Water Quality Analysis of Eutrophication for Lake Habeeb, Allegany County, Maryland

FINAL

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List of Abbreviations

^{O}C	Degrees Celsius
Chl a	Chlorophyll *a*
COMAR	Code of Maryland Regulation
CWA	Clean Water Act
DO	Dissolved Oxygen
Km	Kilometers
m	Meters
MDE	Maryland Department of the Environment
MDDNR	Maryland Department of Natural Resources
mg/l	Milligrams Per Liter
mi^2	Square miles
NPDES	National Pollutant Discharge Elimination System
T	Temperature
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSI	Trophic State Index
USEPA	U.S. Environmental Protection Agency
μg/l	Micrograms Per Liter
USGS	United States Geological Survey
WQLS	Water Quality Limited Segment

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency (USEPA)'s implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

Lake Habeeb (AU-ID: MD-021410020107-Lake_Habeeb) is located in the Evitts Creek watershed (basin code 02141002). The lake was first identified as impaired by nutrients on the State's List of WQLSs (1998) based on sampling in 1993 that found dissolved oxygen (DO) concentrations below the State's numeric criteria of 5.0 mg/L in deeper layers of the lake. Low DO concentrations are typical at lower depths in thermally stratified waters, such as Lake Habeeb, and Maryland's water quality standards have historically allowed for excursions below the DO criteria due to natural conditions. Based on Maryland's interpretation of this narrative criteria, however, the DO levels were deemed to be depleted beyond what would be expected from natural conditions, and a TMDL for Phosphorus in Lake Habeeb was submitted to the USEPA and approved in 2000.

Since the approval of the 2000 TMDL, Maryland has refined its interpretation of the natural conditions clause based on an improved understanding of oxygen depletion in stratified lakes. The current guidelines are laid out in the 2014 Integrated Report of Surface Water Quality. Based on these updated guidelines, and using data from a rigorous monitoring program in 2014, MDE has revisited the assessment of the lake.

The analysis shows the DO criteria, as well as the chlorophyll a criteria for drinking water impoundments, are all being achieved, and that the designated use of the lake is supported. The results of this analysis support the conclusion that a TMDL for nutrients is not necessary to achieve water quality standards. Therefore, the previously developed TMDL will be withdrawn. Any TMDLs for downstream waters or streams within the Lake Habeeb watershed, such as the 2007 TMDL for sediment in the Evitts Creek watershed, will remain in effect.

Barring any contradictory future data, this report will be used as supporting material when the Maryland Department of the Environment (MDE) proposes the revision of Maryland's Integrated Report of Surface Water Quality for public review. Although the waters of Lake Habeeb do not display signs of eutrophication, the State reserves the right to require future controls in the Lake Habeeb watershed if evidence suggests nutrients from the basin are contributing to downstream water quality problems.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency (EPA)'s implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

In addition to the successful implementation of a TMDL, there are four other scenarios that may be used to address an impaired waterbody: 1) more recent data indicate that the impairment no longer exists (*i.e.*, water quality standards are being met); 2) more recent and updated water quality modeling demonstrates that the segment is now attaining standards; 3) refinements have been made to water quality standards, or the interpretation of those standards, which result in standards being met; or 4) errors made in the initial listing have been corrected.

Lake Habeeb (AU-ID: MD-021410020107-Lake_Habeeb) is located in the Evitts Creek watershed (basin code 02141002). The lake was first identified as impaired by nutrients on the State's List of WQLSs (1998) based on sampling in 1993 that found dissolved oxygen (DO) concentrations below the State's numeric criteria of 5.0 mg/L in deeper layers of the lake. Low DO concentrations are typical at lower depths in thermally stratified waters, such as Lake Habeeb, and Maryland's water quality standards have historically allowed for excursions below the DO criteria due to natural conditions. Based on Maryland's interpretation of this narrative criteria, however, the DO levels were deemed to be depleted beyond what would be expected from natural conditions, and a TMDL for Phosphorus in Lake Habeeb was submitted to the USEPA and approved in 2000.

Since the approval of the 2000 TMDL, Maryland has refined its interpretation of the natural conditions clause based on an improved understanding of oxygen depletion in stratified lakes. The current guidelines are laid out in the 2014 Integrated Report of Surface Water Quality. Based on these updated guidelines, and using data from a rigorous monitoring program in 2014, MDE has revisited the assessment of the lake.

An analysis of 2014 monitoring data for Lake Habeeb shows that the criteria associated with nutrients are being met, and its designated uses are supported. Based on this analysis, the conditions of scenario one, described above, are fully met. Additionally, the initial listing was based on the occurrence of low hypolimnetic DO, but this analysis demonstrates that this condition in Lake Habeeb is due to thermal stratification, a natural process in lakes. As stated above, MDE developed guidance on interpreting the standards for lakes where thermal stratification occurs. Based on this guidance, the low DO concentrations in the lake can be attributed to natural conditions, rather than an impairment, meaning that the third scenario also applies.

The remainder of this report lays out the general setting of the waterbody within the Lake Habeeb watershed, presents a discussion of the observed water quality in the lake, and provides conclusions with regard to those characteristics and the current standards. This water quality analysis (WQA) establishes that Lake Habeeb is achieving water quality standards; therefore, the previously developed TMDL will be withdrawn. Because Lake Habeeb is located in the Evitts Creek watershed, the 2007 sediment TMDL for Evitts Creek will continue to apply to Lake Habeeb, as will any other TMDLs developed for Evitts Creek.

2.0 GENERAL SETTING

Lake Habeeb is an impoundment located in Rocky Gap State Park, in Allegany County, Maryland (Figure 1). The surface area of the lake is 243 acres (0.38 mi^2)(MDDNR 2016). The lake lies in a valley between Evitts and Martin Mountains. The impoundment, which is owned by Maryland Department of Natural Resources (MDDNR), lies on Rocky Gap Run, a tributary of the Evitts Creek. An earthen dam was installed for the purpose of recreational uses in 1969. Rocky Gap State Park has swimming, hunting, camping, boat launching facilities, and is home to panfish, trout, catfish and large and smallmouth bass. Brown trout and rainbow trout are stocked throughout the year (MDDNR 2015). A major resort and conference center has been constructed at the south end of the lake, including a Jack Nicklaus signature golf course. Drinking water for the resort and campground is withdrawn from the lake and treated at a newly-constructed plant.

The Lake Habeeb watershed sits on the Allegheny Plateau. The watershed area is 9.5 mi^2, of which 45% (4.3 mi^2), the downstream portion containing Lake Habeeb, lies in Maryland. The remainder is in Pennsylvania. Evitts Mountain is located west of the watershed and Martin Mountain lies east of the watershed. Soils are formed in material weathered from limestone, sandstone, shale and siltstone. The soils in the watershed are in the Elliber-Dekalb-Opequon Association. The Elliber soils are on the top and sides of the ridges and are deep over cherty limestone, and contain large quantities of chert fragments. The Dekalb soils are moderately deep over sandstone and are typically very stony. The Opequon soils are usually situated on the sides of the limestone ridges (U.S. Department of Agriculture 1977).

Inflow to the lake is primarily via Rocky Gap Run and two unnamed tributaries flowing down from the mountains. Discharge from the lake is to the lower portion of Rocky Gap Run which eventually flows into Evitts Creek. The watershed map (Figure 2) shows the land use distribution in the watershed draining to Lake Habeeb. Land use distribution in the watershed is approximately 82% forested/herbaceous, 6% developed, 8% agricultural and 4% water.

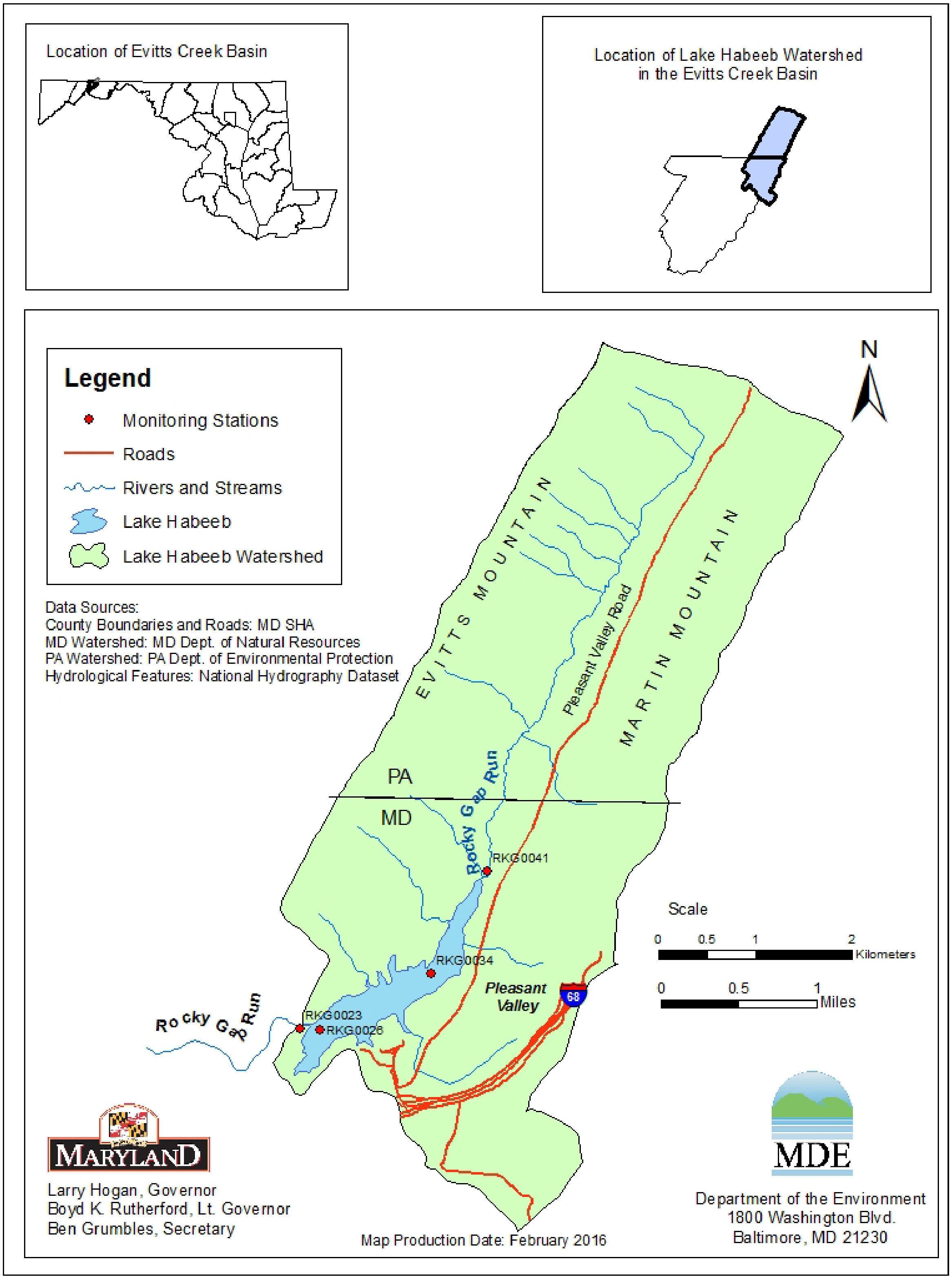

Figure 1: Location Map of Lake Habeeb in the Evitts Creek Watershed

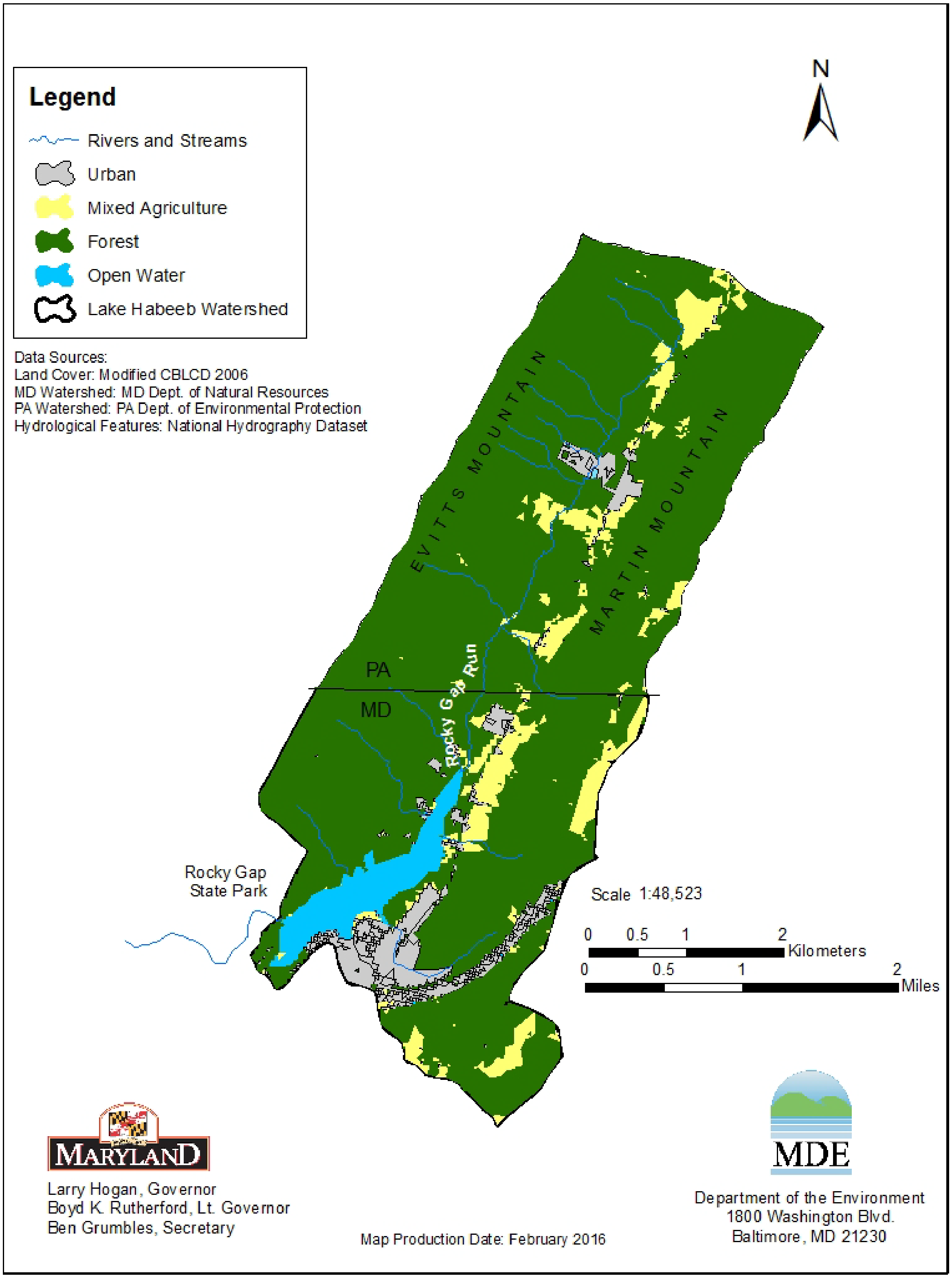

Figure 2: Land Use Distribution within the Lake Habeeb Watershed

3.0 WATER QUALITY CHARACTERIZATION

A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

Maryland's non-tidal water quality standards provide for a minimum dissolved oxygen (DO) criterion of 5.0 mg/l for all waters at all times (Code of Maryland Regulations [COMAR] 2015b) except as resulting from natural conditions (COMAR 2015c). Bottom waters in thermally stratified lakes may naturally become depleted of DO during periods of stratification (Wetzel 2001). The Maryland Surface Water Use Designation (COMAR 2015a) for Lake Habeeb is Use Class III-P: Non-Tidal Cold Water and Public Water Supply. The applicable water quality criteria for Use Class III-P waters are presented below in Table 1.

Table 1: Water Quality Criteria applicable to Use III-P Drinking Water Reservoirs (COMAR 2015b, c)

Parameter	Criterion	Assessment Type	Applicability
Dissolved Oxygen (DO)	5.0 mg/l	Instantaneous minimum[1]	All waters of the state
	6.0 mg/l	Minimum daily average[1]	Non-Tidal Cold Water and Public Water Supply
Chlorophyll *a* (Chl a)	10 µg/l	Maximum 30-day moving average during growing season[2]	Drinking water reservoirs
	30 µg/l	Maximum 90th-percentile of measurements taken during growing season[2]	Drinking water reservoirs

[1] Except where lower DO concentrations result from natural conditions

[2] Growing season is defined as the period from May 1 to September 30

All of Maryland's water-supply reservoirs undergo periods of seasonal thermal stratification similar to that in Chesapeake Bay. Thermal stratification is a seasonal phenomenon resulting from the lower density of warm surface waters, beginning in late spring or early summer, intensifying as summer progresses, decreasing in early fall, and finally ending with the fall turnover, as the lake becomes thermally uniform with depth. As a result of this process, data from May or June will generally show less stratification and higher DO levels in deeper portions of the lake than data from August and September. In the absence of a standard, specifically addressing stratified lakes, MDE published the following guidelines in 2012 for interpreting the DO and chlorophyll *a* criteria in Maryland's seasonally stratified water-supply reservoirs:

- A minimum dissolved oxygen concentration of 5.0 mg/l will be maintained in the surface layer at all times, including during periods of thermal stratification, except during periods of overturn or other naturally-occurring disruption of stratification. Surface layer calculated using the relative thermal resistance to mixing (RTRM) method (Kortmann 2016).

- A minimum dissolved oxygen concentration of 5.0 mg/l will be maintained throughout the water column during periods of complete and stable mixing.

- Hypolimnetic hypoxia will be addressed on a case-by-case basis. In the event of hypoxia observed in the deeper portions of lakes during stratification, Maryland will conduct an analysis to determine if current loading conditions result in a degree of hypoxia that significantly exceeds (in terms of frequency, magnitude and duration) that associated with natural conditions in the lake and its watershed. This analysis may vary from one lake to another in terms of type, approach and scope. Examples may include a review of setting, source assessment and land use, so as to assess current loads; a comparison of estimated current loads exported from the watershed with analogous load estimates under ‘natural’ land cover; and model scenario runs simulating natural conditions. This list is not exhaustive, and Maryland expressly reserves the right to determine and conduct the most appropriate type of analysis on a case-by-case basis.

On Maryland’s 1998 list of WQLS, Lake Habeeb was identified as impaired by nutrients on the basis of seasonally low oxygen levels in the deeper portions of the lake (MDE 2014). At the time, the hypoxic conditions were considered to be a result of accelerated eutrophication due to nutrient from unspecified nonpoint source runoff (MDDNR 1998).

All readily available water quality data pertaining to Lake Habeeb were considered for this WQA. Water quality data from MDE surveys conducted biweekly at two stations within Lake Habeeb from April to October in 2014 were used to perform this analysis. This timespan encompasses the period of thermal stratification, a critical condition for Lake Habeeb. Physical water quality parameters were assessed at both of the stations at various depths. Station RKG0026 lies approximately in the deepest part of the lake and is representative of conditions at various depths throughout the lake. Nutrient and chlorophyll data were collected at both of the stations. Water quality data were also collected at Station RKG0041. This station is located in a small stream that flows into Lake Habeeb, not the lake itself, and it was not included in this analysis.

3.1 Dissolved Oxygen

3.1.1 Thermally Stratified Period

During the 2014 sampling period, DO concentrations measured at the surface (0.3 m depth) ranged from 7.9 to 11.2 mg/l. DO concentrations of 0 mg/l were observed in the hypolimnion. Figure 3 depicts a depth profile of temperature and DO at Station RKG0026 on August 12, 2014. These conditions are representative of maximum thermal stratification throughout the depth profile of the lake. Both temperature and DO decline nonlinearly with depth, with a rapid decrease occurring between a depth of 4 m to 10 m. This layer of rapid temperature change with depth, known as the metalimnion is indicative of a thermally stratified lake. Above the metalimnion, in the epilimnion, both temperature and DO are relatively uniform, ranging from

23.7 to 24.6 ^{O}C and 8.4 to 8.5 mg/l, respectively. Below 10 m, in the hypolimnion, these two parameters decrease more gradually, ranging from 7.6 to 8.8 ^{O}C and 0.2 to 1.3 mg/l, respectively. Within the metalimnion, temperature drops from 16.6 to 9.4 ^{O}C, and DO decreases from 4.5 to 2.2 mg/l. The temperature profile indicates a strong thermal stratification, which occurs naturally in many lakes and is often associated with natural hypolimnetic DO depletion. Tabular data are presented in Table A-1. Additional depth profiles are presented in Appendix B.

The guidance for interpreting water quality criteria in a thermally-stratified impoundment specifies that a minimum DO concentration of 5.0 mg/l must be maintained in the surface layer at all times. The epilimnion was calculated using the relative thermal resistance to mixing (RTRM) (Kortmann 2016). The lowest DO concentration measured in the epilimnion was 6.0 mg/l on September 30, 2014 at station RKG0034, meaning that DO levels were within water quality standards throughout the year. Furthermore, since the lowest observed concentration within the surface layer was equal to the minimum daily average standard of 6.0 mg/l, the data indicate that water quality standard was not exceeded in the epilimnion.

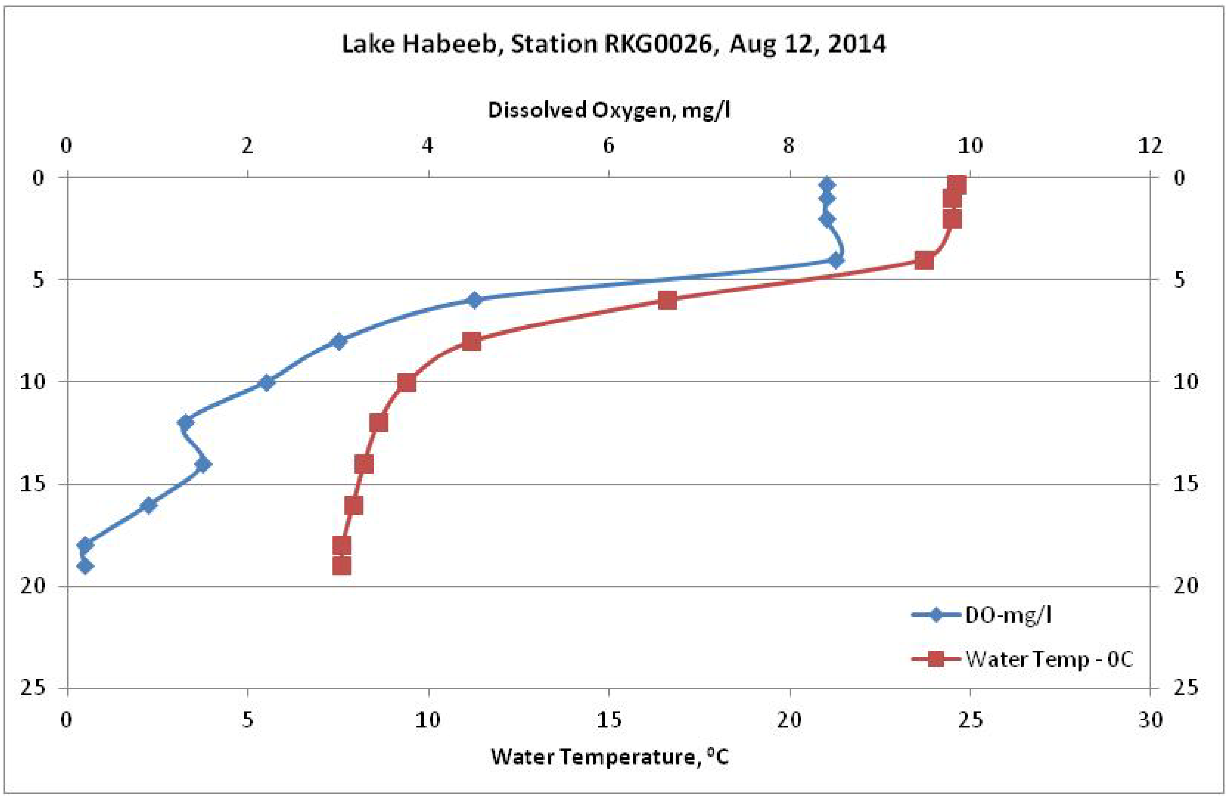

Figure 3: Depth Profile of Temperature and Dissolved Oxygen, Lake Habeeb.

3.1.2 Stable Mixing Periods

The guidance also specifies that a minimum DO concentration of 5.0 mg/l must be maintained during periods of complete and stable mixing. Lake Habeeb is dimictic, meaning that the surface and bottom waters mix twice a year, first during the spring and again in the fall. Spring sampling of the lake began in on April 16, 2014, at which point, a well-developed thermocline was observed at both stations. Measured DO concentrations at both stations did not vary significantly with depth, and the results were all within a narrow concentration range of 10.8 to 11.3 mg/l. This relatively even spatial distribution of DO concentrations, all above 10.8 mg/l, points to a lake that was well above 5.0 mg/l throughout its depth profile during the period of spring mixing.

The fall turnover occurred in October and monitoring results at station RKG0034 showed that the water column at this station became mixed between October 7, and October 21, 2014. Over that two-week period, the DO concentrations at the bottom of the lake increased from 0.0 to 8.9 mg/l. On October 21, as depicted in Figure 4, the water column profile showed little temperature or DO variation through the profile, with a minimum DO concentration of 8.5 mg/l. This was well above 5.0 mg/L, indicating that the minimum DO requirement was met during the period of complete mixing.

The water column profile at station RKG0026 was still thermally stratified on October 21, the last monitoring date. The minimum DO concentration in the epilimnion recorded at this date was 7.9 mg/L, well above the minimum DO standard. Based on this result, along with the relatively high DO readings from RKG0034 during turnover, it is anticipated that DO concentrations in the lake will not be below 5.0 mg/l during the period of fall mixing.

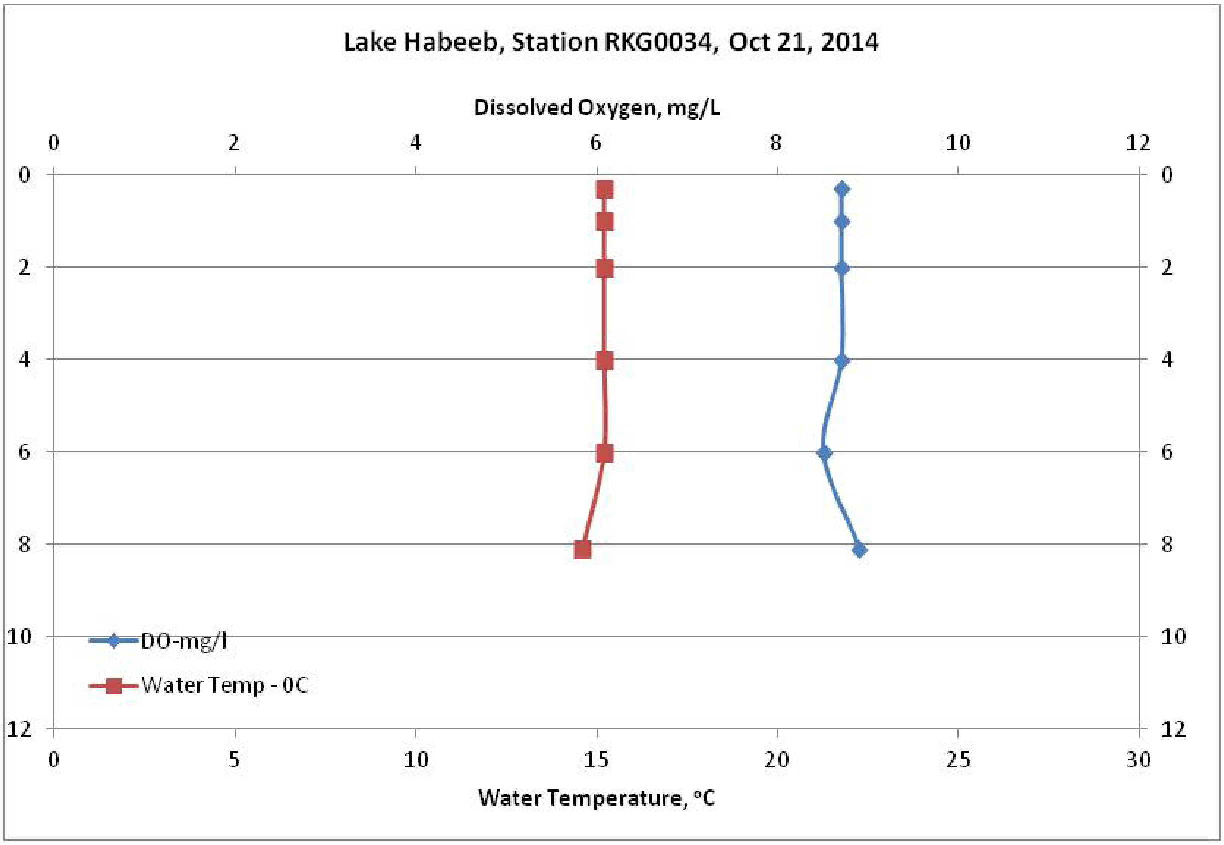

Figure 4: Depth Profile of Temperature and Dissolved Oxygen, Lake Habeeb.

3.2 Chlorophyll *a*

On each sampling date, chlorophyll *a* data were collected at a depth of 0.3 m at both stations in the lake. Chlorophyll *a* concentrations are typically at their peak in lakes during the April to October period when the monitoring was conducted. Observed chlorophyll *a* concentrations were low, ranging from 0.80 to 3.63μg/l, all well below both the 10μg/l moving average and 30μg/l 90th percentile water quality criteria for drinking water reservoirs during the growing season.

3.3 Current Loading Conditions and Hypoxia

Maryland's guidelines for interpreting DO and chlorophyll *a* criteria in a seasonally stratified water-supply reservoir also require an analysis showing that the loading conditions in the lake do not significantly exceed natural loading conditions.

3.3.1 Land Cover Analysis

Although Lake Habeeb is the result of a man-made alteration to the landscape, in this case a dam, it is possible to describe a natural loading condition. In the case of the Lake Habeeb watershed, which sits entirely in the Ridge and Valley physiographic region of Maryland, it would typically be almost entirely covered by forest.

As described in Section 2.0 of this report, the watershed is 82% forest. An analysis of 2014 land cover estimates from the Chesapeake Bay Watershed Model indicate that the Maryland is 49% forested, meaning that the Lake Habeeb watershed has significantly less anthropogenic disturbance than most of the State. Of the remaining non-forested land in the Lake Habeeb watershed, nearly a quarter is covered by the lake itself, and the remainder is comprised of developed and agricultural land running along the floor of the valley. In addition, there is only one National Pollutant Discharge Elimination System (NPDES) regulated point source in the watershed, the Rocky Gap Water Treatment Plant (PADEP 2016). The plant withdraws water from Lake Habeeb and does not contribute phosphorus, so it is not anticipated to be a phosphorus source. The absence of point sources, additions of phosphorus, combined with the high quantity of forest coverage in this watershed, means that there are few potential anthropogenic sources of nutrients into Lake Habeeb.

3.3.2 Trophic State

In addition to showing that there are few potential sources of nutrients to the lake, the conditions within the lake itself can be used to demonstrate that loadings of nutrients are not excessive. Lakes are commonly classified according to their trophic state, a term that describes how 'green' the lake is measured by the amount of algae biomass in the water. Three trophic state categories are used to describe lakes as they grow progressively greener: oligotrophic, mesotrophic and eutrophic (Brown and Simpson 2001). The Carlson Trophic State Index (TSI) is a common method for examining algal biomass as it relates to trophic state using any of three variables: chlorophyll *a*, total phosphorus (TP) or secchi depth. When classifying lakes, priority is often given to the TSI value associated with chlorophyll, since it is the most accurate of the three parameters for predicting algal biomass. TSI values greater than 50 are generally defined as eutrophic. (Brown and Simpson 2001).

Eutrophication is the over-enrichment of aquatic systems from excessive nutrient inputs, typically nitrogen, phosphorus or both. The nutrients act as a fertilizer leading to excessive growth of algae. The algae grow rapidly, die and are subsequently consumed by bacteria. The bacterial consumption of algae uses the available oxygen in the water column, which produces hypoxic (low DO) or anoxic (no DO) conditions. Problems associated with eutrophication are most likely to occur during the growing season, defined in Maryland as May 1 to October 31. The two key water quality parameters associated with eutrophication are chlorophyll *a* and DO.

During the sampling period, the TSI range based on the peak chlorophyll *a* data for the two stations used in the analysis was 28 to 43. Using the total phosphorus (TP) concentrations data, the TSI range was 20 to 35. Based on both ranges, the lake is within the mesotrophic region and well below the mesotrophic-eutrophic threshold at which the lake might be considered impaired. These results suggest that there is no excessive input of nutrients to Lake Habeeb which might be responsible for the observed hypolimnetic hypoxia. See Appendix C for details about the TSI calculation. Tabular data used in this calculation are presented in Appendix A.

Figure 5 displays a summer depth profile of temperature and dissolved oxygen. As shown in the figure, there is a dissolved oxygen peak at 4 meters in the metalimnion. This demonstrates there is good DO, clarity and algal activity. A depth profile such as this would not occur if the lake was eutrophic. There would be reduced clarity and the DO max would occur in the surface layer.

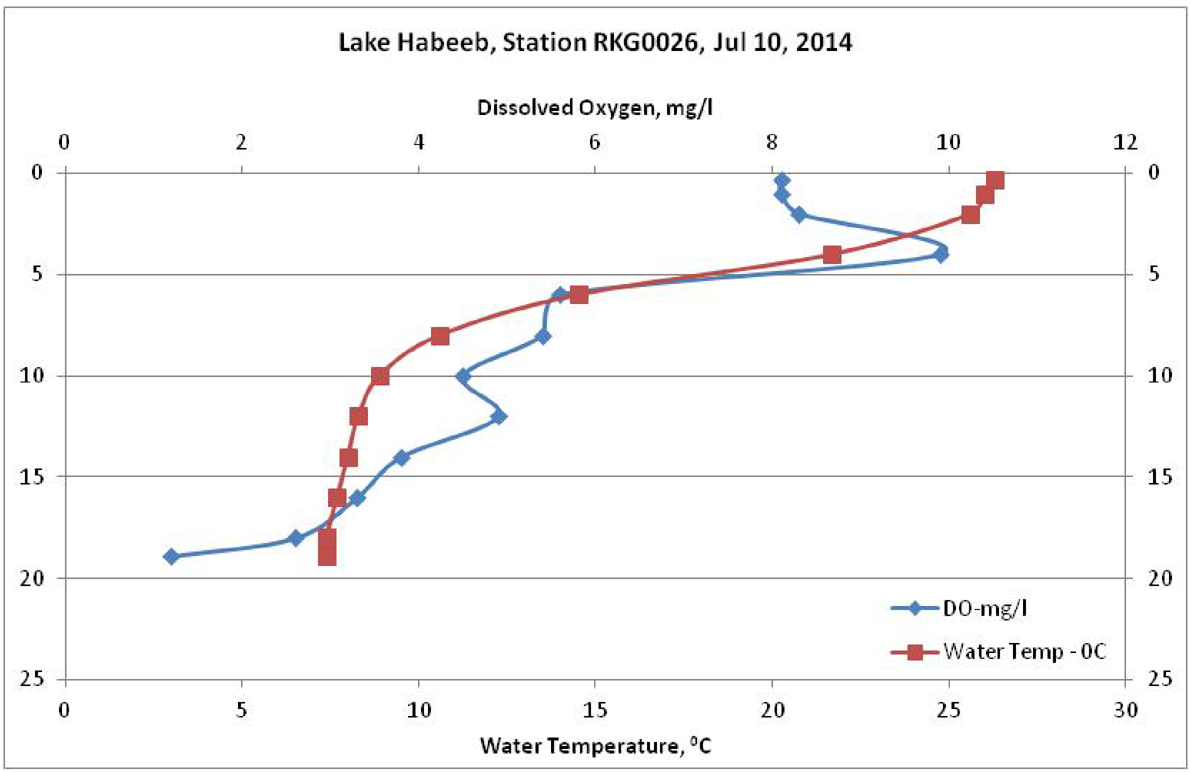

Figure 5: Depth Profile of Temperature and Dissolved Oxygen, Lake Habeeb.

4.0 CONCLUSION

The data presented in this analysis demonstrate that water quality standards are being met in Lake Habeeb. Based on the surveys conducted during 2014, the water quality data indicate that Lake Habeeb has no eutrophication-related water quality impairments. Excessive algal growth does not exist, as indicated by the low observed chlorophyll *a* concentrations. DO levels in the epilimnion remained at acceptable levels throughout the sampling period.

The hypolimnetic hypoxia observed during the summer and fall appears to be the result of natural conditions rather than anthropogenic inputs of nutrients to the lake. Measurements of TP and chlorophyll *a* levels are consistent in providing a trophic state assessment in the oligotrophic to mesotrophic range, which is compatible with the lake's designated use. Furthermore, more than 80% of the watershed is forested, with a small amount (6%) of urban land and agricultural land (8%), and the one NPDES-permitted discharger in the watershed is not considered to add phosphorus to the lake. These details indicate few significant potential sources of anthropogenic nutrient loads. Even under natural conditions, hypolimnetic hypoxia during periods of thermal stratification, would be expected to occur in Lake Habeeb.

Barring any contradictory future data, the analysis provides sufficient justification to remove nutrients as an impairing substance in relation to Lake Habeeb. Water quality standards are being achieved in Lake Habeeb and therefore, a TMDL is unnecessary and the previously developed TMDL will be withdrawn.

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Appendix A: Tabular Water Quality Data

Table A-1: DO and water temperature profile Data at Lake Habeeb (Physical and Chemical Water Quality Data at Lake Habeeb)

Sampling Station ID	Date sampling	Depth-M	Water Temp – ^{O}C	DO-mg/l	Conductivity Micromhos/cm	Turbidity-NTU
RKG0026	4/16/2014	0.3	10.5	11.2	96.0	4.2
RKG0026	4/16/2014	1	10.4	11.2	96.0	4.2
RKG0026	4/16/2014	2	10.2	11.2	96.0	4.3
RKG0026	4/16/2014	4	9.0	11.3	96.0	4.4
RKG0026	4/16/2014	6	9.1	11.2	96.0	4.5
RKG0026	4/16/2014	8	7.0	11.3	96.0	4.5
RKG0026	4/16/2014	10	6.6	11.2	96.0	4.5
RKG0026	4/16/2014	12	6.4	11.1	96.0	4.6
RKG0026	4/16/2014	14	6.3	10.9	96.0	4.6
RKG0026	4/16/2014	16	6.2	10.8	96.0	4.7
RKG0026	4/16/2014	18	6.1	10.8	96.0	4.7
RKG0026	4/16/2014	19	6.1	10.8	96.0	9.2
RKG0026	5/15/2014	0.3	19.8	9.3	97.0	2.7
RKG0026	5/15/2014	1	19.8	9.3	97.0	2.8
RKG0026	5/15/2014	2	18.3	10.1	96.0	2.9
RKG0026	5/15/2014	4	13.5	10.6	98.0	2.9
RKG0026	5/15/2014	6	12.1	10.1	97.0	2.9
RKG0026	5/15/2014	8	9.7	9.9	97.0	2.9
RKG0026	5/15/2014	10	8.1	9.8	98.0	2.8
RKG0026	5/15/2014	12	7.6	9.0	99.0	3.1
RKG0026	5/15/2014	14	7.2	8.7	99.0	3.0
RKG0026	5/15/2014	16	7.0	7.9	100.0	2.9
RKG0026	5/15/2014	18	6.9	7.3	100.0	2.8
RKG0026	5/15/2014	19	6.8	6.8	101.0	8.8
RKG0026	5/28/2014	0.3	21.2	9.0	93.0	2.5
RKG0026	5/28/2014	1	20.6	9.1	93.0	2.7
RKG0026	5/28/2014	2	19.0	9.5	393.0	2.8
RKG0026	5/28/2014	4	15.6	10.3	93.0	2.8
RKG0026	5/28/2014	6	12.7	9.5	97.0	3.0
RKG0026	5/28/2014	8	9.2	8.6	99.0	3.0
RKG0026	5/28/2014	10	8.0	8.3	100.0	3.0
RKG0026	5/28/2014	12	7.6	7.8	100.0	3.2
RKG0026	5/28/2014	14	7.5	7.5	100.0	3.3
RKG0026	5/28/2014	16	7.2	7.1	101.0	3.7

Sampling Station ID	Date sampling	Depth-M	Water Temp – ^{O}C	DO-mg/l	Conductivity Micromhos/cm	Turbidity-NTU
RKG0026	5/28/2014	18	7.1	5.6	102.0	4.5
RKG0026	5/28/2014	19	7.0	5.6	103.0	4.9
RKG0026	6/11/2014	0.3	24.5	8.5	94.0	2.0
RKG0026	6/11/2014	1	24.2	8.5	94.0	2.1
RKG0026	6/11/2014	2	23.9	9.3	94.0	2.0
RKG0026	6/11/2014	4	16.8	10.7	92.0	1.9
RKG0026	6/11/2014	6	12.3	8.7	97.0	2.1
RKG0026	6/11/2014	8	9.9	7.6	98.0	2.1
RKG0026	6/11/2014	10	8.5	7.4	99.0	2.0
RKG0026	6/11/2014	12	8.0	6.9	103.0	2.2
RKG0026	6/11/2014	14	7.7	6.6	100.0	2.4
RKG0026	6/11/2014	16	7.4	4.9	101.0	3.0
RKG0026	6/11/2014	18	7.2	4.0	103.0	3.6
RKG0026	6/11/2014	19	7.1	3.8	104.0	4.1
RKG0026	6/25/2014	0.3	25.2	8.6	93.0	3.1
RKG0026	6/25/2014	1	25.2	8.5	93.0	3.3
RKG0026	6/25/2014	2	24.8	8.6	92.0	3.5
RKG0026	6/25/2014	4	18.2	7.0	79.0	3.8
RKG0026	6/25/2014	6	13.9	7.4	96.0	3.9
RKG0026	6/25/2014	8	10.7	6.4	98.0	4.2
RKG0026	6/25/2014	10	8.7	5.4	100.0	4.0
RKG0026	6/25/2014	12	8.4	5.4	101.0	5.2
RKG0026	6/25/2014	14	7.8	5.0	101.0	25.8
RKG0026	6/25/2014	16	7.5	4.2	101.0	7.2
RKG0026	6/25/2014	18	7.4	3.4	104.0	7.7
RKG0026	6/25/2014	19.6	7.6	2.0	107.0	9.5
RKG0026	7/10/2014	0.3	26.3	8.1	93.0	60.0
RKG0026	7/10/2014	1	26.0	8.1	94.0	60.0
RKG0026	7/10/2014	2	25.6	8.3	93.0	66.0
RKG0026	7/10/2014	4	21.7	9.9	83.0	67.5
RKG0026	7/10/2014	6	14.5	5.6	100.0	128.0
RKG0026	7/10/2014	8	10.6	5.4	104.0	130.0
RKG0026	7/10/2014	10	8.9	4.5	107.0	87.0
RKG0026	7/10/2014	12	8.3	4.9	105.0	65.0
RKG0026	7/10/2014	14	8.0	3.8	108.0	71.6
RKG0026	7/10/2014	16	7.7	3.3	109.0	77.1
RKG0026	7/10/2014	18	7.4	2.6	110.0	98.1
RKG0026	7/10/2014	18.9	7.4	1.2	125.0	59.0
RKG0026	7/29/2014	0.3	24.7	8.2	92.0	17.1
RKG0026	7/29/2014	1	24.6	8.2	92.0	47.0

Sampling Station ID	Date sampling	Depth-M	Water Temp – ^{O}C	DO-mg/l	Conductivity Micromhos/cm	Turbidity-NTU
RKG0026	7/29/2014	3	24.4	8.2	92.0	0.0
RKG0026	7/29/2014	6	14.5	4.5	96.0	0.0
RKG0026	7/29/2014	9	9.9	3.4	99.0	0.0
RKG0026	7/29/2014	12	8.6	2.8	100.0	0.0
RKG0026	7/29/2014	15	7.8	1.8	103.0	0.0
RKG0026	7/29/2014	18	8.1	0.7	104.0	2.2
RKG0026	7/29/2014	18.3	7.8	0.7	104.0	2.2
RKG0026	8/12/2014	0.3	24.6	8.4	95.0	35.4
RKG0026	8/12/2014	1	24.5	8.4	95.0	41.0
RKG0026	8/12/2014	2	24.5	8.4	95.0	34.5
RKG0026	8/12/2014	4	23.7	8.5	94.0	46.9
RKG0026	8/12/2014	6	16.6	4.5	94.0	51.5
RKG0026	8/12/2014	8	11.2	3.0	15.0	93.1
RKG0026	8/12/2014	10	9.4	2.2	107.0	82.3
RKG0026	8/12/2014	12	8.6	1.3	110.0	68.2
RKG0026	8/12/2014	14	8.2	1.5	109.0	64.3
RKG0026	8/12/2014	16	7.9	0.9	110.0	64.1
RKG0026	8/12/2014	18	7.6	0.2	113.0	92.1
RKG0026	8/12/2014	19	7.6	0.2	119.0	90.4
RKG0026	8/26/2014	0.3	23.8	8.6	95.0	1.0
RKG0026	8/26/2014	1	23.6	8.7	95.0	1.0
RKG0026	8/26/2014	3	23.4	8.2	95.0	5.0
RKG0026	8/26/2014	5	20.0	6.0	97.0	9.0
RKG0026	8/26/2014	7	14.5	2.4	103.0	10.0
RKG0026	8/26/2014	9	10.2	1.8	107.0	11.0
RKG0026	8/26/2014	11	9.1	1.7	109.0	12.0
RKG0026	8/26/2014	13	8.5	1.1	112.0	14.0
RKG0026	8/26/2014	15	8.1	0.3	111.0	12.0
RKG0026	8/26/2014	17	7.9	0.2	113.0	11.3
RKG0026	8/26/2014	18.2	7.8	0.3	117.0	13.7
RKG0026	9/10/2014	0.3	23.7	8.4	89.0	1.3
RKG0026	9/10/2014	1	23.7	8.4	89.0	1.5
RKG0026	9/10/2014	3	23.7	8.3	89.0	1.7
RKG0026	9/10/2014	5	22.4	6.7	92.0	2.0
RKG0026	9/10/2014	7	16.3	1.1	96.0	2.5
RKG0026	9/10/2014	9	11.3	0.6	99.0	2.9
RKG0026	9/10/2014	11	9.3	0.5	100.0	3.5
RKG0026	9/10/2014	13	8.9	0.0	104.0	7.0
RKG0026	9/10/2014	14.7	8.7	0.2	103.0	14.2
RKG0026	9/30/2014	0.3	20.3	9.0	92.0	1.0

Sampling Station ID	Date sampling	Depth-M	Water Temp – ^{O}C	DO-mg/l	Conductivity Micromhos/cm	Turbidity-NTU
RKG0026	9/30/2014	1	20.2	8.9	92.0	1.0
RKG0026	9/30/2014	3	20.0	8.9	92.0	1.5
RKG0026	9/30/2014	5	19.2	6.2	93.0	5.1
RKG0026	9/30/2014	7	15.9	1.1	98.0	5.9
RKG0026	9/30/2014	9	10.9	0.0	103.0	7.0
RKG0026	9/30/2014	11	9.3	0.0	103.0	9.5
RKG0026	9/30/2014	13	9.0	0.0	106.0	12.9
RKG0026	9/30/2014	15	8.6	0.0	106.0	15.4
RKG0026	9/30/2014	17	8.3	0.0	107.0	20.4
RKG0026	9/30/2014	18.4	8.3	0.0	109.0	20.3
RKG0026	10/7/2014	0.3	17.8	7.9	92.0	3.4
RKG0026	10/7/2014	1	17.8	7.9	93.0	3.6
RKG0026	10/7/2014	3	17.8	7.9	92.0	3.9
RKG0026	10/7/2014	5	17.8	7.7	92.0	4.5
RKG0026	10/7/2014	7	17.6	6.1	92.0	7.2
RKG0026	10/7/2014	9	12.1	0.0	102.0	7.0
RKG0026	10/7/2014	11	10.0	0.0	103.0	9.0
RKG0026	10/7/2014	13	9.0	0.0	106.0	12.8
RKG0026	10/7/2014	15	8.6	0.0	106.0	14.4
RKG0026	10/7/2014	17	8.3	0.0	109.0	17.4
RKG0026	10/7/2014	19	8.1	0.0	115.0	15.7
RKG0026	10/21/2014	0.3	15.2	8.0	93.0	2.8
RKG0026	10/21/2014	1	15.2	8.0	94.0	2.9
RKG0026	10/21/2014	2	15.1	8.0	93.0	3.1
RKG0026	10/21/2014	4	15.1	7.9	93.0	4.5
RKG0026	10/21/2014	6	15.1	7.9	93.0	5.0
RKG0026	10/21/2014	8	15.1	6.9	93.0	5.8
RKG0026	10/21/2014	10	11.1	0.0	105.0	7.4
RKG0026	10/21/2014	12	9.6	0.0	107.0	8.2
RKG0026	10/21/2014	14	8.9	0.0	108.0	8.8
RKG0026	10/21/2014	16	8.6	0.0	111.0	5.0
RKG0026	10/21/2014	18.9	8.3	0.0	118.0	4.3
RKG0034	4/16/2014	0.3	10.6	11.1	97.0	3.7
RKG0034	4/16/2014	1	10.5	11.2	96.0	3.5
RKG0034	4/16/2014	2	10.2	11.3	96.0	3.4
RKG0034	4/16/2014	3	10.1	11.3	96.0	3.2
RKG0034	4/16/2014	4	9.3	10.9	95.0	3.1
RKG0034	4/16/2014	5	7.2	11.3	96.0	2.9
RKG0034	4/16/2014	6	7.1	11.2	95.0	2.7
RKG0034	4/16/2014	7	7.0	11.1	96.0	2.6

Sampling Station ID	Date sampling	Depth-M	Water Temp – ^{O}C	DO-mg/l	Conductivity Micromhos/cm	Turbidity-NTU
RKG0034	4/16/2014	8	7.0	11.1	98.0	2.4
RKG0034	4/16/2014	8.5	6.9	11.1	98.0	2.2
RKG0034	5/15/2014	0.3	19.2	9.4	95.0	2.2
RKG0034	5/15/2014	1	18.5	9.5	91.0	2.2
RKG0034	5/15/2014	2	16.8	9.6	82.0	2.1
RKG0034	5/15/2014	3	15.3	10.5	91.0	1.7
RKG0034	5/15/2014	4	13.6	10.5	97.0	1.5
RKG0034	5/15/2014	5	13.0	10.4	97.0	1.4
RKG0034	5/15/2014	6	12.5	10.2	97.0	1.2
RKG0034	5/15/2014	7	11.5	9.5	98.0	1.0
RKG0034	5/15/2014	8	9.8	9.7	98.0	0.9
RKG0034	5/15/2014	9	8.7	8.5	99.0	0.7
RKG0034	5/28/2014	0.3	21.5	8.9	94.0	2.0
RKG0034	5/28/2014	1	21.2	9.0	94.0	1.9
RKG0034	5/28/2014	2	18.9	9.3	93.0	1.7
RKG0034	5/28/2014	3	17.9	9.4	92.0	1.8
RKG0034	5/28/2014	4	15.4	9.5	92.0	1.9
RKG0034	5/28/2014	5	13.4	9.6	96.0	1.8
RKG0034	5/28/2014	6	11.9	9.2	98.0	1.8
RKG0034	5/28/2014	7	11.5	9.1	98.0	1.7
RKG0034	5/28/2014	8	11.0	8.2	98.0	1.7
RKG0034	5/28/2014	8.5	10.4	7.2	99.0	1.8
RKG0034	6/11/2014	0.3	23.8	8.8	94.0	3.5
RKG0034	6/11/2014	1	23.6	8.9	94.0	4.3
RKG0034	6/11/2014	2	22.6	8.9	97.0	5.8
RKG0034	6/11/2014	3	20.5	9.1	83.0	7.0
RKG0034	6/11/2014	4	17.1	9.5	89.0	4.9
RKG0034	6/11/2014	5	14.6	9.2	95.0	4.2
RKG0034	6/11/2014	6	12.8	8.5	97.0	4.4
RKG0034	6/11/2014	7	11.9	7.1	90.0	1.4
RKG0034	6/11/2014	8	10.7	5.0	102.0	1.4
RKG0034	6/11/2014	9	9.4	4.4	103.0	8.7
RKG0034	6/11/2014	9.3	9.3	4.5	103.0	1.7
RKG0034	6/25/2014	0.3	24.9	8.7	92.0	0.4
RKG0034	6/25/2014	1	24.7	8.7	93.0	0.4
RKG0034	6/25/2014	2	24.1	9.0	92.0	2.5
RKG0034	6/25/2014	3	21.0	9.5	82.0	3.5
RKG0034	6/25/2014	4	19.5	7.8	75.0	3.7
RKG0034	6/25/2014	5	17.1	6.8	85.0	4.6
RKG0034	6/25/2014	6	14.6	7.3	96.0	2.8

Sampling Station ID	Date sampling	Depth-M	Water Temp – ^{O}C	DO-mg/l	Conductivity Micromhos/cm	Turbidity-NTU
RKG0034	6/25/2014	7	12.4	6.0	99.0	6.9
RKG0034	6/25/2014	8	10.9	5.0	100.0	3.8
RKG0034	6/25/2014	9	10.4	3.6	101.0	3.4
RKG0034	6/25/2014	10.1	9.4	2.8	104.0	10.6
RKG0034	7/10/2014	0.3	26.3	8.4	95.0	25.2
RKG0034	7/10/2014	1	26.0	8.4	95.0	28.6
RKG0034	7/10/2014	2	25.7	8.2	95.0	29.5
RKG0034	7/10/2014	3	25.1	7.9	94.0	28.7
RKG0034	7/10/2014	4	21.2	9.5	86.0	24.0
RKG0034	7/10/2014	5	16.1	6.0	96.0	30.4
RKG0034	7/10/2014	6	13.4	5.4	103.0	57.0
RKG0034	7/10/2014	7	12.5	4.8	104.0	53.0
RKG0034	7/10/2014	8	11.3	4.2	106.0	57.0
RKG0034	7/10/2014	9	10.3	3.1	110.0	59.8
RKG0034	7/29/2014	0.3	25.0	7.9	93.0	0.0
RKG0034	7/29/2014	1	25.0	7.9	92.0	36.0
RKG0034	7/29/2014	2	24.9	7.9	93.0	23.1
RKG0034	7/29/2014	3	25.0	8.0	93.0	25.5
RKG0034	7/29/2014	4	23.5	9.2	89.0	13.2
RKG0034	7/29/2014	5	16.5	5.2	94.0	21.0
RKG0034	7/29/2014	6	14.7	4.3	97.0	0.0
RKG0034	7/29/2014	7	11.8	3.4	100.0	0.0
RKG0034	7/29/2014	8	10.9	2.1	105.0	0.0
RKG0034	7/29/2014	8.8	10.6	1.5	105.0	0.0
RKG0034	8/12/2014	0.3	24.5	8.4	95.0	14.0
RKG0034	8/12/2014	1	24.4	8.6	95.0	17.4
RKG0034	8/12/2014	2	24.4	8.6	95.0	18.9
RKG0034	8/12/2014	3	24.3	8.3	95.0	20.7
RKG0034	8/12/2014	4	24.1	8.1	95.0	21.4
RKG0034	8/12/2014	5	20.9	7.7	94.0	22.7
RKG0034	8/12/2014	6	15.4	3.4	104.0	54.8
RKG0034	8/12/2014	7	13.0	3.2	106.0	47.5
RKG0034	8/12/2014	8	12.3	2.0	108.0	54.4
RKG0034	8/12/2014	9	10.9	1.5	119.0	66.4
RKG0034	8/26/2014	0.3	23.2	8.8	96.0	1.0
RKG0034	8/26/2014	1	23.1	8.8	95.0	1.0
RKG0034	8/26/2014	2	23.1	8.8	96.0	3.0
RKG0034	8/26/2014	3	23.1	8.8	96.0	5.0
RKG0034	8/26/2014	4	23.0	8.5	96.0	9.0
RKG0034	8/26/2014	5	22.5	6.7	100.0	10.0

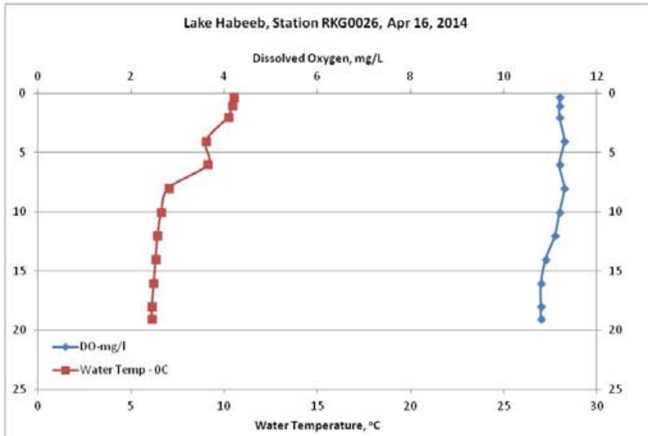
Sampling Station ID	Date sampling	Depth-M	Water Temp – ^{O}C	DO-mg/l	Conductivity Micromhos/cm	Turbidity-NTU
RKG0034	8/26/2014	6	17.8	3.1	101.0	11.3
RKG0034	8/26/2014	7	13.8	1.7	107.0	15.0
RKG0034	8/26/2014	8	11.5	0.9	114.0	20.0
RKG0034	9/10/2014	0.3	23.6	8.1	91.0	1.1
RKG0034	9/10/2014	1	23.6	8.1	91.0	0.9
RKG0034	9/10/2014	2	23.6	8.1	91.0	0.9
RKG0034	9/10/2014	3	23.5	8.1	91.0	1.1
RKG0034	9/10/2014	4	23.6	8.1	91.0	1.3
RKG0034	9/10/2014	5	22.6	6.3	94.0	1.7
RKG0034	9/10/2014	6	19.6	2.0	92.0	2.3
RKG0034	9/10/2014	7	16.3	0.9	96.0	2.8
RKG0034	9/10/2014	8	13.4	0.7	100.0	3.8
RKG0034	9/10/2014	9	12.0	0.1	105.0	6.3
RKG0034	9/30/2014	0.3	20.2	9.0	92.0	2.7
RKG0034	9/30/2014	1	20.1	9.0	92.0	3.0
RKG0034	9/30/2014	2	20.0	8.9	92.0	3.3
RKG0034	9/30/2014	3	19.9	8.7	92.0	3.6
RKG0034	9/30/2014	4	19.6	8.2	92.0	4.6
RKG0034	9/30/2014	5	19.3	7.1	93.0	5.7
RKG0034	9/30/2014	6	19.1	6.0	94.0	7.5
RKG0034	9/30/2014	7	16.8	0.1	99.0	108.0
RKG0034	9/30/2014	8.1	12.2	0.0	111.0	132.0
RKG0034	10/7/2014	0.3	18.2	8.5	92.0	1.6
RKG0034	10/7/2014	1	18.2	8.4	92.0	1.6
RKG0034	10/7/2014	2	18.2	8.4	92.0	1.6
RKG0034	10/7/2014	3	18.2	8.5	92.0	1.5
RKG0034	10/7/2014	4	18.0	8.4	92.0	3.6
RKG0034	10/7/2014	5	17.9	8.2	92.0	4.2
RKG0034	10/7/2014	6	17.6	6.9	92.0	5.2
RKG0034	10/7/2014	7	16.0	2.7	97.0	7.1
RKG0034	10/7/2014	8	13.8	0.0	105.0	11.0
RKG0034	10/7/2014	8.7	13.1	0.0	106.0	22.8
RKG0034	10/21/2014	0.3	15.2	8.7	93.0	1.8
RKG0034	10/21/2014	1	15.2	8.7	93.0	1.8
RKG0034	10/21/2014	2	15.2	8.7	93.0	1.8
RKG0034	10/21/2014	4	15.2	8.7	93.0	1.8
RKG0034	10/21/2014	6	15.2	8.5	93.0	1.8
RKG0034	10/21/2014	8.1	14.6	8.9	96.0	2.1

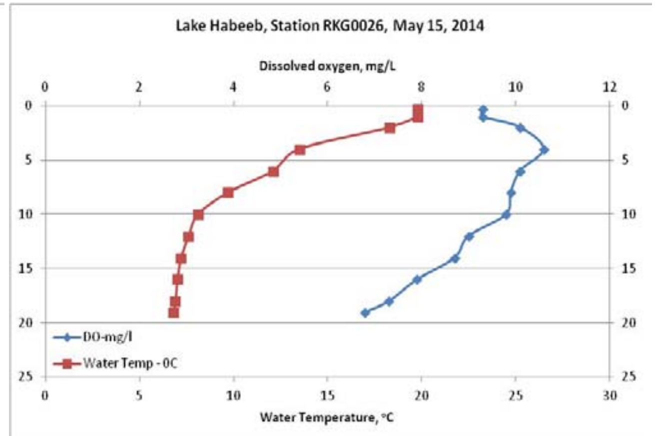
Table A-2 Nutrient and Chla data at Lake Habeeb

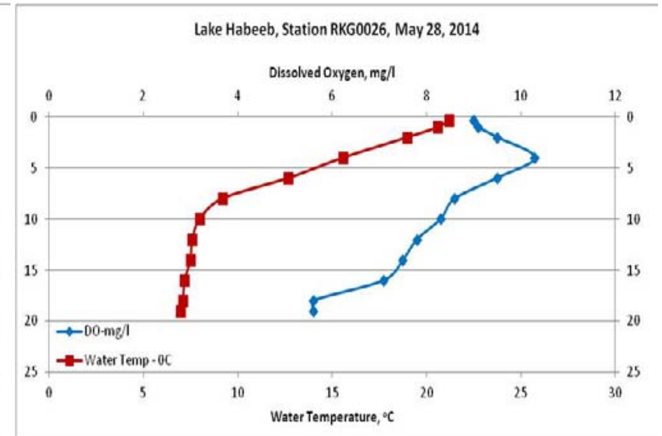
Sample Station	Date	Sample Layer	Actual Depth(m)	TP (mg P/L)	TN (mg N/L)	CHL (ug/L)
RKG0026	4/29/2014	S	0.30	0.0073	0.26	2.03
RKG0026	5/28/2014	S	0.30	0.0073	0.31	1.34
RKG0026	6/25/2014	S	0.30	0.0075	0.30	2.40
RKG0026	7/10/2014	S	0.30	0.0062	0.31	1.17
RKG0026	7/29/2014	S	0.30	0.0040	0.28	2.94
RKG0026	8/12/2014	S	0.30	0.0042	0.27	2.35
RKG0026	8/26/2014	S	0.30	0.0056	0.22	1.83
RKG0026	9/10/2014	S	0.30	0.0054	0.25	2.56
RKG0026	9/30/2014	S	0.30	0.0066	0.25	2.49
RKG0026	10/7/2014	S	0.30	0.0066	0.24	3.63
RKG0034	4/29/2014	S	0.30	0.0083	0.27	2.46
RKG0034	5/28/2014	S	0.30	0.0078	0.30	1.60
RKG0034	6/25/2014	S	0.30	0.0082	0.34	3.07
RKG0034	7/10/2014	S	0.30	0.0075	0.3	2.03
RKG0034	7/29/2014	S	0.30	0.0077	0.29	3.20
RKG0034	8/12/2014	S	0.30	0.0030	0.24	2.14
RKG0034	8/26/2014	S	0.30	0.0070	0.28	2.44
RKG0034	9/10/2014	S	0.30	0.0079	0.28	2.49
RKG0034	9/30/2014	S	0.30	0.0073	0.27	2.49
RKG0034	10/7/2014	S	0.30	0.0083	0.27	3.42

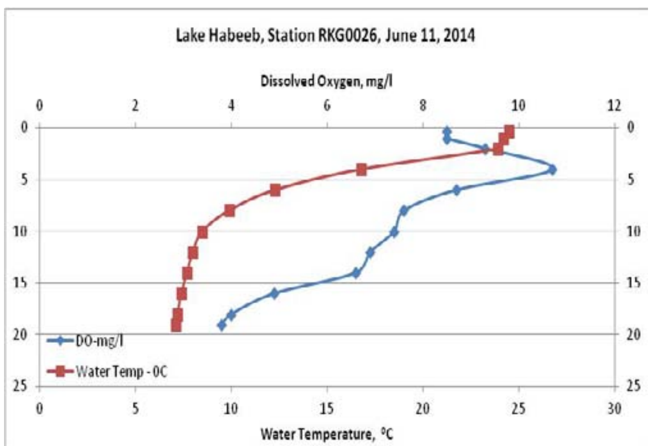
Appendix B: Depth Profiles of Dissolved Oxygen and Temperature by Station

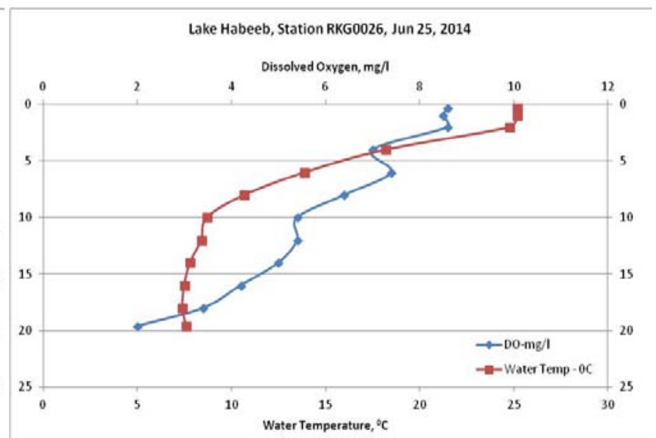
RKG0026

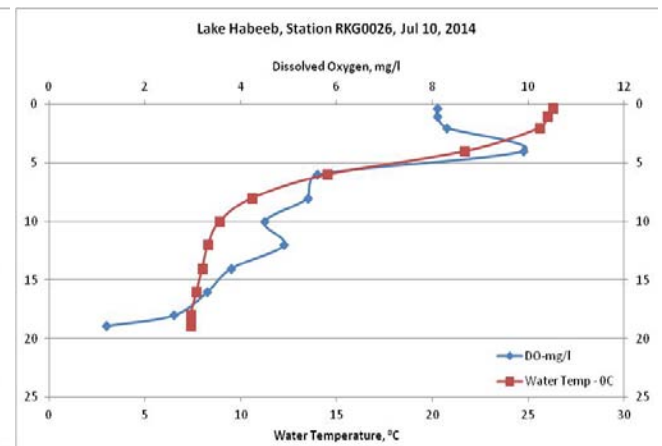




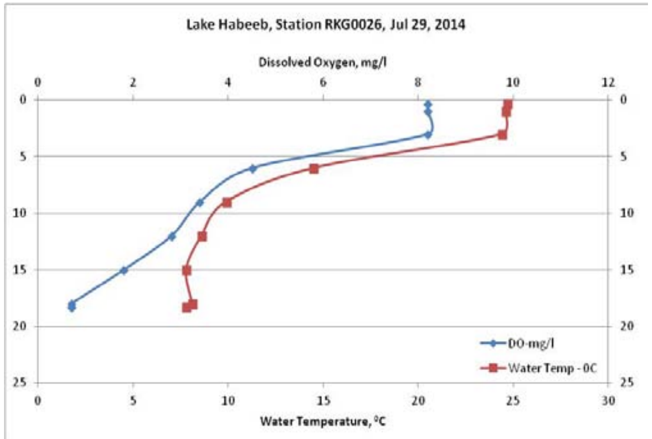


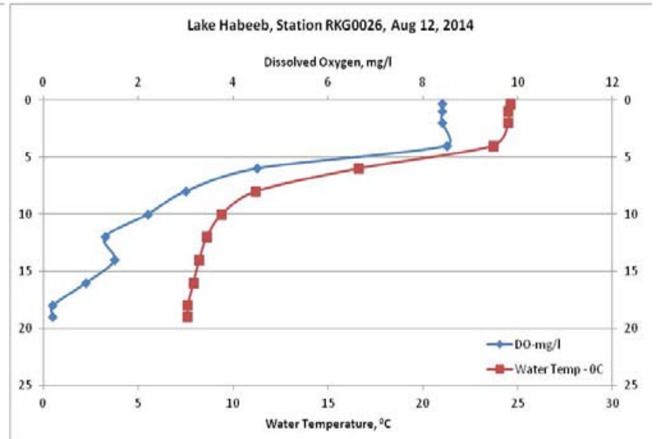


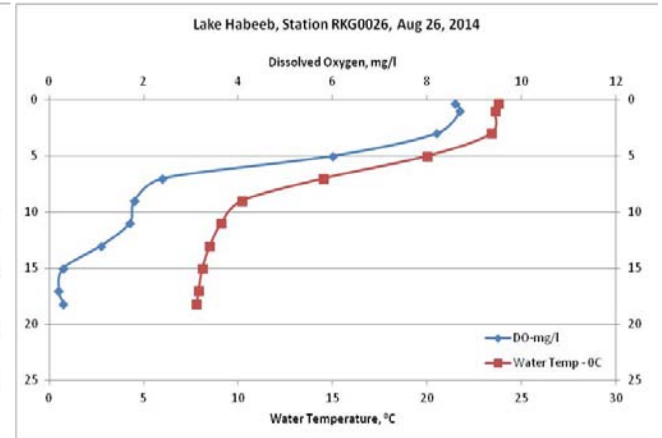


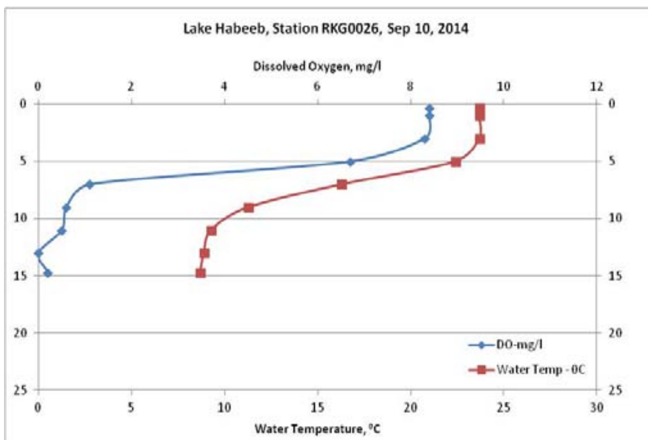


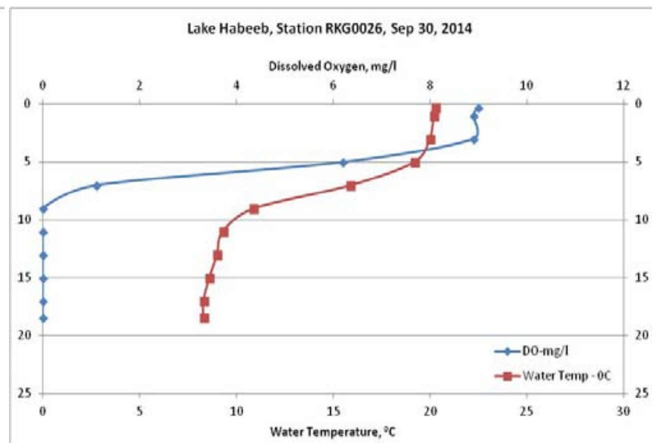
RKG0026

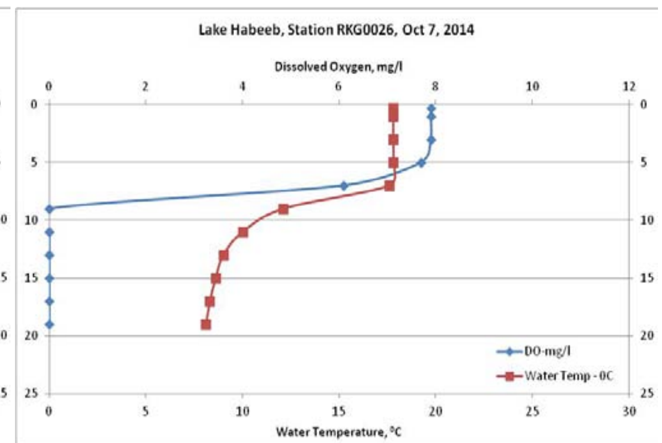

Lake Habeeb, Station RKG0026, Jul 29, 2014
Dissolved Oxygen, mg/l
Water Temperature, °C
DO-mg/l
Water Temp - 0C


Lake Habeeb, Station RKG0026, Aug 12, 2014
Dissolved Oxygen, mg/l
Water Temperature, °C
DO-mg/l
Water Temp - 0C

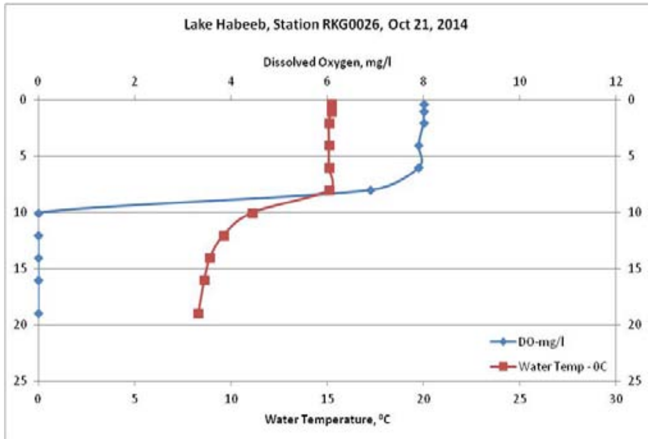

Lake Habeeb, Station RKG0026, Aug 26, 2014
Dissolved Oxygen, mg/l
Water Temperature, °C
DO-mg/l
Water Temp - 0C


Lake Habeeb, Station RKG0026, Sep 10, 2014
Dissolved Oxygen, mg/l
Water Temperature, °C
DO-mg/l
Water Temp - 0C

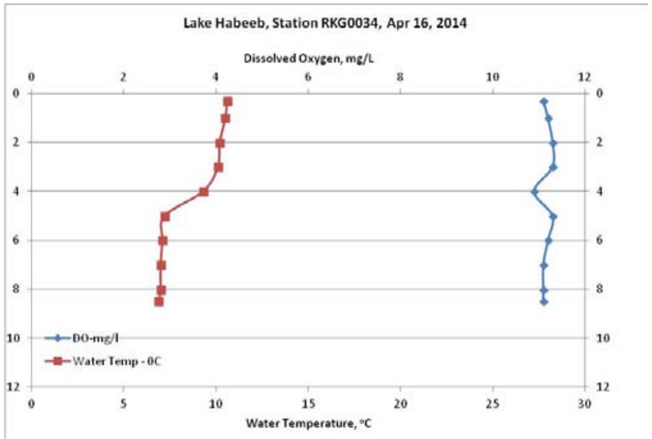

Lake Habeeb, Station RKG0026, Sep 30, 2014
Dissolved Oxygen, mg/l
Water Temperature, °C
DO-mg/l
Water Temp - 0C

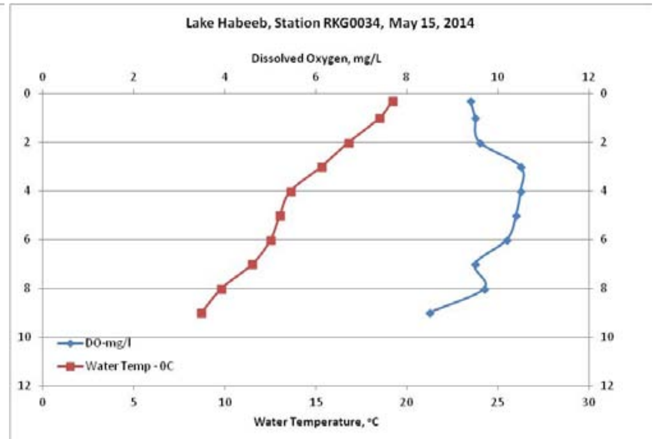

Lake Habeeb, Station RKG0026, Oct 7, 2014
Dissolved Oxygen, mg/l
Water Temperature, °C
DO-mg/l
Water Temp - 0C

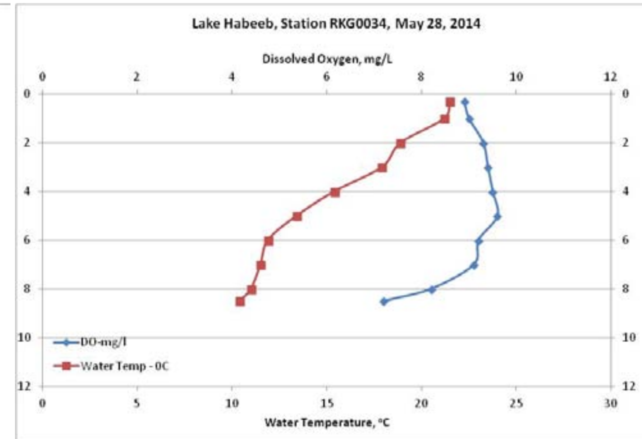
RKG0026

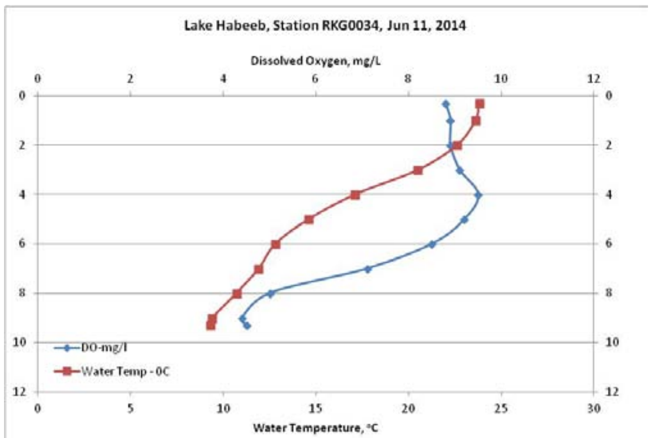

Lake Habeeb, Station RKG0026, Oct 21, 2014
Dissolved Oxygen, mg/l
0
2
4
6
8
10
12
0
5
10
15
20
25
DO-mg/l
Water Temp - 0C
0
5
10
15
20
25
30
Water Temperature, °C

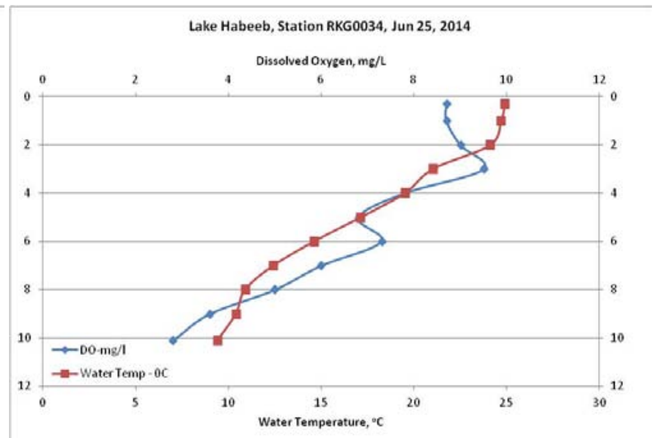
RKG0034

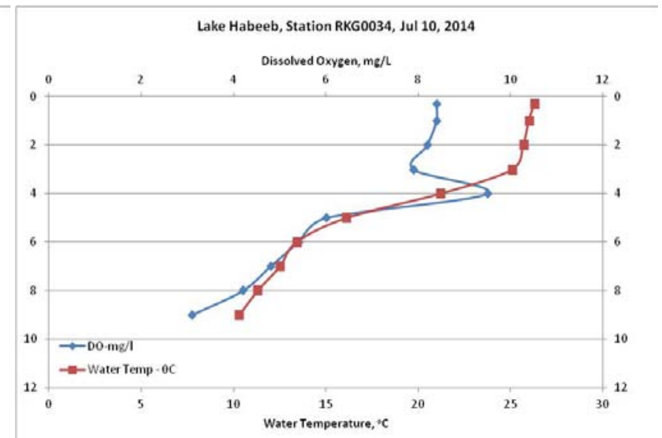

Lake Habeeb, Station RKG0034, Apr 16, 2014
Dissolved Oxygen, mg/L
DO-mg/l
Water Temp - 0C
Water Temperature, °C


Lake Habeeb, Station RKG0034, May 15, 2014
Dissolved Oxygen, mg/L
DO-mg/l
Water Temp - 0C
Water Temperature, °C

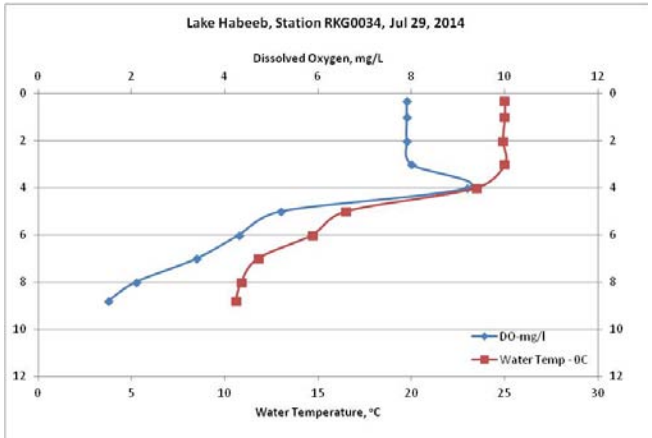

Lake Habeeb, Station RKG0034, May 28, 2014
Dissolved Oxygen, mg/L
DO-mg/l
Water Temp - 0C
Water Temperature, °C

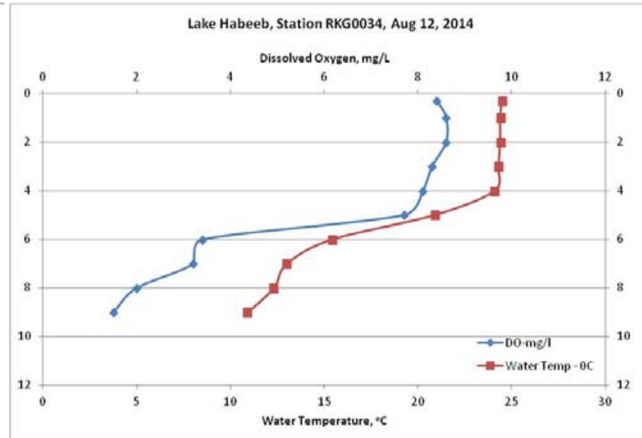

Lake Habeeb, Station RKG0034, Jun 11, 2014
Dissolved Oxygen, mg/L
DO-mg/l
Water Temp - 0C
Water Temperature, °C

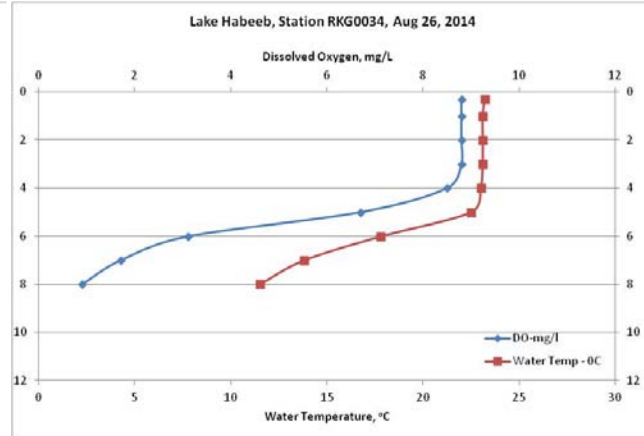

Lake Habeeb, Station RKG0034, Jun 25, 2014
Dissolved Oxygen, mg/L
DO-mg/l
Water Temp - 0C
Water Temperature, °C

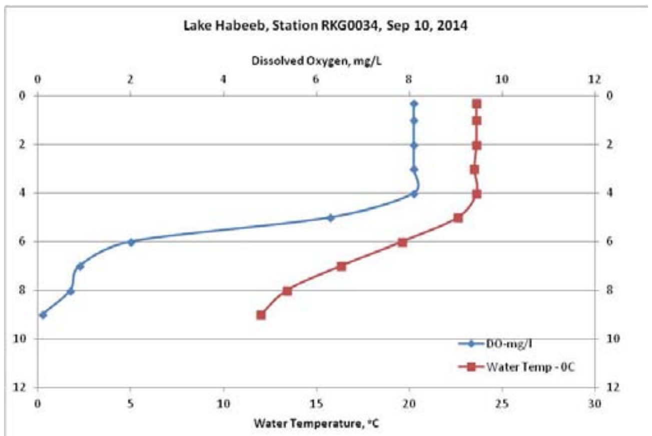

Lake Habeeb, Station RKG0034, Jul 10, 2014
Dissolved Oxygen, mg/L
DO-mg/l
Water Temp - 0C
Water Temperature, °C

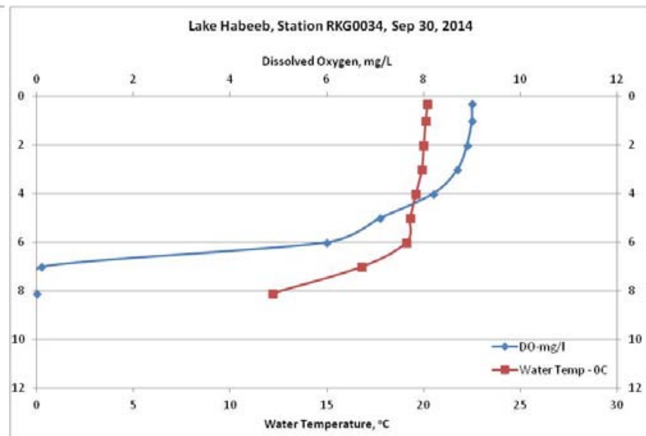
RKG0034

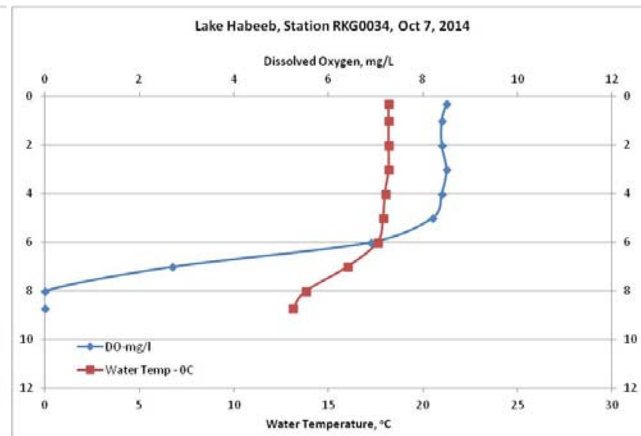

Lake Habeeb, Station RKG0034, Jul 29, 2014
Dissolved Oxygen, mg/L
Water Temperature, °C
DO-mg/l
Water Temp - 0C


Lake Habeeb, Station RKG0034, Aug 12, 2014
Dissolved Oxygen, mg/L
Water Temperature, °C
DO-mg/l
Water Temp - 0C

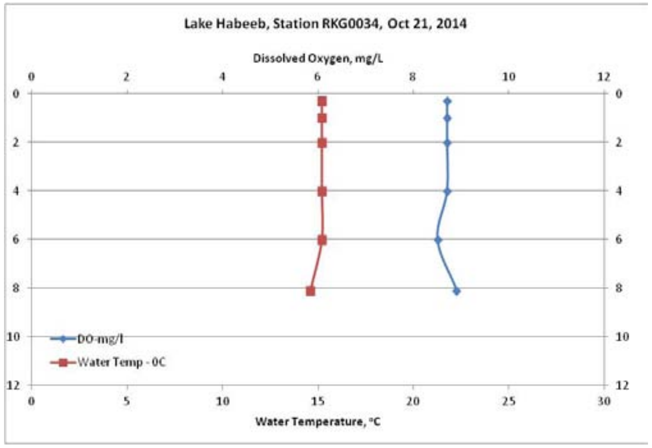

Lake Habeeb, Station RKG0034, Aug 26, 2014
Dissolved Oxygen, mg/L
Water Temperature, °C
DO-mg/l
Water Temp - 0C


Lake Habeeb, Station RKG0034, Sep 10, 2014
Dissolved Oxygen, mg/L
Water Temperature, °C
DO-mg/l
Water Temp - 0C


Lake Habeeb, Station RKG0034, Sep 30, 2014
Dissolved Oxygen, mg/L
Water Temperature, °C
DO-mg/l
Water Temp - 0C


Lake Habeeb, Station RKG0034, Oct 7, 2014
Dissolved Oxygen, mg/L
Water Temperature, °C
DO-mg/l
Water Temp - 0C

RKG0034


Lake Habeeb, Station RKG0034, Oct 21, 2014
Dissolved Oxygen, mg/L
0 2 4 6 8 10 12
0 2 4 6 8 10 12
DO mg/l
Water Temp - 0C
0 5 10 15 20 25 30
Water Temperature, °C

Appendix C: Trophic State Index (TSI) Calculation

Thermal stratification is a seasonal phenomenon, beginning in late spring or early summer, intensifying as summer progresses, decreasing in early fall, and finally ending with the fall turnover, as the lake becomes thermally uniform with depth. Therefore, data from May or June will generally show less stratification and higher hypolimnetic DO levels than data from August and September.

Often, stratified lakes do not exhibit this idealized separation into three distinct layers; the temperature may decrease more or less continuously from the surface to the lake bottom. This phenomenon may be particularly true in the case of artificial impoundments, given the variability in basin and watershed morphometry and geometry. The formulaic determination of the exact point at which one layer grades into another may thus be difficult or impossible; in such cases, managers may need to explore alternative methodologies or resort to professional judgment.

Various factors affect the 'natural' degree of oxygen depletion in a lake or impoundment. These include the degree or 'strength' of stratification; the morphometry of the water body itself (*i.e.*, the depth and geometry of the basin); and watershed characteristics, such as watershed size, land cover, and naturally occurring allochthonous loads of organic material.

Ted Brown and Jon Simpson describe Trophic State Index (TSI) range as a function of lake trophic status. This relationship is summarized in Table C-1 below.

Table C-1: Relationship between Lake Trophic Status and TSI Range

Trophic Status	**TSI Range**	
	Total Phosphorus	**Peak Chlorophyll *a***
Eutrophic	16 - 390	10 - 280
Mesotrophic	11 - 96	5 - 50
Oligotrophic	3 - 18	1.3 - 11

Chlorophyll *a*: TSI(CHL) = 9.81 ln(CHL) + 30.6

Total phosphorus: TSI(TP) = 14.42 ln(TP) + 4.15

Where ln = natural log

Table C-2: TSI Range in Lake Habeeb

Stations	TSI Range	
	Total Phosphorus	Peak Chlorophyll *a*
RKG0026,RKG0034	20 - 35	28 - 43

The station RKG0041 is located in a small stream that flows into Lake Habeeb and it is very shallow, only around six inches deep, the data collected there fluctuated. Therefore only two stations, RKG0026 and RKG0034, were used for the TSI range.