ORNL/TM-2023/3035

Operational and Performance Monitoring of East Tennessee Technology Park Ponds—2023 Results

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OAK RIDGE National Laboratory

ORNL IS MANAGED BY UT-BATTELLE LLC FOR THE US DEPARTMENT OF ENERGY

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Environmental Sciences Division

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ABBREVIATIONS

CRM	Clinch River mile
DO	dissolved oxygen
EPA	US Environmental Protection Agency
ETTP	East Tennessee Technology Park
HCGPT	Heritage Center Greenway Powerhouse Trail
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
PCB	polychlorinated biphenyl
PCM	Poplar Creek mile
SD	Storm Drain
SRP	soluble reactive phosphorus
TP	total phosphorus
TSS	total suspended solids

1. INTRODUCTION

Performance and operational monitoring are regulatory requirements associated with a non–time-critical removal action for three surface water bodies at the East Tennessee Technology Park (ETTP) in Oak Ridge, Tennessee (Figure 1): the K-1007-P1 Pond, the K-901-A Pond, and the K-720 Slough. This progress report summarizes the monitoring activities and results from fiscal year (FY) 2023. The goal of ecological enhancement of the K-1007-P1 and K-901-A Ponds is to reduce risk from polychlorinated biphenyl (PCB) contamination in fish to humans and wildlife. Lowering PCB concentrations in the water column and in the food that fish eat is expected to decrease PCB bioaccumulation in fish. Performance monitoring of the K-1007-P1 Pond focuses on annual PCB trends in water, clams, and fish. PCBs in fish also are sampled annually at the K-720 Slough.

Operational monitoring ensures that ecological enhancement measures—including water quality, plant community, fish community, and wildlife actions—have been implemented as intended. Monitoring provides the information necessary to determine whether modifications are needed to attain the design end state (i.e., a heavily vegetated, clearwater pond dominated by sunfish with significantly diminished or at least downwardly trending PCB levels in fish). In FY 2023, fish removal efforts and vegetation planting primarily focused on the K-901-A Pond. These actions were implemented to help push the systems toward the desired end state. Descriptions of the various monitoring activities and preliminary 2023 results are provided in the following sections. An update on fish and plant management actions in FY 2023 is also included in this report. A summary of the more detailed information in this report will be presented as required in the upcoming Remediation Effectiveness Report.

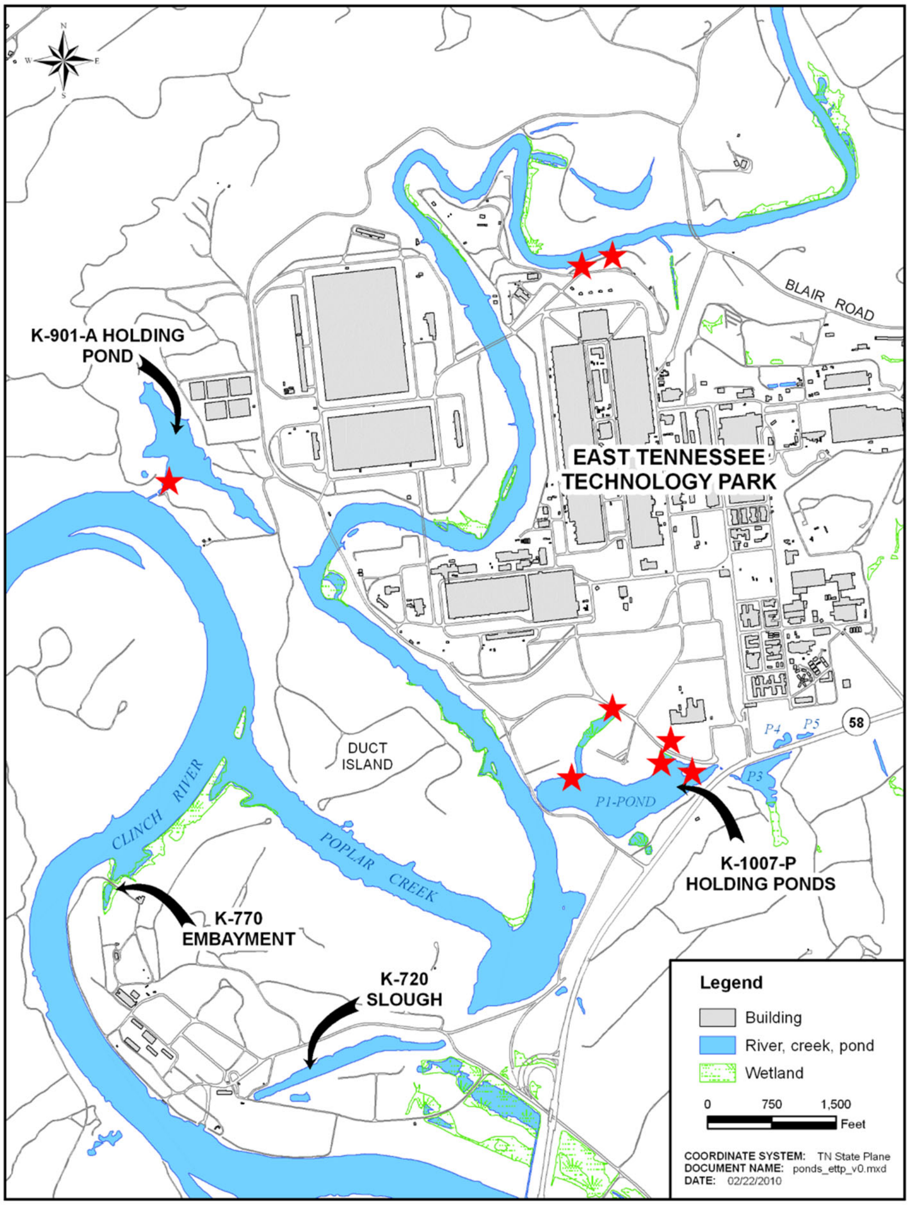

Figure 1. Location of ponds and other surface water bodies at East Tennessee Technology Park (ETTP).
FY 2023 clam sampling locations are marked with a red star (★).

2. PERFORMANCE MONITORING

Performance monitoring for the K-1007-P1 Pond in FY 2023 included the collection and analysis of water, clam, and fish (fillet and whole-body) samples for PCB analysis. Fish samples were also collected from the K-901-A Pond and K-720 Slough for PCB analysis.

2.1 PCB MONITORING APPROACH

Water samples were collected in and around the K-1007-P1 Pond and the K-901-A Pond for PCB analysis. Fish were collected from the three ponds (Figure 1), primarily from the shore areas that had suitable structure and sufficient depth for fish. Asiatic clams were deployed near ETTP outfalls at the east end of the K-1007-P1 Pond and at the weir areas near the outfalls of both ponds.

Water samples for PCB analysis were collected four times (March, June, July, and August) from three locations in or near the K-1007-P1 Pond and K-901-A Pond and twice (June and August) from an uncontaminated reference location on upper First Creek near the US Department of Energy's Oak Ridge National Laboratory (ORNL). On each collection day, 2 L of water were collected in certified clean 1 L amber glass bottles and transported to ORNL on ice in a cooler. Water samples from the K-1007-P1 Pond were collected near the weir on the west end of the pond and from the upper and lower reaches of Storm Drain (SD) 100. Water samples were collected concurrently with aqueous PCB samples in clean plastic sample bottles for total suspended solids (TSS) analysis. Upon arrival at the laboratory, aqueous PCB samples were custody-sealed and held in a secure refrigerator until delivery to a subcontracted laboratory for analysis. PCBs in water were analyzed for 209 congeners following US Environmental Protection Agency (EPA) Method 1668. TSS samples were filtered on the day of collection and dried for 24 h.

Caged Asiatic clams (*Corbicula fluminea*) were placed near and within various storm drains at ETTP for an exposure period of 4 weeks (May 11 to June 8, 2023). Two clam baskets were placed at each site, with 10 clams in each basket. The soft tissues of all 10 clams from each cage were combined and homogenized, and aliquots were taken for PCB analysis.

Bluegill sunfish (*Lepomis macrochirus*) were collected for PCB analysis from the K-1007-P1 Pond by boat electrofishing in February 2022 in conjunction with fish community studies in this pond. In total, 20 bluegill were kept for analysis of tissue from fillets, and another 60 bluegill were split among 6 composites of 8 fish each for whole-body analysis. All fish were processed at the laboratory within 24 h of collection. Each bluegill collected for analysis of fillets was weighed (to the nearest 0.1 g), measured (total length to the nearest 0.1 cm), scaled, and filleted. Fillets from each fish were wrapped in aluminum foil, labeled (unique sample identification number, site, date, and species), and stored at −20°C in a locked freezer. Fillets were homogenized and delivered to the analytical laboratory for PCB analysis. The same laboratory procedures were used to process fillet samples from the K-901-A Pond and the K-720 Slough. The K-1007-P1 Pond bluegill collected for fillet analysis in 2023 were smaller (82.3 ± 16.3 g) than those collected in 2022 (91.4 ± 13.9 g). The bluegill collected for analysis of whole-body composites in the K-1007-P1 Pond in 2023 were smaller in size to those collected in 2022 (53 g), with an average mass of 36 g/fish.

Similar to previous years, the target fish species for PCB analysis in the K-901-A Pond and K-720 Slough were gizzard shad (*Dorosoma cepedianum*, whole-body tissue) and largemouth bass (*Micropterus salmoides*, fillets). In 2023, bluegill were also collected from the K-901-A Pond (for analysis of fillets and whole-body tissue), and bluegill and gizzard shad (for analysis of whole-body tissue) were also collected from Clinch River mile (CRM) 11.0 and Poplar Creek mile (PCM) 1.0 for analysis of whole-body tissue. At the K-901-A Pond, it was not possible to collect the target number of any species of fish for fillets or whole-body samples. The plantings in this pond have been so successful and have covered so much of the habitat that it was not possible to maneuver the sampling boat to collect the fish. The plants are attaining the goals for water quality in this pond as well; water clarity was extremely high, making sampling even more difficult. Though the target number of fish was not collected, the samples that were collected (12 bluegill and 1 carp) show concentrations that are significantly lower than in previous years. Common carp (*Cyprinus carpio*) are collected as a surrogate species for largemouth bass. These fish are widely distributed and have been used historically in other monitoring efforts on the Oak Ridge Reservation (ORR) for contaminant analyses. In total, 1 common carp (4,900 g) was collected from the K-901-A Pond. In total, 12 bass (153.3–1,810.3 g) and 8 carp (2,800–7,460 g) were collected from the K-720 Slough. No gizzard shad were collected or observed in the K-901-A Pond in 2023. The gizzard shad collected from the K-720 Slough in 2023 were slightly larger when compared to those collected in 2022 (average weight of 80.0 g/fish in 2023 compared with 71.1 g/fish in 2022). After collection, the fish were placed on ice for transport to the laboratory, where all fish were processed within 24 h of collection.

Each fish collected for whole-body analysis (from all three ponds) was weighed, measured, and wrapped in aluminum foil by composite sample. Each composite sample was labeled as described previously for fillet samples. Samples were placed in a secure freezer (−20°C) until homogenization. For homogenization, frozen fish were partially thawed, cut into small pieces, and passed through a stainless-steel grinder three times. Subsamples (approximately 20 g) of the ground tissue were wrapped in aluminum foil, labeled, and stored in the freezer (−20°C) until being delivered for PCB analysis. A subcontracted laboratory analyzed all fish samples for PCBs following EPA Method 8082 (quantification as Aroclor mixtures).

2.2 PCB MONITORING RESULTS

Results for aqueous PCB and TSS samples collected concurrently in 2023 are shown in Table 1, and results for the analyses of aqueous PCBs and TSS are summarized in Figure 2. Average aqueous PCB concentrations and average TSS concentrations at the K-1007-P1 Pond outfall have declined since a moderate increase was recorded in 2016 and 2017. Concentrations of PCBs at the K-1007-P1 Pond outfall were slightly higher in 2023 than in 2022 and have generally decreased since sampling began in 2007 (161 ng/L in 2007 to 50 ng/L in 2023). However, slight fluctuations have occurred over that time; the lowest concentrations were measured in 2015 at 26 ng/L, and similar concentrations have been recorded in recent years. Similar to PCB concentrations, TSS concentrations in the K-1007-P1 Pond have decreased with slight fluctuations since 2007 (20 mg/L); the average concentration in 2023 was 3.6 mg/L. Lower SD100 empties into the K-1007-P1 Pond. Additional monitoring of PCBs in water collected at upper and lower SD100 showed a seasonal increase in concentrations and consistently higher concentrations at lower SD100 compared with upper SD100 (Table 1).

Table 1. Total PCB and TSS concentrations in water samples from K-1007-P1 Pond, SD100, K-901-A Pond, and First Creek reference site, 2023

Date	Total PCBs (ng/L)	TSS (mg/L)
	K-1007-P1 Pond	
March 28, 2023	63.46	5.44
June 7, 2023	76.92	5.64
July 6, 2023	24.90	1.45
August 16, 2023	35.25	2.05
	Upper SD100	
March 28, 2023	41.96	3.52
June 7, 2023	398.38	2.94
July 6, 2023	--[a]	3.97
August 16, 2023	91.57	3.96
	Lower SD100	
March 28, 2023	190.34	3.48
June 7, 2023	1901.22	6.94
July 6, 2023	389.30	3.76
August 16, 2023	611.40	7.03
	K-901-A Pond	
March 28, 2023	2.41	7.62
June 7, 2023	1.91	4.67
July 6, 2023	0.80	1.86
August 16, 2023	0.51	1.00
	First Creek	
June 7, 2023	0.13	1.10
August 16, 2023	0.18	2.85

[a]Issue with sample extraction in the laboratory resulted in a limited number of PCB congeners being reported. As such, the total PCB value for this sample is not directly comparable to the other samples, and thus the value is not reported.

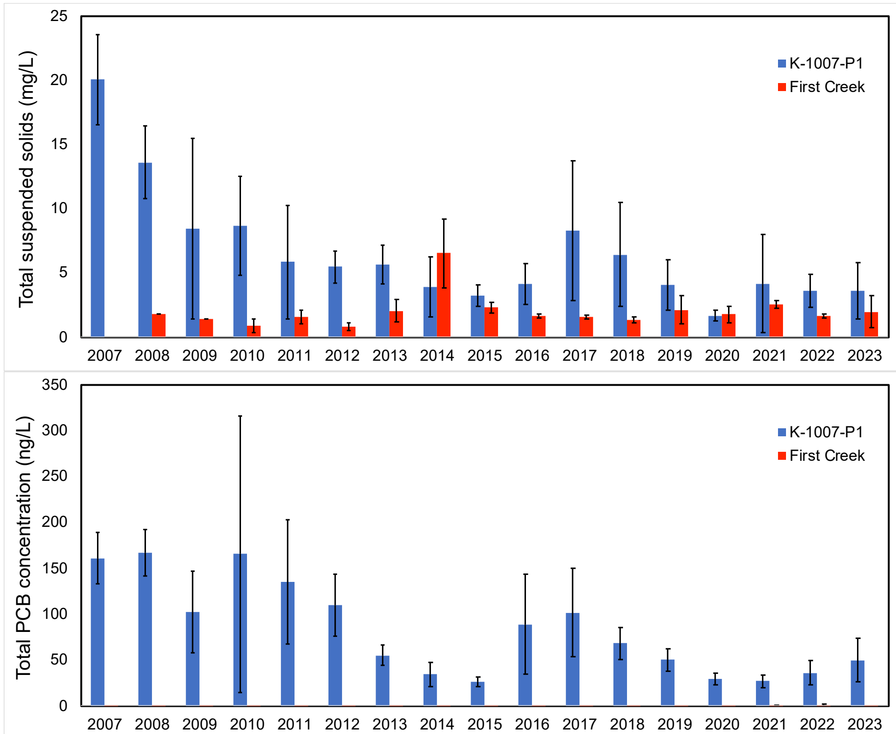

Figure 2. Means (± standard deviation) for (top) total suspended solid (TSS) and total PCB concentrations (bottom) in water, 2007 to 2023, for the K-1007-P1 Pond and the First Creek reference site. Means for PCBs in water and TSS are based on results across the four collections made each year. Mean concentrations of PCBs in water from First Creek were <0.8 ng/L in all years.

Mean PCB concentrations in clams placed near lower SD100 have fluctuated significantly since remediation actions in 2009. SD100 was historically the most contaminated outfall in the network, but PCB concentrations have been trending downward since 2009 such that concentrations in clams placed in this storm drain from 2012 to 2016 were comparable to concentrations at the reference site. Since 2017, however, concentrations in clams placed in both upper and lower SD100 have increased to concentrations seen in the early 2000s, suggesting that PCB inputs to the K-1007-P1 Pond have increased. In 2023, mean PCB concentrations in clams at upper SD100 (3.66 µg/g) increased from 2022 concentrations (3.08 µg/g); at the lower SD100 site, mean PCB concentrations in clams increased from 5.61 µg/g in 2022 to 9.88 µg/g in 2023 (Table 2). Concentrations at the K-1007-P1 Pond weir have steadily declined since 2017 but have been increasing slightly since 2022. In 2023, mean PCB concentrations at the K-1007-P1 Pond weir were 0.78 µg/g (compared with 0.46 µg/g in 2022). Further analysis of temporal trends in clam PCB concentrations in the K-1007-P1 Pond will be presented in the upcoming Remediation Effectiveness Report.

Table 2. PCBs (shown as Aroclor 1248, 1254, and 1260 and total Aroclors; µg/g, wet weight) in caged Asiatic clams placed in baskets (A and B) near storm drains and pond outfalls for a 4-week period[a], 2023

Site	Sample ID		Aroclor 1248	Aroclor 1254	Aroclor 1260	Total Aroclors
Reference site						
Sewee Creek	21917	A	ND	0.0091	ND	0.0091
		B	ND	0.009	ND	0.009
K-1007-P1 Pond						
SD490	21922	A	0.0132	0.0819	0.0269	0.122
		B	ND	0.0578	0.0179	0.0757
SD100 (upper)	21920	A	2.61	1.05	ND	3.66
		B	2.6	1.05	ND	3.65
SD100 (lower)	21921	A	6.49	3.49	0.406	10.386
		B	5.91	3.09	0.364	9.364
SD120	21919	A	0.123	0.275	0.0348	0.4328
		B	0.0975	0.194	0.0239	0.3154
K-1007-P1 Pond outfall	21923	A	0.375	0.351	0.0451	0.7711
		B	0.387	0.359	0.0458	0.7918
K-901-A Pond						
K-901-A outfall	21924	A	ND	ND	0.0157	0.009
		B	ND	ND	0.0208	0.0101

Note: ND = not detected.
[a]From May 11 to June 8, 2023.

In 2023, mean fillet and whole-body PCB concentrations in bluegill collected from the K-1007-P1 Pond were again below the targets for this pond. Mean PCB concentrations in fillets in the K-1007-P1 Pond were 0.23 µg/g, significantly lower than concentrations seen in 2022 and below the remediation goal for this pond (1 µg/g total PCBs in fillets). Mean concentrations in whole-body bluegill were 0.99 µg/g, also lower than concentrations seen in 2022 and below the remediation target for this pond (2.3 µg/g in whole-body composites).

At the K-901-A Pond, it was not possible to collect the target number of any species of fish for fillets or whole-body samples. The plantings in this pond have been so successful and have covered so much of the habitat that it was not possible to maneuver the sampling boat to collect the fish. The plants are attaining the goals for water quality in this pond as well; water clarity was extremely high making sampling even more difficult. Though the target number of fish was not collected, the samples that were collected (12 bluegill and 1 carp) show concentrations that are significantly lower than in previous years. Mean total PCB concentrations in bluegill fillets also decreased significantly, from 0.42 µg/g in 2022 to 0.05 µg/g in 2023. Concentrations in fish fillets from the K-720 Slough in 2023 were low and similar to those seen in 2022.

Table 3. Total PCB (Aroclor 1248, 1254, and 1260) concentrations (µg/g) in fish from the K-1007-P1 Pond, K-720 Slough, K-901-A Pond, CRM 11.0, and PCM 1.0 in FY 2023. Values presented include the mean and range of concentrations, as well as the number of samples that exceed target remediation concentrations in the K-1007-P1 Pond.

Site	Species	Sample type	Sample size (n)	Total PCBs (mean ± SD)	Range of PCB values	No. > target[a] (PCBs)/n	Total Hg (mean + SD)
K-1007-P1 Pond	Bluegill	Fillet	20	0.23 ± 0.21	0.03–0.89	0/20	—
		Whole-body composite	6	0.99 ± 0.33	0.58–1.43	0/6	—
K-901-A Pond	Common carp	Fillet	1	0.54	—	0/1	—
	Bluegill	Fillet	12	0.05 ± 0.02	0.03–0.08	0/20	—
K-720 Slough	Largemouth bass	Fillet	12	0.02 ± 0.01	0.02–0.03	0/12	—
	Common carp	Fillet	8	0.09 ± 0.08	0.02–0.24	0/8	—
	Gizzard shad	Whole-body composite	6	0.12 ± 0.01	0.10–0.13	0/6	—
CRM 11	Bluegill	Whole-body composite	6	0.02 ± 0.002	0.02–0.03	0/6	—
	Gizzard shad	Whole-body composite	6	0.09 ± 0.02	0.05–0.13	0/6	—
PCM 1.0	Bluegill	Whole-body composite	6	0.06 ± 0.03	0.05–0.12	0/6	—
	Gizzard shad	Whole-body composite	1	0.23	—	0/1	—

Note: SD = standard deviation.
[a]1 µg/g total PCBs in fish fillets and 2.3 µg/g in whole-body fish.

3. OPERATIONAL MONITORING

Operational monitoring in the K-1007-P1 Pond in FY 2023 included water quality, plant community, fish community, and wildlife surveys. New planting efforts focused on the K-901-A Pond in FY 2023. Fish management efforts in the K-1007-P1 Pond and K-901-A Pond included fish population surveys and nuisance fish removals in FY 2023.

3.1 WATER QUALITY

3.1.1 Water Quality Monitoring in the K-1007-P1 Pond

Water quality conditions in the K-1007-P1 Pond were characterized annually in June, July, and August from 2010 to 2023 (excluding 2019). Two prior sampling events took place in summer 2004 and summer 2007. Samples were collected from the three permanent north–south–oriented transects established in the pond in 2008 (Figure 3). Within each transect, water depth, Secchi depth (i.e., water clarity), and near-surface measurements at a depth of approximately 10 cm—including temperature, conductivity and specific conductivity, dissolved oxygen (DO, in mg/L and % saturation), turbidity, and pH—were obtained from three cells located at distances of approximately one-third of the pond width for that transect. Additionally, grab samples of surface water were collected at the all three cells of each transect for analysis of TSS, and the two northernmost cells of each transect for analysis of chlorophyll *a* and nutrients, including total phosphorus (TP), soluble reactive phosphorus (SRP), NH_4^+ (the ionized form of ammonia), and nitrate (NO_3^-). Finally, depth profiles for temperature and DO were measured at all cells at intervals of approximately 50 cm.

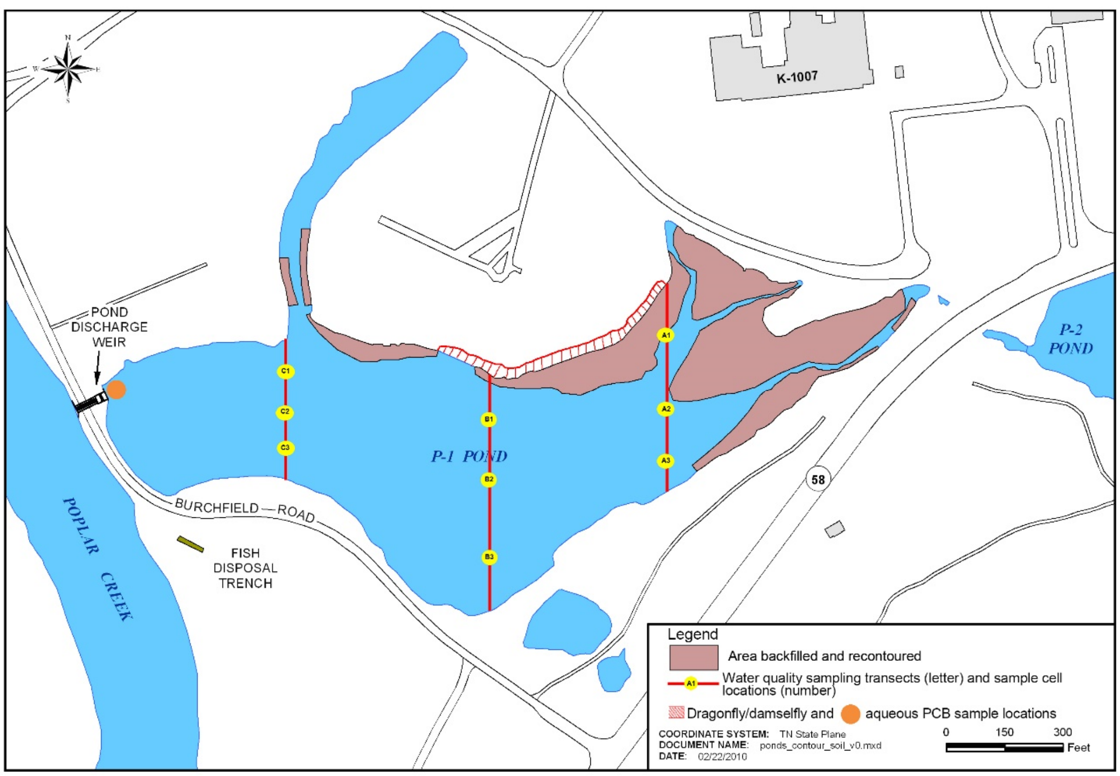

Figure 3. Map of water quality sampling locations in the K-1007-P1 Pond.

In FY 2023, surface temperature, conductivity, pH, DO, and turbidity were measured with a YSI ProDigital (ProDSS) handheld meter. In prior years, a Hanna Industries HI9829 portable meter was used. Furthermore, in prior years, on some sampling dates, an Accumet AP71 pH meter was also used. Secchi depth was measured with a standard 200 mm Secchi disk attached to a nylon rope demarcated at 50 cm intervals. To acquire the final measurement, the rope was grabbed at the water–air interface, and a meter stick was used to measure the distance from the nearest 50 cm marking to calculate the Secchi depth. After the Secchi depth was recorded, the disk was allowed to sink to the bottom of the pond to measure total water depth.

Separate water samples were collected in clean, high-density polyethylene bottles from each transect cell at a depth of approximately 10 cm for analysis of TSS (1 L), chlorophyll *a* (1 L), and nutrients (250 mL). Amber bottles were used for collection of chlorophyll *a* samples to minimize light exposure. Samples were immediately placed in a cooler with ice and returned to the laboratory. In the laboratory, nutrient samples were stored in a freezer until analysis, whereas samples for TSS and chlorophyll *a* analysis remained on ice until they were filtered (within 24 h). TSS samples were analyzed following standard EPA procedures (Method 160.2), chlorophyll *a* samples were analyzed following procedures outlined by Arar and Collins (1997), and nutrient samples were analyzed following procedures outlined by Eatone, Closceri, and Greenberg (1995).

Conductivity increased with time after the remediation actions in the K-1007-P1 Pond and has remained fairly consistent (at approximately 290 µS/cm) from 2014 to 2023, but conductivity declined slightly in 2022 (Figure 4). Water temperature, local geology, and the presence of inorganic dissolved solids affect conductivity measurements. Surface water temperature appears to be related to plant cover because summer temperatures were generally cooler in the years with peak plant cover (2012 to 2015; Figure 4). DO concentrations have also fluctuated since the remediation actions and also appear to be related to plant cover. DO concentrations were generally lowest across Transect A, where lotus coverage was usually the greatest. The highest concentrations of DO were generally present at Transect C and were likely related to the absence of lotus leaves. Without the leaves blocking light penetration, more gas exchange occurs across the air–water interface, and microalgae productivity is greater, producing more oxygen. DO concentrations have been relatively similar over the past 4 years (Figure 4). The pH of surface water in the K-1007-P1 Pond is slightly basic and generally decreased from 2010 to 2014, and then increased slightly through 2022 with slightly lower values in 2023 (Figure 5). pH is likely also related to plant cover in the pond; pH in freshwater ponds can range between 7 and 11 daily because of fluctuations in photosynthetic activity. Concentrations of TSS were high in the pond before remediation actions. TSS has generally decreased since 2010, with some fluctuations coinciding with changes in plant coverage in the pond between 2014 and 2018 (Figure 5). Mean TSS concentrations in 2023 were similar to those measured in 2021 and 2022 (Figure 5). Secchi depth was highest between 2014 and 2016, also coinciding with increased vegetation coverage across the pond (Figure 5 and Table 4). In 2023, the average Secchi depth remained below the target goal of 150 cm; however, this was because of aquatic vegetation rather than turbidity. At most locations, the Secchi disk became covered by the vegetation and was not visible at the surface even with low turbidity.

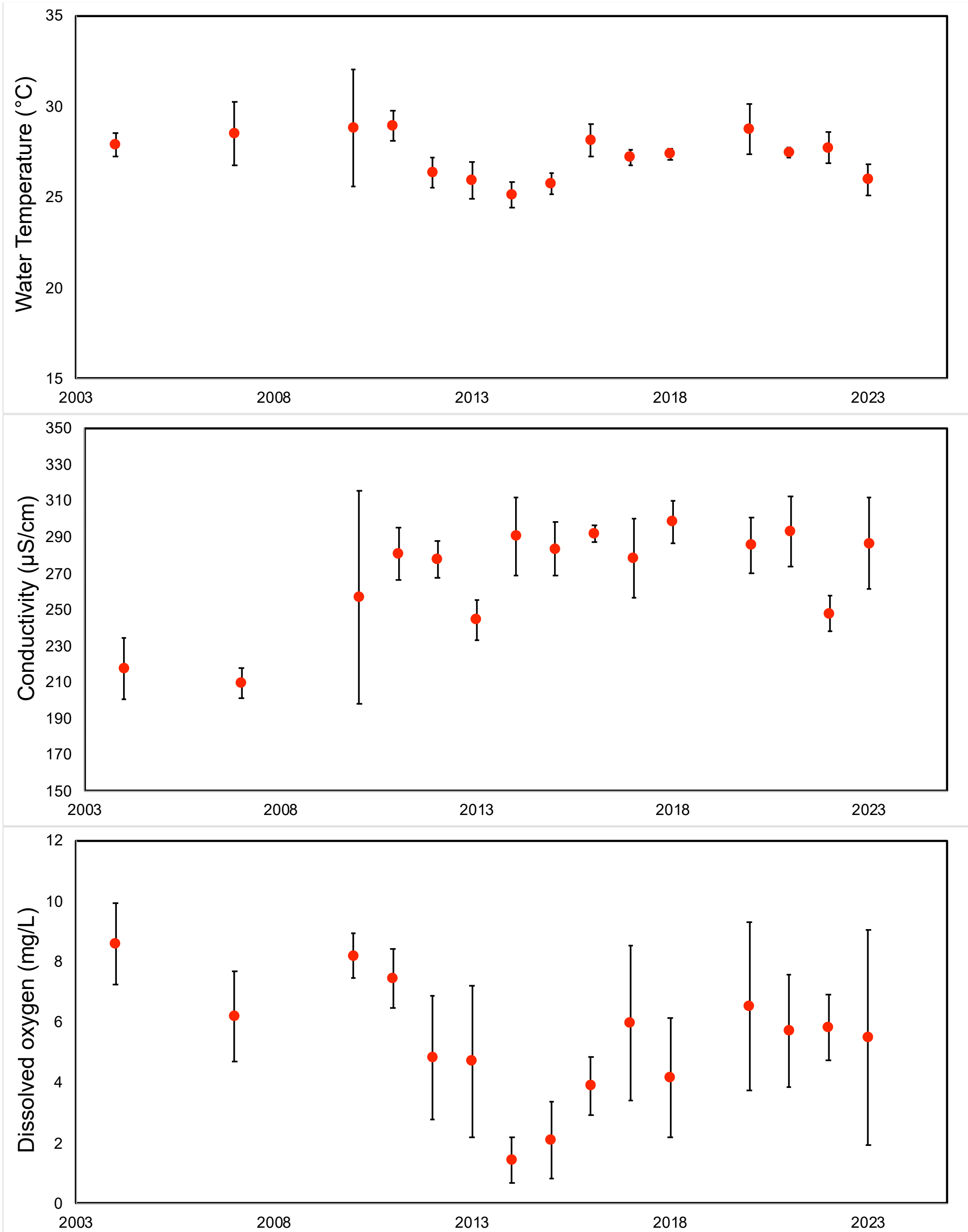

Figure 4. Mean (± standard deviation) of (top) near-surface water conductivity, (middle) temperature, and (bottom) DO for the K-1007-P1 Pond, 2004 to 2023.

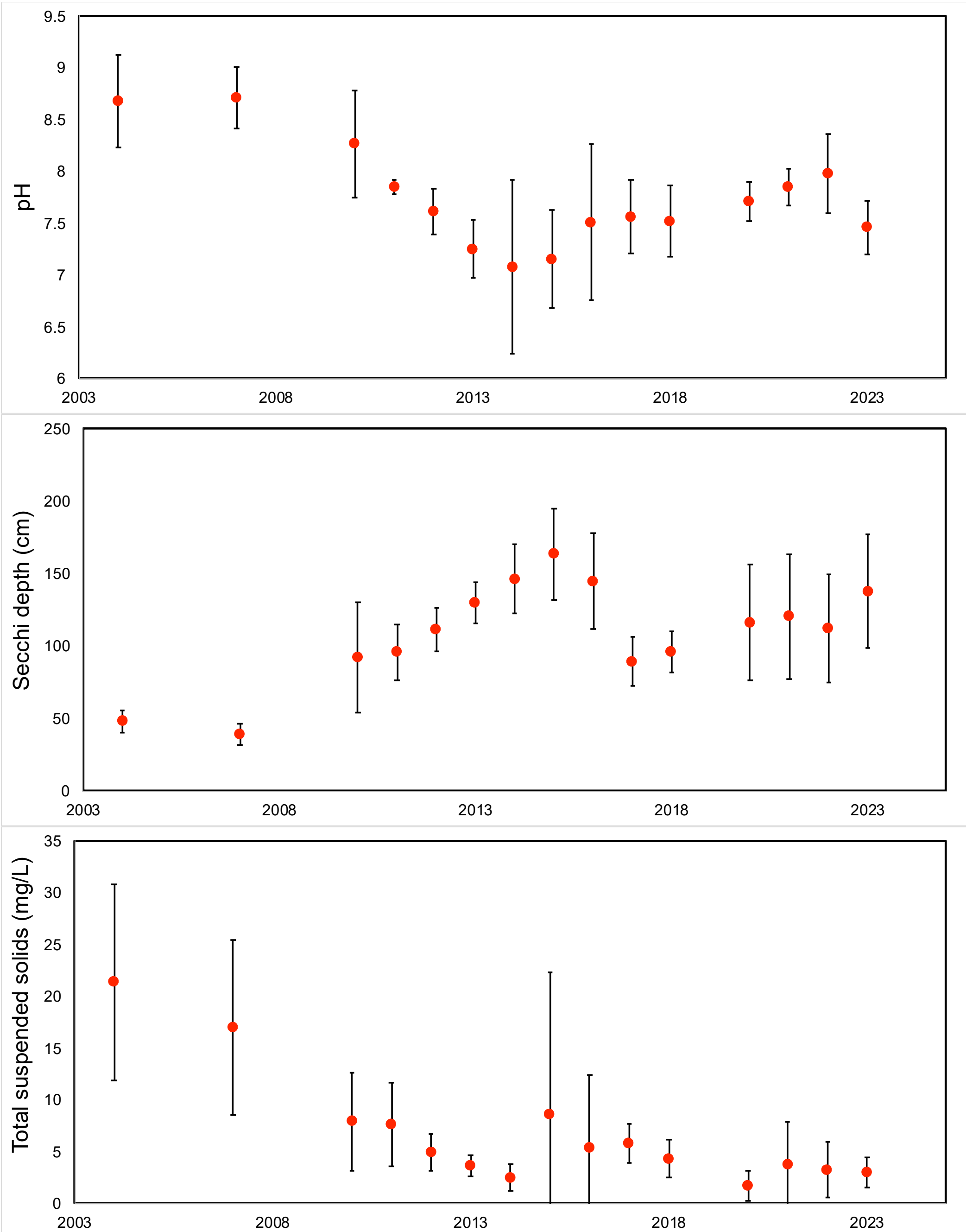

Figure 5. Mean (± standard deviation) (top) mean annual pH, (middle) Secchi depth (water clarity), and (bottom) TSS for the K-1007-P1 Pond, 2004 to 2023. A Secchi depth of 150 cm is the target for the K-1007-P1 Pond.

Table 4. Chemical and physical conditions for surface water samples collected from permanent transects in the K-1007-P1 Pond, 2023. Results for temperature, conductivity, DO, pH, TSS, and nutrients are based on measurements/samples taken at a depth of approximately 10 cm

Transect cell number (distance from north shore) and date	Water depth (cm)	Temperature (°C)	Conductivity (µS/cm)	DO (mg/L)	pH	TSS (mg/L)	Secchi depth (cm)	Turbidity (FNU)	Nutrients (µg/L)[a]			
									TP	SRP	NH_4-N	NO_3-N
A1 (34 m)												
June 7	41	25.5	300.0	5.33	7.31	4.89	41	5.05	—	—	—	—
July 6	74	26.9	295.8	2.39	7.23	1.16	74	3.62	—	—	—	—
August 16	82	25.0	266.5	1.76	7.19	2.45	82	4.06	—	—	—	—
A2 (61 m)									—	—	—	—
June 7	142	25.8	313.7	6.61	7.47	5.56	135	5.57	—	—	—	—
July 6	158	27.0	—	4.93	—	2.88	—	—	—	—	—	—
August 16	164	24.9	285.7	2.31	7.15	3.65	133	3.16	—	—	—	—
A3 (82 m)												
June 7	123	25.9	327.3	6.21	7.39	3.89	123	5.02	—	—	—	—
July 6	169	27.0	306.6	4.90	7.48	1.46	169	1.09	—	—	—	—
August 16	169	25.6	293.6	5.25	7.39	4.65	141	4.65	—	—	—	—
B1 (45 m)												
June 7	168	26.1	271.3	9.31	7.91	5.25	120	1.09	—	—	—	—
July 6	206	27.1	311.7	6.20	7.60	1.16	118	0.49	—	—	—	—
August 16	217	25.0	259.6	1.01	7.43	4.02	133	1.68	—	—	—	—
B2 (85 m)									—	—	—	—
June 7	176	26.1	298.0	7.55	7.55	5.42	90	9.05	—	—	—	—
July 6	228	27.1	307.9	4.73	7.52	2.75	165	0.98	—	—	—	—
August 16	233	24.9	264.6	2.02	7.27	1.59	128	2.60	—	—	—	—
B3 (121 m)												
June 7	173	26.0	289.1	8.37	7.75	3.14	168	2.20	—	—	—	—
July 6	228	27.1	308.1	5.57	7.60	4.79	98	2.89	—	—	—	—
August 16	235	24.9	268.0	1.44	7.28	2.20	129	0.53	—	—	—	—
C1 (32 m)												
June 7	164	26.0	245.4	13.11	8.50	1.72	164	0.86	—	—	—	—
July 6	190	27.0	309.4	5.03	7.53	2.65	173	1.33	—	—	—	—
August 16	196	24.8	301.2	0.83	7.19	3.03	196	1.15	—	—	—	—

Table 4. Chemical and physical conditions for surface water samples collected from permanent transects in the K-1007-P1 Pond, 2023 (continued)

Transect cell number (distance from north shore) and date	Water depth (cm)	Temperature (°C)	Conductivity (µS/cm)	DO (mg/L)	pH	TSS (mg/L)	Secchi depth (cm)	Turbidity (FNU)	Nutrients (µg/L)[a]			
									TP	SRP	NH_4-N	NO_3-N
C2 (52 m)												
June 7	191	26.0	248.7	12.52	8.56	3.65	191	0.88	—	—	—	—
July 6	223	27.0	310.1	5.01	7.51	1.86	152	1.06	—	—	—	—
August 16	136	24.7	266.2	1.45	7.26	2.32	120	1.14	—	—	—	—
C3 (84 m)												
June 7	225	26.0	246.1	13.71	8.65	1.24	171	0.78	—	—	—	—
July 6	267	27.0	308.8	6.82	7.74	1.71	201	0.64	—	—	—	—
August 16	271	24.8	245.3	3.74	7.53	1.65	160	1.30	—	—	—	—

[a]Nutrients are analyzed in cells 1 and 2 of each transect only. Data for 2023 are still pending at the time of submission of this report.

The mean concentrations of nutrients measured in the K-1007-P1 Pond in 2007 and 2010–2022 are provided in Figure 6; data from 2023 are pending analysis at the time of submission of this report. Temporal trends since 2007 indicate that concentrations of all four nutrients have been highly variable over the years (Figure 6). In general, NH_4^+ concentrations have decreased over time. When the pH is high, the more toxic unionized ammonia (NH_3) dominates; as the pH decreases, NH_4^+ becomes increasingly dominant (Thurston, Russo, and Emerson 1979). Thus, the proportion of NH_3 has declined considerably since 2007. In 2007, about 30.7% (approximately 36.1 µg N/L) of the total NH_3 was unionized NH_3, whereas in 2022, about 8.6% (approximately 0.78 µg N/L) was unionized NH_3.

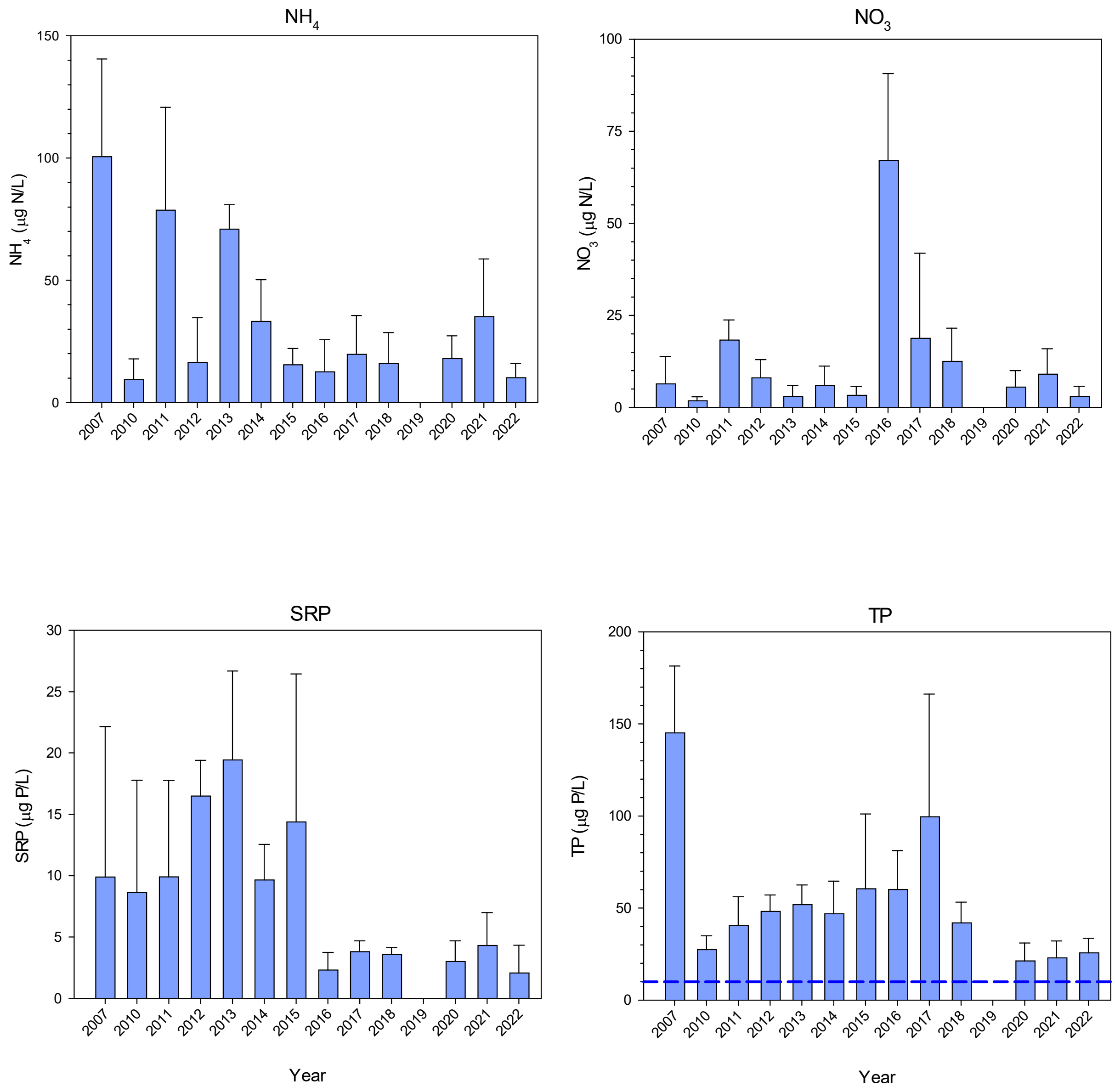

Figure 6. Mean (± standard deviation) nutrient concentrations of ammonium (NH_4^+), nitrate (NO_3^-), soluble reactive phosphorus (SRP), and total phosphorus (TP) in the K-1007-P1 Pond, 2007 to 2022. The blue dashed line shown in the graph for TP is the target for the K-1007-P1 Pond.

**Nutrient data for 2023 are still pending at the time of submission of this report.*

In 2022, mean NO_3^- concentration in the K-1007-P1 Pond was 10.2 µg N/L, well below t he EPA-recommended criterion. After a high of nearly 150 µg P/L in 2007, mean TP had consistently been <50 µg P/L most years, and by 2022, TP had decreased to a mean of 25.6 µg P/L. However, the concentration remains above the target concentration of 10 µg P/L for the K-1007-P1 Pond.

Temporal means in chlorophyll *a* concentrations were highly variable between 2010 and 2023 (Figure 7). A slight decrease in concentrations between 2013 and 2016 followed by an increase since 2016 may be attributed to changes in coverage of lotus, as described previously. As plant cover spread across the pond, the vegetation provided more shading and less sunlight penetration, causing algae to be less productive. Later, when vegetation cover retreated, algae were more productive, and chlorophyll *a* concentrations increased.

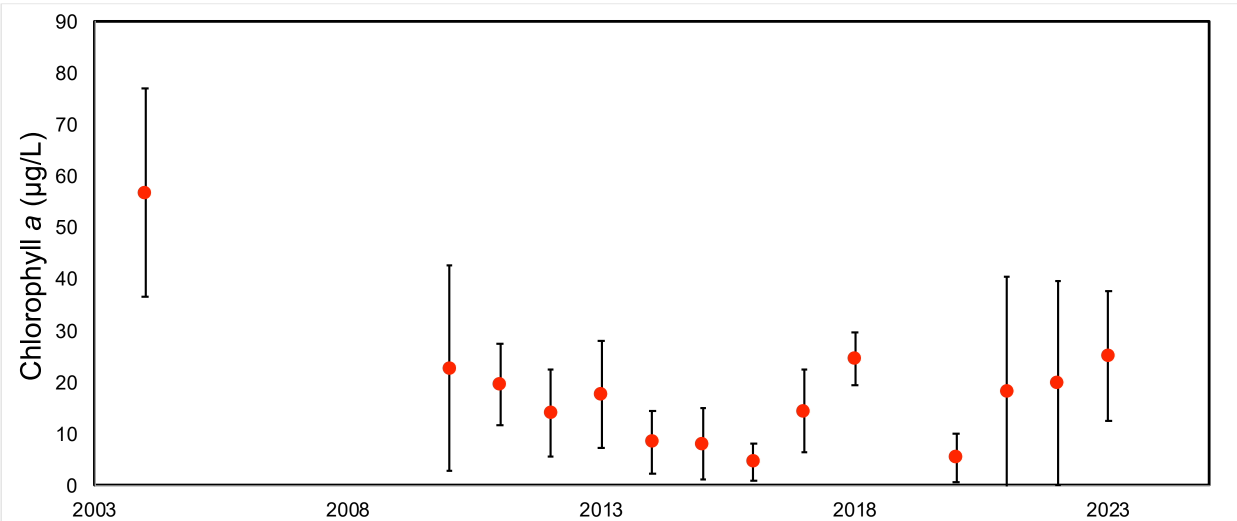

Figure 7. Mean chlorophyll *a* concentrations (± standard deviation) in the K-1007-P1 Pond, 2010 to 2023.

3.1.2 Water Quality Monitoring at the K-901-A Pond

Water quality data were collected annually in June, July, and August at the K-901-A Pond beginning in 2018. Similar to water quality monitoring in the K-1007-P1 Pond, two east–west transects were established in the K-901-A Pond with three sampling cells located about one-third of the distance across each transect (Figure 8). Within each transect, measurements of water depth, Secchi depth, and near-surface measurements (at a depth of approximately 10 cm) of temperature, conductivity and specific conductivity, dissolved oxygen (DO in mg/L and % saturation), turbidity, and pH were collected at each sampling location. The distance of each cell from the western shore was measured with a Nikon Monarch Gold Laser 1200 Rangefinder. Additionally, grab samples of near-surface water were collected at each cell of each transect for analysis of TSS, nutrients (TP, SRP, NH_4^+, and NO_3^-), and chlorophyll *a*. Because pH and chlorophyll *a* concentrations can vary daily, water quality measurements and collections were made mostly between 9:00 a.m. and noon. Finally, depth profiles for temperature and DO were measured at each cell at intervals of approximately 25–50 cm. The K-901-A Pond is shallow and normally allows for only one or two additional measurements beyond the 10 cm near-surface measurement. Details of field measurements, sample collection, and analyses are described in Section 3.1.1.

Figure 8. Map of water quality sampling locations in the K-901-A Pond.

Baseline water quality measurements from 2023 are listed in Table 5. From 2018 to 2021, DO increased steadily in the K-901-A Pond, decreased in 2022, and then in 2023, returned to values observed in 2021 (Figure 9). Over the 6-year monitoring period (2018–2023), conductivity has remained fairly stable (Figure 9). In the past, this pond remained quite turbid, although turbidity has steadily decreased as vegetation becomes established and sediment-disturbing fish are removed. Specifically, TSS has decreased considerably since 2018 (Figure 10), ranging from <1 to 7 mg/L in 2023 compared with 28 to 92 mg/L in 2018. Turbidity and TSS in the K-901-A Pond are now comparable to values measured in the K-1007-P1 Pond. pH values were generally slightly basic, which is typical for freshwater ponds in the East Tennessee region (Figure 10). Water clarity has steadily improved over the 6 years this pond has been sampled (Figure 10). Nutrient concentrations in the K-901-A Pond have typically decreased over the monitoring period; data from 2023 are pending analysis at the time of submission of this report (Figure 11). Decreases in NH_4^+, NO_3^-, and SRP (Figure 11) observed in 2018–2022 may reflect uptake by aquatic vegetation as it continues to be established, and decreases in TP (Figure 11) are likely correlated with the decreased TSS concentrations that may be associated with the removal of sediment-disturbing fish. Chlorophyll *a* concentrations were highest in 2018 and have been consistently over the next five sampling years (2019-2023) (Figure 12).

Table 5. Chemical and physical conditions for near-surface water samples collected from permanent transects in the K-901-A Pond, 2023. Results for temperature, conductivity, DO, pH, TSS, and nutrients are based on measurements and samples taken at a depth of approximately 10 cm

Transect cell number (distance from north shore) and date	Water depth (cm)	Temperature (°C)	Conductivity (µS/cm)	DO (mg/L)	pH	TSS (mg/L)	Secchi depth (cm)	Turbidity (FNU)	Nutrients[a] (µg/L)			
									TP	SRP	NH_4-N	NO_3-N
A1 (36 m)												
June 7	54	23.4	246.2	5.38	7.91	5.75	54	4.11	—	—	—	—
July 6	106	26.6	242.9	11.67	8.58	0.79	106	0.43	—	—	—	—
August 16	132	25.2	296.7	6.18	7.57	0.75	122	0.57	—	—	—	—
A2 (74 m)												
June 7	60	23.7	247.0	5.49	7.85	3.99	56	6.06	—	—	—	—
July 6	124	26.6	248.1	9.54	8.20	2.20	124	1.53	—	—	—	—
August 16	134	25.1	301.4	8.24	7.88	0.52	134	0.24	—	—	—	—
A3 (111 m)												
June 7	53	23.7	241.3	3.52	7.96	6.90	35	1.55	—	—	—	—
July 6	113	26.8	247.8	9.76	8.23	1.54	113	1.70	—	—	—	—
August 16	128	25.1	306.1	7.70	7.77	0.39	128	0.61	—	—	—	—
B1 (39 m)												
June 7	42	21.9	221.4	10.93	8.62	6.40	42	5.93	—	—	—	—
July 6	96	26.9	263.6	10.66	8.38	1.43	96	0.41	—	—	—	—
August 16	111	25.2	302.2	6.28	7.64	0.54	111	0.49	—	—	—	—
B2 (75 m)												
June 7	49	21.6	248.2	8.53	8.04	5.99	35	3.56	—	—	—	—
July 6	95	26.9	239.5	12.14	8.55	1.50	95	0.60	—	—	—	—
August 16	115	25.2	280.8	6.47	7.71	0.44	115	0.10	—	—	—	—
B3 (100 m)												
June 7	45	22.2	262.5	1.56	7.62	6.52	30	4.43	—	—	—	—
July 6	83	26.9	292.8	4.87	7.62	1.70	83	6.44	—	—	—	—
August 16	97	25.0	324.9	2.11	7.33	1.71	49	1.01	—	—	—	—

[a]Data for 2023 are still pending at the time of submission of this report.

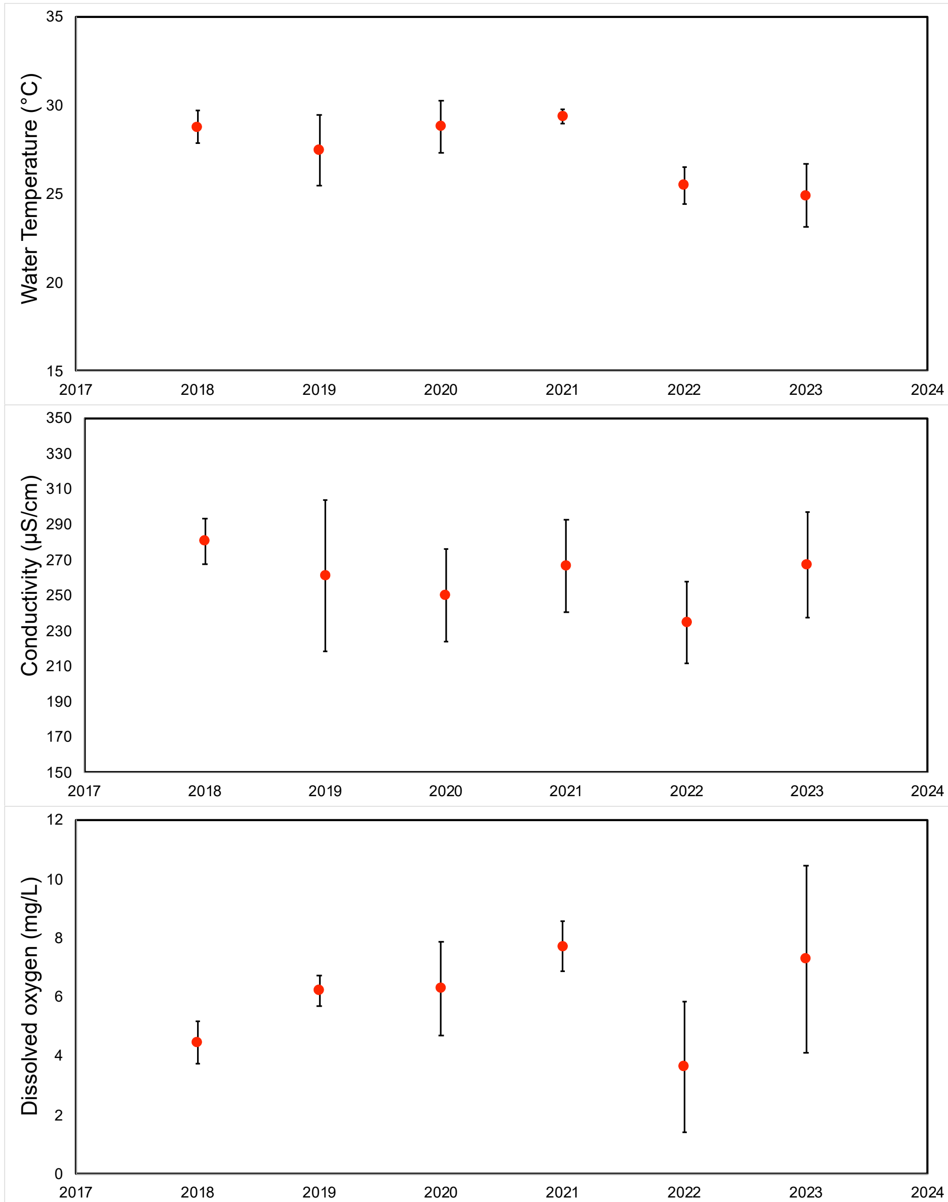

Figure 9. Mean (± standard deviation) (top) near-surface water temperature, (middle) conductivity, and (bottom) DO for the K901A Pond, 2018 to 2023.

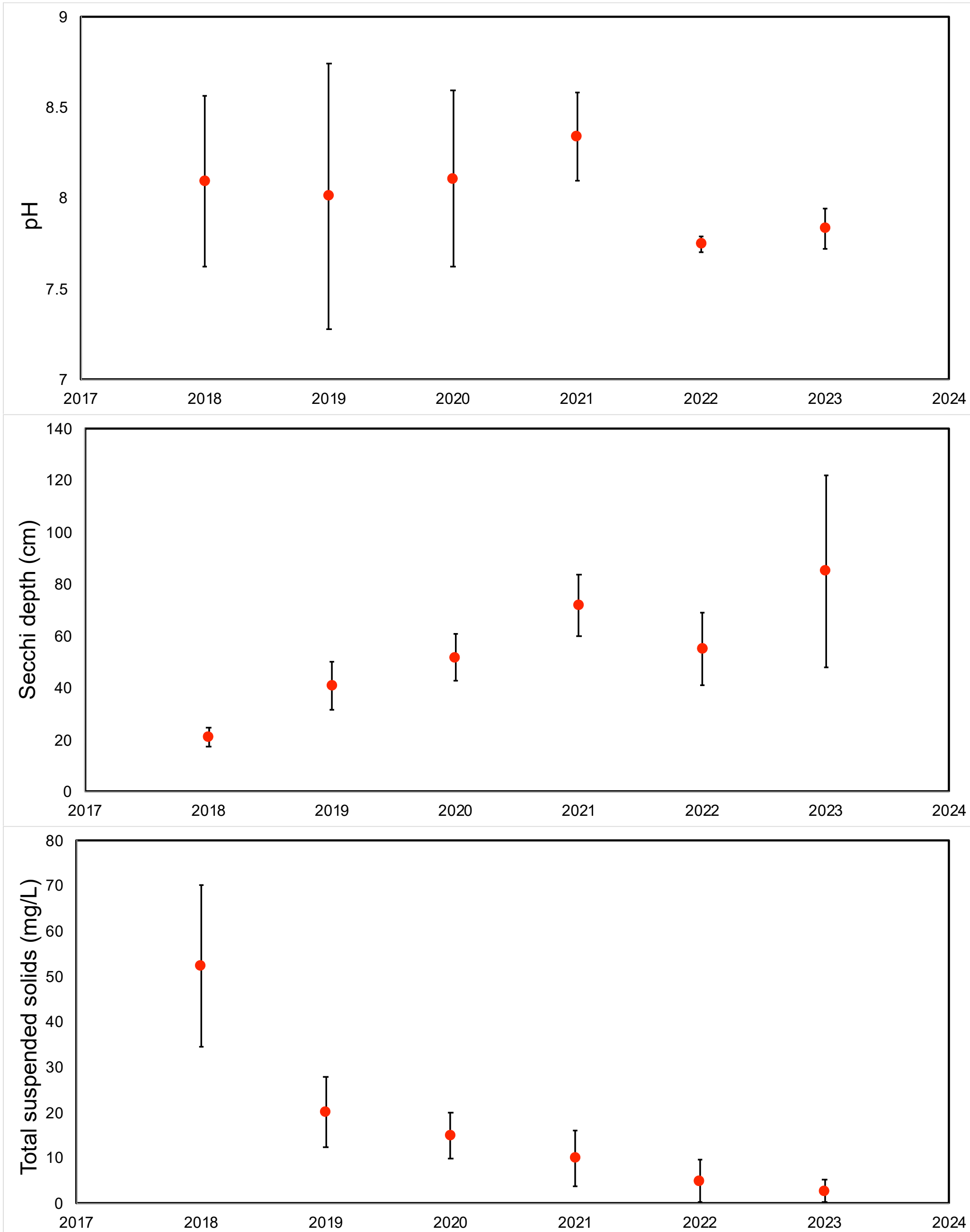

Figure 10. Mean (± standard deviation) (top) mean annual pH, (middle) Secchi depth (water clarity), and (bottom) TSS for the K-901-A Pond, 2018 to 2023.

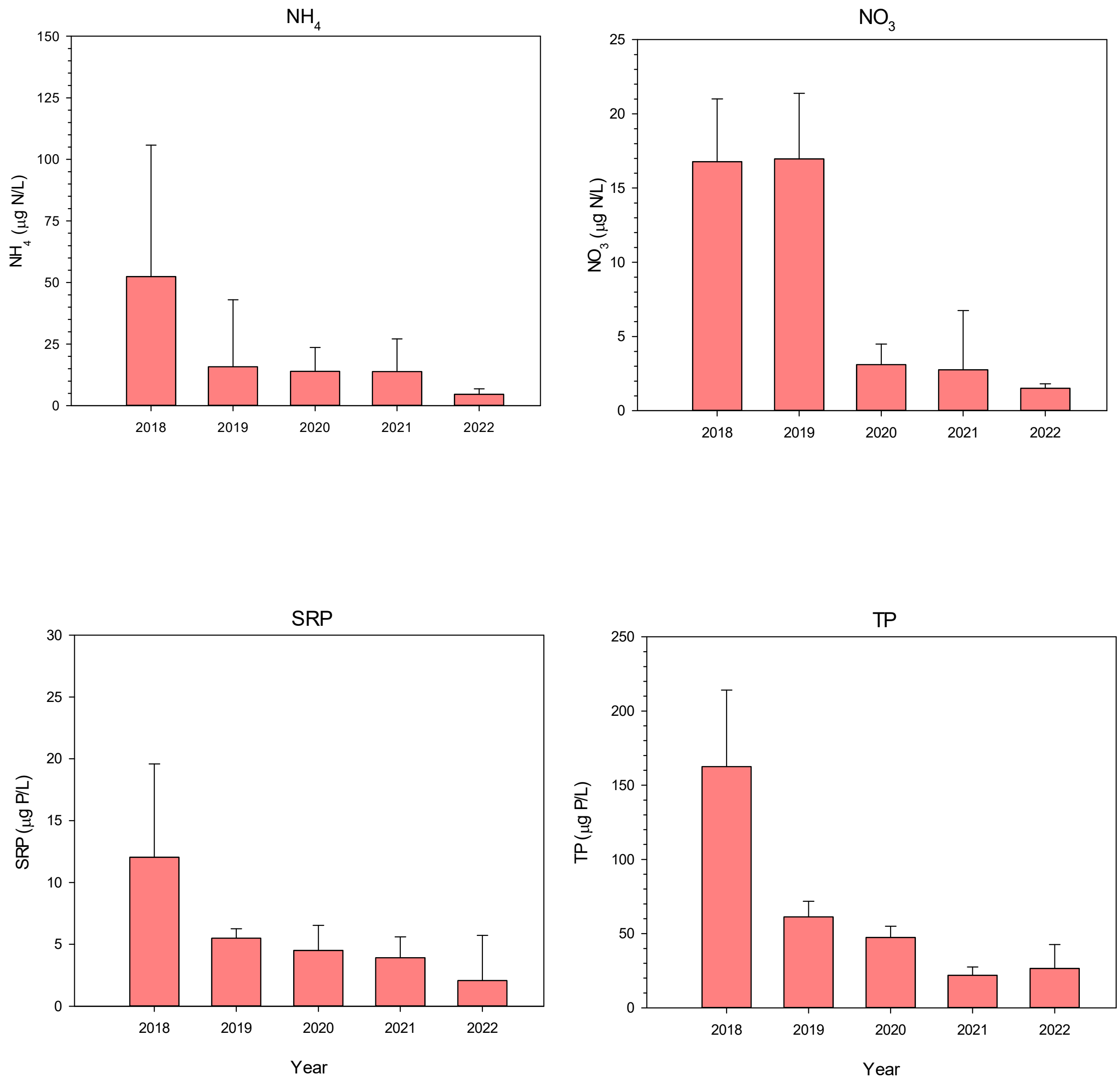

Figure 11. Mean (± standard deviation) concentrations of ammonium (NH_4^+), nitrate (NO_3), soluble reactive phosphorus (SRP), and total phosphorus (TP) in the K-901-A Pond, 2018 to 2022.

**Nutrient data for 2023 are still pending at the time of submission of this report.*

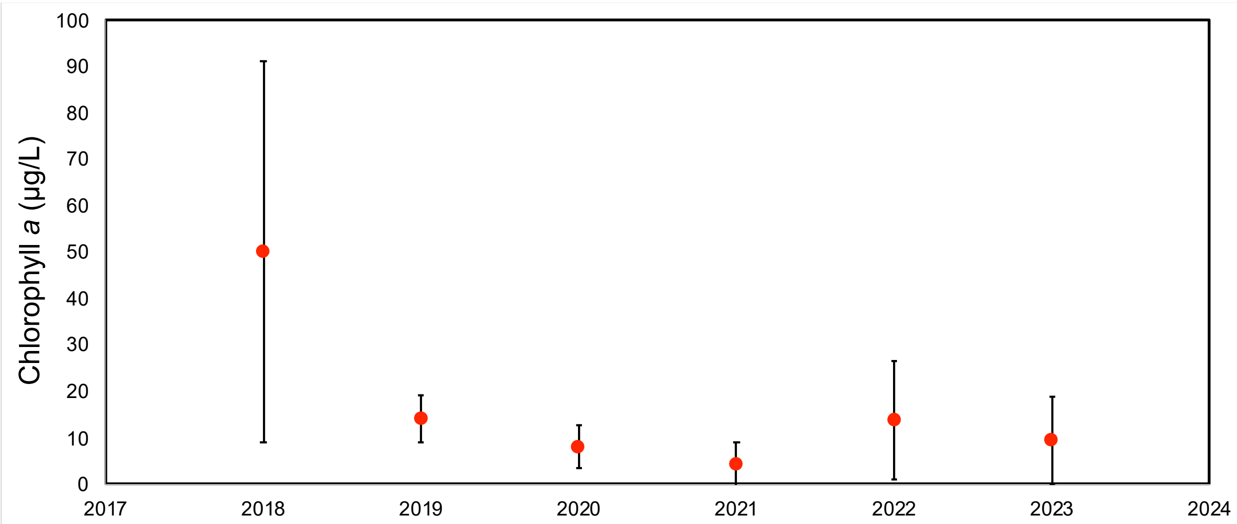

Figure 12. Mean chlorophyll *a* concentration (± standard deviation) in the K-901-A Pond, 2018 to 2023.

3.2 AQUATIC AND RIPARIAN VEGETATION

The vegetation community component of the ETTP ponds aims to establish aquatic plants in the ponds to stabilize sediments in addition to creating a riparian buffer around the perimeters of the ponds. Work toward this aim began in the K-1007-P1 Pond, where plantings were installed in all sediment-capped areas of the pond along with manipulation of the vegetation in the riparian buffer areas. Operational monitoring provided feedback on the initial plantings in FY 2009 and subsequent plantings in the following years. Performance monitoring continued at four established transects in the K-1007-P1 Pond in FY 2023.

Partially because of the success of the plantings in K-1007-P1 Pond, this program was expanded to include aquatic plant establishment in the K-901-A Pond, which began in the fall of FY 2017 and has continued through FY 2023. Plantings included rooted emergent and floating native plant species. Transects and baseline data were collected in FY 2018, and operational monitoring began in FY 2019 and has continued through FY 2023. No riparian plantings are planned at this time in the K-901-A Pond.

3.2.1 K-1007-P1 Pond Aquatic and Wetland Plants

The effectiveness of previous planting efforts was evaluated in summer surveys from 2010 to 2023 and was compared with baseline data collected in 2007 before the pond underwent modifications. Qualitative plant growth, sediment, and water measurements were collected along four transects for the duration of the monitoring. These transects were along the east and north shores where sediments were added for remediation (T1–T3), except for the fourth transect (T4), which was in an unmodified area along the north shore. Additionally, an evaluation of the survival and abundance of floating-leaf plant species using aerial photographs was conducted each year that photographs were available (September 2009 to 2022).

Along each transect, researchers evaluated the existing conditions using a 0.25 m square to subsample at 7–9 locations; the initial subsample was at the water–shore interface where aquatic and riparian plant species occur. Within each square, researchers identified plant species, estimated relative abundances, and measured water and sediment depths (i.e., the distance a probe could easily penetrate sediment). These transects were surveyed 2–3 times annually from 2010 to 2023.

Plant diversity was slightly lower in 2023 in most of the transects compared with previous years, including in the unmodified transect T4 (Figure 13). However, the plant communities continued to show a definite improvement between the pre-remediation survey (2007) and all transects (T1–T3). The water depths in 2023 were slightly higher compared to 2022 values. Sediment profiles remained stable in 2023 and were once again higher than the samples immediately following remediation activities. This increase is largely influenced by the prolific vegetative growth, especially by cattails (*Typha* sp.) and pickerelweed (*Pontederia cordata*), which have created a dense root mat in many shallow areas of the pond. These findings are consistent with project plans to stabilize sediments with extensive aquatic plant establishment. The water surface in all three of the modified transects was 50–75% covered with vegetation in 2023 (Figure 14) and demonstrates the establishment of a rich aquatic plant community within the measured transects. The plant community in the pond continues to develop and adapt to changes as they occur. Some of the increases in water level and reduced plant coverage in T1 is associated with beaver activity in the far east side of the pond, which has inundated some of the transect in slightly deeper water.

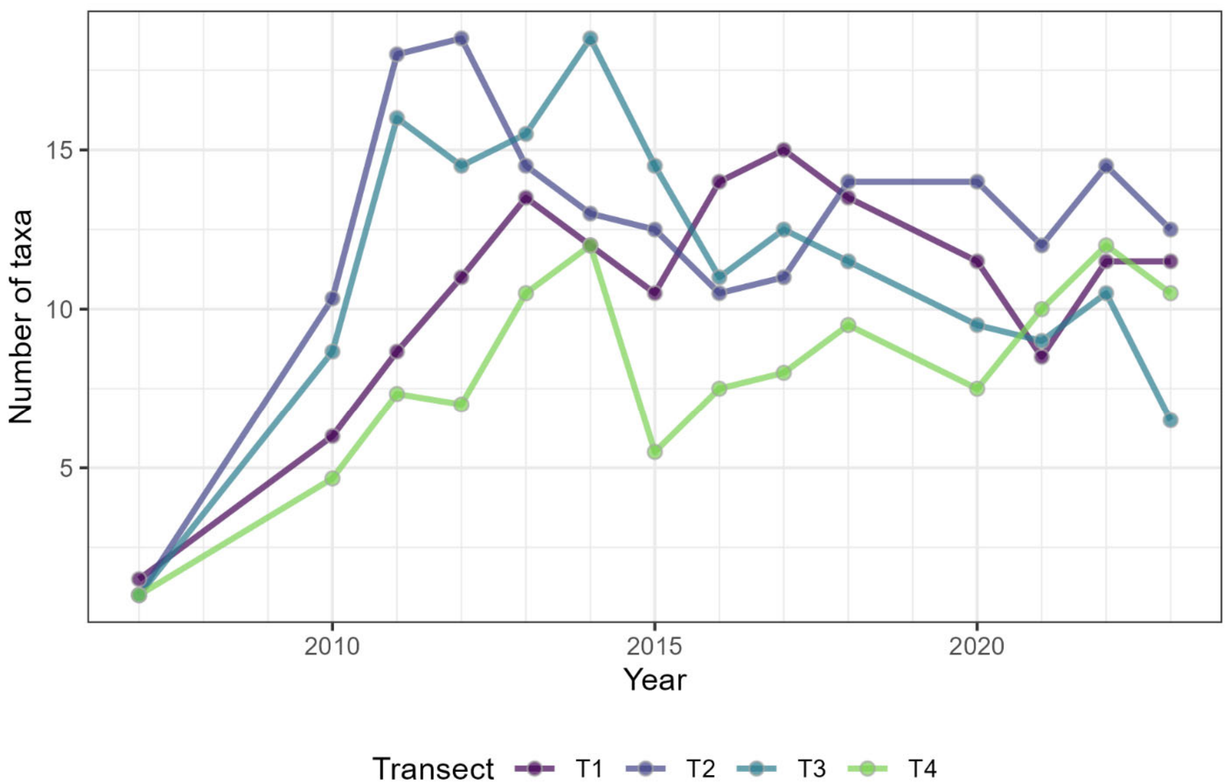

Figure 13. Mean plant taxon richness (number of taxa) measured along four transects in the K-1007-P1 Pond from 2007 to 2023.

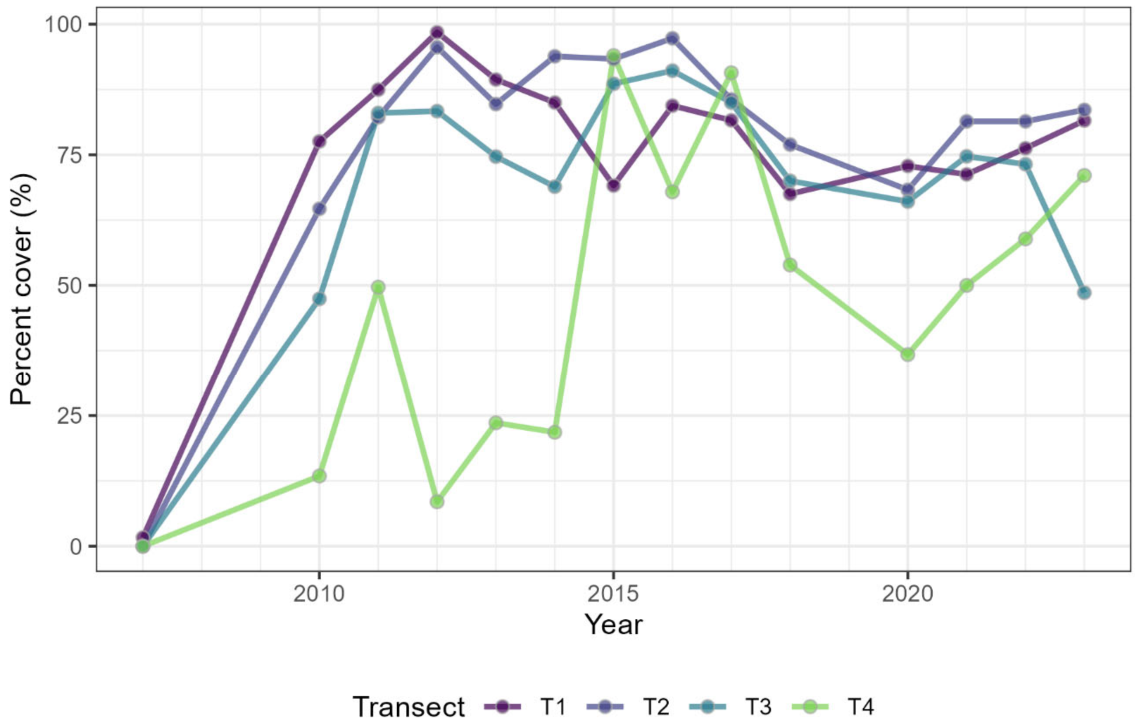

Figure 14. Mean percentage of plant cover (excluding algae) measured along four transects in the K-1007-P1 Pond from 2007 to 2023.

The carnivorous humped bladderwort (*Utricularia gibba*) continues to persist in the pond, although its presence is not as dominant as it had been in the previous few years. The humped bladderwort is relatively common in Middle and far West Tennessee but is fairly rare in East Tennessee. It is predominantly a floating plant with very little root structure and is generally found in wetland bogs or seeps. Additionally, coontail (*Ceratophyllum demersum*) has become established in the K-1007-P1 Pond in recent years and is creating very large mats throughout the medium depths of the pond. This species requires clear water because it is completely submergent except for late summer growth, which can break the water's surface. It is a highly valuable food source for waterfowl. These plants' presence in the pond indicates increasing plant and animal diversity in the pond post-remediation.

The aquatic plant community in the K-1007-P1 Pond grew substantially in the initial years after remediation. Plant diversity and plant density increased from fewer than 3 species to more than 15 species, and density values have reached nearly 100% in the modified portions of the pond at times. Sediment depths and root growth also adjusted over the 10 years of monitoring to reflect the dense plant growth and thick root systems of a shallow, heavily vegetated pond environment. Plant abundance can totally change the nature of a transect, and the appearance of most of the planted areas of the pond is now more like a wetland marsh than an open water body. American lotus continues to dominate the planted areas in waters deeper than 30–40 cm, but other emergent species, such as fragrant water lily (*Nymphaea odorata*), pickerelweed, and cattail, continue to flourish as well, especially in the shallower areas of the pond (Figure 15).

Figure 15. K-1007-P1 Pond showing (top) increased plant diversity in areas <40 cm in depth and (bottom) American lotus domination in areas >40 cm in depth.

Aerial photographs taken at the end of the summer growing season documented the increased surface area coverage by floating-leaf and emergent plants. Aerial photographs in 2009 showed only algal blooms because individual plants were too small to be noticeable. By the fall of 2011, the planted areas had considerable coverage by emergent plants, and the coverage of floating plants had extended extensively outside of the fences. The surface area covered by plants in 2011 was approximately 20% of the pond; by fall of 2014, the surface area covered by plants had increased to approximately 90% of the pond. The pond inside the fenced areas and the slough downstream of Outfall 490 also were covered almost completely by emergent and floating plants. This increase in total pond coverage has not been consistent every year since 2014 and was significantly reduced in 2016 when coverage was estimated at only approximately 50%. Since 2016, plant coverage has fluctuated in the pond each growing season, but in late summer 2020–2023 the mostly submergent species coontail reached very high densities in the middle and western edge of the pond, and estimated coverage was approximately 80%–90% again (Figure 16).

Figure 16. Aerial photographs of the K-1007-P1 pond over time. (Top left) Fenced areas of the pond after initial plantings with mostly algal blooms visible, (top right) highest emergent plant coverage observed extending over most of the pond, (bottom left) plant coverage in 2020 with emergent and submergent plant coverage over most of the pond, and (bottom right) plant coverage in 2022. Aerial photos for 2023 were taken in September and will be included in future reports.

Overall, the plant communities in the K-1007-P1 Pond have increased significantly since the remedial actions and have continued to flourish. The number of species, extent of coverage, and colonization by new species reflect improved conditions and plant growth, especially in the sediment-modified zones on the east side of the pond. Continued development of plants is expected as the plant community grows and diversifies. The only limitations to plant establishment by most species has been in the areas of the pond where the water is too deep, where soils were not added, where nutrients within the sediment may be limited, or where rocky or poor-quality substrates remain. Overall, this pond plant community has developed well and should continue to help stabilize the substrate and limit movement of PCB-contaminated sediments out of the K-1007-P1 Pond system.

3.2.2 K-901-A Pond Aquatic and Wetland Plants

Planting efforts to increase native aquatic vegetation in the K-901-A Pond began in September 2017 and have continued through FY 2023. Plantings during this time have included purchased lotus as well as lotus that were germinated, bagged, and planted following an approach developed successfully by ORNL for the K-1007-P1 Pond (Ryon et al. 2013). Other plant species were purchased from various native aquatic nurseries and planted as plugs or bare roots directly into the pond sediment.

Because the water level in the K-901-A Pond fluctuates throughout the year, much of the planting efforts in previous years has focused on species that could tolerate the greatest changes in water level or tolerate being inundated for only part of the year. This is particularly important around the pond edges and in some of the shallower portions of the pond. During the past few years, plant selection has focused on species that can grow in deeper water, such as lotus, waterlilies, and pondweed. Although these plant species can grow in deeper water, planting efforts are still concentrated in shallow areas to allow plants time to establish. These species are spreading to deeper waters of the pond (Figures 17 and 18) and are expected to continue this pattern over time in a way similar to the lilies and lotus in the K-1007-P1 Pond

Figure 17. Lotus planted in the K-901-A Pond in 2020 now going to seed in 2023.

In August 2023, 5,620 plants were purchased from a native plant nursery. In previous years, plant species selection focused on three categories: deep water species, emergent species, and shallow water species. In 2021, focus shifted heavily toward the species that have been or have the potential to be successful in deeper water. In 2021, 1,000 lotus and 1,775 waterlilies were planted in the K901A Pond. In 2022, only 25 lotus and 200 waterlilies were available because of low nursery stock; however, 3,000 spatterdock were obtained. Spatterdock plantings from previous years have shown successful survival rates and continue to spread. In 2023, the primary focus remains the selection of species that are more tolerant to deeper water levels. Although very few lotus were available to plant this year, lotus planted from previous years have sprouted seed heads and are spreading well (Figure 17).

While planting this season, multiple observations on past plantings were recorded. Vegetative cover has increased within the pond because of the spread of new plants into previously unplanted areas (Figure 18) and a continued planting effort (Figure 19). Previous plantings have been successful along the shorelines and shallow areas of the ponds. As of 2023, the lotus have established well, most notably along the southern portion of the pond. Many of the previously planted waterlilies and pondweed have spread into deeper areas as well. In particular, pondweed is prolific in the pond and accounts for a large portion of the vegetation in its deeper sections. The amount of the pondweed visible in aerial photographs can vary year to year depending on water levels and how many leaves are submerged at the time of photography. The percent cover and location of filamentous algae and muskgrass (*Chara* sp., also an algae) also varies year to year. Often algae and plants grow in the same location and can make vegetative percent cover more difficult to discern. Even if some of the plants are submerged or covered with algae at the time of photography, the plants are still rooted in the soil and contribute to soil stabilization throughout the year.

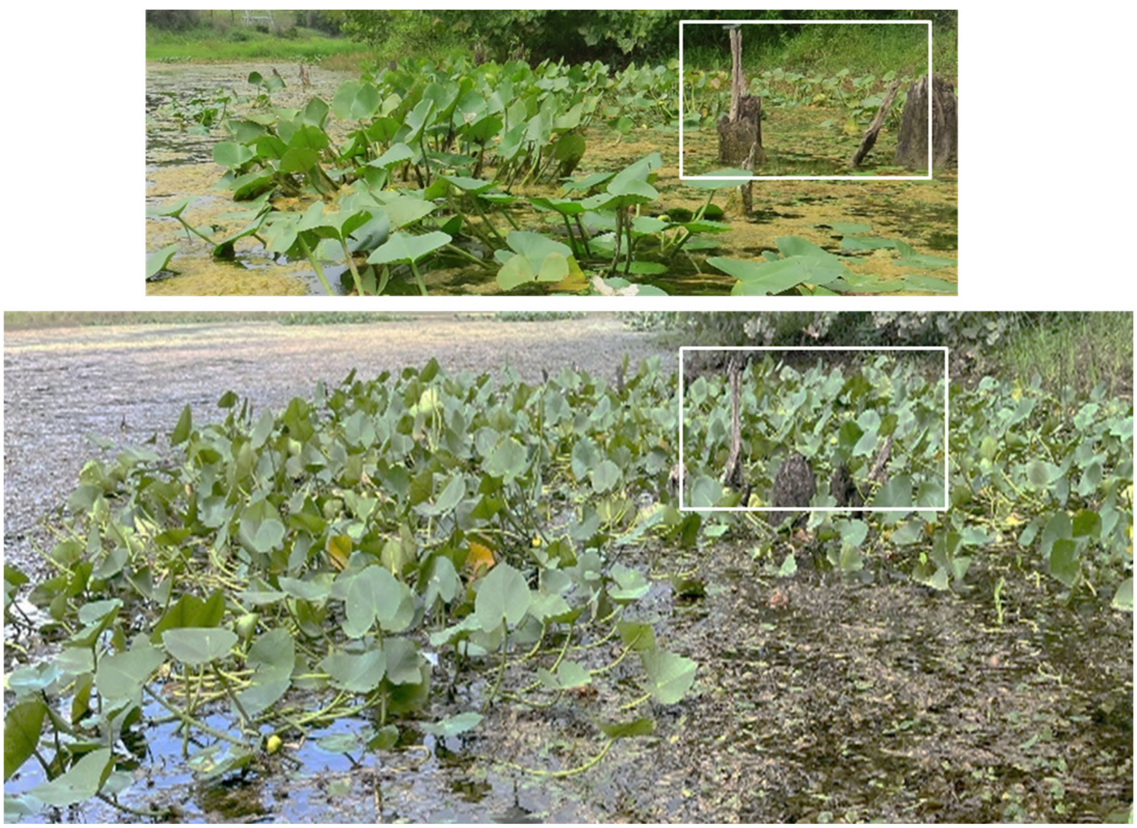

Figure 18. Spread of spatterdock between (top) 2020, one year after planting and 2023 (bottom), four years after planting. Photographs show the change in distance and density from the tree stumps shown in the white rectangles.

Figure 19. New plantings of spatterdock in K-901-A Pond.

In conjunction with the planting efforts, plant surveys were completed at the K-901-A Pond from 2018 to 2023 at three established transects. These transects are surveyed annually in the summer growing season to assess plant establishment and community within the pond. These transects were surveyed once in the summer of 2018 to establish a baseline for assessing future plant growth, and they were surveyed twice from 2019 to 2023 during the summer growing season. All three transects were somewhat limited in plant diversity and remained stable compared to 2022 values. Plant coverage increased considerably in 2021–2022 and decreased only slightly in 2023 (Figures 20 and 21). Plant diversity remained at 18 plant species observed within the three transects combined in 2023, although no single transect contained more than 10 species. Some of the species present were from the 2018 to 2022 planting efforts, and the species are expected to continue to increase as new plants become more established within the pond. Overall plant cover in 2023 was similar to 2022 values and is estimated to cover 80% of the pond. This is expected to remain consistent as plants grow and diversify with the additional plantings—and especially with the removal of herbivorous fish, such as common carp and grass carp.

Figure 20. Mean plant taxon richness (number of taxa) measured along three transects in the K-901-A Pond from 2018 to 2023.

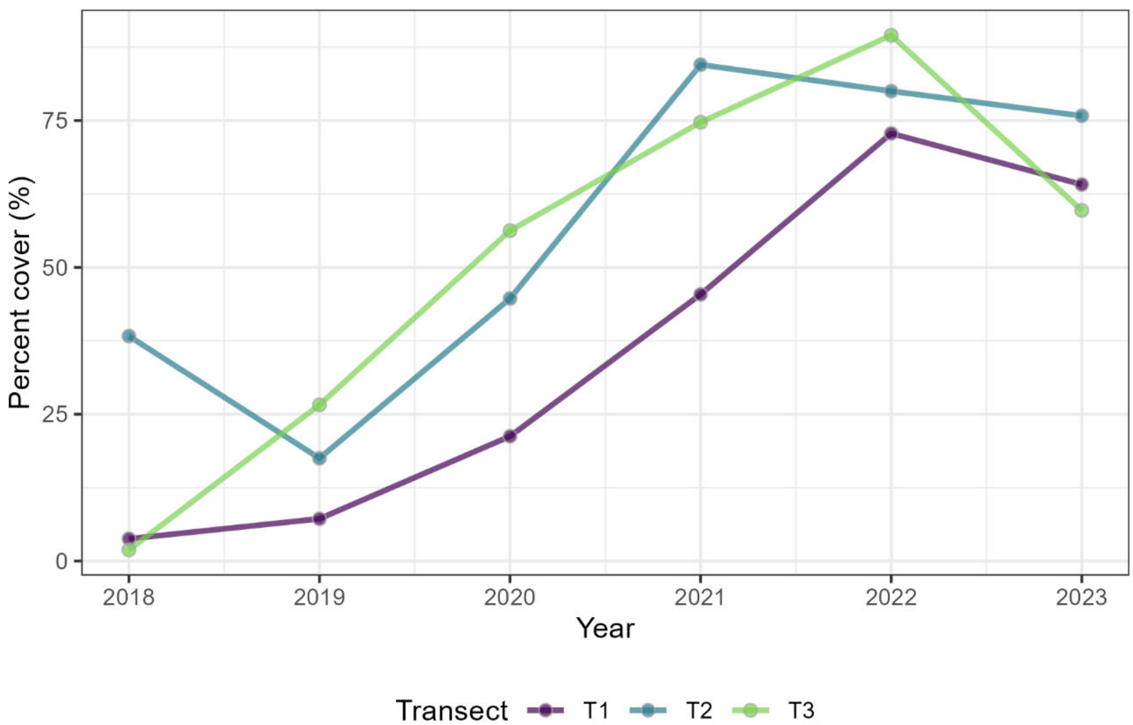

Figure 21. Mean percentage of plant cover (excluding algae) measured along three transects in the K-901-A Pond from 2018 to 2023.

3.3 FISH COMMUNITY

The K-1007-P1 Pond fish community has undergone numerous changes since remediation activities began, largely because of the following activities:

- Application of the piscicide rotenone (June 2009)
- Remediation efforts, including depth reduction of the east end of the pond by capping existing sediments with clean fill dirt (spring 2009)
- Supplemental plantings of aquatic vegetation (spring 2009 to spring 2018)
- Stocking with native fish species from area streams as well as hatchery-reared bluegill sunfish (December 2009 to March 2010 and September 2017 to September 2020)
- Emigration of fish from Poplar Creek via a damaged weir grate (May 3, 2010; Figure 22)
- Removal of detrimental fish species (May 2010 to February 2023; Figure 23)

Figure 22. High water event at the K-1007-P1 Pond outfall, similar to the May 2010 event that allowed Poplar Creek fish to bypass the damaged grate and enter the pond.

Figure 23. Boat electrofishing on ETTP ponds to remove detrimental fish species.

Fish community surveys have been conducted annually in the K-1007-P1 Pond since 2009. Before remediation efforts began, surveys were also conducted in 2004 and 2007 (Table 6). Data were collected each year by boat electrofishing in deeper waters, and shorelines were surveyed using backpack electrofishers from 2011 to 2023.

Table 6. Actual catch per minute of boat electrofishing during fish community surveys in the K-1007-P1 Pond, 2004 to 2023. Only selected years are reported.

Species	Aug 2004	May 2007	Nov 2009[a]	June 2010[b]	Feb 2022	Feb 2023
Chestnut lamprey (*Ichthyomyzon castaneus*)	—	—	—	<0.01	—	—
Spotted gar (*Lepisosteus oculatus*)	—	0.01	—	—	—	—
Gizzard shad (*Dorosoma cepedianum*)	0.07	1.30	—	0.02	0.05	0.10
Bluntnose minnow (*Pimephales notatus*)	0.20	—	—	—	—	—
Common carp (*Cyprinus carpio*)	0.02	0.03	—	0.03	0.02	—
Smallmouth buffalo (*Ictiobus bubalus*)	0.01	0.02	—	0.01	—	—
Spotted sucker (*Minytrema melanops*)	0.02	—	—	—	0.04	0.03
Black bullhead (*Ameiurus melas*)	—	—	—	—	0.01	—
Yellow bullhead (*Ameiurus natalis*)	0.08	0.01	—	0.03	0.03	0.01
Western mosquitofish (*Gambusia affinis*)	0.01	—	0.08	0.70	0.07	0.13
Green sunfish (*Lepomis cyanellus*)	0.56	0.01	0.96	2.42	0.02	—
Warmouth (*Lepomis gulosus*)	0.59	0.01	0.44	0.31	0.46	0.69
Bluegill (*Lepomis macrochirus*)	7.29	0.49	1.84	1.02	5.05	5.84
Redear sunfish (*Lepomis microlophus*)	0.02	—	—	<0.01	1.01	0.43
Hybrid sunfish (*Lepomis*)	0.02	—	—	0.01	0.03	—
Largemouth bass (*Micropterus salmoides*)	0.55	0.16	—	—	0.19	0.17
White crappie (*Pomoxis annularis*)	0.01	0.08	—	—	—	—
Black crappie (*Pomoxis nigromaculatus*)	<0.01	—	—	—	0.03	0.12
Total species caught	**14**	**10**	**4**	**10**	**12**	**9**

[a]Survey conducted after rotenone application but before fish introductions.
[b]Survey conducted after Poplar Creek fish bypassed the damaged fish barrier and entered the K-1007-P1 Pond.

3.3.1 K-1007-P1 Pond Fish Removals

Fish removal actions have also been conducted annually since 2009 (Table 7). The primary concern relative to the success of the action was related to an unexpected May 2010 flooding event that caused damage to the outfall weir grate, which allowed numerous fish from Poplar Creek to bypass the grate and gain access to the K-1007-P1 Pond. Substantial numbers of gizzard shad, threadfin shad (*Dorosoma petenense*), largemouth bass, common carp, and smallmouth buffalo (*Ictiobus bubalus*) were removed from the K-1007-P1 Pond from May 2010 to February 2023 (Table 7). These species are considered undesirable in the pond because of their role in the bioaccumulation of contaminants (food chain dynamics) and/or the resuspension of potentially contaminated sediments. Fish removals are conducted annually during the fish community study, and additional removals are conducted based on results from that survey.

Table 7. Numbers of fish removed from the K-1007-P1 Pond since rotenone application in 2009. Only selected years reported.

Species	2010	2015	2020	2023	Total across years[e]
Chestnut lamprey (*Ichthyomyzon castaneus*)	1	0	0	0	1
Spotted gar (*Lepisosteus oculatus*)	1	0	0	0	1
Gizzard shad (*Dorosoma cepedianum*)	121	504	1,150	18	7,117
Threadfin shad (*Dorosoma petenense*)	1	0	117	0	1,040
Hybrid shad (*Dorosoma* sp.)	0	0	4	0	9
Bluntnose minnow (*Pimephales notatus*)	1	0	0	0	2
Common carp (*Cyprinus carpio*)	226	3	7	0	442
Smallmouth buffalo (*Ictiobus bubalus*)	86	6	0	0	163
Spotted sucker (*Minytrema melanops*)	0	0	5	6	72
Yellow bullhead (*Ameiurus natalis*)	22	11	8	1	245
Black bullhead (*Ameiurus melas*)	2	5	3	0	69
Blue catfish (*Ictalurus furcatus*)	9	0	0	0	9
Channel catfish (*Ictalurus punctatus*)	2	0	0	0	2
Western mosquitofish (*Gambusia affinis*)	18	0	0	0	19
Green sunfish[a] (*Lepomis cyanellus*)	826	0	0	0	1,572
Warmouth[a] (*Lepomis gulosus*)	149	0	0	0	210

Table 7. Numbers of fish removed from the K-1007-P1 Pond since rotenone application in 2009 (continued)

Species	2010	2015	2020	2023	Total across years
Bluegill (*Lepomis macrochirus*)	166[b]	88[c]	86[c]	80[c]	1,413
Redear sunfish (*Lepomis microlophus*)	1	0	0	0	8
Largemouth bass (*Micropterus salmoides*)	1	127	36	30	1,547
Black crappie (*Pomoxis nigromaculatus*)	0	0	19	21	243
Total fish removed	**1,633**	**744**	**1,435**	**156**	**14,184**

[a]Removed because of competition with bluegill.
[b]Eighty-seven fish were collected for PCB analysis; any remaining fish were incidental mortalities.
[c]Eighty fish were collected for PCB analysis; any remaining fish were incidental mortalities.
[d]All fish collected in 2009 presumably survived the rotenone application and were removed because of potential PCB contamination.
[e]Total fish removed from all years since 2009, not just those reflected on table.

The largemouth bass is a species of interest in the K-1007-P1 Pond because it occupies a high trophic level (which usually correlates with high bioaccumulation potential), is popular with anglers as a sport fish, and has potential for population growth in suitable habitat. These fish have been found in both K-1007-P1 and -P3 Ponds since the rotenone application, and multiple age classes have been observed. Largemouth bass become reproductively mature at 2 or 3 years of age, depending on when they were spawned. Therefore, any removal efforts that capture these individuals should be effective at reducing the dominance of this species from within the ponds.

Other important fish removed from the K-1007-P1 Pond since the weir breach in May 2010 include >7,000 gizzard shad, >400 common carp, and >150 smallmouth buffalo (Table 7). Although carp and smallmouth buffalo were fully gravid when first discovered in the K-1007-P1 Pond in May 2010, successful reproduction by these species in the K-1007-P1 Pond has not been documented thus far. This is not the case for the black crappie (*Pomoxis nigromaculatus*), which appear to have successfully spawned in the K-1007-P1 Pond based on the number of individuals collected every year since 2017.

3.3.2 K-1007-P1 Pond Fish Community Results

K-1007-P1 Pond fish community surveys conducted in February 2023 revealed the presence of 9 species of fish (Table 6). The fish diversity in the K-1007-P1 Pond since the weir breach is slightly lower than the diversity found before remediation efforts (Table 6). However, the abundance of sunfish species is notably higher, especially bluegill (Figure 24). Their presence in combination with the abundance of other sunfish species present (redear sunfish [*Lepomis microlophus*], warmouth [*Lepomis gulosus*], and green sunfish [*Lepomis cyanellus*]) has remained very high compared with pre-remediation values. This presence is consistent with the population goals of the remediation actions.

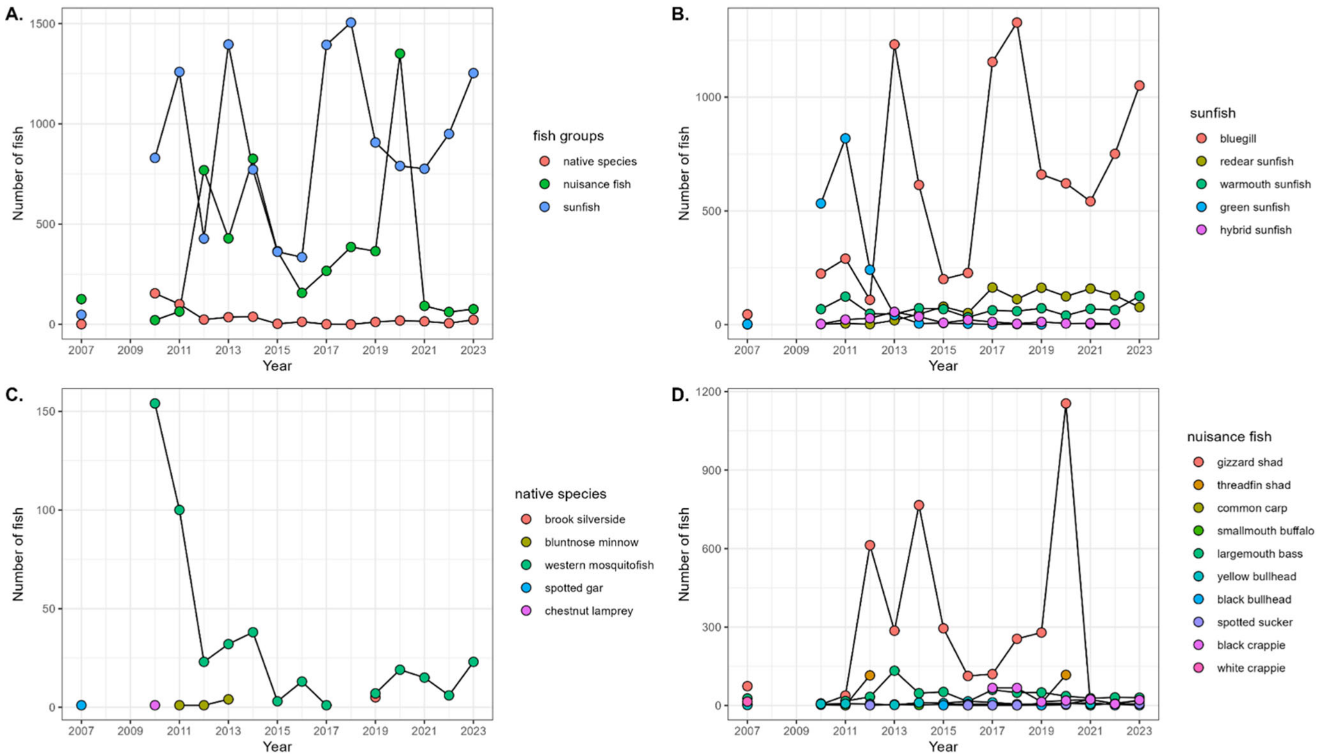

Figure 24. Comparison of the K-1007-P1 Pond fish community since pre-remediation efforts (2007 to 2023).

Whereas white crappie (*Pomoxis annularis*) appear to have been removed successfully from the K-1007-P1 Pond since it was treated with rotenone (Table 6), an increasing number of black crappie have been observed in the pond since 2016. These fish are suspected to have been artificially introduced because two large adult fish were observed in 2016, followed by observations of 78 juvenile fish in 2017 and multiple year classes of black crappie in the following years. Threadfin shad (*Dorosoma petenense*), which were fairly abundant in the pond in 2012 and then were not observed again for several years, have been observed multiple times since 2012 but never in great numbers. These fish, which are very mobile as small juveniles and during high-water events, likely find access to the pond during such high-water events. This species is prone to large die-offs during winter months, which may explain their inconsistent presence in the pond.

Gizzard shad were almost absent in 2021–2023 sampling (Figure 24) but remain present in the pond as evidenced by a population explosion in 2020. Gizzard shad are a species with very high fecundity and can experience large population explosions in localized environments. Gizzard shad prefer open pelagic systems, where they feed predominantly on phytoplankton and zooplankton. In systems with little aquatic vegetation, such as shallow reservoir embayments, they can disturb the substrate by their feeding activities (Etnier and Starnes 1993). However, because the aquatic vegetation in the K-1007-P1 Pond continues to dominate most of the open shallow areas during the growing season, the shad population does not likely affect the resuspension of sediments. Moreover, the dominance of aquatic vegetation such as coontail in the medium depths of the pond limits the available habitat of this species, thus further reducing their abundances.

In 2023, no common carp or smallmouth buffalo were collected (Table 7). Carp and buffalo that have been collected have always been very large, indicating that they are old fish. Both species can live up to 20 years. They are highly mobile and can be difficult to capture using traditional electrofishing equipment, which could explain their persistence in the pond over the years since the weir breach.

Fortunately, there is no evidence of successful carp or buffalo reproduction in the K-1007-P1 Pond, and the decreasing numbers of individuals captured is a positive sign that they are likely a remnant population from the 2010 weir breach.

The 2023 K-1007-P1 Pond fish community sampling reaffirmed several apparent benefits of the remediation efforts, including the following:

- Sunfish are successfully reproducing, and recruitment is high with sustained populations of three different species.
- The preferred sunfish species appears to be maintaining healthy densities (approximately 93% of population) in the pond.
- Largemouth bass densities continue to remain lower post-remediation and do not seem to impede bluegill reproduction and recruitment.
- Common carp and smallmouth buffalo do not appear to be reproducing successfully.
- The overall fish population appears to be reaching a more balanced state with a higher diversity of native fish since remediation began.

The various remediation efforts at the K-1007-P1 Pond have had dramatic effects on the fish community, facilitating its shift from a shad-, bluegill-, and crappie-dominated system in 2007 to a sunfish-dominated system in 2021–2023. The creation of vast shallow areas and the introduction of a variety of aquatic plants created much-needed refuge areas for many species of fish in the K-1007-P1 Pond. These refuge areas make eradicating certain undesirable species, such as largemouth bass, difficult. However, the refuge areas limit gizzard shad and common carp densities and their disturbance potential. Fortunately, with the exception of common carp, all the fish currently known to be present in the pond are native to the region and are expected to occur in similar habitats throughout East Tennessee waterways.

3.3.3 K-901-A Pond Fish Community Results

In addition to the K-1007-P1 Pond fish community, the fish community in the K-901-A Pond was assessed in 2023 (Table 8). This work followed the same approach as that for the K-1007-P1 Pond, including fish community assessment and nuisance fish removal.

Table 8. Actual catch per minute of electrofishing during fish community surveys in the K-901-A Pond, 2023

Species	January 2023	Total number of fish collected
Spotted gar (*Lepisosteus oculatus*)	0.12	11
Gizzard shad (*Dorosoma cepedianum*)	0.22	20
Common carp (*Cyprinus carpio*)	0.01	1
Golden shiner (*Notemigonus crysoleucas*)	0.01	1
Spotted sucker (*Minytrema melanops*)	0.17	15
Green sunfish (*Lepomis cyanellus*)	0.02	2
Warmouth (*Lepomis gulosus*)	0.16	14
Bluegill (*Lepomis macrochirus*)	2.40	216
Redear sunfish (*Lepomis microlophus*)	0.78	70
Hybrid sunfish (*Lepomis*)	0.03	3
Largemouth bass (*Micropterus salmoides*)	0.19	17
White crappie (*Pomoxis annularis*)	0.13	12
Black crappie (*Pomoxis nigromaculatus*)	0.08	7
Yellow perch (*Perca flavescens*)	0.02	2
Total		**387**

The fish community was surveyed in January 2023 using a boat electrofisher. The survey revealed 11 species of fish to be present in the pond. Bluegill were by far the most dominant fish found in the pond, followed by redear sunfish. The planting efforts that began in earnest in the summer of 2018 are establishing and beginning to cover very large areas of the pond. This coverage is expected to create a more sheltered pond habitat that is less suitable to open-water fish such as gizzard shad and more appropriate for sunfish while also stabilizing pond sediments. To facilitate this shift in population, multiple fish removal efforts were made from 2018 to 2023 to reduce the population of undesirable fish species, especially gizzard shad, common carp, and largemouth bass (Table 9). These efforts appear to have had a significant effect on certain species, such as common carp, which were much less abundant in the 2021–2023 surveys. Their removal is likely one of the major factors driving the success of the plant establishment and the decreased turbidity of the pond. In addition, no gizzard shad were observed in the pond in 2023. This is a major shift from populations seen in the pond before the aquatic vegetation had begun to cover most of the ponds open waters.

Table 9. Numbers of nuisance fish removed from the K-901-A Pond, 2023.

Species	2023
Common carp (*Cyprinus carpio*)	1
Spotted sucker (*Minytrema melanops*)	8
Largemouth bass (*Micropterus salmoides*)	25
Black crappie (*Pycnonotus nigromaculatus*)	2
Total	**36**

3.4 WILDLIFE

3.4.1 Nuisance Wildlife Control

Nuisance wildlife control actions are ongoing at ETTP, including in and around the K-1007-P1 Pond, since before pond remediation activities began in 2009. Many of these actions were undertaken to minimize potential wildlife effects on newly planted vegetation at the K-1007-P1 Pond. Nuisance wildlife control actions were conducted by ORNL, the Tennessee Wildlife Resources Agency, and the Wildlife Services branch of the US Department of Agriculture's Animal and Plant Health Inspection Service. Routine surveys of the K-1007-P1 Pond and its vicinity have been conducted to look for the following signs of nuisance wildlife activity:

- Active beaver or muskrat slides
- Fresh beaver cuttings
- Beaver lodges or bank dens
- Muskrat houses or bank dens
- Canada goose presence and nesting
- General signs of vegetation damage

Standard beaver and muskrat control methods, including trapping and removal of beaver dam materials, were used at the site until 2019. Since 2019, nuisance wildlife activity at the site has subsided. Nonetheless, ETTP ponds are near a larger consistent source of beaver and muskrat (e.g., Poplar Creek), and those off-site populations cannot be controlled. Accordingly, passive beaver management devices are recommended. Exclusion devices would be especially effective to reduce debris buildup at the K-1007-P1 Pond weir.

3.4.2 Wildlife Monitoring Results

Wildlife surveys have been conducted with varying frequency in and around the K-1007-P1 Pond since November 2009. Birds and wildlife using the K-1007-P1 Pond are recorded through direct observations or by positive identifications of their signs (e.g., tracks, droppings) or sounds (e.g., calls, songs).

Pond perimeter walk-through surveys were conducted to record any bird, mammal, reptile, or amphibian activity on the pond or in the adjacent riparian zone. These included evening surveys to record anuran (frog and toad) calls and bat foraging activity. Minnow traps and hoop nets were also set during the study to assist further in determining reptile and amphibian presence.

Waterfowl

Increased waterfowl diversity was an expected result of mitigation actions undertaken at the K-1007-P1 Pond. Specifically, transformation from a typical suburban pond setting to a more natural habitat was expected to result in fewer Canada geese (*Branta canadensis*) and increased numbers of other waterfowl. Based on the known seasonal occurrence of waterfowl species in East Tennessee, the main changes were expected during winter months, when the region supports waterfowl populations that migrate from other areas in North America.

Management actions to discourage Canada geese from using the K-1007-P1 Pond continue to be effective (Figure 25). Likewise, observations of more favorable waterfowl, such as ring-necked duck (*Aythya collaris*), gadwall (*Anas strepera*), and mallard (*Anas platyrhynchos*), have continued to increase since 2009 (Figure 26). Although these numbers may seem low in general, most ducks are present in East Tennessee only in winter, and the data are presented as mean numbers of observations throughout each year.

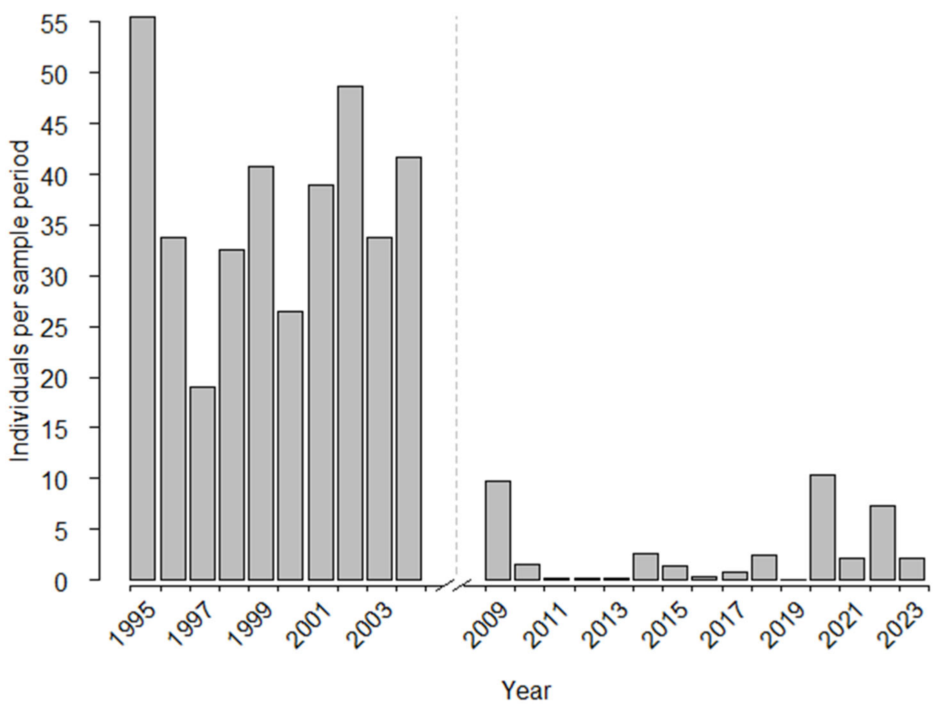

Figure 25. Mean numbers of Canada geese observed per survey at the K1007P1 Pond before (1995 to 2004) and after (2009 to 2023) remedial actions. All observations are based on calendar years except 2009, which contains no data from January through April. The number of surveys conducted each year is as follows: 1995 to 1997, 1999, and 2013 (*n* = 24); 1998 and 2015 (*n* = 22); 2000 (*n* = 17); 2001 (*n* = 18); 2002, 2004, 2018, and 2021 (*n* = 11); 2003 (*n* = 12); 2005 to 2008 (no formal surveys conducted); 2009 (*n* = 30); 2010 (*n* = 49); 2011 (*n* = 44); 2012 (*n* = 50); 2014 (*n* = 14); 2016 (*n* = 9); 2017 (*n* = 12); 2018 (*n* = 11); 2019 (*n* = 2); 2020 (*n* = 9); 2021 (*n* = 11); and 2022 (*n* = 9); and 2023 (*n* = 11).

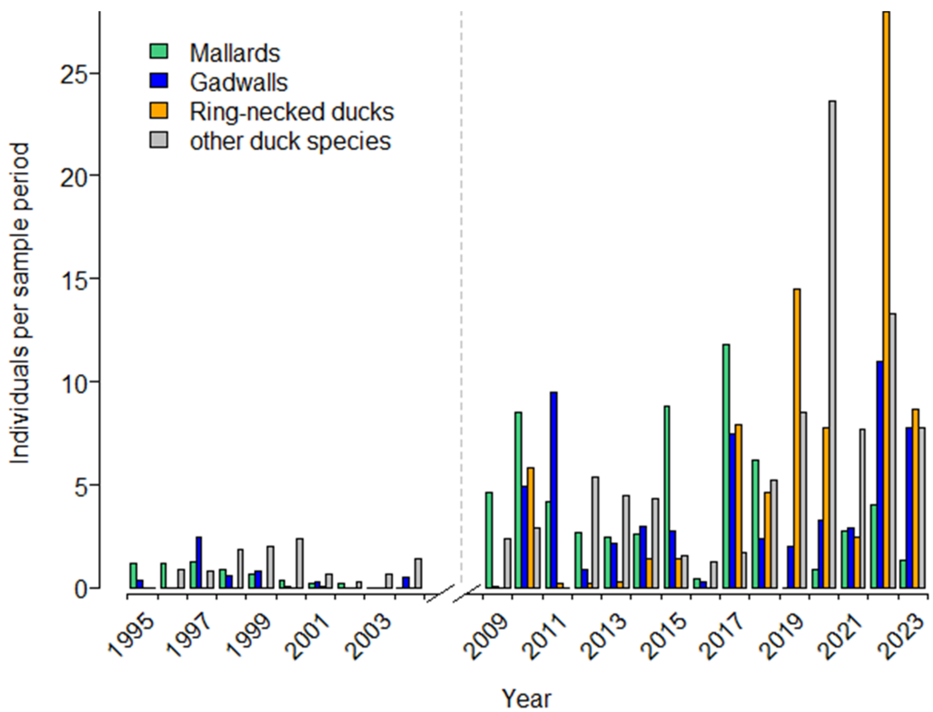

Figure 26. Mean numbers of ducks observed per survey at the K-1007-P1 Pond before (1995 to 2004) and after (2009 to 2023) remedial actions. All observations are based on calendar years except 2009, which contains no data from January through April. The number of surveys conducted each year is as follows: 1995 to 1997, 1999, and 2013 (*n* = 24); 1998 and 2015 (*n* = 22); 2000 (*n* = 17); 2001 (*n* = 18); 2002, 2004, 2018, and 2021 (*n* = 11); 2003 (*n* = 12); 2005 to 2008 (no formal surveys conducted); 2009 (*n* = 30); 2010 (*n* = 49); 2011 (*n* = 44); 2012 (*n* = 50); 2014 (*n* = 14); 2016 (*n* = 9); 2017 (*n* = 12); 2018 and 2023 (*n* = 11); 2019 (*n* = 2); and 2020 and 2022 (*n* = 9) .

Numerous other species of waterfowl have been observed at the K-1007-P1 Pond since 2009. These include snow goose (*Chen caerulescens*), blue-winged teal (*Anas discors*), green-winged teal (*Anas crecca*), northern shoveler (*Anas clypeata*), redhead (*Aythya americana*), lesser scaup (*Aythya affinis*), bufflehead (*Bucephela albeola*), ruddy duck (*Oxyura jamaicensis*), and red-breasted merganser (*Mergus serrator*).

Other waterbirds

A number of bird species other than ducks and geese have strong associations with water, and many of these may be considered water-body obligates. Most of these species are listed in Table 10, which lists representative species of nine different families. Other species occurring at the K-1007-P1 Pond with strong associations to aquatic environments are not included in this table, such as northern waterthrush (*Parkesia noveboracensis*), prothonotary warbler (*Protonotaria citrea*), and yellow warbler (*Setophaga petechia*). As with waterfowl, the presence of these species at the K-1007-P1 Pond serves as another indicator of the overall success of remediation activities and the goal to return the K-1007-P1 Pond (and its vicinity) to a more natural habitat than what existed before 2009. The K-1007-P1 pond has become a birding hotspot over the years and is a popular nature viewing area known as Heritage Center Greenway on ebird.org (https://ebird.org/hotspot/L2104673). As a result, bird enthusiasts visit this area often and have documented rare species such as Greater scaup (*Aythya marila*) and redhead (*Aythya americana*) in 2022, and the least bittern (*Ixobrychus exilis*), an uncommon migrant and summer resident in Tennessee, was also recorded the same year.

The numbers of observations of these water birds at the K-1007-P1 Pond are listed in Table 10 for each year from January 2010 through August 2023. Presenting the data in this way makes for good abundance comparisons in a relative sense, but it can be easily misunderstood because total numbers of observations, rather than total numbers of individuals, are represented. The 63 observations of bald eagles (*Haliaeetus leucocephalus*), for example, likely represent no more than approximately 6 individuals being observed repeatedly. Caution should also be exercised when viewing this table because the number of surveys conducted each year varied widely.

Table 10. Total numbers of observations of water birds other than ducks and geese using the K-1007-P1 Pond in CY 2010 to CY 2015 and FY 2016 to FY 2023

Common name	Scientific name	2010 n = 49	2011 n = 44	2012 n = 50	2013 n = 24	2014 n = 14	2015 n = 17	2016 n = 11	2017 n = 12	2018 n = 11	2019 n = 2	2020 n = 9	2021 n = 11	2022 n = 9	2023 n=11
Pied-billed grebe	*Podilymbus podiceps*	32	42	52	19	4	3	5	11		2	—	3	9	9
Horned grebe	*Podiceps auritus*	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Double-crested cormorant	*Phalacrocorax auritus*	14	19	7	6	21	20	14	17	4	—	40	7	—	—
Least bittern	*Ixobrychus exilis*	—	—	1	3	—	—	—	—	—	—	—	—	—	—
Great blue heron	*Ardea herodias*	43	47	70	34	21	16	11	24	16	6	19	13	12	8
Great egret	*Ardea alba*	2	11	4	1	1	1	—	—	—	—	6	—	—	—
Little blue heron	*Egretta caerulea*	3	—	—	—	—	—	—	—	—	—	—	—	—	—
Green heron	*Butorides virescens*	41	27	33	9	11	21	4	1	2	—	5	3	8	5
Black-crowned night heron	*Nycticorax nycticorax*	3	1	2	3	4	1	1	—	—	—	1	—	1	1
Osprey	*Pandion haliaetus*	32	33	46	24	29	22	13	21	5	—	9	17	19	20
Bald eagle	*Haliaeetus leucocephalus*	—	15	30	12	5	1	—	1	1	—	—	—	—	—
Sora	*Porzana carolina*	—	—	2	5	2	1	10	1	—	—	—	—	—	—
American coot	*Fulica americana*	8	36	39	44	298	356	256	41	62	16	39	9	15	5
Common moorhen	*Gallinula chloropus*	1	—	1	—	—	—	—	—	—	—	—	—	—	—
Killdeer	*Charadrius vociferus*	32	4	29	9	13	11	17	16	5	9	19	19	20	32
Spotted sandpiper	*Actitis macularius*	—	1	3	4	—	1	—	—	—	—	—	—	—	—
Solitary sandpiper	*Tringa solitaria*	31	3	1	13	—	3	—	—	—	—	—	—	—	—
Lesser yellowlegs	*Tringa flavipes*	—	—	—	3	—	—	—	—	—	—	—	—	—	—
Wilson's snipe	*Gallinago delicata*	1	4	—	7	3	1	—	1	—	—	—	—	1	—
American woodcock	*Scolopax minor*	1	—	1	—	—	—	—	—	—	—	—	—	—	—
Ring-billed gull	*Larus delawarensis*	—	3	10	36	2	5	2	20	—	1	—	—	—	—
Belted kingfisher	*Megaceryle alcyon*	50	41	25	12	10	3	5	6	9	1	12	5	9	11
Annual totals		294	287	357	244	424	496	338	158	104	35	150	76	85	91

One species in Table 10, the least bittern, has never been observed anywhere else on the ORR and was not known to occur in the area before July 2012 (Roy et al. 2014). Also of particular note are observations of the common gallinule (*Gallinula galeata*) and sora (*Porzana carolina*), which, along with the least bittern, are species that have undoubtedly benefited from the abundant aquatic vegetation and marsh-like habitat created by remedial actions. The least bittern and common gallinule are listed by the State of

Tennessee as in need of management. The sora is seen mainly during migration, but it is a rare breeder in Tennessee (Tennessee's Watchable Wildlife 2011–2013).

The little blue heron (*Egretta caerulea*) is another noteworthy species in Table 10. Two immature little blue herons (three observations of two individuals) were observed at the K-1007-P1 Pond in late July 2010. The little blue heron is an uncommon to fairly common late summer visitor and rare nesting bird in Tennessee, mainly occurring in the western part of the state (Nicholson 1997). This species is rarely seen on the ORR and is deemed in need of management in Tennessee.

A wood stork (*Mycteria americana*) made a brief appearance at the Heritage Center Greenway Powerhouse Trail (HCGPT), which is approximately 1 km southwest of the K-1007-P1 Pond, on August 13, 2016. This species is extremely rare in East Tennessee and is not known to have occurred previously on the ORR (Roy et al. 2014). The stork at HCGPT was well documented with quality photographs but is not listed in Table 11 because it was not sighted at the K-1007-P1 Pond.

A purple gallinule (*Porphyrio martinicus*) was photographed with a trail camera at HCGPT on May 11, 2017. Like the wood stork, this species is not listed in Table 11 because it occurred at the nearby HCGPT rather than at the K-1007-P1 Pond. This purple gallinule record is a first not only for the ORR but also for Roane County (Roy et al. 2017).

Terrestrial birds

Terrestrial bird populations that use developing riparian zones along the K-1007-P1 Pond perimeter were surveyed routinely to determine any changes in species diversity and density. Robust riparian zones with diverse structures provide excellent cover and foraging habitat for wintering bird populations. Riparian zone habitat quality adjacent to the K-1007-P1 Pond has improved continually since remedial actions were initiated in 2009. A significant shrub buffer developed along this perimeter and was augmented by supplemental planting with native herbaceous species. The quality of the habitat was bolstered by the increasing development of adjacent switchgrass fields. The planting of native warm season grasses, wildflowers, and forbs in other fields near the K-1007-P1 Pond has further increased habitat diversity in the area. Prescribed burns of the switchgrass fields in February 2014 and March 2016 helped to maintain and improve these early succession habitats.

Continued improvement in habitat quality and structure along riparian zones is evidenced by recent changes in bird populations. Specifically, the number of wintering bird species recorded using riparian zones around the K-1007-P1 Pond increased significantly during the winters of 2009 to 2010 ($n = 7$), 2010 to 2011 ($n = 14$), 2011 to 2012 ($n = 23$), and 2012 to 2013 ($n = 28$). The swamp sparrow (*Melospiza georgiana*), a bird of freshwater marshes and swamps, was notably absent in the winter of 2009 to 2010, but it has been present every winter since then. Ten sparrow species have been recorded at the K-1007-P1 Pond since 2009, including four just since 2014: vesper sparrow (*Pooecetes gramineus*), fox sparrow (*Passerella iliaca*), American tree sparrow (*Spizella arborea*), and Lincoln's sparrow (*Melospiza lincolnii*).

Table 11 summarizes the numbers of select breeding bird species observed per survey in the K-1007-P1 Pond riparian zones between 2010 and 2023. These nine species represent nine different families, and hopefully, they give a good overall perspective of remediation success relative to riparian zone breeding birds. The numbers of observations of most species have increased since the first breeding season (in 2010) following initial remediation actions, with the notable exception of northern bobwhite (*Colinus virginianus*). This species is noted as a species of regional importance in Partners in Flight assessments because of overall declines in the Appalachian Mountains region.

Table 11. Numbers of select breeding bird species observed per survey in the K-1007-P1 Pond riparian zones, May through September 2010 to 2023

		Mean number of observations per survey[a]													
Common name	**Scientific name**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
		(*n* =22)	(*n* =21)	(*n* =19)	(*n* =10)	(*n* =6)	(*n* =9)	(*n* =3)	(*n* =5)	(*n* =4)	(*n* =2)	(*n* =4)	(*n* =4)	(*n* =9)	(n=11)
Northern bobwhite	*Colinus virginianus*	0.05	0.52	0.11	0	0	0.67	0	0	0	0	0	0	0	0
Willow flycatcher	*Empidonax traillii*	0.23	0.52	0.42	1.1	0.17[b]	1.11[b]	0.33	0.6	0.5	0	0	0.75	0.11	0.09
Eastern bluebird	*Sialia sialis*	0	1.81	2.95	3.2	3.83	2	3	2.8	2	0	3.75	3.5	5.2	3.64
Gray catbird	*Dumetella carolinensis*	0	0.38	2.32	2.7	4	2.33	1	1.2	2	0	1.75	1.5	1	.55
Yellow warbler	*Setophaga petechia*	0.2	0.48	0.53	0.6	0.17	0.33	1	0.6	0.75	0	0.5	0.75	0.33	0
Song sparrow	*Melospiza melodia*	2.14	3.48	3.79	4.9	5.33	4.22	6.33	6	4.5	6.5	7	5	8.1	7.73
Indigo bunting	*Passerina cyanea*	2.45	4.86	5.32	1.7	5.5	2	2	1.6	0.75	0	2.25	2.75	0.67	1.0
Red-winged blackbird	*Agelaius phoeniceus*	2.82	9.38	10.53	13.6	36.33	21	13	12.4	7.25	6	11.3	23.5	11.67	1.73
American goldfinch	*Spinus tristis*	0.73	7.62	12.16	22.6	14.67	4.78	3	5.8	4	2	8.75	6.75	4	5.27

[a]*n* = total number of surveys conducted from May to September.
[b]Includes one observation of one nonvocal *Empidonax*, identification tenuous.

Reptiles and amphibians

Reptile and amphibian populations were monitored by direct observations and through evening anuran (frog and toad) call surveys. The four species of turtles depicted in Figure 27 have been captured at the K-1007-P1 Pond each year from 2010 to 2023, and all turtle species captured from 2014 to 2023 are noted in Table 12. No turtle trapping occurred in 2019. However, all but one previously observed species, the midland painted turtle (*Chrysemys picta marginata*), was observed during routine fish and wildlife surveys.

Figure 27. Four species of turtles encountered most frequently in the K-1007-P1 Pond: (A) eastern spiny softshell turtle, (B) snapping turtle, (C) eastern musk turtle, and (D) Cumberland slider.

Turtle surveys resumed in September 2020 following previous trapping protocols, but additional information on size and sex of individuals captured was included. All 20 individuals from all six species recorded in 2020 were male, whereas females comprised a mean 23.1% of captures across all species in 2021 and a yet higher 36.8% in 2022. Midland painted turtles were not captured during trapping efforts in 2019, but at least one individual was noted basking during routine fish and wildlife surveys, and a single male was captured in both 2021 and 2022. A red-eared slider (*Trachemys scripta elegans*) was recorded for the first time at the K-1007-P1 Pond during 2020 trapping efforts. It is unclear whether the individual captured in 2020 was transient or whether a prior survey failed to identify it. The species is ecologically similar to the other slider species observed but is known to be associated with human-modified environments owing to broad-scale introductions. One female river cooter (*Pseudemys concinna*) was captured in 2021–2023. This species does not typically inhabit ponds, but its occasional presence is expected given proximity of the K-1007-P1 Pond to Poplar Creek and the Clinch River and the species' propensity to move over well-vegetated landscapes.

Overall, K-1007-P1 Pond supports an increasing number of resident turtle species, and resident turtle populations are decreasingly male-biased. These patterns might be explained by the relative isolation of K-1007-P1 Pond, as well as higher rates of overland movement and consequent road mortality of female freshwater turtles. Notably, K-1007-P1 Pond is surrounded by roads or other impervious habitat, and the weir serves to exclude aquatic movement. Thus, colonization of the pond from the only feasible source—Poplar Creek—would be relatively slow because turtles must travel over approximately 20 m of well-traveled road surface and manicured shoulder (road mortalities are observed regularly). Although Perimeter Road remains a partial barrier to colonization, the terrestrial habitat adjacent to K-1007-P1 Pond has continued to be improved, and successful resident female turtles have been afforded an increasing amount of suitable terrestrial nesting habitat immediately adjacent to the pond. This increase would eliminate extended movements by females in search of nesting habitats and thus reduce road mortality and predation in resident females over time (Aresco 2005).

Table 12. Species of turtles, frogs, and toads detected at the K-1007-P1 Pond, FY 2014 to 2023. The black circle indicates turtles captured and released on-site and frogs and toads identified by calls

Common name	Scientific name	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Common snapping turtle	*Chelydra serpentina*	●	●	●	●	●	●	●	●	●	●
Midland painted turtle	*Chrysemys picta marginata*	●	—	—	●	●	—	●	●	●	●
Cumberland slider	*Trachemys scripta troostii*	●	●	●	●	●	●	●	●	●	●
Eastern musk turtle	*Sternotherus odoratus*	—	●	●	●	●	●	●	●	●	—
Eastern spiny softshell turtle	*Apalone spinifera spinifera*	●	●	●	●	●	●	●	●	●	●
Red-eared slider	*Trachemys scripta elegans*	—	—	—	—	—	—	●	—	—	●
River cooter	*Pseudemys concinna*	—	—	—	—	—	—	—	●	●	●
Eastern narrow-mouthed toad	*Gastrophryne carolinensis*	—	●	●	●	●	—	●	●	●	●
American toad	*Anaxyrus americanus*	—	—	—	●	●	—	●	—	—	—
Upland chorus frog	*Pseudacris feriarum*	—	—	●	●	●	—	●	●	●	●
Spring peeper	*Pseudacris crucifer*	●	●	●	●	●	●	●	●	●	●
Cope's gray treefrog	*Hyla chrysoscelis*	—	●	●	●	●	●	●	●	●	●
American bullfrog	*Lithobates catesbeianus*	—	●	●	●	●	—	●	●	●	●
Green frog	*Rana clamitans*	—	●	●	●	●	●	●	●	●	●
Southern leopard frog	*Lithobates sphenocephalus*	●	●	●	●	●	—	●	●	●	●
Pickerel frog	*Lithobates palustris*	●	●	●	—	●	—	●	●	●	●
Northern cricket frog	*Acris crepitans*	—	●	●	—	—	—	●	●	●	●

Although snakes are not routinely sampled at ETTP sites, northern water snakes (*Nerodia sipedon*) are common in the K-1007-P1 Pond. Northern black racers (*Coluber constrictor constrictor*) and gray ratsnakes (*Pantherophis spiloides*; i.e., black ratsnakes) have also been observed during post-remediation surveys, as have five-lined skinks (*Plestiodon fasciatus*) and a single broad-headed skink (*Plestiodon laticeps*).

A diverse anuran community has been observed at the K-1007-P1 Pond and its vicinity during post-remediation surveys. Six anuran surveys, one each month from February to July, were conducted in FY 2023. Frog and toad species observed included northern cricket frog (*Acris crepitans*), eastern narrow-mouthed toad (*Gastrophryne carolinensis*), Cope's gray treefrog (*Hyla chrysoscelis*), bullfrog (*Lithobates catesbeianus*), green frog (*L. clamitans*), pickerel frog (*L. palustris*), southern leopard frog (*L. sphenocephalus*), spring peeper (*Pseudacris crucifer*), and upland chorus frog (*P. feriarum*) (Table 12). The only anuran species detected in prior years but not in 2023 was the American toad (*Anaxyrus americanus*). Surveys likely did not overlap with the early spring breeding season of this species, which is when its detectability is highest.

The higher anuran species diversity observed since 2019 might be related to greater survey efforts. Even so, the FY 2020 season saw the highest detected diversity of frogs at K-1007-P1 Pond since surveys commenced in 2014. These included rare and more sensitive taxa, such as cricket frogs, eastern narrow-mouthed toads, southern leopard frogs, and pickerel frogs, which are indicative of healthier, well-vegetated, wetland–upland complexes (Table 13). Considering the anuran surveys that are conducted concurrently elsewhere across the ORR, the K-1007-P1 Pond and immediately adjacent wetlands are among the most anuran-diverse sites on the ORR.

Mammals

Mammal species observed at the K-1007-P1 Pond include muskrat, beaver (2016 to 2021), river otter (*Lontra canadensis*; 2011), white-tailed deer (*Odocoileus virginianus*), coyote (*Canus latrans*), bobcat (*Lynx rufus*; 2014 and 2016 to 2018), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), hispid cotton rat (*Sigmodon hispidus*), and eastern cottontail (*Sylvilagus floridanus*). Fox and various *Peromyscus* spp. have also been observed at the K-1007-P1 Pond.

No bat surveys have been conducted at the K-1007-P1 Pond since summer 2015, when 11 species of bat were detected via acoustic monitors just west of the K-1007-P1 Pond. The levels of confidence associated with 8 of these 11 species were considered high; these included the big brown bat (*Eptesicus fuscus*), eastern red bat (*Lasiurus borealis*), silver-haired bat (*Lasionycteris noctivagans*), gray bat (*Myotis grisescens*), little brown bat *(Myotis lucifugus*), evening bat (*Nycticieus humeralis*), northern long-eared bat (*Myotis septentrionalis*), and tricolored bat (*Perimyotis subflavus*). Three other species, recorded with less confidence, were the hoary bat (*Lasiurus cinereus*), Brazilian free-tailed bat (*Tadarida brasiliensis*), and Rafinesque's big-eared bat (*Corynorhinus rafinesquii*). On the nearby Black Oak Ridge Conservation Easement, acoustic detections have also been made for the Indiana bat (*Myotis sodalis*; low confidence in 2015 and 2017) and southeastern bat (*Myotis austroriparius*; high confidence in 2017). Indiana and gray bats are federally listed as endangered, the northern long-eared bat is federally listed as threatened, and the little brown bat and tricolored bat are currently under review for federal listing. Any of these bat species could be expected at the K-1007-P1 Pond based on proximity to actual detections, similarity of habitat (principally calm water corridors adjacent to forested areas), or both.

Table 13. Summary of pre-action conditions, remedial actions taken, and the current status of the K-1007-P1 and K-901-A Ponds in FY 2023

Site	Pond attribute	Pre-action	Actions (2009 to 2023)	Current status
K-1007-P1 Pond	PCBs in biota	PCBs high in fish and clams and especially high in bass	Fish management: convert to community dominated by low bioaccumulators	PCB concentrations in sunfish fillets and whole bodies are below remediation targets. Largemouth bass concentrations have decreased 10-fold from pre-remediation concentrations.
K-1007-P1 Pond	Fish community	Large number of grass carp and other undesirables (80%)	Fish management: remove grass carp that eat vegetation; remove undesirable species; stock desirable species	Sunfish species are the dominant species in the pond. No grass carp and very few common carp and buffalo were observed. Since the weir breach, undesirable species such as largemouth bass and shad have reproduced. These species are at relatively low numbers compared with historical levels.
K-1007-P1 Pond	Plant community	No aquatic emergent vegetation	Plant management: add stabilizing soil and plant native vegetation (70,000 specimens in 2009; 5,000 in 2010; 3,000 in 2011; 1,400+ in 2017; 1,400 in 2018)	Percentage of plant cover at pond transects ranged from 70% to 80%, but there are substantial areas with open water, especially in unmodified areas.
K-1007-P1 Pond		Poor riparian habitat	Habitat management: Improve riparian zones to limit goose use by allowing riparian zone to grow, also to prevent erosion	No obvious erosion was observed; Riparian zone is robust and native species are dominant.
K-1007-P1 Pond	Wildlife	High goose population contributing to poor water quality	Wildlife management: remove or harass geese and other herbivores; make riparian habitat less suitable for geese	Geese are now in low numbers; the number of other waterfowl observations are higher post-action.
K-1007-P1 Pond	Water quality	High suspended algae, poor water clarity	Water quality changes: use no algaecide, remove geese, add plants, and modify riparian habitat	Water clarity and quality improved substantially between pre- and post-remediation. Water quality mirrors plant trends, with less clarity when there are fewer plants.
K-901-A Pond	PCBs in biota	PCBs high in fish and clams and especially high in bass	Plant and fish management: plant native vegetation from 2017 to 2023, remove undesirable fish species, and restock desirable fish species	Whole-body bluegill concentrations are lower than those in the K-1007-P1 Pond, although concentrations in gizzard shad and carp remain elevated. As plants take root and as fish community is restructured, PCB concentrations are expected to decrease.

Table 13. Summary of pre-action conditions, remedial actions taken, and current status of the K-1007-P1 and K-901-A Ponds in FY 2023 (continued)

Site	Pond attribute	Pre-action	Actions (2009–2023)	Current status
K-901-A Pond	Fish community	Large number of common carp and other undesirables	Fish management: remove common carp that eat vegetation; remove undesirable species that disturb sediment and biomagnify toxins; stock desirable species	Sunfish species are the dominant species in the pond with much lower numbers of common carp and grass carp. Undesirable species such as largemouth bass and shad have reproduced but are at lower numbers compared with historical levels.
K-901-A Pond	Plant community	Minimal aquatic vegetation	Plant management: plant native vegetation (500 specimens in 2017; 2,600 in 2018; 2,000 in 2019; 3,200 in 2020; 2,775 in 2021; 3,225 in 2022; 5,620 in 2023)	Plant cover at pond transects is increasing, and open areas of the pond are mostly vegetated. There was a slight increase in diversity. Diversity is expected to continue to increase as new plants become more established.
K-901-A Pond	Water quality	High turbidity and suspended solids, poor water clarity	Water quality changes: add plants, modify riparian habitat, and remove undesirable fish	Water clarity and quality continue to improve as plants become established and fish species that increase turbidity are removed.

4. SUMMARY

Summary conclusions from the performance and operational monitoring efforts at the K-1007-P1 and K-901-A Ponds are provided in Table 13. In general, the K-1007-P1 Pond fish community continues to be dominated by sunfish. Gizzard shad and other undesirable species, such as largemouth bass, remain at low numbers. PCB concentrations in fish are significantly lower than pre-action, dropping below target concentrations in both fillets and whole-body fish.

Richness and abundance of desirable wildlife associated with the K-1007-P1 Pond have continued to increase since remediation began in 2009. The riparian zone vegetation has been allowed to grow, thus providing increased nesting and foraging opportunities for migratory songbirds; natural cover to facilitate colonization by terrestrial and semi-aquatic wildlife, such as amphibians and reptiles; and less desirable habitats for some nuisance wildlife, such as Canada geese. Likewise, aquatic and emergent vegetation provide necessary food and cover to support greater numbers of waterfowl and aquatic wildlife.

Plant cover appears to be correlated with many water quality variables in the K-1007-P1 Pond, including PCB concentrations in water and fish. Rooted vegetation is key to stabilizing sediment and decreasing particle-associated suspended PCBs in the water column and subsequent uptake in the food chain. In general, the plant coverage in the pond and water clarity have improved since pond planting, which may help address the recent PCB trends. Although plants appear to have a significant effect on PCB concentrations in fish, ongoing PCBs from SD100 have led to fluctuations in previous years. Future monitoring will tell whether the significant increase in aqueous concentrations at SD100 in 2023 will lead to increases in fish PCB concentrations in 2024.

Based on the success seen with planting in the K-1007-P1 Pond, focus has shifted to planting in the K-901-A Pond, where plants have continued to become more established. Future monitoring will indicate whether the increased plant cover in the K-901-A Pond will have the desired effect of reduced PCB concentrations in fish.

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