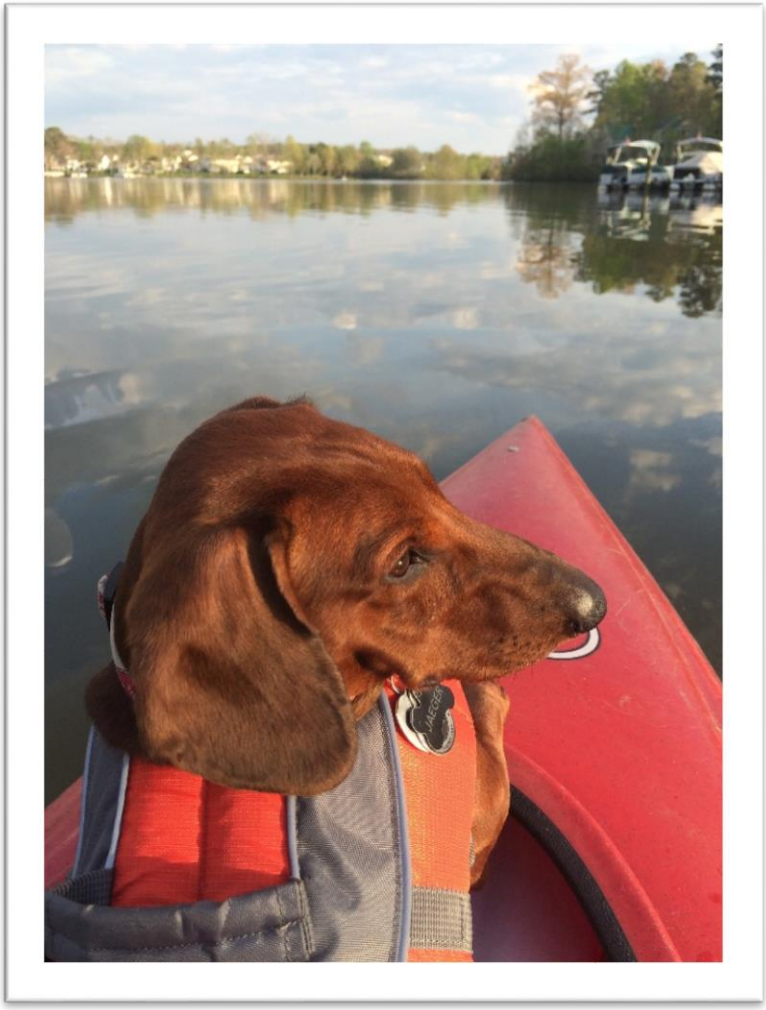
Swift Creek Reservoir
Water Quality Data Report 2016



Chesterfield County
Department of Environmental Engineering
Water Quality Section
&
Department of Utilities
Addison-Evans Water Production/Laboratory Facility

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Executive Summary

This report presents the water quality data collected by the Addison-Evans Water Production and Laboratory Staff for the period of January through December 2016 and represents the twenty fourth consecutive year of monitoring of the Swift Creek Reservoir. During 2016, pool elevations measured at the dam ranged from 175.4 to 178.2 feet above mean sea level, corresponding to an approximate reservoir volume between 3.7 to 5.2 billion gallons. Reservoir sampling occurred once a month at eight stations with additional samples obtained every other week at the lacustrine zone stations. Rainfall over the reservoir and its watershed totaled 46.17 inches, 3.26 inches above the long-term average. During 2016, approximately 3,000 pounds of copper sulfate were applied in July throughout the reservoir to treat algae growth. The applications of copper sulfate assists to improve source water quality for the optimization of the water treatment process.

A higher concentration of chlorophyll *a* was observed in 2016 as compared to the previous year indicating an increased presence of algae in the reservoir. The growing season 90th percentile concentration for the mainstem reservoir stations (Stations 4, 5, 6 and 8) was 57.1 µg/L (Table 4), a 52% percent increase from the 37.5 µg/L observed in 2015. Six stations (Stations 1, 2, 4, 5, 6, and 8) exceeded the 35 µg/L criteria value for the growing season 90th percentile indicating higher than acceptable levels of algal growth.

Throughout the reservoir, total phosphorus concentrations increased slightly in 2016 but remained consistent with previous years observations. The growing season median total phosphorus concentration for the surface water of the main body stations (Stations 4, 5, 6 and 8) was 0.039 mg/L as P; below the Virginia Department of Environmental Quality (VADEQ) nutrient threshold of 0.04 mg/L as P. The annual median phosphorus concentration for the surface water at all eight sites in Swift Creek Reservoir was 0.044 mg/L as P, below the county goal of 0.05 mg/L as P.

During 2016, the reservoir exhibited consistent thermal and dissolved oxygen stratification in its deeper areas beginning in early May and lasting through mid-September/October. During the stratification period, dissolved oxygen concentrations within the epilimnion were above the VADEQ minimum criterion of 4.0 mg/L for all stations.

Median growing season Secchi disk readings ranged from 1.0 to 2.0 feet, a slight decrease from the values noted in prior reports. The growing season turbidity median (7.8 NTUs) throughout the reservoir was 85% higher than the median observed in 2015 (4.2 NTUs). The 2016 Secchi disk depth and turbidity values are indicative of a slight loss of water clarity throughout the reservoir system. The 2016 growing season median total suspended solids concentration for all stations (5.2

mg/L) was slightly increased compared to the concentration observed in 2015 (3.4 mg/L). Total nitrogen levels remained consistent with 2015 concentrations throughout the reservoir with growing season median concentrations ranging from 0.44 to 0.52 mg/L as N. *E. coli* median densities remained acceptable with six individual values greater than the VADEQ single sample maximum of 235 *E. coli* colonies/100mL observed during the growing season.

Water temperature in Swift Creek Reservoir varied normally according to season during 2016. Surface pH values ranged from 6.0 to 8.6 units with an annual in-lake median of 7.1 units. Conductivity measurements within the reservoir ranged from 47 to 375 µS/cm with an annual median of 74 µS/cm. Lead concentrations ranged from below the reporting limit (<0.0025 mg/L) to 0.0097 mg/L with two measurable concentration recorded during 2016. There was one measurable zinc concentration observed (0.0884 mg/L).

A total of 46 individual genera of algae representing six phyla were documented during 2016. Analysis of the general types of algae by phyla in the reservoir indicated that the community structure continued to be comprised largely of green algae (Chlorophyta) and golden algae/diatoms (Chrysophyta). The frequency of occurrence for the taste and odor producing blue-green algae concentration decreased by approximately one third as compared to 2015. There were no widespread taste and odor related problems resulting from algae reported in 2016.

The more vegetative structures of the *Hydrilla* plant had been minimal in 2012 and 2013; in 2014, the *Hydrilla* biomass reestablished itself in the reservoir. In April of 2015, an additional 1,000 triploid grass carp were stocked in the reservoir with the goal of maintaining the *Hydrilla* biomass at a manageable level. An additional 3,000 triploid grass carp were stocked in April of 2016 to establish several class of triploid grass carp within the reservoir. Overall, the multiple classes of grass carp were very effective in controlling *Hydrilla* in 2016.

Introduction

This report presents the water quality data collected by the Addison-Evans Water Production and Laboratory staff between January and December 2016 and is the twenty fourth consecutive year of monitoring of the Swift Creek Reservoir. The Swift Creek Reservoir is a public water supply for Chesterfield County located approximately 20 miles southwest of Richmond, Virginia. The reservoir is a 1,700-acre impoundment containing approximately 5.0 billion gallons of water at full pool elevation (177.0 feet above mean sea level). The portion of the Swift Creek Reservoir watershed located within the northwest corner of the county encompasses approximately 55.9 square miles. Although residential development is common in the reservoir's drainage area (37.8% for all residential categories), the most recent land use data (Table 1) indicates the majority (49.7%) of the watershed is comprised of vacant (undeveloped) properties.

Table 1. Land Use Characteristics of the Swift Creek Reservoir Watershed within Chesterfield County. Data obtained from the Chesterfield County Planning Department Development Potential Database 2016. Categories are arranged in descending order of prevalence.

Land Use Category	Area (acres)	Area (miles^2)	Percent of Watershed
Vacant (Undeveloped)	17784	27.8	49.7
Residential - Single Family	7081	11.1	19.8
Residential Single Family (Subdivisions)	6103	9.5	17.1
Residential - Multi-Family	149	0.2	0.4
Residential - Condominium	102	0.2	0.3
Residential - Townhouse	79	0.1	0.2
Water	1607	2.5	4.5
Public/Semi-Public	1879	2.9	5.3
Commercial	523	0.8	1.5
Utility	290	0.5	0.8
Office	141	0.2	0.4
Industrial	38	0.1	0.1
Total	35,776	55.9	100.0

During 2016, pool elevations measured at the dam ranged from 175.4 to 178.2 feet above mean sea level, corresponding to an approximate reservoir volume between 3.7 to 5.2 billion gallons. Reservoir sampling occurred once a month at eight stations with additional samples obtained every other week at the lacustrine zone Stations 5 and 8 (Figure 1). At these deeper water sites, discrete epilimnion, metalimnion, and hypolimnion samples were taken for nutrient analysis. All other stations in the reservoir (sites 1, 2, 3, 4, 6 and 7) were sampled at the surface only.

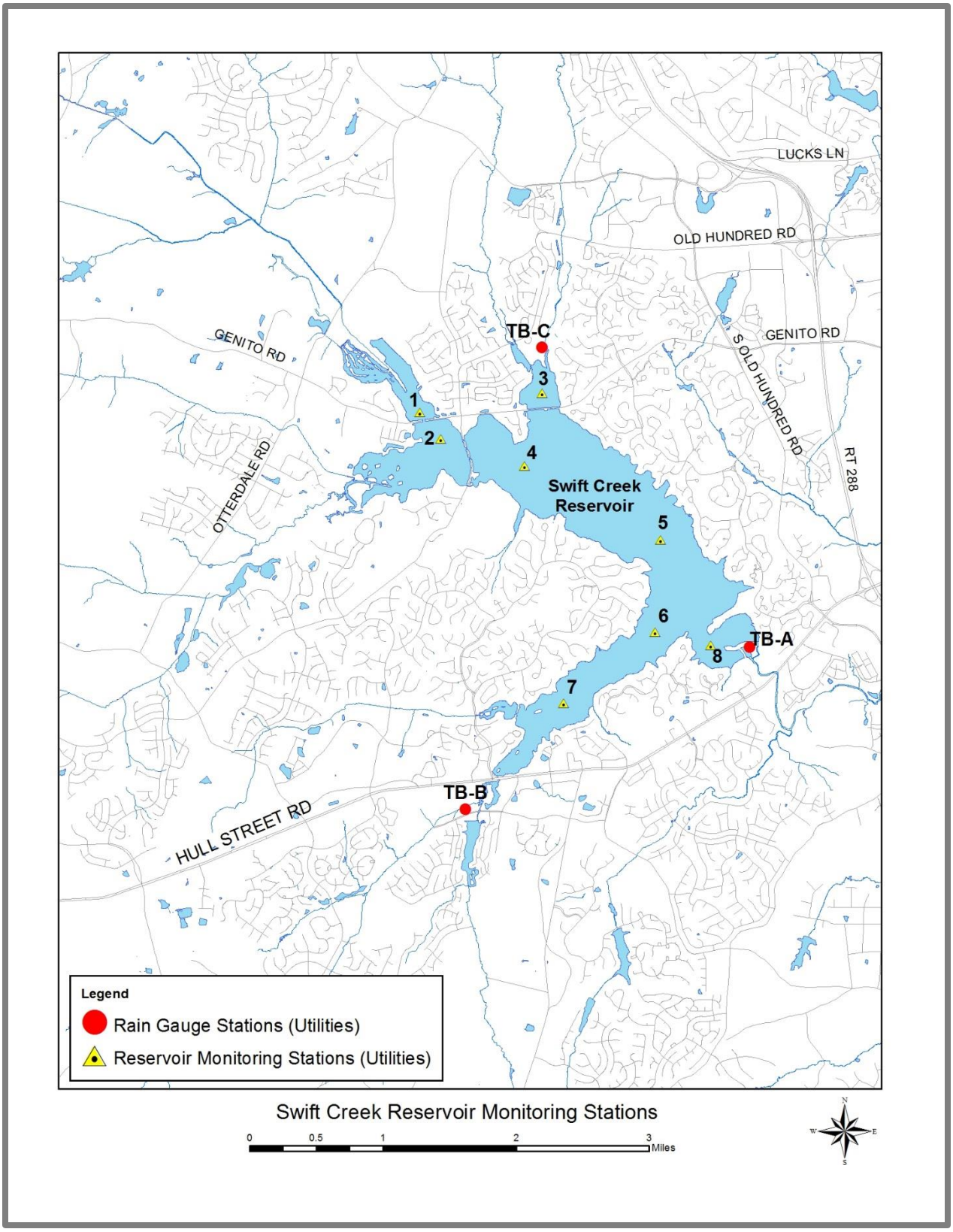


Figure 1. Map of Swift Creek Reservoir monitoring stations.

Water quality parameters (Table 2) were chosen to provide information on basic water quality and the ecological health of the reservoir. Details concerning specific analytical procedures are listed in Table 3.

Table 2. Sampling Regime for Swift Creek Reservoir 2016.

PARAMETER	RESERVOIR STATIONS 1,2,3,4,7	RESERVOIR STATIONS 5,6,8
DEPTH	X1	X1A
SECCHI DISC	X	X
WATER TEMPERATURE	X1	X1A
DISSOLVED OXYGEN (Given as mg/L & % saturation)	X1	X1A
CONDUCTIVITY	X1	X1A
pH	X1	X1A
OXIDATION REDUCTION POTENTIAL	X1	X1A
TOTAL PHOSPHORUS	X2	X3
ORTHO PHOSPHATE PHOSPHORUS	X2	X3
TOTAL KJELDAHL NITROGEN	X2	X3
OXIDIZED NITROGEN	X2	X3
AMMONIA NITROGEN	X2	X3
TOTAL ORGANIC CARBON	X2, 1/QTR	X2, 1/QTR
LEAD	X2, 1/QTR	X2, 1/QTR
ZINC	X2, 1/QTR	X2, 1/QTR
SUSPENDED SOLIDS/TURBIDITY	X2	X2
CHLOROPHYLL *a*	X4	X4
PHEOPHYTIN *a*	X4	X4
ALGAE COUNTS	X4	X4
Escherichia coli (E. coli)	X2	X2

X1 – ONE METER INTERVALS
X1A – ONE FOOT INTERVALS
X2 – SURFACE SAMPLING ONLY
X3 – DISCRETE SAMPLES OF EPILIMNION, METALIMNION AND HYPOLIMNION WHEN STRATIFICATION EXISTS **OR** SURFACE, MID-DEPTH AND NEAR BOTTOM WHEN NO STRATIFICATION IS PRESENT
X4 – A COMPOSITE OF BENEATH SURFACE, 1/2/ SECCHI DEPTH, SECCHI DEPTH AND 1-1/2 SECCHI DEPTH SAMPLES

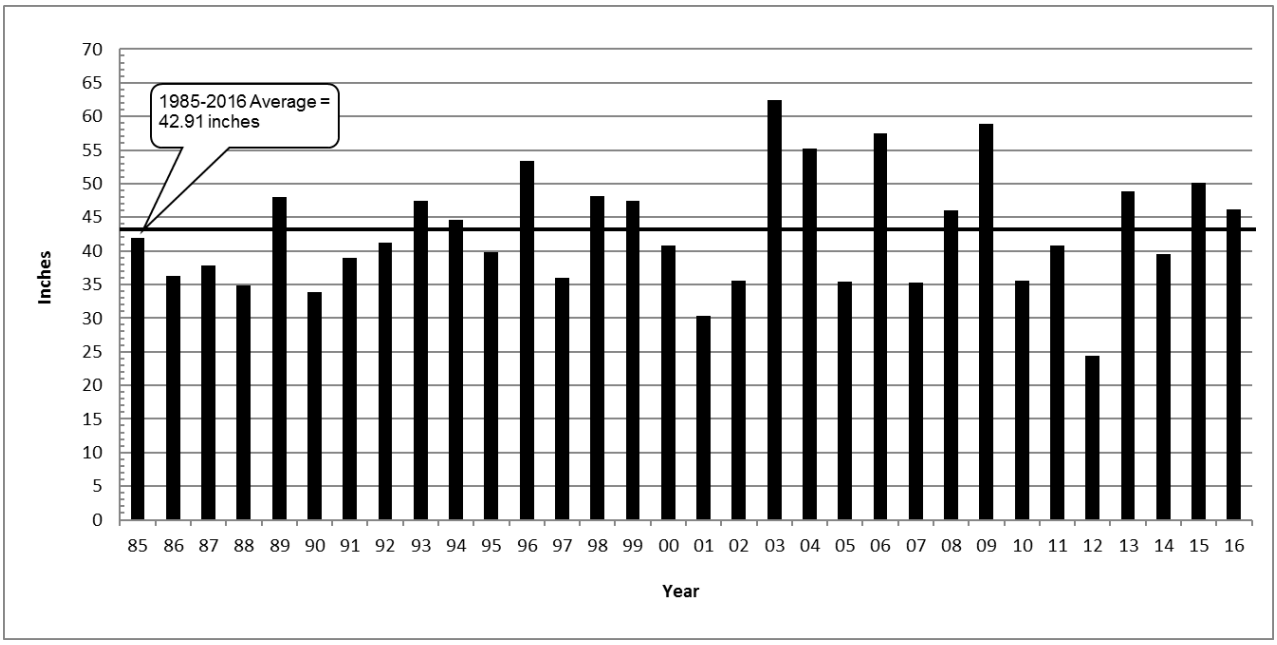
Table 3. Parameters and Analytical Methods 2016. When Reporting Limit based upon detection is not an applicable measurement for a parameter, it has been replaced by an estimation of accuracy (e.g. pH measurement has an estimated accuracy of 0.2 units) as indicated by (*).

Parameter	Analytical Method	Detection Limit
Depth	Probe: Hydrolab MiniSonde	± 0.08 m*
Dissolved Oxygen	Probe: Hydrolab MiniSonde	± 0.2 mg/L*
Oxidation Reduction Potential	Probe: Hydrolab MiniSonde	± 20mV*
Water Temperature	Probe: Hydrolab MiniSonde	± 0.1 ^{o}C*
Conductivity	Probe: Hydrolab MiniSonde	± 0.1 µmhos/cm*
pH	Probe: Hydrolab MiniSonde	± 0.2 units
Secchi Depth	20 cm Standard Secchi Disk	± 0.1 ft*
Total Phosphorus	Skalar:EPA Approved, Autom.	0.005 mg/L as P
Orthophosphate	Skalar:EPA Approved, Autom.	0.005 mg/L as P
Total Kjeldahl Nitrogen	Skalar:EPA Approved, Autom.	0.05 mg/L as N
Oxidized Nitrogen	Skalar:EPA Approved, Autom.	0.01 mg/L as N
Ammonia-N	Hach, Method 10205	0.015 mg/L as N
Total Organic Carbon	Standard Methods, 5310C	0.5 mg/L
Lead	EPA 200.9, Platform Furnace	2.5 µg/L
Zinc	EPA 289.1, Flame	50 µg/L
Total Suspended Solids	Standard Methods, 2540D	1.0 mg/L
Chlorophyll *a*	Standard Methods, 10200H-3, Fluorom.	1.0 µg/L
Pheophytin *a*	Standard Methods, 10200H-3, Fluorom.	1.0 µg/L
Algae Counts	Standard Methods, 10200F	1 cell/mL
Escherichia coli (E. coli) Density	Standard Methods, 9222B (Quanti-Tray)	1.0 MPN/100mL

NOTE: Standard Methods for the Examination of Water and Wastewater, 22th Edition.

Rainfall was measured at three automated tipping bucket rain gages within the watershed. The average rainfall over the watershed totaled 46.17 inches during 2016 (Figure 2). Rainfall was 3.26 inches above the long-term average observed over the last 30 years (42.91 inches).

Figure 2. Total Annual Estimated Rainfall Recorded for Swift Creek Reservoir Watershed from 1985-2016 (Source data: Department of Utilities).



Quality Assurance and Quality Control

All analytical methods used were EPA approved, in accordance with *Standard Methods for the Examination of Water and Wastewater* (Standard Methods) with the exception of free ammonia analyses which were made following the Hach Chemical Company's test kit procedure. For each parameter analyzed, Method Detection Limits (MDL) were calculated following the EPA procedure as detailed in the *Code of Federal Regulations (CFR), Volume 46, Part 136 Appendix B (EPA, 1984).* Stock and standard solutions were prepared from American Chemical Society reagent grade materials for preparation of calibration standards. Correlation coefficients were evaluated for each calibration curve and had to be greater than or equal to 0.995 to be used for analysis. To ensure calibration validity throughout an analysis, Continuing Calibration Verifications (CCV) standards were tested after every 10 samples analyzed. Similarly, Continuing Calibration Blanks (CCB) were evaluated after every 10 samples to detect any baseline drift errors. With each analysis, field blanks and digestion/analytical blanks were evaluated to ensure detection of contamination during sampling or sample preparation. Independent source Standard Reference

Materials (SRM) were purchased and used to verify the accuracy of each analysis calibration. When any standard (or SRM) was not within 10 percent (per EPA guidelines) of the true value, or CCB showed baseline drift, corrective actions were implemented. An ERA performance evaluation of blind nutrient samples in a split sampling study is performed annually. Reported concentrations for orthophosphate and total phosphorus, ammonia, oxidized nitrogen, and total Kjeldahl nitrogen continue to be within the limits of the ERA's acceptable analytical values. Manufacturers recommended preventive maintenance procedures were followed for all instruments.

Results and Discussion

Eight stations in the reservoir were sampled monthly during 2016. Stations 5 and 8 were sampled twice per month throughout the year to obtain additional data for the deep-water areas. Sampling at all stations included surface grab samples and water column profiles of physical parameters. Supplemental bottom water quality samples were obtained at the mainbody Stations 5 and 8. Specific reports concerning reservoir data are available upon request from the Departments of Environmental Engineering or Utilities.

The county's water quality goal for the annual median concentration of total phosphorus in surface waters is 0.05 mg/L as P or less and was originally based on a Nutrient Controls Standards Workshop held in 1987 by the Virginia Department of Environmental Quality (VADEQ). In June 2006, VADEQ adopted freshwater nutrient standards for 116 lakes and reservoirs in Virginia, including the Swift Creek Reservoir. The EPA approved regulations in July of 2007 and the amended water quality standards [9 VAC 25 - 260] became effective August 14, 2007. These regulations set growing season (April through October) chlorophyll *a* and total phosphorus criteria for Swift Creek Reservoir at 35 µg/L (0.035 mg/L) and 40 µg/L (0.040 mg/L as P) respectively. These growing season measurements are intended not to be exceeded for two consecutive years as measured by the State in their Lake Monitoring Program. Specifically, VADEQ considers the reservoir nutrient enriched if the 90^{th} percentile of the chlorophyll *a* data in surface waters of the main body of the reservoir (Stations 4, 5, 6, and 8) during the growing season exceeds the criteria for two consecutive years. However, algaecide use can make chlorophyll *a* measurements unreliable. If algaecides are used, then both chlorophyll *a* and total phosphorus criteria are applicable. In the Swift Creek Reservoir, the algaecide copper sulfate is used occasionally to spot treat algal blooms. The algaecide use is variable over the reservoir between months and between years. Because of the algaecide treatments, analysis of the reservoir data has always included both the total phosphorus and chlorophyll *a* criteria. Additionally, VADEQ would consider the reservoir nutrient enriched if the growing season median concentration of total phosphorus in

surface waters of the main body of the reservoir exceeded the criterion for two consecutive years.

During 2016, approximately 3,000 pounds of copper sulfate were applied in July to treat algae growth in the reservoir. The 3,000 pounds were applied at a rate of 1,000 pounds per application on July 8, July 20 and July 21 throughout the reservoir covering areas in the mainbody, fore and intake bays. All applications of copper sulfate were performed to improve source water quality for the optimization of the water treatment process within the plant. Algal blooms are known causes of taste and odor issues in drinking water and can clog filters, thereby decreasing available potable water production and supply.

Chlorophyll *a*

VADEQ has identified chlorophyll *a* as the most important parameter that can be measured to determine the nutrient enrichment status of a reservoir. Chlorophyll *a*, a green photosynthetic pigment found in algae, is an indirect measure of biological response to nutrient loadings. VADEQ considers the threshold value for nutrient enrichment in Swift Creek Reservoir to be the 90th percentile concentration that exceeds 35 µg/L, measured between April and October (*i.e.* the growing season) within the main body for two consecutive years. Seventy (70) chlorophyll *a* samples from the eight sites were collected and analyzed during the growing season.

An increased concentration of chlorophyll *a* was observed in 2016 as compared to the previous year indicating an increased presence of algae in the reservoir. The growing season 90th percentile concentration for the mainstem reservoir stations (Stations 4, 5, 6 and 8) was 57.1 µg/L (Table 4), a 52 percent increase from the 37.5 µg/L observed in 2015. In 2016, all eight of the stations combined had a 90th percentile concentration during the growing season of 57.4 µg/L, a 37 percent increase from the 41.8 µg/L observed in 2015. The greatest individual measurement observed (110.7 µg/L) occurred at the lacustrine Station 8 on May 16, 2016. The highest growing season 90th percentile concentration (66.7 µg/L) was also observed at Station 8. Six stations (Stations 1, 2, 4, 5, 6, and 8) exceeded the 35 µg/L criteria value for the growing season 90th percentile indicating higher than acceptable levels of algal growth. Increased concentrations of chlorophyll *a* above the 35 µg/L VADEQ threshold have now been observed in Swift Creek Reservoir for two consecutive years and are reflective of increased algal growth.

Table 4. Growing Season Chlorophyll a Concentrations (Surface) 2016.

Station	Growing Season 90th Percentile Chlorophyll *a* (µg/L)
1	65.9
2	54.8
3	24.3
4	50.5
5	44.6
6	49.8
7	30.9
8	66.7
Mainbody Stations (4, 5, 6, 8)	**57.1**
Shallow Stations (1, 2, 3, 7)	**55.8**
All Stations	**57.4**

Total Phosphorus

Total phosphorus is measured as an indicator of nutrient enrichment. The VADEQ has adopted a freshwater nutrient criterion of 40 µg/L (0.040 mg/L as P) for the surface waters of the reservoir's main body for the growing season. Seventy (70) total phosphorus samples from the eight sites were collected and analyzed during the growing season. The growing season (April – October) median total phosphorus concentrations for each reservoir station are provided in Table 5.

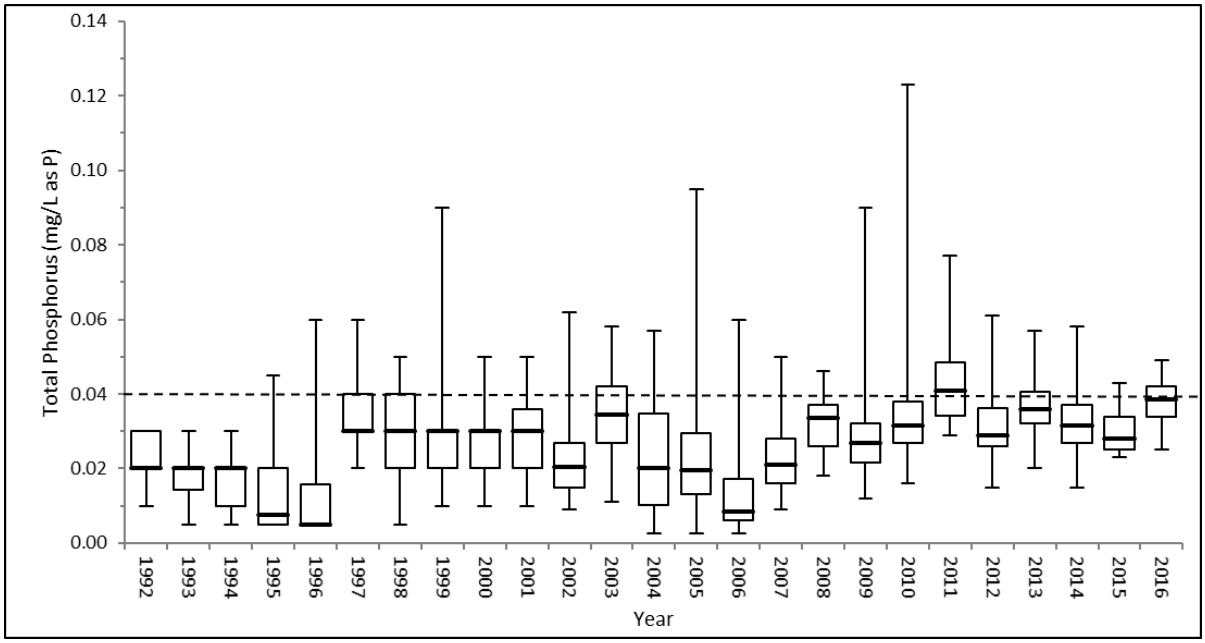
Table 5. Growing Season Median Total Phosphorus Concentrations (Surface) for 2016.

Station	Growing Season Median Total Phosphorus (mg/L as P)
1	0.067
2	0.061
3	0.053
4	0.039
5	0.039
6	0.037
7	0.041
8	0.038
Mainbody Stations (4, 5, 6, 8)	**0.039**
Shallow Stations (1, 2, 3, 7)	**0.059**
All Stations	**0.040**

In 2016, the growing season median total phosphorus concentration in the reservoir for all sites combined was 0.040 mg/L as P, an observation below the county goal of 0.05 mg/L as P. This

observation was increased from the total phosphorus concentration observed in 2015 (0.033 mg/L as P) but still consistent with concentrations observed in previous years (Figure 3). The growing season median total phosphorus concentration for the surface waters of the main body stations (Stations 4, 5, 6 and 8) was 0.039 mg/L as P, an increase from the 0.028 mg/L as P concentration noted in 2015. The growing season median value observed in the mainbody continues to remain below the VADEQ freshwater nutrient criterion threshold of 0.04 mg/L as P (Figure 3). The reservoir's mainbody stations each had median phosphorus concentrations below the 0.04 mg/L as P threshold during the growing season. Each of the shallow stations' growing season phosphorus medians exceeded that threshold, indicating nutrient enrichment in the shallow areas of the reservoir (Table 5). It should be noted that the state phosphorus criterion is only applicable for the lacustrine zone (Stations 4, 5, 6 and 8) and is not intended as a regulatory value for the shallow, backwater areas of the reservoir. During 2016, for all sites monitored in the reservoir, 73 individual measurements (62.9%) were at or exceeded 0.04 mg/L as P, a two-fold increase from the 2015 observations (n=34; 29.8%). The annual median phosphorus concentration for all eight sites was 0.044 mg/L as P. The total phosphorus levels present in Swift Creek Reservoir indicate that in 2016 this water body exhibited a consistent level of nutrient enrichment.

Figure 3. Box plot demonstrating the growing season median total phosphorus concentrations and ranges of observations for the surface waters of main body sites within Swift Creek Reservoir 1992 - 2016 Dashed line denotes VADEQ maximum threshold of 0.04 mg/L as P for acceptable water quality.



Higher concentrations of total phosphorus in anoxic (oxygen depleted) bottom waters as compared with surface water concentrations indicate active phosphorus release from sediments. The release of phosphorus from the sediments results in additional nutrient loading to the reservoir, as this phosphorus is then mixed with the upper water layers during de-stratification. At Stations 5 and 8 during 2016, there were 22 instances where the concentrations of total phosphorus in the benthic sample were greater than the values obtained at the surface; a slight decrease from the 24 observed in 2015. Of these 22 instances, three were considered substantial (*i.e.* ≥ 50% difference); a decrease from the eight observed substantial differences in 2015. The bottom phosphorus concentrations at Stations 5 and 8 ranged from 0.025 to 0.073 mg/L as P. This represented a median bottom concentration of 0.042 mg/L as P; similar to the median surface concentration of 0.044 mg/L as P. The 2016 bottom concentration was increased when compared to the 2015 bottom concentration of 0.033 mg/L. All other differences noted were minor (≤ 50% difference). While total phosphorus contributions from the sediment were not significant this year, in previous years the higher concentrations in the anoxic hypolimnion may have contributed to loading within the reservoir.

Dissolved Oxygen

Adequately oxygenated water is critical for a healthy aquatic environment and as good quality source water for municipal treatment facilities. Hypoxic conditions occur when dissolved oxygen drops below 5.0 mg/L, resulting in stress on fish and other aquatic life. An anoxic condition occurs when dissolved oxygen drops below 1.0 mg/L, which can result in fish kills and the release of phosphorus, iron, manganese and other elements from the sediments. The release of these elements can result in increased algal blooms and treatment problems (undesirable tastes and odors) in the production of drinking water.

In July 2007, EPA approved the VADEQ's proposed dissolved oxygen standard (5.0 mg/L daily average, 4.0 mg/L minimum), which had been modified to account for naturally occurring decreases in dissolved oxygen due to thermal stratification in reservoirs. These new standards apply to the entire water column when the reservoir is well mixed and only to the surface waters (epilimnion) when the water column is vertically stratified. The most recent 2014 VADEQ's 303(d) listing of impaired water bodies lists the Swift Creek Reservoir as fully supporting in all categories: aquatic life, fish consumption, recreational contact and wildlife.

Thermal stratification is a natural process in many lakes and reservoirs that occurs when summer conditions warm the upper water column while the lower water column remains cooler. The warmer surface waters become lighter than the colder and denser bottom waters, resulting in layers of water separated by a zone of sharply changing temperature, known as a thermocline, which

inhibits vertical mixing. The thermal stratification continues until falling temperatures in the autumn cool the surface water sufficiently and disrupt the thermocline. Often a large fall storm event will result in rapid destratification of the lake.

During 2016, the reservoir exhibited consistent thermal and dissolved oxygen stratification in its deeper sections beginning in early May and lasting through mid-September at Station 5 and through the end of October at Station 8. Thermal stratification of Swift Creek Reservoir was first observed on May 2, 2015 at both Station 5 and 8, corresponding with the first substantial drop in dissolved oxygen levels at and near the bottom. Stratification continued at both Station 5 until September 19 and at Station 8 until October 24, 2016, when the lake completed the seasonal turn over and became thoroughly mixed. During the stratification period, dissolved oxygen concentrations within the epilimnion were above the VADEQ standard of 4.0 mg/L minimum for all stations. The time period and degree of thermal and dissolved oxygen stratification within Swift Creek Reservoir were consistent with past observations.

Secchi Depth, Total Suspended Solids, Turbidity, Total Nitrogen and *E. coli*

During the growing season of 2016, 73 secchi depth readings and 67 turbidity, total suspended solids, total nitrogen and *E. coli* samples from the eight sites were collected and analyzed. Secchi depth is a measurement of water transparency using a weighted black and white disk that is lowered into the water until the distinction between the black and white portions are no longer visible. The depth at which the distinction is no longer visible is then recorded as "Secchi disk transparency." Secchi disk transparency is a function of the reflection of light from the surface off the disk. Secchi disk transparency is affected by the light absorption characteristics of the water as well as by dissolved and suspended particulate matter. It provides an estimate of water clarity and is closely related to turbidity.

All stations had median growing season Secchi disk readings ranging from 1.0 to 2.0 feet (Table 6); these results are a decrease in clarity when compared with previous years. The 2016 growing season median value for all sites (1.8 feet) was nearly half the median observed in 2015 (3.0 feet) with the decrease in clarity attributed to the increased algae density observed throughout the reservoir. Individual site growing season medians for turbidity ranged from 5.1 to 17.5 NTUs with the greatest turbidity observed in the shallow backwater stations. The growing season turbidity median (7.8 NTUs) was 86% higher than the median observed in 2015 (4.2 NTUs). The observed decreases in Secchi disk depth and increases in turbidity indicate a slight decline in overall water clarity throughout the reservoir system.

Table 6. Growing Season Median Values for Select Parameters (Surface) 2016.

STATION	SECCHI DEPTH (Feet)	E. coli DENSITY (MPN/100 mL)	TOTAL NITROGEN (mg/L as N)	TOTAL SUSPENDED SOLIDS (mg/L)	TURBIDITY (NTUs)
1	1.0	4.1	0.48	13.6	14.0
2	1.0	3.1	0.51	8.4	12.0
3	1.3	109.2	0.52	7.8	17.5
4	2.0	2.0	0.42	4.8	7.0
5	2.0	2.6	0.47	4.6	5.1
6	2.0	5.2	0.47	4.0	6.5
7	1.8	24.3	0.44	4.8	7.6
8	2.0	12.2	0.51	4.8	6.5
Mainbody Stations (4, 5, 6, 8)	**2.0**	**4.1**	**0.49**	**4.8**	**6.2**
Shallow Stations (1, 2, 3, 7)	**1.0**	**4.1**	**0.48**	**9.2**	**13.2**
All Stations	**1.8**	**4.1**	**0.48**	**5.2**	**7.8**

The 2016 growing season median total suspended solids concentration for all stations (5.2 mg/L) was slightly increased compared to the concentration observed in 2015 (3.4 mg/L). In spite of the slight increase, the total suspended solids concentrations in the reservoir are consistently low. As in previous years, total nitrogen levels remained consistent throughout the reservoir with growing season median concentrations ranging from 0.44 to 0.52 mg/L as N (Table 6). The 2016 growing season median for all stations (0.48 mg/L as N) was a slight decrease from the 2015 observation (0.60 mg/L as N) and indicated a nominal decrease in nitrogen enrichment throughout the reservoir. The mainbody stations' growing season medians were again consistent with the shallow backwater stations.

E. coli densities as expressed as the Most Probable Number (MPN) of *E. coli* per 100mL ranged from a growing season median of 2.0 MPN/100mL at Station 4 to 109.2 MPN/100mL at Station 3. The growing season median for all stations in 2016 was 4.1 MPN/100mL. There were six individual values greater than the VADEQ single sample maximum of 235 *E. coli* colonies/100mL during the growing season. The observed *E. coli* exceedances were spread across the reservoir with two at Station 1 (325.5 MPN/100mL and 1299.7 MPN/100mL) and one each at Stations 2 (1299.7 MPN/100mL), 3 (866.4 MPN/100mL), 4 (238.2 MPN/100mL) and 7 (325.5 MPN/100mL); Station 8 (closest to the water plant intake tower) did not have any exceedances. During the non-growing season months, there were thirteen (13) instances in the reservoir when *E. coli* densities were greater than the VADEQ maximum threshold (11.2% of total observations). In these occurrences, coliform densities ranged from 238.2 to 1299.7 *E. coli* MPN/100mL. Four (4) observations exceeding the state standard were observed at Station 5, which had the most frequent occurrence of exceedances and the remaining occurred at Station 1 (n=2), 2 (n=1), 3

(n=2), 4 (n=2), 6 (n=1), and 7(n=1) throughout the reservoir. The reservoir is populated by migratory and resident waterfowl and the isolated measurements of high *E. coli* densities are likely related to the sporadic movements and presence of the birds.

Temperature, pH, Conductivity, Lead and Zinc

Water temperature in Swift Creek Reservoir varied normally according to season during 2016. Surface temperatures throughout the reservoir ranged from 4.2 to 32.8ºC during the year with a median value of 17.4ºC. Eleven (11) individual surface temperatures exceeded the VADEQ maximum standard of 32.0ºC during 2016. The temperature exceedances occurred in the mainbody of the reservoir (Station 8: n=4, Station 6: n=3, and Station 5: n=4). Surface pH values ranged from 6.0 to 8.6 units with an annual in-lake median of 7.1 units, consistent with pH concentrations previously observed. None of the individual surface values measured in 2016 fell outside of the 6.0 to 9.0 unit VADEQ acceptable range for pH. Conductivity measurements within the reservoir ranged from 47 to 375 µS/cm with an annual median of 74 µS/cm; an observation consistent with previously recorded values. Thirty lead and twenty-two zinc samples each were collected and analyzed from the eight sites during the year. Lead concentrations ranged from below the reporting limit (<0.0025 mg/L) to 0.0097 mg/L with two measurable concentration observed 2016. There was one measurable zinc concentration observed in 2106 (0.0884 mg/L). All other zinc concentrations were below the laboratory's detection limit (0.05 mg/L).

Algal Community Structure of Swift Creek Reservoir

A total of 46 individual genera of algae representing six phyla were documented in Swift Creek Reservoir during 2016. The 2016 median algal density per month doubled (6219 cells/mL) when compared with the 2015 (2884 cells/mL) density. Analysis of the general types of algae by phyla in Swift Creek Reservoir (Figure 4) indicated that the community structure continued to be comprised largely of golden algae/diatoms (Chrysophyta, 50.2%) and green algae (Chlorophyta, 24.7%). These two phyla combined represented 74.9% of the algal community observed; this was an increase in dominance from the 56.6% composition observed in 2015. The frequency of occurrence for the taste and odor producing blue-green algae (Cyanoprokaryota, 18.7%) decreased by approximately one third as compared to 2015 (28.3%) and slightly greater than double the quantity observed in 2014 (6.9%).

The ten most common algal genera were identified (Table 7). These ten genera combined represented approximately 85% of all algae observed in 2016. While most of these genera are potentially known to affect the taste and odor of the production water, there were no widespread taste and odor related problems resulting from algae in 2016.

Figure 4. A comparison of the frequency of occurrence of six algae phyla observed in Swift Creek Reservoir 2014 - 2016.

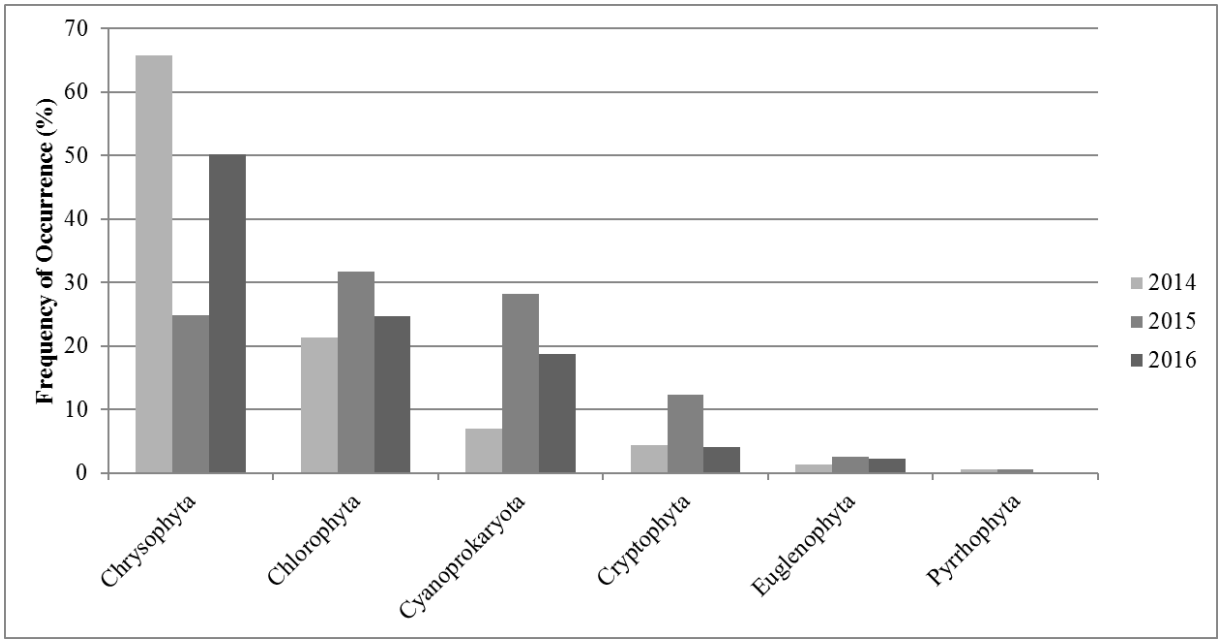


Table 7. Ten most common taxa of algae observed in Swift Creek Reservoir 2016.

Number	Phyla	Genus	% of Total Observed	Taste/Odor Produced
1	Chrysophyta	*Melosira*	22.0	Musty
2	Chrysophyta	*Chrysochromulina*	19.3	Not Known
3	Cyanoprokaryota	*Anabaena*	17.4	Rotten/Septic
4	Chlorophyta	*Crucigenia*	6.9	Not Known
5	Chlorophyta	*Scenedesmus*	4.5	Grassy
6	Chlorophyta	*Ankistrodesmus*	4.4	Grassy/Musty
7	Chlorophyta	*Dictyosphaerium*	3.7	Fishy
8	Cryptophyta	*Cryptomonas*	2.5	Sweet/Fishy
9	Chrysophyta	*Rhizosolenia*	2.1	Not Known
10	Chrysophyta	*Nitzschia*	1.8	Not Known

Status of *Hydrilla* and its Control in the Swift Creek Reservoir

As discussed in the previous Swift Creek Reservoir Water Quality Data Reports, the rapid growing invasive aquatic weed, *Hydrilla verticillata*, was first identified in the Swift Creek Reservoir in August 2009. After studying the problem, action for the long-term management of *Hydrilla* was initiated by the introduction of triploid grass carp (*Ctenopharyngodon idella*) to the reservoir in

April 2010. An electrofishing survey conducted in September 2011 observed that the population was healthy and the fish were growing in size, which correlated with the observed reduction in the density and distribution of *Hydrilla* within the reservoir. Both 2011 summertime surveys indicated no visible areas of *Hydrilla* were present and this observation was confirmed again in the October survey. Surveys conducted during 2012 and again in 2013 confirmed the grass carp continued to be effective in controlling the growth of *Hydrilla*.

While the more vegetative structures of the *Hydrilla* plant had been minimalized in 2012 and 2013, in 2014 the *Hydrilla* biomass reestablished itself in the reservoir. Some reestablishment of *Hydrilla* was anticipated as a function of the plant's reproductive strategies such as root structures that produce tubers, which prevent the complete removal of the plant from a water body and the aging grass carp population being unable to continue to consume the plant at the same rate as juveniles. In April of 2015, an additional 1,000 triploid grass carp were stocked into the reservoir to maintain the *Hydrilla* biomass at a manageable level.

An additional 3,000 triploid grass carp were stocked in April of 2016 to establish several classes of triploid grass carp within the reservoir. Overall, the multiple classes of grass carp were very effective in controlling *Hydrilla* in 2016. The majority of the reservoir remained clear of *Hydrilla* coverage through the 2016 growing season with only 45 acres of coverage observed. The greatest quantity of observed and documented growth of *Hydrilla* was near Station 3 in the Tomahawk Creek confluence with the reservoir where the growth of *Hydrilla* was related to the infrastructure work on the Genito Bridge crossing. As part of the bridge construction, a turbidity curtain was placed across the width of the forebay to protect the reservoir during the project. Although the curtain inhibited the large-scale movement of grass carp into the area, a small population of grass carp isolated behind the turbidity curtain was observed feeding on the *Hydrilla* at Station 3 when the barrier was in place. Once the bridge construction project was completed, the curtain was removed and more aggressive feeding was observed in September.

The Swift Creek Reservoir *Hydrilla* Management Group will continue to meet regularly in 2017 and monitor both the *Hydrilla* coverage and adequacy of the of current and future control measures. The maintenance of a modest coverage of aquatic vegetation within Swift Creek Reservoir is thought to be paramount in the prevention of opportunistic algae blooms. Localized control measures for *Hydrilla* may need to be investigated for the shallower areas of the reservoir in order to balance the maintenance of excellent source water quality with adequate boating access.

Conclusions

While indicators of water quality continue to suggest acceptable conditions in the Swift Creek Reservoir, there were multiple observations in 2016 that were suggestive of increased algal activity. Among these observations were increased concentrations of chlorophyll *a*, noted declines in water clarity as measured by Secchi disk depth and turbidity, and higher algae counts. The increased concentration of chlorophyll *a* observed in 2016 was 52 percent greater (57.1 µg/L) compared to the previous year (37.5 µg/L) and represented the second consecutive year of values above the 35.0 µg/L VADEQ threshold. Throughout the reservoir, total phosphorus concentrations remained consistent with observations from previous years. The growing season median total phosphorus concentration for the surface waters of the main body stations (Stations 4, 5, 6 and 8) was 0.039 mg/L as P and continued to be below the VADEQ nutrient threshold of 0.04 mg/L as P. The annual median phosphorus concentration for the surface water at all eight sites in Swift Creek Reservoir was 0.044 mg/L as P, below the county goal of 0.05 mg/L as P.

As in prior years, the reservoir exhibited consistent thermal and dissolved oxygen stratification in its deeper sections beginning in early May and lasting through mid-September/October. During this stratification period, dissolved oxygen concentrations within the epilimnion remained above the VADEQ standard of 4.0 mg/L for all stations.

The median Secchi disk transparency readings during the growing season ranged from 1.0 to 2.0 feet and were decreased from the medians noted in prior reports. Individual site growing season medians for turbidity ranged from 5.1 to 7.8 NTUs with the greatest measurements observed in the shallow backwater stations. Both of these observations indicate a slight loss of water clarity. The growing season total nitrogen concentrations continued to be similar to those observed in past years with site medians ranging from 0.44 to 0.52 mg/L as N and indicated a nominal decrease in nitrogen enrichment. There were six observations of individual *E. coli* density values greater than the VADEQ single sample maximum of 235 *E. coli* colonies/100mL during the growing season. Water temperature in Swift Creek Reservoir varied normally throughout the year. Surface pH values ranged from 6.0 to 8.6 units. Conductivity values within the reservoir were acceptable with an annual median of 74 µS/cm. Lead concentrations ranged from below the reporting limit (<0.0025 mg/L) to 0.0097 mg/L with two measurable concentration recorded during 2016. There was one measurable zinc concentration observed in 2106 (0.0884 mg/L). All other zinc concentrations were below the laboratory's detection limit (0.05 mg/L).

A total of 46 individual genera of algae representing six distinct phyla were documented in Swift Creek Reservoir during 2016 and analysis of the general types of algae indicated that the community structure continued to be dominated by golden algae/diatoms and green algae. The 2016 median algal density per month doubled (6219 cells/mL) when compared with the 2015

(2884 cells/mL) density indicating a substantial increase in algal growth in the reservoir. There were no indications of algae related taste and odor problems reported in 2016. The management of *Hydrilla* in the reservoir has been ongoing. In April of 2015, an additional 1,000 triploid grass carp were stocked into the reservoir to maintain the *Hydrilla* biomass at a manageable level. An additional 3,000 triploid grass carp were stocked in April of 2016 to establish several classes of triploid grass carp within the reservoir. Overall, the multiple classes of grass carp were very effective in controlling *Hydrilla* in 2016. The majority of the reservoir remained clear of *Hydrilla* coverage through the 2016 growing season with only 45 acres of plant coverage reported. The Swift Creek Reservoir *Hydrilla* Management Group and consulting scientists will continue to investigate strategies to manage aquatic vegetation within the reservoir at a sufficient level to prevent algae blooms and maintain excellent source water quality.