Technical Memorandum
Lake Wequaquet Water Quality Trend Analysis

To: **Gail Maguire, Lake Wequaquet Protective Association**

From: **Ed Eichner, Senior Water Scientist**

RE: **Lake Wequaquet Water Quality Trend Analysis**

Date: **May 24, 2013**

Overview

Lake Wequaquet is the largest pond in the Town of Barnstable and the third largest on Cape Cod with a surface area of nearly 600 acres. The Wequaquet Lake Protective Association, Inc. (WLPA) was formed in 1993 to address lake-specific issues, including use of the lake, water levels and water quality. Water quality in the lake has been subject of two year-long studies: one published in 1989[1] and another in 2008.[2] It has also been regularly monitored by the town and the WLPA as part of the Cape Cod Pond and Lake Stewards (PALS) program annual water quality snapshot, which has been conducted since 2001[3], as well as more recent summer-long monitoring in 2010, 2011, and 2012. Providing feedback on water quality data is important part of any volunteer monitoring programs and the WLPA asked me to review the available data to evaluate whether any water quality trends were indicated.

Available Data

There are five historic water quality sampling sites in Lake Wequaquet: 1) the main basin, 2) Bearses Pond, 3) Gooseberry Pond, 4) a northern portion of the main basin, and 5) the southern basin (Figure 1). All sampling sites are at the deepest points in these basins. These sites were sampled approximately monthly during the course of the two year-long studies (1985/86 and 2007). Among these sites only the deep main basin and Bearses Pond sites have been regularly sampled during the annual PALS Snapshots, although all five sites have been sampled regularly through recent town efforts (2010[4], 2011, and 2012). Since statistical trend analysis only gains strong reliability from longer term datasets, only the deep main basin and Bearses Pond site have

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[1] IEP, Inc. and K-V Associates. 1989. Diagnostic/Feasibility Study of Wequaquet Lake, Bearses, and Long Pond. Prepared for Town of Barnstable, Conservation Commission. Sandwich and Falmouth, MA.

[2] Eichner, E. 2008. Lake Wequaquet Water Quality Assessment. Completed for the Town of Barnstable and the Cape Cod Commission. Coastal Systems Program, School of Marine Science and Technology, University of Massachusetts Dartmouth. 81 pp.

[3] The PALS Snapshot is a coordinated project of the Coastal Systems Program, School of Marine Science and Technology, University of Massachusetts Dartmouth (CSP-SMAST) and the Cape Cod Commission. The CSP-SMAST provides free water quality laboratory analysis for any pond samples collected during the late summer that following the PALS protocol.

[4] Eichner, E. and B. Howes. March 23, 2011. Technical Memorandum: Lake Wequaquet Summer 2010 Water Quality Monitoring. To: Rob Gatewood, Director, Conservation Division, Town of Barnstable.

sufficient data to complete trend analysis. However, inferences can be made regarding trends at the other three sites by comparing average concentrations during different time periods.

Main Basin Trends

The deepest point in a lake is typically chosen as the key sampling station because water quality at that location is generally a mix of water quality throughout the lake and is not subject to localized shoreline impacts. Since the deep basin usually is also where pond sediments are gathered by mixing actions, the deepest readings at this station provide some sense of the impacts that lake sediments are having on water quality. Since Lake Wequaquet has a tortuous shoreline and multiple basins, its monitoring profile is relatively complex, but the main basin sampling point does provide a sense of the water quality of the whole lake.

Water clarity in Cape Cod ponds is directly related to nutrient concentrations since nutrients additions prompt phytoplankton growth and phytoplankton growth is directly related to water clarity. The more phytoplankton, the less clear the water is. Secchi disks are used to measure water clarity and Secchi readings have been collected regularly at the deep basin sampling point in Lake Wequaquet since 2001. Clarity in the main basin has a statistically significant ($\rho<0.05$) downward trend between 2001 and 2012 (Figure 2). This trend means that the water in Lake Wequaquet is getting less clear every year. Review of the average readings confirms this trend (Table 1).

Review of the surface chlorophyll and nutrient (total phosphorus and total nitrogen) concentrations do not have corresponding statistically significant increasing trends, but average concentrations in all cases are higher in more recent samples (see Table 1). Comparison of summer IEP/KV and SMAST concentrations for total phosphorus and total nitrogen show significantly ($\rho<0.05$) higher concentrations in 2007 compared to 1986. Average concentration for both nutrients and chlorophyll from 2010 to 2012 data were also significantly ($\rho<0.05$) higher than the averages for 2001 to 2007 data. Most of the groupings of these datasets show increasing average concentrations with time, but the variability of the concentrations keep the trends from being statistically significant.

Bearses Pond Trends

Bearses Pond is a separate basin of Lake Wequaquet located to the east of the main basin (see Figure 1). Review of the stream and nutrient outflows and nutrient masses in the pond suggest that Bearses Pond on average exports water and nutrients to the main basin, which also suggests that it functions in somewhat of an isolated fashion.[5]

Review of September water clarity/Secchi measurements show a decreasing trend (Figure 3), but it is not statistically significant ($\rho<0.05$). Interestingly, the decreasing clarity trends for the months of July and August are both statistically significant ($\rho<0.05$). These readings suggest that late summer clarity in Bearses Pond is relatively stable from year to year, but earlier summer clarity is decreasing on average each year. Review of nutrient concentrations, which tend to be predominantly PALS Snapshot data collected in September, do not show statistically significant trends.

[5] Eichner, E. 2008. Lake Wequaquet Water Quality Assessment.

Comparison of average concentrations seem to show that Bearses Pond experienced an increase in nutrient concentrations between 1985/86 (IEP/KV) and 2007 (CSP-SMAST), but that average concentrations have not increased since then (see Table 1). No statistically significant increases are seen for average concentrations in chlorophyll, total phosphorus, or total nitrogen in the comparisons between 2001 to 2007 and 2010 to 2012 datasets. Total phosphorus concentrations show some evidence of large swings, which are often observed in impaired ponds,[6] but the total nitrogen and chlorophyll concentrations are relatively stable (see Figure 3).

Other Basins

Neither Gooseberry Pond nor the southern basin (Stations 4 and 3, respectively, in Figure 1) have been sampled regularly as part of the PALS Snapshots, so there is insufficient data for trend analysis. Review of average Secchi readings show that both basins have seen a significant ($\rho<0.05$) decrease in clarity between both 1985/86 (IEP/KV) and 2007 (CSP-SMAST), as well as 2007 (CSP-SMAST) and 2010 to 2012 periods (see Table 1). In the south basin, significant increases ($\rho<0.05$) in average TP and TN, but not chlorophyll, were seen between the 1985/86 (IEP/KV) and 2007 (CSP-SMAST) datasets, but no significant changes in the average in the more recent dataset comparison. In Gooseberry Pond, the same pattern was seen plus a significant increase in TN averages between the 2007 (CSP-SMAST) and 2010 to 2012 periods. Since average clarity decreased in the most recent averages, but average nutrient concentrations generally did not increase, the comparisons seem to suggest that factors other than nutrients may also be playing a role in determining the clarity in these two basins.

Conclusions

A. Trend Analysis: Clarity is declining in the main basin and Bearses Pond

Trend analysis was only possible for two of the Lake Wequaquet water quality stations (the main basin and Bearses Pond). Trend analysis of the water quality data shows that clarity is significantly decreasing ($\rho<0.05$) at both stations, but in different ways. Both of these basins also have increasing average total phosphorus concentrations, but the trends are not statistically significant. Increasing average concentrations are consistent with the decreasing clarity. Review of average TP concentrations suggests that the increasing nutrient additions in the main basin are a relatively recent change (*e.g.*, the last 5-10 years). Bearses Pond trend analysis shows statistically significant ($\rho<0.05$) downward trends in July and August, but not in September. These trends suggest that September conditions are relatively stable in Bearses Pond, but conditions are worsening in the earlier summer.

Decreases in clarity in freshwater ponds are generally due to additions of phosphorus. Since the shoreline of most ponds on the Cape have not experienced large development additions, significant phosphorus additions to Cape ponds generally come from one of two sources: 1) delayed additions of septic system wastewater or 2) internal sediment regeneration. The water quality readings in Lake Wequaquet suggest that phosphorus additions from one or both of these sources have progressively increased over the last 10 years. Increases in internal sediment regeneration are typically related to increases in low oxygen conditions. Data gathering in other Cape Cod ponds has shown that these conditions can occur more briefly than monthly sampling can detect and often lead to blue-green algal blooms similar to those experienced recently in

[6] *e.g.,* Eichner, E.M. 2004. Flax Pond Water Quality Review. Final Report to the Town of Harwich. Cape Cod Commission. Barnstable, MA

Lake Wequaquet.[7] Blue-green algal blooms typically occur when a large pulse of phosphorus is released into a well-mixed water column.

Wastewater phosphorus movement in sandy aquifer materials like those surrounding Lake Wequaquet tend to be very slow given the propensity of phosphorus to bind to iron coating the sand particles. In the 2008 CSP-SMAST phosphorus loading analysis[8], project staff concluded that loading from the watershed was relatively stable and there were very few additional parcels that could be developed. This evaluation would tend to suggest that the increase in average phosphorus concentrations and decreasing trends in clarity in the two basins is due to internal pond changes.

It is suggested that two datasets be collected to evaluate the internal functions in Lake Wequaquet: 1) installation of continuous monitoring devices in each of the basins for dissolved oxygen, temperature, chlorophyll and depth and 2) collection and incubation of sediment cores for evaluation of nutrient regeneration under oxic, transitional, and anoxic conditions. Data from continuous monitoring devices with accompanying water sampling will clarify if dissolved oxygen conditions change frequently enough to increase sediment phosphorus regeneration enough to prompt the recent blue-green algal blooms. Collection of sediment cores with sufficient distribution and at various depths will clarify whether oxic or transitional dissolved oxygen conditions could release enough phosphorus to prompt the blooms.

B. Average comparisons: Clarity is declining in Gooseberry Pond and the southern basin

Historic data is insufficient to complete trend analysis for the Gooseberry Pond and the southern basin monitoring stations. However, comparison of average Secchi clarity in the various datasets show that clarity has significantly decreased ($\rho<0.05$). Further these decreases have continued for each increment of time: a) summer 1986 vs. summer 2007, b) 1985/86 dataset vs. 2001 to 2012 dataset, and c) 2007 dataset vs. 2010 to 2012 dataset. Interestingly, review of total phosphorus and chlorophyll average concentrations show no significant increases in recent dataset comparison. This lack of accompanying nutrient increases suggests that some other factor may be contributing to the decreases in clarity at these two stations. Potential sources to consider would be stormwater runoff and/or sediment resuspension due to boating. Refined sampling would be necessary to clarify the causes.

C. Water quality conditions are worsening, but still meet regulatory standards

The occurrence of noticeable blue-green algal blooms means that Lake Wequaquet has passed a nutrient threshold and these blooms are likely continue to occur without some sort of management intervention. Given the lack of causative data, however, it is difficult to discern a pattern for developing future management strategies. The water quality, however, continues to meet state surface water regulatory standards[9] at all stations, largely because the numeric limits in these standards are only for dissolved oxygen, pH, temperature, and bacteria. These conditions mean that management of this system and efforts to address the worsening water quality conditions are largely dependent on local actions. Local actions should be based on what

[7] Eichner, E. and B. Howes. January 16, 2013. Mill Ponds Complex Project: Technical Memorandum. To: Lem Skidmore, Chair, Town of Brewster Comprehensive Water Planning Committee and Sue Leven, Town Planner.

[8] Eichner, E. 2008. Lake Wequaquet Water Quality Assessment

[9] 314 Code of Massachusetts Regulations 4.00: Massachusetts Surface Water Quality Standards

data indicates so that management funds are spent wisely and have the best chance of achieving improvements in water quality.

The 2008 water quality[10] assessment recommended that the town consider four steps for determining future water quality and use management of Lake Wequaquet:

1) Collect and test lake sediment cores,
2) Conduct a refined aquatic plant survey of the lake,
3) Establish a regular monitoring program, and
4) Develop a management plan for the lake.

The town has completed step #2 and addressed step #3. The monitoring program (step #3) data collected between 2010 and 2012 was used in this review and, based this review, shows it worth for development of future management options. The plant survey (step #2) was completed in 2010.[11] Step #4, development of a management plan, was contracted by the town in 2011 and is still proceeding. Sediment cores (step #1) have not been collected and would still provide crucial insight for evaluation of conditions in the lake and development of a management plan. Development of a management plan should include a review of the existing datasets, previous studies and recommended actions based on the available data and any supplemental data developed specifically for the management plan.

The review of data in this technical memorandum shows that water quality conditions in the pond are worsening and pointed out the importance of resolving the sediment interactions and the source of the nutrients prompting the blue-green algal blooms. Community and WLPA concerns that have been raised in the past, including water level management[12], sewering around the lake[13], and minimizing conflicts between users of the watersheet would be expected to be addressed in the management plan. Development of a management plan that effectively and cost-efficiently addresses the negative water quality trends and rising nutrient concentrations identified in this review is a key for ensuring the water quality that the WLPA and the Town desires.

[10] Eichner, E. 2008. Lake Wequaquet Water Quality Assessment.

[11] Lycott Environmental, Inc. 2010. Aquatic Vegetation Report for Wequaquet Lake, Barnstable, Massachusetts.

[12] Eichner, E.M., T.C. Cambareri, V. Morrill, and B. Smith. 1998. Lake Wequaquet Water Level Study. Cape Cod Commission. Barnstable, MA.

[13] Tighe & Bond, Inc. 2003. Lake Wequaquet, Long Pond, and Cape Cod Community College Sewer Extension, Preliminary Design Final Report. Completed for the Town of Barnstable Department of Public Works. 315 pp.

Table 1. Trends and Average Water Quality Parameters in Lake Wequaquet.

Trend analysis is based on evaluation from 2001 through 2012 data if available, while comparison of averages are based on the three time periods listed: a) summer 1986 *vs*. summer 2007, b) 1985/86 IEP/KV dataset *vs*. 2001 to 2012 dataset, and c) 2001 to 2007 dataset *vs*. 2010 to 2012 dataset. Trend analyses for laboratory analytes (chlorophyll, TN and TP) were completed on PALS data since this dataset provided the most complete long-term dataset. Triangles indicate direction of trends or comparison of averages and are colored red if the trend or average comparison is statistically significant ($\rho<0.05$).

		TREND		AVERAGES									
Measure	Station #	Station Location	Trend	Units	1986 IEP/KV summer avg	2007 SMAST summer avg	AVG	1985/86 Whole IEP/KV avg	2001 to 2012 avg	AVG	2001 to 2007 avg	2010 to 2012 avg	AVG
Clarity	1	Main	▼	meters	4.09	3.56	▼	4.11	3.29	▼	3.82	2.29	▼
	5	Bearses	▼[1]	meters	3.51	2.88	▼	3.41	2.83	▼	3.39	2.29	▼
	3	South	none[2]	meters	5.00	3.57	▼	4.59	3.33	▼	4.19	2.54	▼
	4	Gooseberry	none[2]	meters	5.24	3.28	▼	4.66	2.93	▼	3.36	2.42	▼
Surface Chloro-phyll	1	Main	▲	µg/L	3.0	3.1	▲	2.9	5.4	▲	3.4	7.5	▲
	5	Bearses	▼	µg/L	3.3	4.7	▲	3.2	5.2	▲	5.0	5.4	▲
	3	South	none[2]	µg/L	2.5	3.5	▲	2.8	3.3	▲	2.9	3.6	▲
	4	Gooseberry	none[2]	µg/L	2.8	4.8	▲	2.5	3.9	▲	3.9	3.8	▼
Surface Total P	1	Main	▲	µg/L	11.0	20.6	▲[3]	26.3	19.2	▼	16.5	22.7	▲
	5	Bearses	▲	µg/L	10.4	24.5	▲[3]	30.8	20.4	▼	21.4	18.7	▼
	3	South	none[2]	µg/L	7.8	20.6	▲[3]	26.2	20.5	▲	18.5	21.6	▲
	4	Gooseberry	none[2]	µg/L	11.0	20.2	▲[3]	30.7	22.2	▼	19.2	24.3	▲
Surface Total N	1	Main	▲	mg/L	0.47	0.41	▼	0.47	0.45	▼	0.40	0.51	▲
	5	Bearses	▼	mg/L	0.38	0.43	▲	0.52	0.44	▼	0.44	0.46	▲
	3	South	none[2]	mg/L	0.30	0.45	▲	0.35	0.46	▲	0.42	0.48	▲
	4	Gooseberry	none[2]	mg/L	0.28	0.46	▲	0.43	0.48	▲	0.43	0.51	▲

NOTES:

1) September clarity data in Bearses Pond shows a downward, but not significant trend. Trend analysis of July and August clarity both have significant ($\rho<0.05$) downward trends.
2) Data is insufficient to complete trend analysis since these stations were not regularly sampled during PALS Snapshots. These stations have been regularly sampled between 2010 and 2012.
3) Total P analyses completed in the IEP/KV study contain a large percentage of below detection limit findings. Later analyses completed at the SMAST Coastal Systems Program Analytical Facility Laboratory used more refined laboratory techniques with lower detection limits.

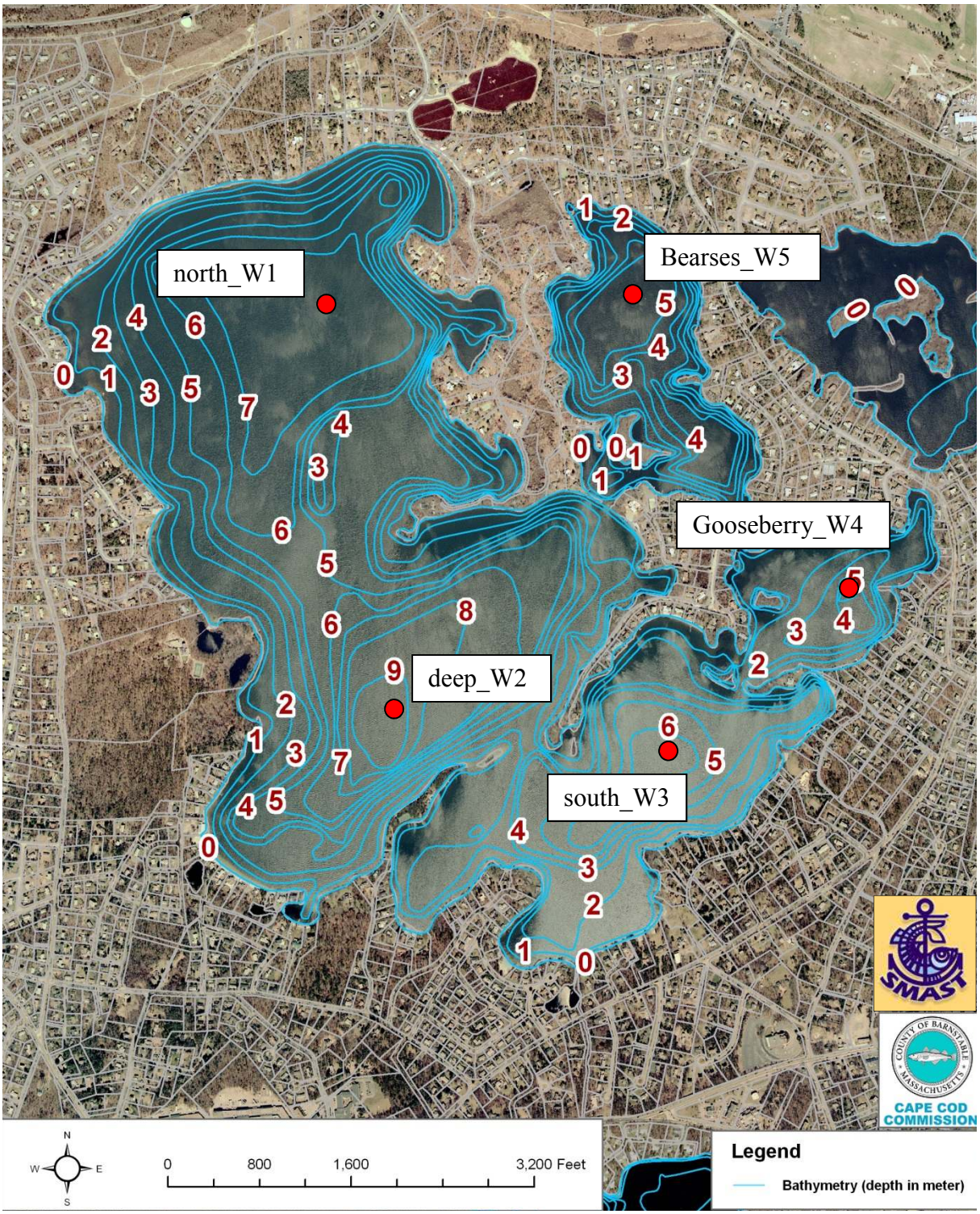

Figure 1. Lake Wequaquet Water Quality Sampling Stations

Red circles indicate five in-pond locations where water quality samples have been historically collected. Figure is modified from Figure II-1 in Eichner (2009).

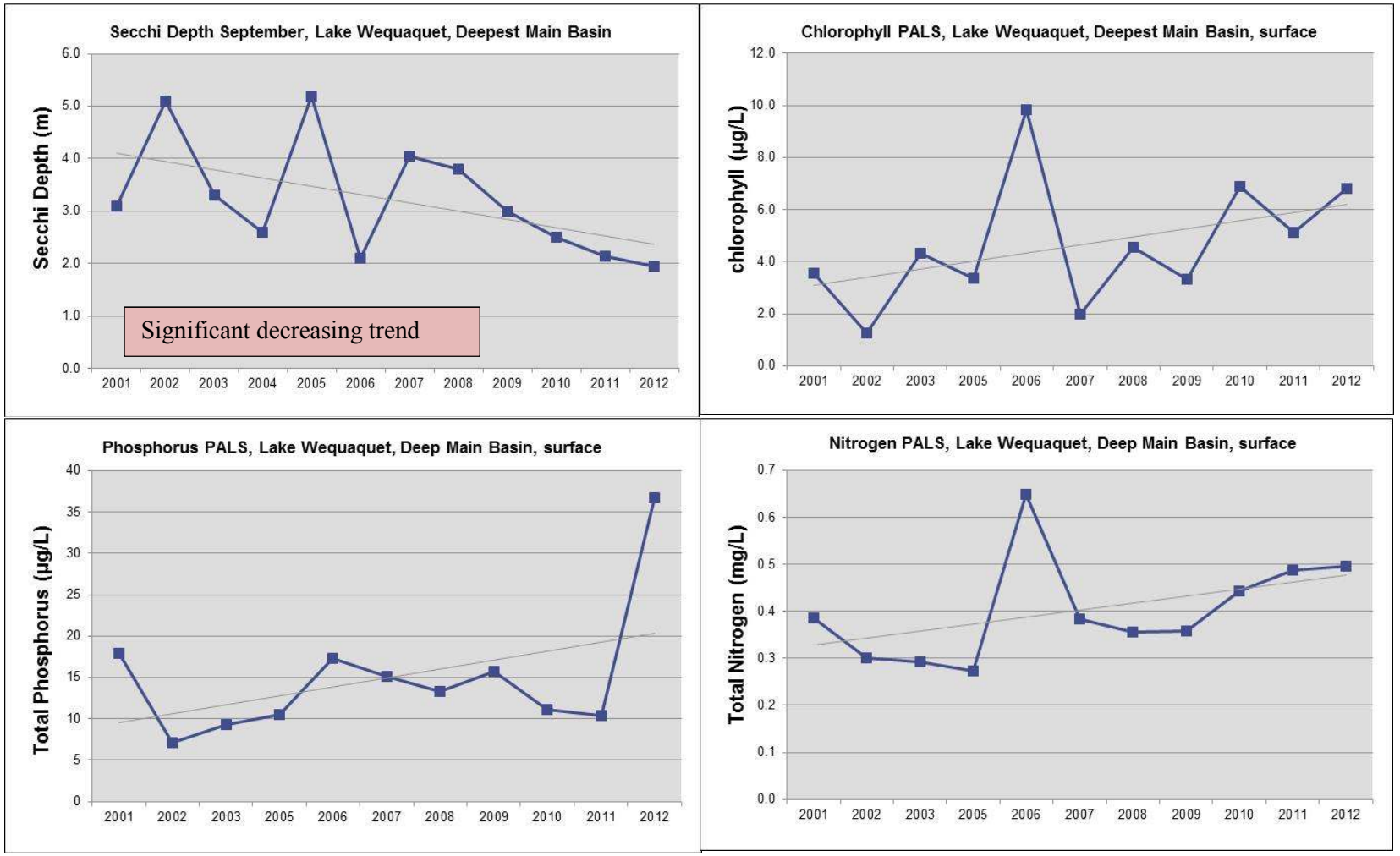

Figure 2. Deep Basin Trend Analysis – Lake Wequaquet

Clarity/Secchi was the only statistically significant ($\rho<0.05$) trend among the factors shown here. Trends for chlorophyll, total phosphorus, and total nitrogen all show upward trends, but they are not statistically significant. Trend analysis focused on September readings since these were the most consistently collected. Two of the annual readings used above were collected in late August (2001 and 2004). Trend analysis was completed using the Mann-Kendall trend statistic.

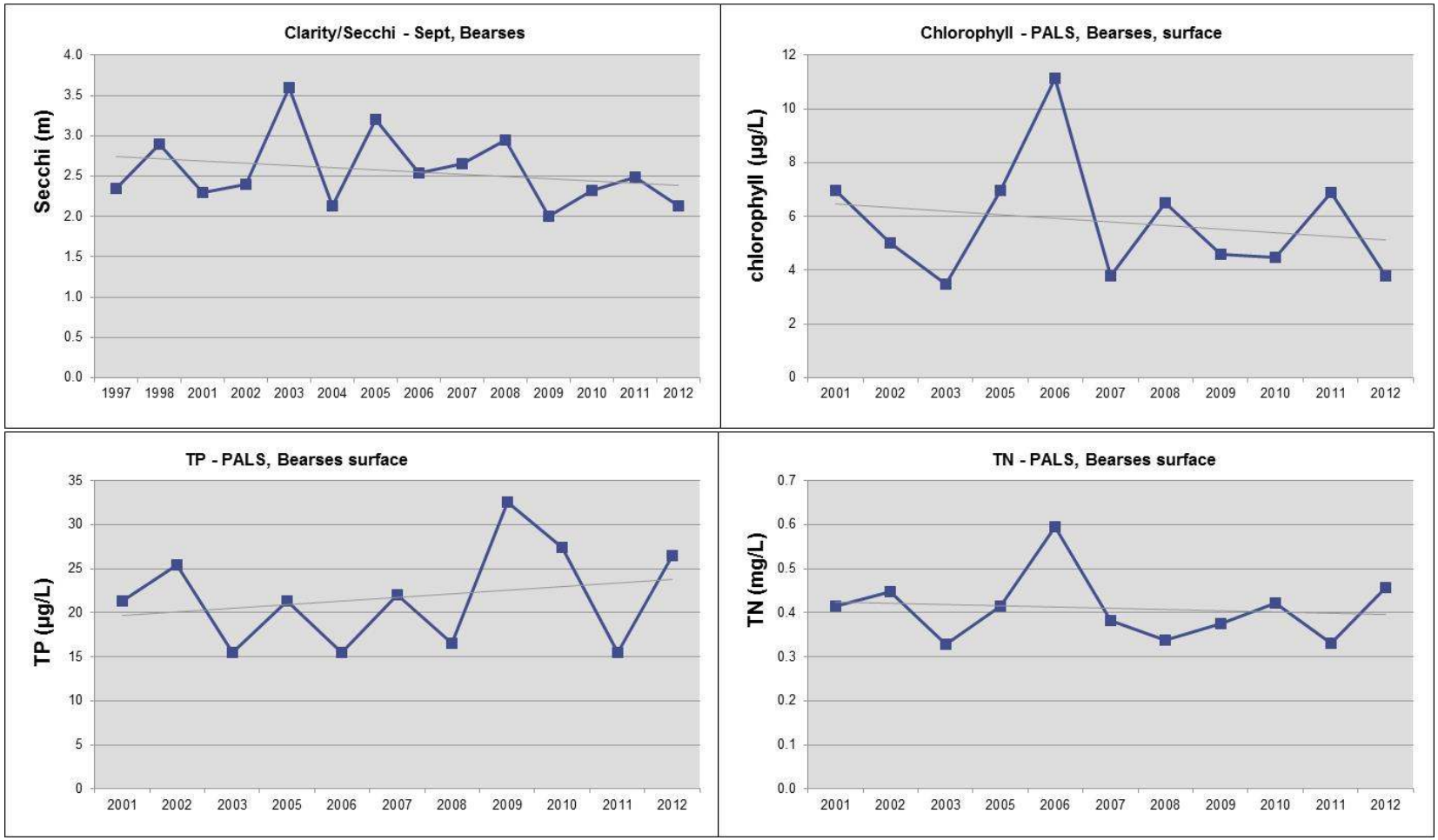

Figure 3. Bearses Pond Trend Analysis – Lake Wequaquet

None of the factors shown here have statistically significant ($\rho<0.05$) trends. However, review of July and August clarity readings show statistically significant ($\rho<0.05$) decreasing trends. Phosphorus and chlorophyll samples have not been collected regularly in July and August until recently (2010-2012), so trend analysis cannot be completed for these factors to see if they are increasing to match the decreasing clarity. Trend analysis focused on September readings since these were the most consistently collected. Two of the annual readings used above were collected in late August (2001 and 2004). Trend analysis was completed using the Mann-Kendall trend statistic