LAKE & RESERVOIR ASSESSMENTS
PASQUOTANK RIVER BASIN

Lake Phelps

Intensive Survey Branch
Water Sciences Section
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December 3, 2015

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GLOSSARY

Algae Small aquatic plants that occur as single cells, colonies, or filaments. May also be referred to as phytoplankton, although phytoplankton are a subset of algae.

Algal biovolume The volume of all living algae in a unit area at a given point in time. To determine biovolume, individual cells in a known amount of sample are counted. Cells are measured to obtain their cell volume, which is used in calculating biovolume

Algal density The density of algae based on the number of units (single cells, filaments and/or colonies) present in a milliliter of water. The severity of an algae bloom may be determined by the algal density as follows:

Mild bloom = 10,000 to 20,000 units/ml
Moderate bloom = 20,000 to 30,000 units/ml
Severe bloom = 30,000 to 100,000 units/ml
Extreme bloom = Greater than 100,000 units/ml

Algal Growth Potential Test (AGPT) A test to determine the nutrient that is the most limiting to the growth of algae in a body of water. The sample water is split such that one sub-sample is given additional nitrogen, another is given phosphorus, a third may be given a combination of nitrogen and phosphorus, and one sub-sample is not treated and acts as the control. A specific species of algae is added to each sub-sample and is allowed to grow for a given period of time. The dry weights of algae in each sub-sample and the control are then measured to determine the rate of productivity in each treatment. The treatment (nitrogen or phosphorus) with the greatest algal productivity is said to be the limiting nutrient of the sample source. If the control sample has an algal dry weight greater than 5 mg/L, the source water is considered to be unlimited for either nitrogen or phosphorus.

Centric diatom Diatoms are photosynthetic algae that have a siliceous skeleton (frustule) found in almost every aquatic environment including fresh and marine waters, as well as moist soils. Centric diatoms are circular in shape and are often found in the water column.

Chlorophyll *a* Chlorophyll *a* is an algal pigment that is used as an approximate measure of algal biomass. The concentration of chlorophyll *a* is used in the calculation of the NCTSI, and the value listed is a lake-wide average from all sampling locations.

Clinograde In productive lakes where oxygen levels drop to zero in the lower waters near the bottom, the graphed changes in oxygen from the surface to the lake bottom produces a curve known as clinograde curve.

Coccoid Round or spherical shaped cell

Conductivity This is a measure of the ability of water to conduct an electrical current. This measure increases as water becomes more mineralized. The concentrations listed are the range of values observed in surface readings from the sampling locations.

Dissolved oxygen A measurement of oxygen concentrations found at the sampling locations.

Dissolved oxygen saturation The capacity of water to absorb oxygen gas. Often expressed as a percentage, the amount of oxygen that can dissolve into water will change depending on a number of parameters, the most important being temperature. Dissolved oxygen saturation is inversely proportion to temperature, that is, as temperature increases, water's capacity for oxygen will decrease, and vice versa.

Eutrophic Describes a lake with high biological productivity and low water transparency.

Eutrophication	The process of physical, chemical, and biological changes associated with nutrient, organic matter, and silt enrichment and sedimentation of a lake.
Limiting nutrient	The plant nutrient present in lowest concentration relative to need limits growth such that addition of the limiting nutrient will stimulate additional growth. In northern temperate lakes, phosphorus (P) is commonly the limiting nutrient for algal growth
Manganese	A naturally occurring metal commonly found in soils and organic matter. As a trace nutrient, manganese is essential to all forms of biological life. Manganese in lakes is released from bottom sediments and enters the water column when the oxygen concentration in the water near the lake bottom is extremely low or absent. Manganese in lake water may cause taste and odor problems in drinking water and require additional treatment of the raw water at water treatment facilities to alleviate this problem.
Mesotrophic	Describes a lake with moderate biological productivity and water transparency
NCTSI	North Carolina Trophic State Index was specifically developed for North Carolina lakes as part of the state's original Clean Lakes Classification Survey (NRCD 1982). It takes the nutrients present along with chlorophyll *a* and Secchi depth to calculate a lake's biological productivity.
Oligotrophic	Describes a lake with low biological productivity and high water transparency.
pH	The range of surface pH readings found at the sampling locations. This value is used to express the relative acidity or alkalinity of water.
Photic zone	The portion of the water column in which there is sufficient light for algal growth. DWR considers 2 times the Secchi depth as depicting the photic zone.
Secchi depth	This is a measure of water transparency expressed in meters. This parameter is used in the calculation of the NCTSI value for the lake. The depth listed is an average value from all sampling locations in the lake.
Temperature	The range of surface temperatures found at the sampling locations.
Total Kjeldahl nitrogen	The sum of organic nitrogen and ammonia in a water body. High measurements of TKN typically results from sewage and manure discharges in water bodies.
Total organic nitrogen (TON)	Total Organic Nitrogen (TON) can represent a major reservoir of nitrogen in aquatic systems during summer months. Similar to phosphorus, this concentration can be related to lake productivity and is used in the calculation of the NCTSI. The concentration listed is a lake-wide average from all sampling stations and is calculated by subtracting Ammonia concentrations from TKN concentrations.
Total phosphorus (TP)	Total phosphorus (TP) includes all forms of phosphorus that occur in water. This nutrient is essential for the growth of aquatic plants and is often the nutrient that limits the growth of phytoplankton. It is used to calculate the NCTSI. The concentration listed is a lake-wide average from all sampling stations.
Trophic state	This is a relative description of the biological productivity of a lake based on the calculated NCTSI value. Trophic states may range from extremely productive (Hypereutrophic) to very low productivity (Oligotrophic).
Turbidity	A measure of the ability of light to pass through a volume of water. Turbidity may be influenced by suspended sediment and/or algae in the water.
Watershed	A drainage area in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Overview

The Pasquotank River Basin consists of 3,697 square miles of flat lands and vast open waters of the northeastern portion of the state. The Pasquotank River is freshwater upstream of Elizabeth City and becomes brackish and tidally influenced downstream. The Alligator River near Lake Phelps is a large blackwater river that is designated as an Outstanding Resource Water. The Alligator National Wildlife Refuge extends along the entire eastern shore of the Alligator River. Lake Phelps is owned by the NC State Parks and is also designated as an Outstanding Resource Water. The lake shore of Lake Phelps consist of wooded swampland transitioning to agricultural land.

A statewide fish consumption advisory from the North Carolina Department of Health and Human Resources, Division of Public Health is in place due to mercury contamination (http://epi.publichealth.nc.gov/oee/programs/fish.html.) Fish such as blackfish (bowfin), largemouth bass and chained pickerel (jack fish) have been found to have high mercury levels.

Assessment Methodology

For this report, data from January 1, 2011 through December 31, 2015 were reviewed. Lake monitoring and sample collection activities performed by DWR field staff are in accordance with the Intensive Survey Unit Standard Operating Procedures Manual (http://portal.ncdenr.org/c/document_library/get_file?uuid=522a90a4-b593-426f-8c11-21a35569dfd8&groupId=38364) An interactive map of the state showing the locations of lake sites sampled by DWR may be found at http://portal.ncdenr.org/web/wq/ambient-lakes-map.

All lakes were sampled during the growing season from May through September. Data were assessed for excursions of the state's Class C water quality standards for chlorophyll *a*, pH, dissolved oxygen, water temperature, turbidity, and surface metals. Other parameters discussed in this report include Secchi depth and percent dissolved oxygen saturation. Secchi depth provides a measure of water clarity and is used in calculating the trophic or nutrient enriched status of a lake. Percent dissolved oxygen saturation gives information on the amount of dissolved oxygen in the water column and may be increased by photosynthesis or depressed by oxygen-consuming decomposition.

For algae collection and assessment, water samples are collected from the photic zone, preserved in the field and taken concurrently with chemical and physical parameters. Samples were quantitatively analyzed to determine assemblage structure, density (units/ml) and biovolume (m^3/mm^3).

Additional data considered as part of the use support assessment include historic DWR water quality data, documented algal blooms and/or fish kills, problematic aquatic macrophytes, or listing on the EPA's 303(d) List of Impaired Waters.

For a more complete discussion of lake ecology and assessment, please go to http://portal.ncdenr.org/web/wq/ess/isu. The 1992 North Carolina Lake Assessment Report (downloadable from this website) contains a detailed chapter on ecological concepts that clarifies how the parameters discussed in this review relate to water quality and reservoir health.

Quality Assurance of Field and Laboratory Lakes Data

Data collected in the field via multiparameter water quality meters are uploaded into the Ambient Lakes Database within 24 hours of the sampling date. These data are then reviewed for accuracy and completeness within a week of entry. Data that have not been reviewed are given a 'P' code for

'Provisional' (data has been entered but not been verified for accuracy and/or completeness). Data that have been verified are given an 'A' code for 'Accepted'.

Chemistry data from the DWR Water Quality Laboratory are uploaded into the Lakes Database. As with the field data, laboratory results are coded 'P' until the entered data is verified for entry accuracy and completeness, after which, the code is changed to 'A'. Generally, laboratory data entered into the Lakes Database are verified within a week following the initial entry. Data, either laboratory or field, which appear to be out of range for the lake sampled are double checked against field sheets or the laboratory results by the Lakes Data Administrator for possible data entry error. If there are data entry mistakes, possible equipment, sampling, and/or analysis errors, these are investigated and corrected if possible. If the possible source of an error cannot be determined, the data remains in the database. If an error is determined, the data value is removed from the appropriate database parameter field and placed in the 'Notes' field along with a comment regarding the error. Chemistry results received from the laboratory that are given a qualification code are entered along with the assigned laboratory code.

Additional information regarding the Quality Assurance Program is covered in the Ambient Lake Monitoring Program Quality Assurance Plan. Version 2.0 (March 28, 2014) of this document is available on the ISB website (http://portal.ncdenr.org/web/wq/ess/isu).

LAKE & RESERVOIR ASSESSMENTS

HUC 03010205

Lake Phelps

Ambient Lakes Program Name	Lake Phelps		
Trophic Status (NC TSI)	Oligotrophic		
Mean Depth (meters)	2.0		
Volume ($10^6 m^3$)	98.7		
Watershed Area (mi^2)	n/a		
Classification	B Sw ORW		
Station	PAS012B	PAS012C	PAS012D
Number of Times Sampled	5	5	5

Lake Phelps, the second largest natural lake in North Carolina, is located in the eastern part of the state in Washington and Tyrrell Counties. It lies on a vast peninsula between Albemarle Sound on the north and the Pamlico River on the south. This peninsula contains numerous low-lying swampy areas underlain by thick organic muck and relatively well-drained areas with fertile mineral and organic soils. Much of the region has been cleared of vegetation, drained, and put into large scale agricultural use Lake Phelps is recharged by natural precipitation with a small fraction coming from underground aquifers. There is no known overland flow into the lake as it occupies the highest elevation in the area. Lake Phelps has an average retention time of 1161 days, and, because of its shallow depth and wind mixing, the water column does not stratify. Lake Phelps is a Carolina Bay Lake. These lakes are characteristically shallow, oval in shape with a northwest to southeast orientation and have low pH waters that are usually tea-colored from tannins leached from underlying peat beds.

Lake Phelps is owned by the State of North Carolina and is associated with Pettigrew State Park and is used for recreational activities such as fishing and boating. Lake Phelps is unique in that it is inhabited by *Myriophyllum tenellum*, a species of milfoil not previously found south of New Jersey. The lake currently supports a high quality fishery of largemouth bass, yellow perch, and sunfishes. Historically, Lake Phelps has been used as a water source for fighting local peat fires in the immediate region.

Lake Phelps was monitored five times in 2015 by DEQ field staff. Nutrient concentrations and chlorophyll *a* values were similar to those previously observed for this lake (Table 1). Secchi depths were generally greater than one meter, indicating that the clarity of the water was very good and agreed with the low turbidity values that were measured each month the lake was monitored. Overall, chemical and physical characteristics of Lake Phelps remained consistent with those previously observed by DEQ staff.

The water in Lake Phelps is clearer than that of typical Carolina Bay Lakes, which allows for more accurate Secchi depth measurements and calculation of NC Trophic State Index Score (NCTSI). In 2015, the trophic status of this lake was oligotrophic (demonstrated very low biological productivity) in May, June, August and September. In July, the trophic state was mesotrophic (moderate biological

productivity). Calculated NCTSI scores from previous monitoring efforts by DEQ field staff have indicated similar shifts between oligotrophic and mesotrophic conditions in Lake Phelps beginning in 1981 when this lake was first monitored.

Table 1. Water Quality Data for Phelps Lake, Pasquotank River Basin.

	SURFACE PHYSICAL DATA							PHOTIC ZONE DATA									Total	
			Water			Secchi										Solids	Solids	
Date	Sampling	DO	Temp.	pH	Cond.	Depth	Percent	TP	TKN	NH3	NOx	TN	TON	TIN	Chla	Total	Suspended	Turbidity
m/d/yr	Station	mg/L	C	s.u.	µmhos/cm	meters	SAT	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	NTU
HUC 03050105																		
May 13, 2015	PAS012B	8.4	24.3	5.3	92	2.0	100.4%	<0.02	0.26	0.02	<0.02	0.27	0.24	0.03	1.8	71	<6.2	3.3
May 13, 2015	PAS012C	8.4	24.2	5.7	94	1.8	100.2%	0.02	0.27	0.03	<0.02	0.28	0.24	0.04	2.4	68	<6.2	6.6
May 13, 2015	PAS012D	8.3	24.3	5.4	93	0.8	99.2%	0.03	0.32	0.03	0.02	0.34	0.29	0.05	4.5	74	16.0	13.0
June 8, 2015	PAS012B	8.2	25.0	5.5	94	2.0	98.7%	<0.02	0.31	0.02	<0.02	0.32	0.29	0.03	3.2	63	<6.2	3.4
June 8, 2015	PAS012C	8.2	25.1	5.3	93	1.8	99.9%	<0.02	<0.30	<0.02	<0.02	0.16	0.14	0.02	2.5	57	<6.2	2.7
June 8, 2015	PAS012D	8.1	25.3	5.3	93	1.6	98.0%	<0.02	<0.30	0.02	<0.02	0.16	0.13	0.03	3.8	67		6.0
July 13, 2015	PAS012B	7.4	28.3	5.6	93	1.8	95.1%	<0.02	0.21	0.02	<0.02	0.22	0.19	0.03	3.2	59	<6.2	3.8
July 13, 2015	PAS012C	7.6	28.3	5.4	93	1.3	97.6%	0.03	0.22	0.02	<0.02	0.23	0.20	0.03	4.4	60	<6.2	3.5
July 13, 2015	PAS012D	7.2	28.3	5.5	93	1.1	92.5%	0.03	0.28	0.02	<0.02	0.29	0.26	0.03	6.1	64	11.0	8.4
August 5, 2015	PAS012B	7.3	29.6	5.8	100	1.6	95.9%	<0.02	0.22	<0.02	<0.02	0.23	0.21	0.02	3.1	69		2.3
August 5, 2015	PAS012C	7.6	29.7	5.7	98	1.4	100.1%	<0.02	0.20	<0.02	<0.02	0.21	0.19	0.02	6.0	69	<6.2	2.2
August 5, 2015	PAS012D	7.5	29.7	5.4	99	1.2	98.7%	0.02	0.21	<0.02	<0.02	0.22	0.20	0.02	3.5	74	3.5	7.8
September 15, 2015	PAS012B	8.0	24.5	5.8	93	1.8	96.0%	<0.02	0.27	0.01	0.01	0.28	0.26	0.02	2.4	61		1.9
September 15, 2015	PAS012C	8.4	23.9	5.6	94	1.7	99.6%	<0.02	0.26	0.01	0.01	0.27	0.25	0.02	1.8	62	<6.2	1.9
September 15, 2015	PAS012D	8.0	24.3	5.8	94	2.1	95.6%	<0.02	0.23	0.01	0.01	0.24	0.22	0.02	2.6	68	<6.2	3.3