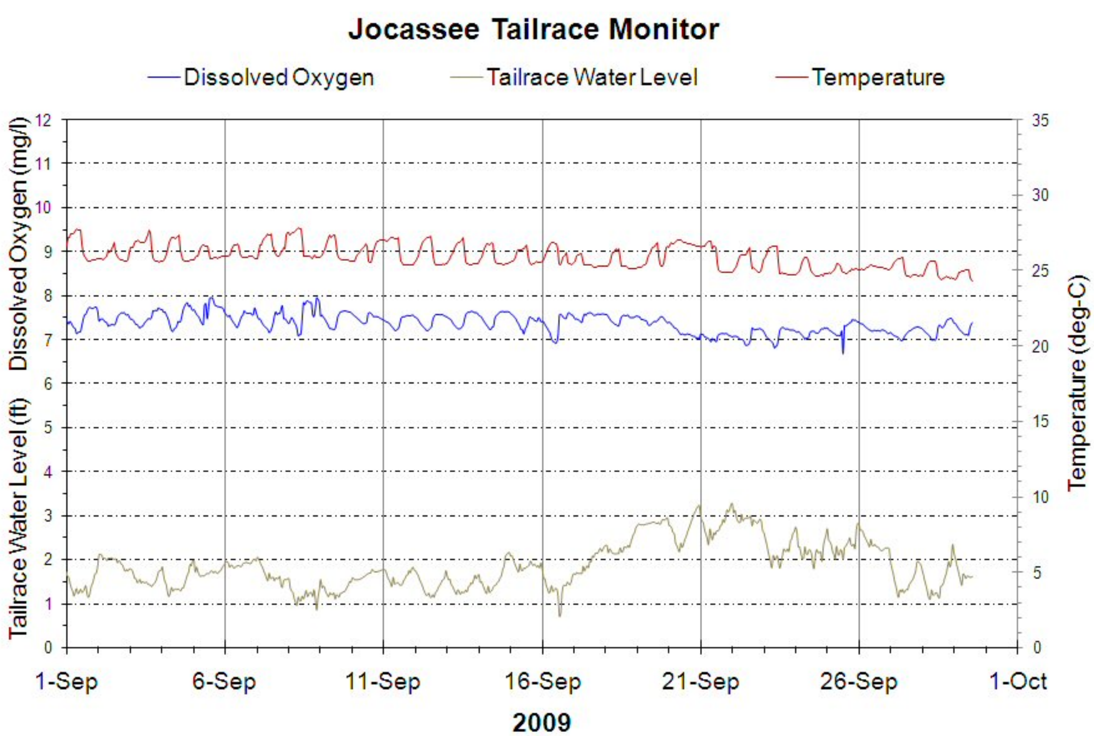


Figure C-25 Hourly Temperature, DO, and Tailrace Water Level in the Keowee Tailrace, March 2009

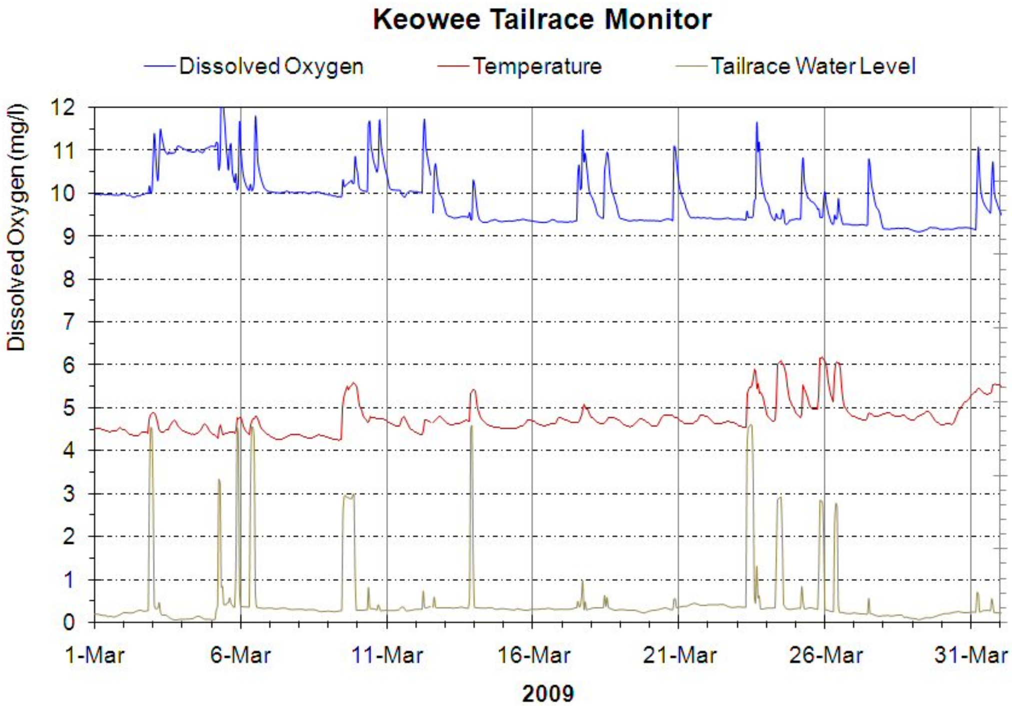
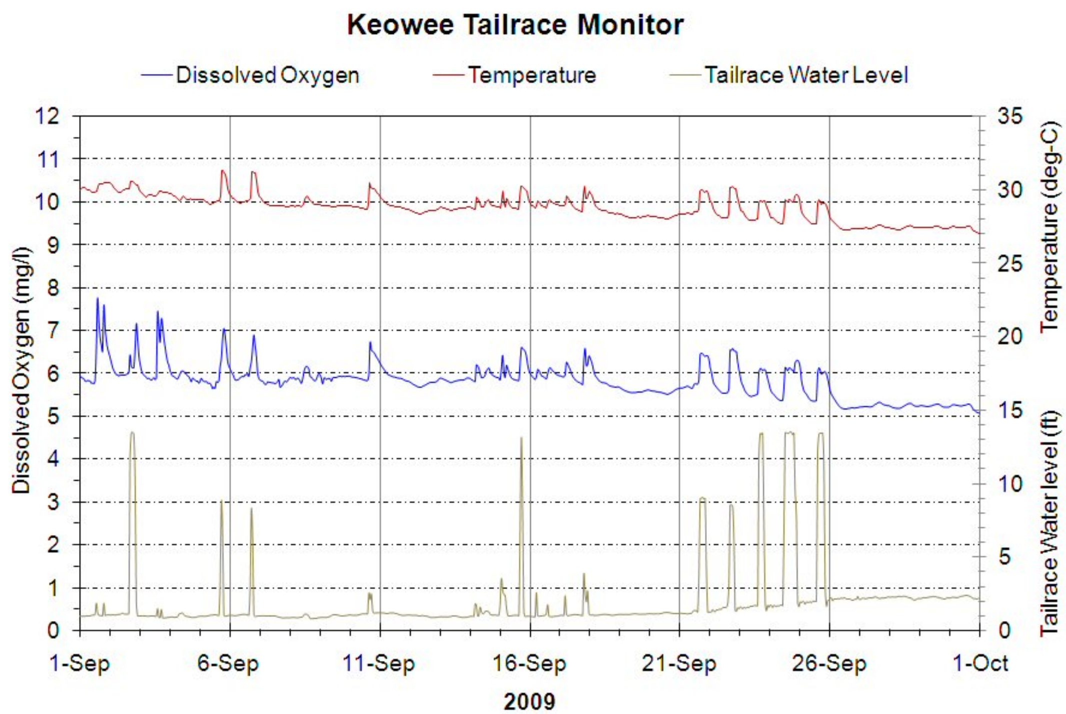


Figure C-26 Hourly Temperature, DO, and Tailrace Water Level in the Keowee Tailrace, September 2009



During 2012, temperature and DO data were collected in both the forebay and tailwaters to evaluate the effects of project operations on the water quality of the Keowee-Toxaway Project and to support the requirements of the 401 Water Quality Certification (WQC). Throughout this study period, DO and temperature from the forebay and the tailwater monitoring locations were very similar, and both locations exhibited DO values significantly higher than state water quality standards. Details of the 2012 study are included in the *Jocassee Forebay and Tailwater Water Quality Report*, dated February 2013. Four years of Jocassee tailwater monitoring have demonstrated that the water released from Lake Jocassee has DO concentrations well above South Carolina State Water Quality Standards. Monthly statistics for 2012 show the same conditions in 2012.

Table C-10 Forebay and Tailwater Temperature and DO 2012 Continuous Monitoring Data - Jocassee Reservoir

Data Collected Every 5-Minutes												
Month	Jocassee Tailwater						Jocassee Forebay					
	Dissolved Oxygen (mg/L)			Temperature (°C)			Dissolved Oxygen (mg/L)			Temperature (°C)		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Jan	8.78	9.06	9.42	11.0	12.0	14.3	-	-	-	-	-	-
Feb	9.05	9.69	10.20	10.5	11.3	14.0	8.92	9.62	10.70	10.5	11.0	13.3
Mar	9.03	9.82	10.36	11.0	14.0	19.2	9.00	9.64	10.04	11.8	14.0	17.2
Apr	8.37	9.33	10.04	14.1	18.1	24.4	8.77	9.33	9.88	13.8	16.7	20.7
May	8.22	8.87	9.29	18.1	20.9	24.7	8.49	8.95	9.43	18.4	20.7	23.8
June	7.63	8.37	8.93	21.3	23.7	27.7	8.18	8.63	9.45	20.2	22.1	24.4
July	7.00	7.75	8.33	24.5	26.5	29.6	7.06	7.77	8.87	23.6	26.6	29.3
Aug	6.41	7.37	8.79	24.8	27.5	29.9	6.46	7.41	8.80	26.3	27.5	29.2
Sep	6.74	7.41	7.76	24.5	26.3	28.7	6.83	7.44	8.05	24.4	26.1	28.3
Oct	7.11	7.74	8.58	19.2	22.6	25.7	7.04	7.73	8.87	19.2	19.2	19.2
Hourly Average												
Month	Jocassee Tailwater						Jocassee Forebay					
	Dissolved Oxygen (mg/L)			Temperature (°C)			Dissolved Oxygen (mg/L)			Temperature (°C)		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Jan	8.83	9.06	9.33	11.0	12.0	14.3	-	-	-	-	-	-
Feb	9.11	9.69	10.05	10.5	11.3	13.7	9.17	9.62	9.95	10.5	11.0	13.3
Mar	9.09	9.82	10.23	11.0	14.0	18.9	9.21	9.64	9.97	11.9	14.0	17.1
Apr	8.86	9.46	9.97	14.3	17.2	22.2	8.92	9.34	9.62	14.1	16.7	18.5
May	8.31	8.95	9.63	17.0	20.5	24.3	8.50	8.94	9.27	18.5	20.7	23.8
June	7.73	8.37	8.89	21.4	23.7	27.3	6.56	8.32	8.95	20.2	22.0	24.2
July	7.17	7.75	8.30	24.7	26.5	29.2	5.82	7.70	8.23	24.0	26.6	28.9
Aug	6.80	7.37	8.44	26.4	27.5	29.7	6.61	7.47	7.91	26.4	27.3	29.4
Sep	6.55	7.41	7.72	24.5	26.3	28.5	6.91	7.45	7.85	24.4	26.1	28.2
Oct	7.29	7.74	8.35	19.3	22.6	25.7	7.17	7.73	8.35	19.3	22.4	25.5
Daily Average												
Month	Jocassee Tailwater						Jocassee Forebay					
	Dissolved Oxygen (mg/L)			Temperature (°C)			Dissolved Oxygen (mg/L)			Temperature (°C)		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Jan	8.92	9.06	9.22	11.1	12.0	13.7	-	-	-	-	-	-
Feb	9.15	9.69	9.92	10.6	11.3	12.7	9.46	9.63	9.82	10.6	11.0	11.7
Mar	9.57	9.82	10.03	11.3	14.0	16.9	9.52	9.63	9.78	13.0	14.0	15.5
Apr	9.08	8.63	9.79	15.4	17.2	19.6	9.18	9.35	9.50	15.0	16.6	17.3
May	8.61	8.95	9.39	18.1	20.1	22.9	8.68	8.94	9.12	19.5	20.8	22.7
June	8.04	8.37	8.67	22.1	23.7	25.4	7.35	8.31	8.77	20.7	22.8	25.6
July	7.43	7.75	8.09	25.4	26.5	27.9	7.15	7.70	8.03	25.4	26.6	27.9
Aug	7.21	7.37	7.64	26.9	27.5	29.1	7.06	7.47	7.65	26.9	27.3	28.0
Sep	7.23	7.41	7.58	25.0	26.9	29.1	7.25	7.45	7.60	24.6	26.1	27.2
Oct	7.45	7.75	8.24	19.5	22.6	24.8	7.45	7.73	8.24	19.5	22.4	24.4

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