APPENDIX 9.2
ENTRAINMENT, BOWLINE

Appendix 9.2 Entrainment Estimates for the United Water Intake Based on Bowline Point Entrainment Data

Background and Approach

Bowline Point power plant is located at river mile 37 on the western shore of the Hudson River, adjacent to Haverstraw Bay. The cooling water intake structure of Bowline Point power plant is located on the shore of a 56 acre man-made embayment to the Hudson River called Bowline Pond (Figure 1) which has a maximum depth of 39-40 feet (CHG&E, et.al. 1999). The historically permitted water withdrawal rate for Bowline Point power plant was 1,106 mgd (CHG&E, et.al. 1999), or 3,394 acre-feet per day. Although the intake is located within Bowline Pond, due to the volume of water withdrawn and the size of the embayment, the actual water source is the Hudson River. The mouth of the Bowline Pond embayment is roughly 1,000 feet from the main shoreline (Figures 1 and 2), and the Hudson River is roughly 1.5 miles wide at that point (CHG&E, et.al. 1999).

Due to the proximity of Bowline Point power plant to the proposed water treatment plant, historical estimates of entrainment at Bowline Point power plant were used to ascertain likely orders of magnitude of entrainment that might be caused by water withdrawals by the water treatment plant. The historical entrainment estimates from Bowline Point power plant were scaled down to reflect water withdrawal rates of the water treatment plant.

Methods and Results

Estimates of numbers of organisms entrained at Bowline Point power plant from 1981 through 1987 were listed in the 1999 Draft Environmental Impact Statement (1999 DEIS) for State Pollution Discharge Elimination System (SPDES) Permits for Bowline Point, Indian Point 2&3, and Roseton Steam Electric Generating Stations (Appendix VI-I-D-2, CHG&E, et.al. 1999). Those estimates were based on in-plant entrainment sampling at Bowline Point power plant. Entrainment estimates were listed for eggs, yolk-sac larvae, post yolk-sac larvae and juvenile bay anchovy, striped bass, river herring, white perch (Tables 1a – 1d)[1]. Although entrainment estimates of juvenile fish were listed in the 1999 DEIS, juvenile entrainment is not addressed in this assessment

[1] Estimates of numbers of American shad entrained were also listed; however, because the estimates of numbers of American shad entrained at Bowline Point power plant were very small, American shad were not included in this assessment.

because a substantial portion of juvenile fish would be excluded from entrainment by the proposed wedge-wire screen intake of the water treatment plant.

The entrainment estimates listed in the 1999 DEIS were for actual daily water withdrawal rates for the years 1981 through 1987; however those withdrawal rates were not documented in the Appendices to the 1999 DEIS. The 1999 DEIS listed the maximum permitted water withdrawal rate as 768,000 gpm (Table X-5, Appendix VI-I-B, CHG&E, et.al. 1999), or 1,106 mgd. For the purpose of this assessment, the entrainment estimates listed in the 1999 DEIS were assumed to be for a water withdrawal rate of 1,106 mgd. Also, for the purpose of this assessment, the withdrawal rate of the water treatment plant was assumed to be 10 mgd (HDR 2008).

Based on the assumed water withdrawal rates described above, the historical entrainment estimates for Bowline Point power plant were scaled down by multiplying the entrainment estimates in the 1999 DEIS by the ratio of 10 divided by 1,106. The resulting estimates (Tables 2a – 2d) reflect the expected entrainment with an intake in the vicinity of Bowline Point and a water withdrawal rate of 10 mgd.

In comparison, predicted entrainment for the water treatment plant (from HDR 2008) was based on region-wide densities of ichthyoplankton in the Hudson River (rather than in-plant entrainment sampling). The predictions of entrainment for the water treatment plant for 1981 through 1987, for bay anchovy, striped bass, river herring, and white perch (Tables 3a-3d), generally were higher than the scaled estimates based on Bowline Point power plant entrainment data. The differences may, in part, be due to differences in densities of ichthyoplankton at the intake versus region-wide densities in the Hudson River (on which the HDR predictions of entrainment were based). The 1999 DEIS addressed the issue of possible differences in densities, and estimated adjustment factors to account for those differences.

In the 1999 DEIS, two methods were used to estimate conditional mortality rates (CMR) due to entrainment. One method was based on data from in-plant entrainment sampling, and the other method was based on distribution patterns of ichthyoplankton in the Hudson River. The two methods were inter-calibrated by estimating values for a parameter (referred to as a W-ratio) that represented the ratio of ichthyoplankton densities at the intake to region-wide ichthyoplankton densities in the Hudson River (Appendix VI-I-B, CHG&E, et.al. 1999). For most fish species, the W-ratio estimates for eggs and larvae (Table X-12a, Appendix VI-I-B, CHG&E, et.al. 1999) were less than one for Bowline Point, indicating that the ichthyoplankton densities in the vicinity of the Bowline Point intake were lower than the region-wide densities.

Applying the W-ratio estimates from the 1999 DEIS to the predictions of entrainment from HDR (2008) produced adjusted predictions of entrainment for the water treatment plant (Table 4). The adjusted predictions of entrainment for the water treatment plant are remarkably similar to the scaled estimates of entrainment at Bowline Point power plant (Table 5).

Tables 1a-1d. Estimated annual number or organisms entrained at Bowline Point power plant, based on in-plant entrainment abundance sampling (from Table 3, Appendix VI-I-D-2, CHE&G, et.al. 1999).

Table 1a. Bay anchovy

Year	Life Stage		
	Eggs	Yolk-sac Larvae	Post Yolk-sac Larvae
1981	0	0	52,100,000
1982	0	0	221,000
1983	32,500	348,000	41,600,000
1984	173,000	0	288,000,000
1985	3,850,000	0	32,100,000
1986	130,000	333,000	46,600,000
1987	805,000	42,500	94,600,000
Average	712,929	103,357	79,317,286

Table 1b. Striped bass

Year	Life Stage		
	Eggs	Yolk-sac Larvae	Post Yolk-sac Larvae
1981	0	546,000	11,700,000
1982	0	6,250,000	4,040,000
1983	1,530	2,840,000	6,160,000
1984	24,300	1,570,000	45,700,000
1985	2,010	67,700	1,150,000
1986	0	14,200,000	36,000,000
1987	1,020	91,700	8,080,000
Average	4,123	3,652,200	16,118,571

Tables 1a-1d (cont.). Estimated annual number or organisms entrained at Bowline Point power plant, based on in-plant entrainment abundance sampling (from Table 3, Appendix VI-I-D-2, CHE&G, et.al. 1999).

Table 1c. River herring

Year	Life Stage		
	Eggs	Yolk-sac Larvae	Post Yolk-sac Larvae
1981	39,100	0	2,540,000
1982	11,200	0	8,540,000
1983	18,000	29,300	29,700,000
1984	173,000	0	53,600,000
1985	14,200	332,000	50,300
1986	12,300	0	1,090,000
1987	0	0	191,000
Average	38,257	51,614	13,673,043

Table 1d. White perch

Year	Life Stage		
	Eggs	Yolk-sac Larvae	Post Yolk-sac Larvae
1981	1,360,000	0	15,500,000
1982	3,730,000	123,000	6,410,000
1983	3,840,000	1,600,000	20,400,000
1984	4,100,000	1,280,000	20,200,000
1985	198,000	207,000	1,290,000
1986	167,000	798,000	9,830,000
1987	1,120	0	302,000
Average	1,913,731	572,571	10,561,714

Tables 2a-2d. Scaled estimates of annual number or organisms entrained at Bowline Point power plant, assuming water withdrawal rate of 10 MGD.

Table 2a. Bay anchovy

Year	Life Stage		
	Eggs	Yolk-sac Larvae	Post Yolk-sac Larvae
1981	0	0	471,067
1982	0	0	1,998
1983	294	3,146	376,130
1984	1,564	0	2,603,978
1985	34,810	0	290,235
1986	1,175	3,011	421,338
1987	7,278	384	855,335
Average	6,446	935	717,154

Table 2b. Striped bass

Year	Life Stage		
	Eggs	Yolk-sac Larvae	Post Yolk-sac Larvae
1981	0	4,937	105,787
1982	0	56,510	36,528
1983	14	25,678	55,696
1984	220	14,195	413,201
1985	18	612	10,398
1986	0	128,391	325,497
1987	9	829	73,056
Average	37	33,022	145,738

Tables 2a-2d (cont.). Scaled estimates of annual number or organisms entrained at Bowline Point power plant, assuming water withdrawal rate of 10 MGD.

Table 2c. River herring

Year	Life Stage		
	Eggs	Yolk-sac Larvae	Post Yolk-sac Larvae
1981	354	0	22,966
1982	101	0	77,215
1983	163	265	268,535
1984	1,564	0	484,629
1985	128	3,002	455
1986	111	0	9,855
1987	0	0	1,727
Average	346	467	123,626

Table 2d. White perch

Year	Life Stage		
	Eggs	Yolk-sac Larvae	Post Yolk-sac Larvae
1981	12,297	0	140,145
1982	33,725	1,112	57,957
1983	34,720	14,467	184,448
1984	37,071	11,573	182,640
1985	1,790	1,872	11,664
1986	1,510	7,215	88,879
1987	10	0	2,731
Average	17,303	5,177	95,495

Tables 3a-3d. Predicted annual number or organisms entrained by water treatment plant intake, assuming 10 MGD water withdrawal rate (from Tables 4, 12, 20 and 24, HDR 2008).

Table 3a. Bay anchovy

Year	Life Stage		
	Eggs	Yolk-sac Larvae	Post Yolk-sac Larvae
1981	5,153,710	496	2,291,980
1982	0	0	9,162
1983	3,991,754	0	1,175,883
1984	9,973,809	1,182	1,764,738
1985	3,736,435	822	1,601,316
1986	105,062	147	463,105
1987	4,068,107	945	1,157,320
Average	3,861,268	513	1,209,072

Table 3b. Striped bass

Year	Life Stage		
	Eggs	Yolk-sac Larvae	Post Yolk-sac Larvae
1981	3,165	79,905	435,476
1982	840	86,305	964,783
1983	36,711	168,603	390,625
1984	80,382	99,265	240,826
1985	0	624	42,128
1986	0	90,965	258,849
1987	0	347	148,744
Average	17,300	75,145	354,490

Tables 3a-3d (cont.). Predicted annual number or organisms entrained by water treatment plant intake, assuming 10 MGD water withdrawal rate (from Tables 4, 12, 20 and 24, HDR 2008).

Table 3c. River herring

Year	Life Stage		
	Eggs	Yolk-sac Larvae	Post Yolk-sac Larvae
1981	0	3,593	84,182
1982	0	85	108,736
1983	0	2,075	1,088,309
1984	491	23,554	1,079,047
1985	0	0	1,520
1986	0	0	80,839
1987	0	0	2,696
Average	70	4,187	349,333

Table 3d. White perch

Year	Life Stage		
	Eggs	Yolk-sac Larvae	Post Yolk-sac Larvae
1981	549	25,543	350,242
1982	343	6,503	1,065,769
1983	2,607	83,081	1,129,309
1984	9,066	80,649	507,019
1985	210	210	9,480
1986	922	4,579	1,076,119
1987	72	580	25,616
Average	1,967	28,735	594,793

Table 4. Predicted annual number or organisms entrained by water treatment plant intake (assuming 10 MGD water withdrawal rate) adjusted for apparent differences in region-wide ichthyoplankton densities and intake densities at Bowline Point power plant. W-ratio (intake ichthyoplankton density divided by region-wide density) estimates are from Table X-12a, Appendix VI-I-B, CHE&G, et.al. 1999.

Taxon	Life Stage	Predicted Annual Water Treatment Plant Entrainment (average 1981-1987)	W-ratio Estimate	Adjusted Prediction of Annual Water Treatment Plant Entrainment (average 1981-1987)
Bay anchovy	Egg	3,861,268	0.0015	5,792
	Yolk-sac Larvae	513	0.0396	20
	Post Yolk-sac Larvae	1,209,072	0.4450	538,037
Striped bass	Egg	17,300	0.0289	500
	Yolk-sac Larvae	75,145	0.1959	14,721
	Post Yolk-sac Larvae	354,490	0.4104	145,483
River herring	Egg	70	0.5584	39
	Yolk-sac Larvae	4,187	0.1202	503
	Post Yolk-sac Larvae	349,333	0.4637	161,986
White perch	Egg	1,967	3.8776	7,627
	Yolk-sac Larvae	28,735	0.2157	6,198
	Post Yolk-sac Larvae	594,793	0.3828	227,687

Table 5. Comparison of scaled estimates of annual number or organisms entrained at Bowline Point power plant (assuming water withdrawal rate of 10 MGD) to W-ratio-adjusted predictions of annual number or organisms entrained by water treatment plant intake (assuming 10 MGD water withdrawal rate).

Taxon	Life Stage	Adjusted Prediction of Annual Water Treatment Plant Entrainment (average 1981-1987)	Scaled (10 MGD) Annual Entrainment at Bowline Point (average 1981-1987)
Bay anchovy	Egg	5,792	6,446
	Yolk-sac Larvae	20	935
	Post Yolk-sac Larvae	538,037	717,154
Striped bass	Egg	500	37
	Yolk-sac Larvae	14,721	33,022
	Post Yolk-sac Larvae	145,483	145,738
River herring	Egg	39	346
	Yolk-sac Larvae	503	467
	Post Yolk-sac Larvae	161,986	123,626
White perch	Egg	7,627	17,303
	Yolk-sac Larvae	6,198	5,177
	Post Yolk-sac Larvae	227,687	95,495

Figure 1. Schematic diagram depicts spatial relationships between the Bowline Point power plant intake, Bowline Pond, and the Hudson River (from CHG&E et.al. 1999). The diffuser at the end of the discharge pipe is approximately 1,300 feet from the shoreline (CHG&E et.al. 1999).

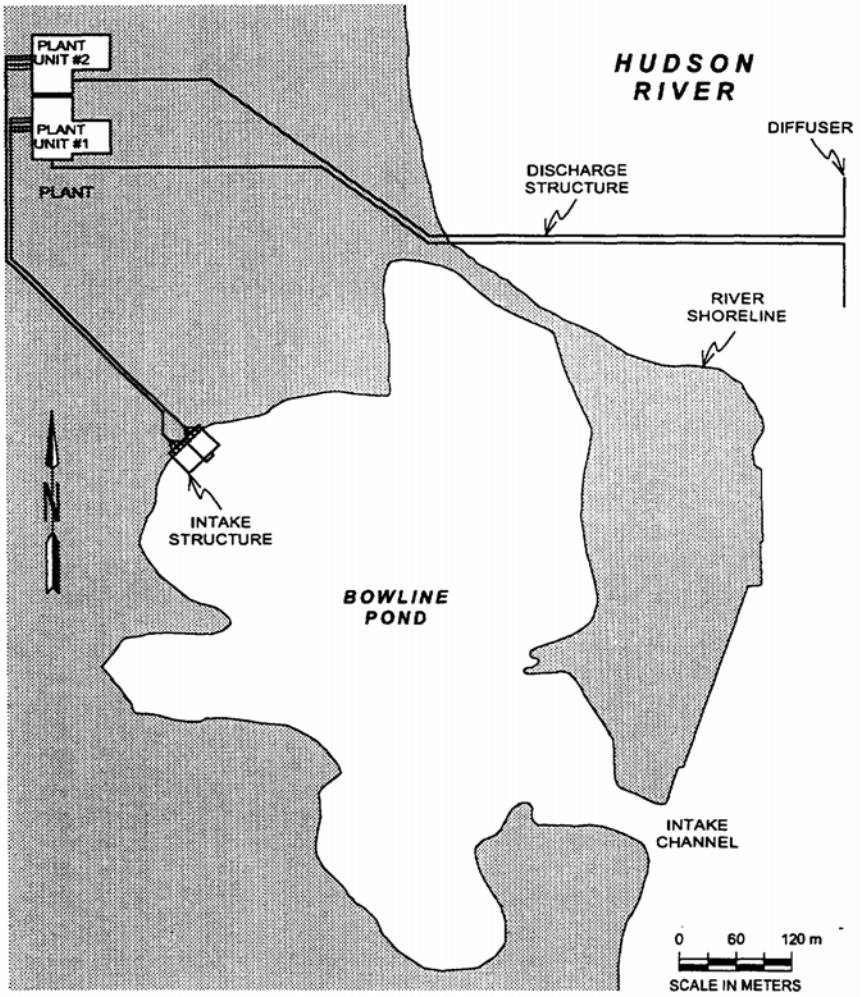
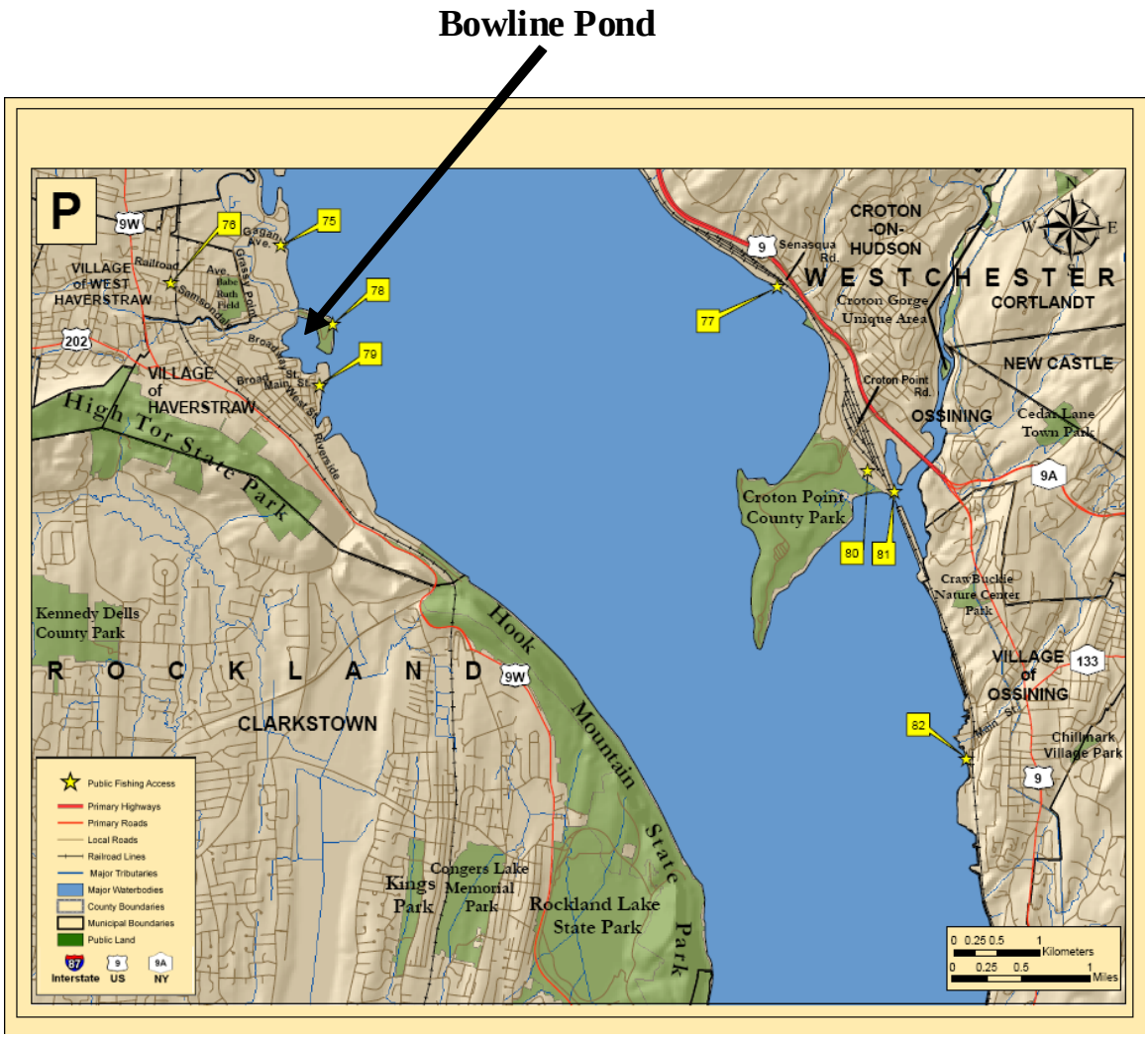


Figure IV-19. Schematic of Bowline Point.

Figure 2.Hudson River Estuary Public Fishing and Boating Access Map “P”, showing size and location of Bowline Pond in relation to the Hudson River.



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Central Hudson Electric and Gas Corp. (CHE&G), et.al. 1999. Draft Environmental Impact Statement for State Pollution Discharge Elimination System Permits for Bowline Point, Indian Point 2&3, and Roseton Steam Electric Generating Stations.

HDR. 2008. Entrainment Effects of the Proposed United Water Desalinization Plant.