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May 25, 2011

Mr. Robert Race
Lake Onota Preservation Association
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Dear Bob,

Please see the accompanying revised review of data from LOPA monitoring of Onota Lake. I have focused on what, where and when to monitor, based on the historic program, and provided a lot of graphics to illustrate issues and options. Areas we discussed yesterday have been addressed.

What this boils down to is an opportunity to monitor fewer things less frequently with little loss of assessment capability, but with recommendations to monitor a few additional variables at a few different locations to enhance assessment value. Final decisions will depend on specific monitoring goals and budgets, so some LOPA discussion of my review is warranted.

Sincerely yours,

Kenneth J. Wagner, Ph.D., CLM
Water Resources Manager, WRS INC.

Lake Onota Monitoring Review

Lake Onota has been monitored for over a decade as part of multiple aquatic management programs. Stations, water quality variables, frequency and related methods have varied over time, but enough data have been collected to facilitate an analysis of what appears linked to what, which stations are most needed, how often they should be sampled, and what one might deduce from the data. I have taken a minimalist approach to verbiage and provided graphics with text bullets to explain what I see in the data.

Monitoring has three key components: what gets assessed, where it is assessed, and when (including how often) assessments are made. There is no such thing as too much data, so it is never wrong to overmonitor, but it does cost more and the knowledge gained is subject to diminishing returns. Therefore, it is appropriate to evaluate data from longer term monitoring programs to determine what is most needed to meet program goals. The creates a challenge for Lake Onota, as goals have changed over time with the management program and various grant requirements, but it is assumed that at this point the water quality monitoring program is intended to provide data that can serve as a warning of potential problems to facilitate responsive action, and to allow for long term trend evaluation.

What to assess

Over the last decade, LOPA has tested at various times for Secchi disk transparency (SDT) temperature (T), dissolved oxygen (DO), pH, total phosphorus (TP), and chlorophyll (Chl). There are some measurements for nitrate nitrogen and dissolved phosphorus, but not enough to derive any real pattern or meaning. All of these are useful for water quality evaluation in the context of lake management. SDT, TP and Chl should correlate to a fair degree, if TP is the limiting nutrient (which it normally is in this area) and algae (represented by Chl) are the main cause of reduced water clarity (which is normally the case, assessed as SDT). These relationships are represented in the Figures 1-8. The following observations are offered:

1. SDT is moderately high and Chl (as just Chl or the total of Chl and phaeophytin, a degradation produce of Chl) is moderately low, suggesting conditions in the lake that will be suitable for both contact recreation and fish and wildlife production. There is no evidence of algal blooms or low clarity from algae or suspended non-algal solids.
2. SDT and Chl correlate fairly well. There is substantial variability that is probably related to both natural sources and sampling or lab error, but it is apparent that clarity is mainly a function of Chl. As such Chl can be reasonably predicted from SDT values.
3. SDT tends to be higher and Chl lower at D6 than at D2; this is probably a function of nutrient loading being greater at D2, as it lies between all the larger tributaries and the outlet, while D6 is in a large, deep basin offset to the south and not in the direct path of the bulk of incoming nutrients.
4. TP and SDT do not correlate so well. There is a relationship, but it is weak. The translation of TP through Chl to SDT involves many other factors (temperature, forms of P, types of algae), so this is not surprising, but it is not reasonable to predict TP from SDT or vice versa.
5. The TP to SDT relationship is stronger at D2 than D6; this undoubtedly relates to forms of P changing between these sites, with related effects on algae and clarity. D6 is subject to less

Fig 1. Chl vs. SDT at D2

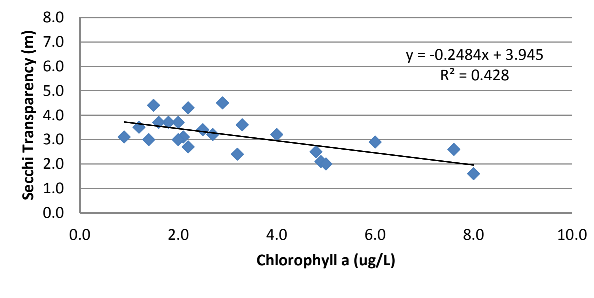


Fig 2. Chl vs. SDT at D6

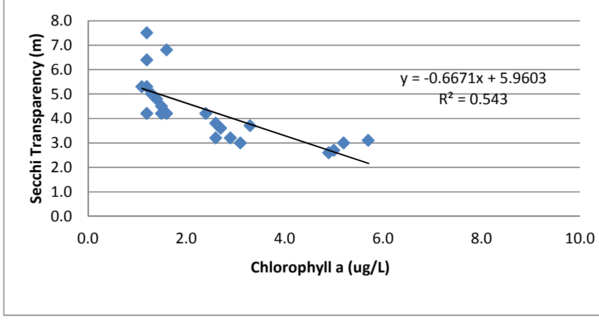


Fig 3. Total Chl vs. SDT at D2

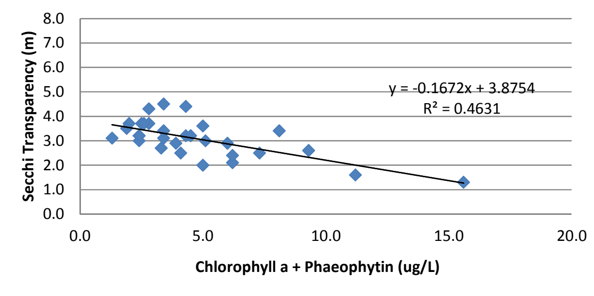


Fig 4. Total Chl vs. SDT at D6

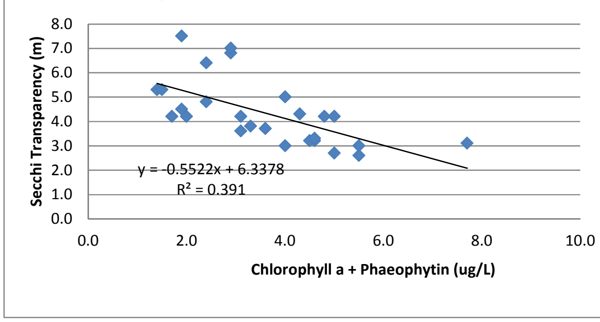


Fig 5. TP vs. SDT at D2

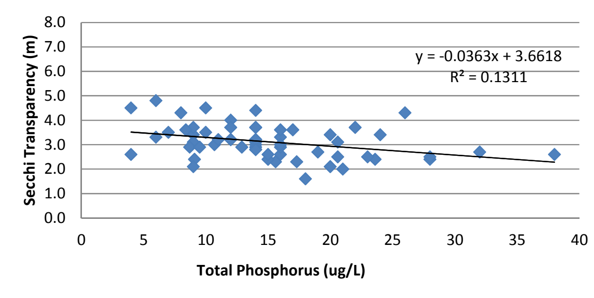


Fig 6. TP vs. SDT at D6

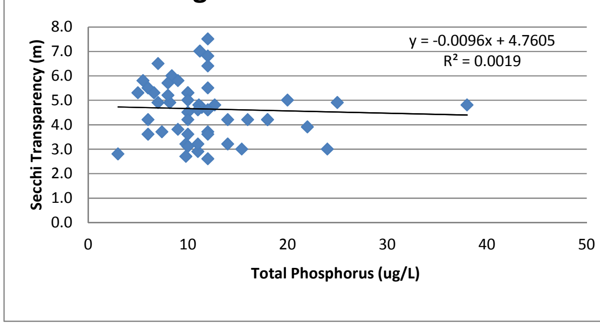


Fig 7. TP vs. Chl at D2

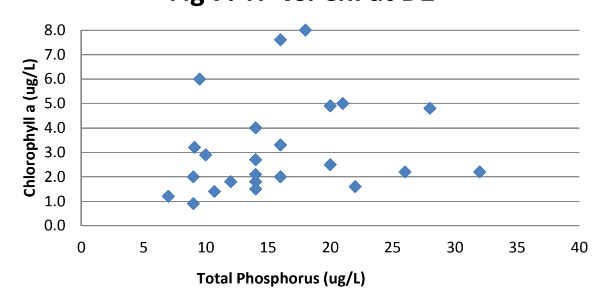
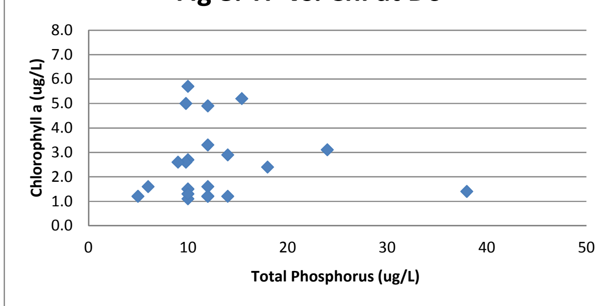


Fig 8. TP vs. Chl at D6



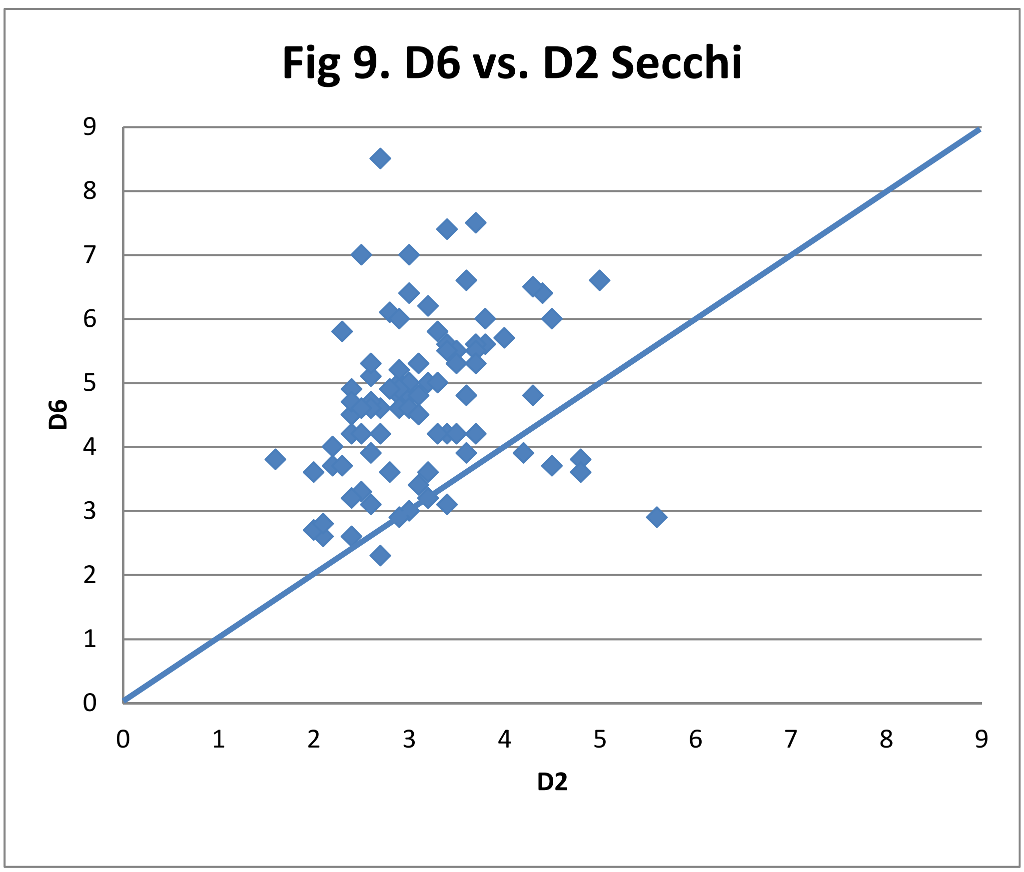
direct loading except by internal processes (e.g., from the sediment) and provides more dilution by virtue of greater depth and overall volume in this basin.

6. The relationship of TP and Chl is rather poor. This may be a function of a relatively narrow range of values for each, and may also be related to lab variation in both measures.
7. T and DO measures indicate strong seasonal patterns and vertical variability; the former is typical in New England and the latter expected at deep stations (D2 and D6). With the small range of SDT and Chl values, relations to T or DO are not expected at any meaningful level.
8. Four tributaries were assessed in 2006 through 2009 for a variety of water quality features, all apparently during dry weather. It is still useful information, but without wet weather data, it gives an incomplete impression of incoming water quality. Features like T, DO, conductivity/total dissolved solids, and pH are not important enough in dry weather flows to continue monitoring, and cessation after 2009 was appropriate.
9. Fecal coliform data from tributaries can be important when flows are high, but lower dry weather flows will not yield values high enough to have more than a very localized impact on the lake, and fecal coliform levels are likely to be low then anyway. Based on four years of data for four tributaries, further dry weather sampling of fecal coliform is not justified.
10. Collecting data from the tributaries on nutrient levels can be valuable, but sampling only during dry weather provides a skewed impression of inputs. Flows will be lower then, and the influence of inputs will be less than during storms, when both pollutant content and volume of incoming water are expected to be much higher. For three years of data (about 17 values per stream), the range for Daniels Brook was 6 to 21 ug/L, the range for Churchill Brook was 4 to 27 ug/L, the range for Parker Brook was 7 to 40 ug/L, and the range for Blythewood Brook was 9 to 62 ug/L. These are not especially elevated values, and the conclusion one would draw is that dry weather water quality is generally acceptable, although some improvement in the more urbanized Blythewood Brook is warranted. Further dry weather sampling of tributaries is not necessary.
11. Wet weather data are lacking, and at least TP should be sampled during wet weather. Additional sampling for dissolved P, forms of nitrogen and possible fecal coliform would be useful for wet weather as well, but TP would have the highest priority.
12. The outlet below the dam has also been monitored during the 2006 to 2009 period. Values for T, DO, pH, conductivity/TDS and fecal coliform have limited utility and do not need to be measured further. TP data are useful in any modeling exercise, as comparison of outgoing TP to inlake TP can be used to calculate a retention coefficient for P. Values from 17 samplings over 3 years indicate a range of 11 to 41 ug/L with an average of 20 ug/L. The average value for D2 over the same period is only 16 ug/L, with a lower overall range, which is somewhat unusual (the outlet is not a deep discharge, so values should match nearby surface water). It may be that the higher TP in Blythewood Brook may be influencing the outlet in a disproportionate manner. The existing data for outlet TP may be useful in any future modeling, but further assessment does not appear warranted, except perhaps during drawdown, which would represent a large discharge of water and TP.

Where to assess

The collection of data at the various Lake Onota stations is erratic over time. Only D1, D2 and D6 have extensive multi-year data for most variables. D1 is shallow, so surface vs. bottom values are of limited utility, and SDT extends to the bottom on most dates (and loss of clarity may be related to non-algal solids in this area). So most in-lake comparisons are between D2 and D6.

13. Figure 9 shows the relation of SDT between D2 and D6. D6 has greater clarity most of the time (more values are above the line that represents a 1:1 relationship). This is as expected from review of Chl:SDT graphs (Figs 1-4); Chl is lower and SDT is higher at D6 than at D2, most likely representing differences in loading attributable to the position of these two deep basins relative to the main inlets.
14. Differences in SDT among stations are sufficient to warrant measurement of SDT at both D2 and D6, especially given the low cost of that measurement.
15. Data for pH are limited, tend to be between 8.0 and 8.5 SU at the surface (Figs 10 and 11) and 7 to 8 SU at the bottom, with slight surface increase progressing from D2 to D6, but any station will probably be sufficient to allow a reliable approximation of pH in the lake.



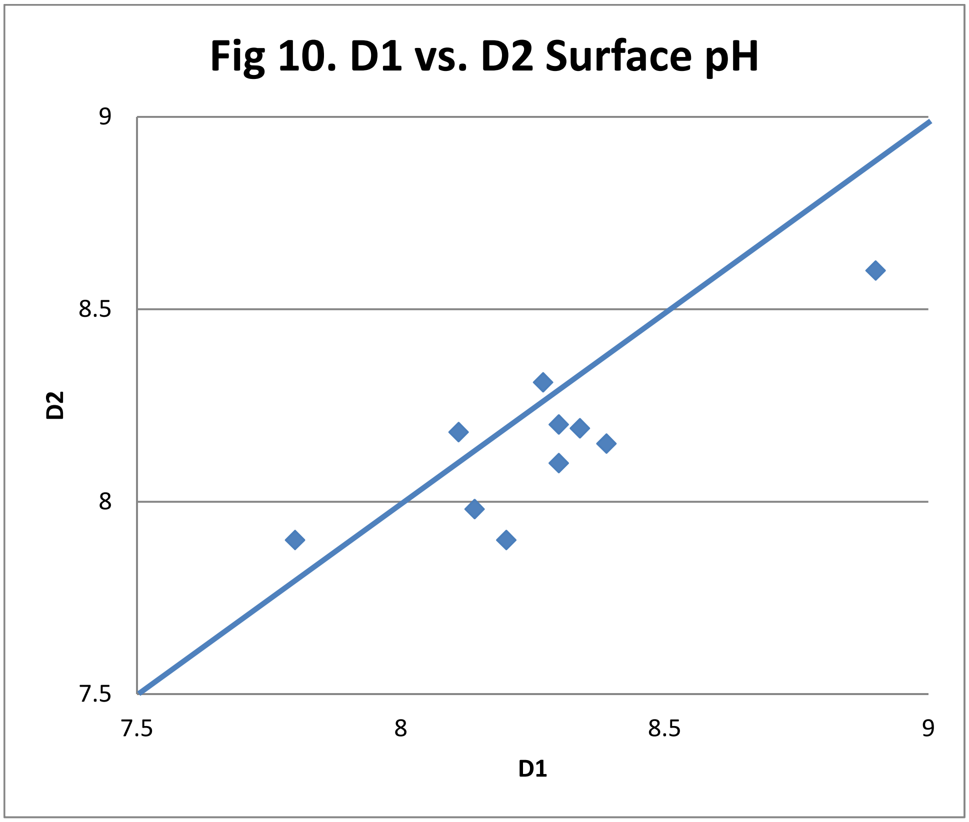


Fig 10. D1 vs. D2 Surface pH
9
8.5
8
7.5
D2
7.5
8
8.5
9
D1

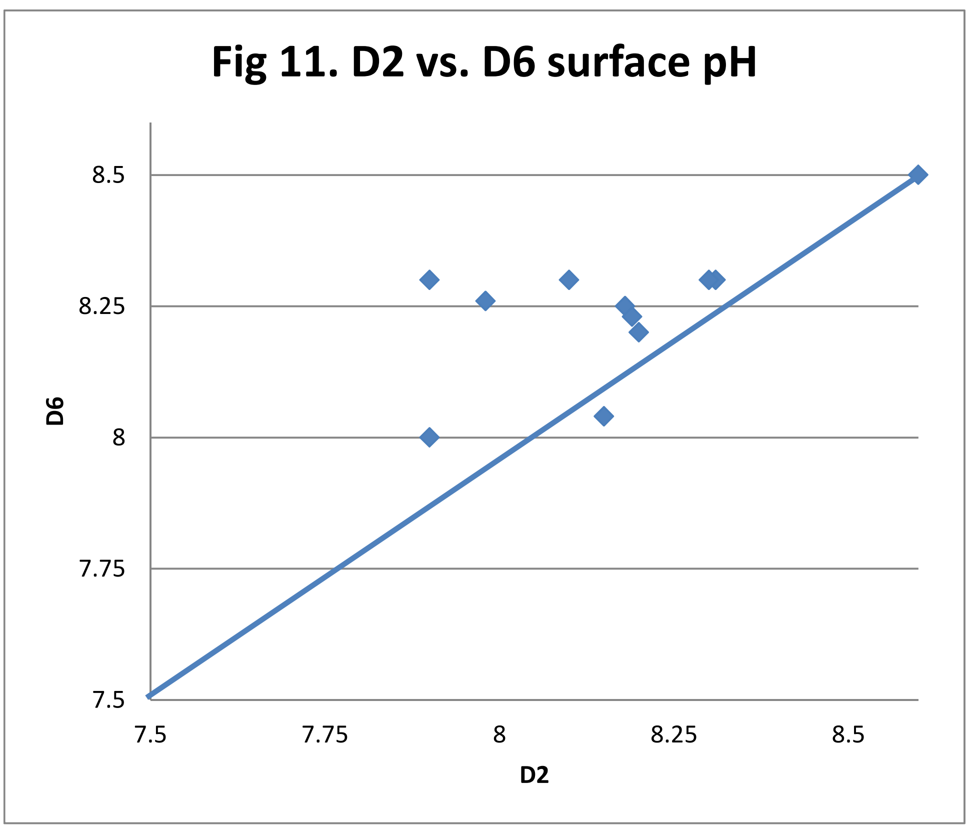


Fig 11. D2 vs. D6 surface pH
8.5
8.25
8
7.75
7.5
D6
7.5
7.75
8
8.25
8.5
D2

16. Figures 12 and 13 illustrate the TP relationship for D1 vs. D2 and D2 vs. D6. There are more high values at D1 than at D2 and at D2 than at D6 (more values below the 1:1 line). This further suggests loss of TP as the water moves between these stations, and is as expected in a lake of the size, depth and configuration of Onota. D1 reflects direct inputs from two of the three largest inlets, while water from the three largest tributaries passes through D2 on the way to the outlet. D6 is offset to the south, has a longer detention time, and receives water from the northern part of the lake mainly as a consequence of wind or larger inflows from storms. The progression of declining mean TP among these stations is as it would be expected to be.
17. Values at one station are not easily predictable on any given date from values at other stations, but on average, it is apparent that there is about a 35% reduction in TP between D1 and D2 and another 20% decrease when comparing D6 to D2.

Fig 12. D1 vs D2 Surface TP

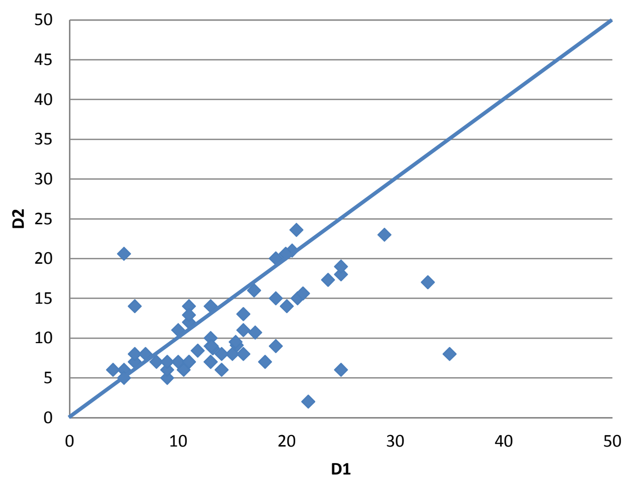
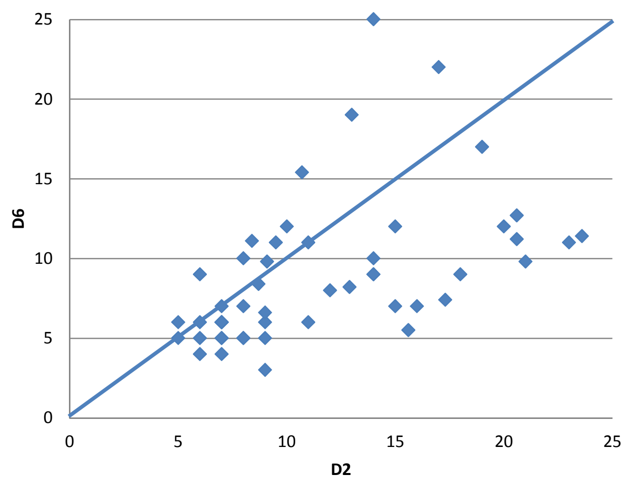


Fig 13. D6 vs. D2 surface TP



18. Chl or total chlorophyll (which includes the degradation product phaeophytin, which can come from natural decay or sample handling), exhibits considerable variability in paired measures for either D1 vs. D2 (Figs 14 and 15) or D2 vs. D6 (Figs 16 and 17). Chl represents algae, which will not be uniformly distributed, so this is not surprising.
19. The average relationship for D1 vs. D2 is roughly 1:1 with substantial variation, but values are higher on average at D2 vs. D6. This is consistent with TP and SDT values for D2 vs. D6, and suggests that only one of those two stations needs to be monitored for Chl.
20. However, as SDT was a reasonable predictor of Chl, and this is a more difficult and expensive variable to measure, Chl may not have to be assessed in the future.

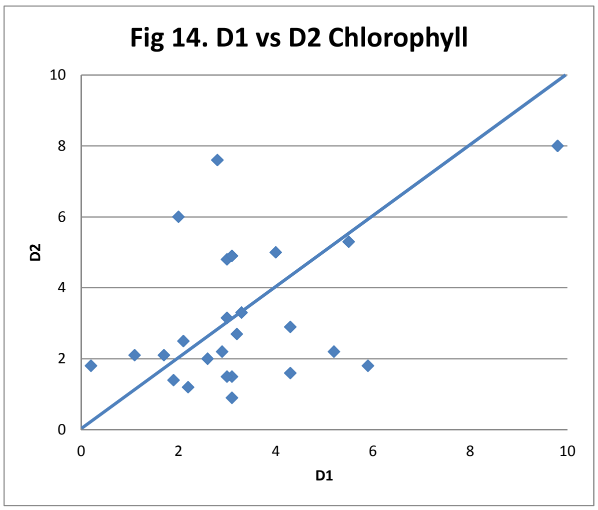


Fig 14. D1 vs D2 Chlorophyll

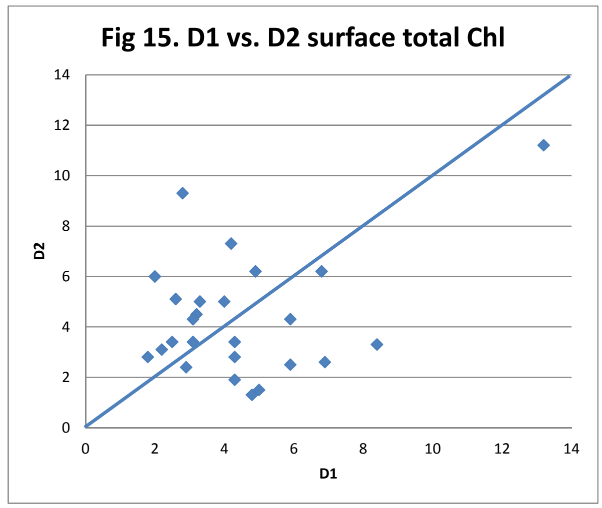


Fig 15. D1 vs. D2 surface total Chl

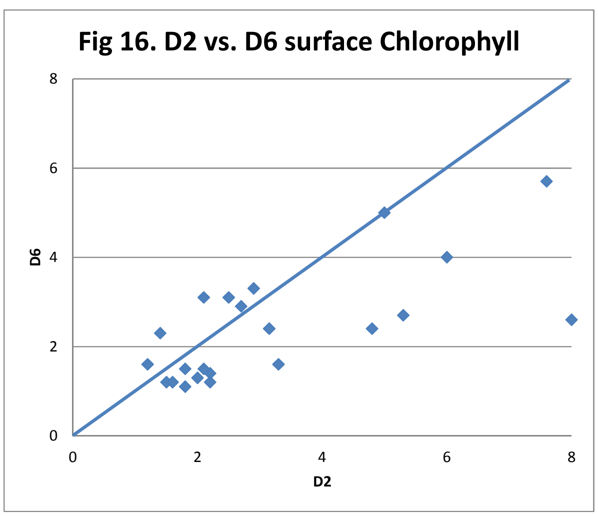


Fig 16. D2 vs. D6 surface Chlorophyll

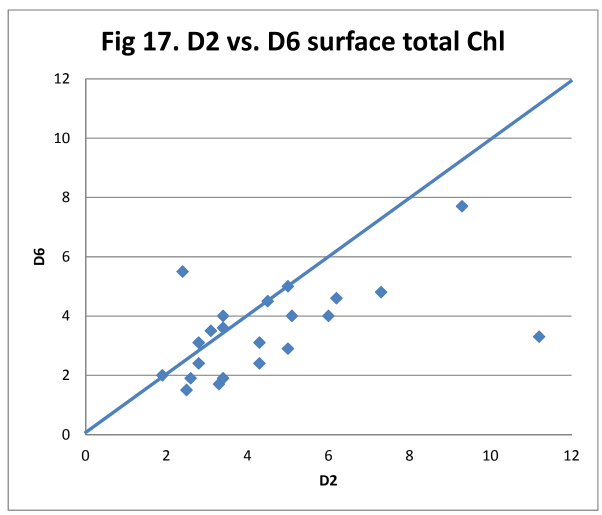


Fig 17. D2 vs. D6 surface total Chl

21. T and DO are fairly consistent at the surface of all stations at any given time (Figs 18 and 19), and are lower but similar near the bottom of D2 and D6, the two deep stations.
22. A single T/DO profile over depth at D2 or D6 should sufficiently characterize conditions, although there are some temporal differences between these stations; deep T rises more over summer at D2, DO is lost later in the spring and recovered more slowly in fall at D6, so maintaining these two stations for field measurement of T and DO is justifiable.

Figure 18. Temperature at Lake Onota Stations, 2000-2010.

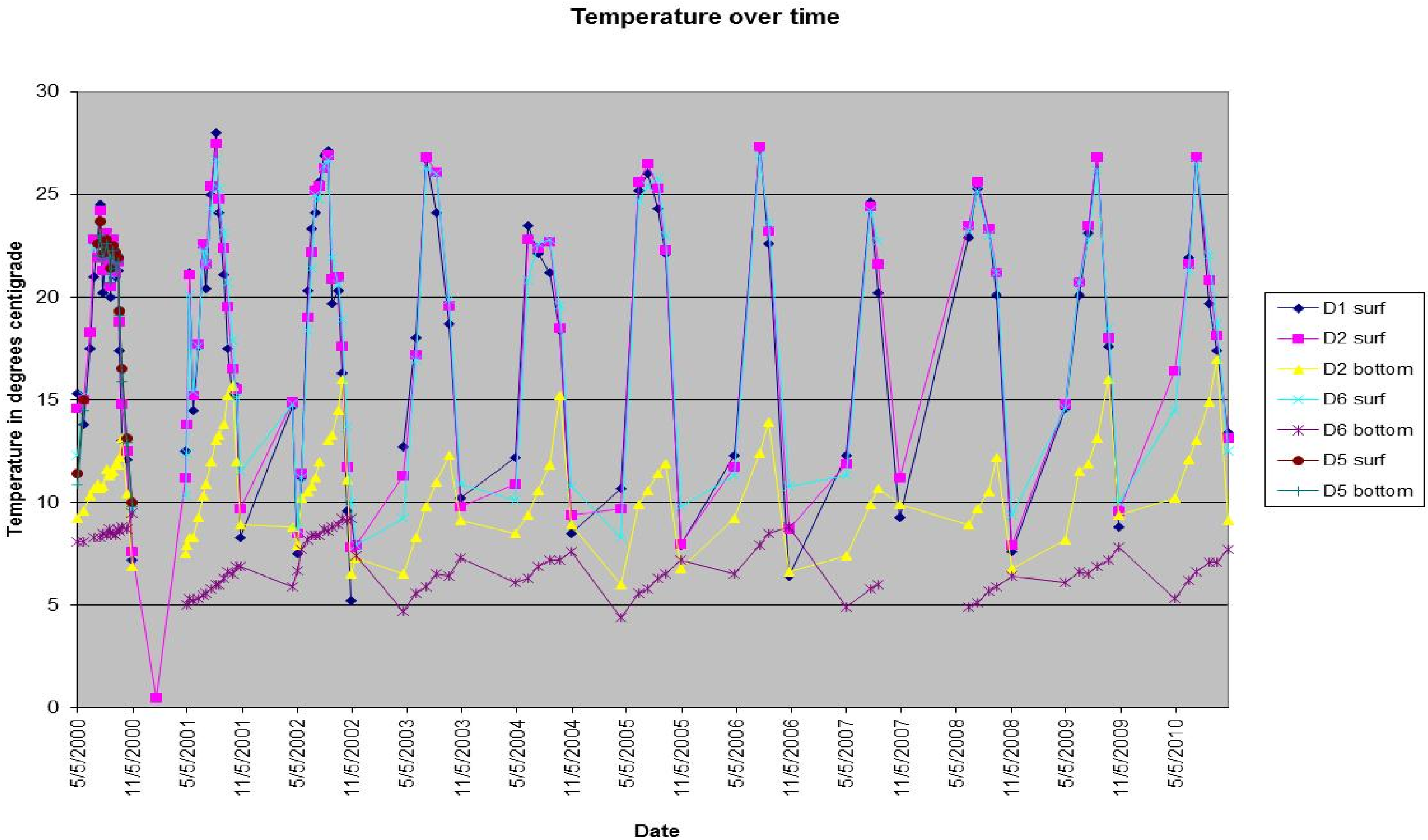
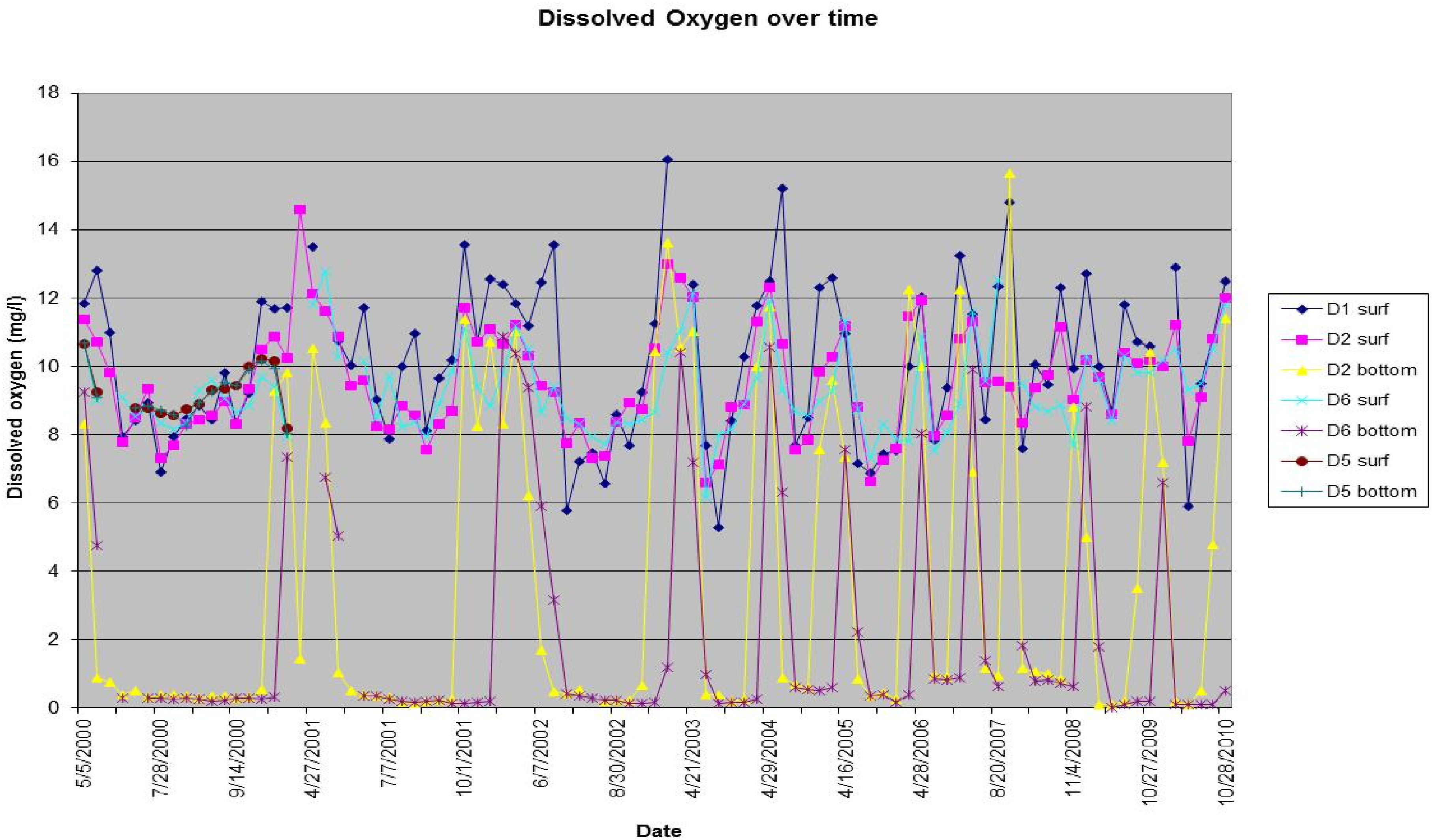


Figure 19. Dissolved Oxygen at Lake Onota Stations, 2000-2010.



23. The number of vertical measures of T or DO made at each station is not a major factor in cost, but it does require more time in the field to make more measurements. Measurements have been made at 3 ft intervals in most past efforts, but the pattern is not very different when fewer values are graphed. It is suggested that one could measure every 6 ft or 2 m and still capture the vertical pattern of T or DO adequately in Lake Onota.
24. Tributaries have been monitored in four years, 2006-2009, apparently always during dry weather. Flows will be lower then, and the potential impact on the standing body of Lake Onota will be small. Measurement of T, DO, pH, conductivity and even fecal coliform are not particularly relevant. Nutrient values are of interest, but unless values are very high during dry weather flows, the influence on the lake will be minimal. TP values for Daniels, Churchill, Parker Brook were measured between 2006 and 2009 and were generally low. Values for Blythewood Brook were somewhat higher, but still not a major influence on the lake. These tributaries warrant wet weather monitoring, but not further dry weather assessment.

When to assess

The available data are mostly from summer on a monthly basis, sometimes every two weeks. The pattern of T/DO is fairly regular and predictable (Figs 18 and 19), while the pattern of other variables is less predictable.

25. SDT is easy and inexpensive to measure, and given the range and variability observed (Fig 20), it should be measured as often as possible at D2 and D6, but not at D1, which is too shallow. It could be assessed at other locations as well, as long as they are deep enough to get a reading before the bottom is reached. Once every two weeks is reasonable, but more often could be useful in characterizing long term patterns and comparing seasonal averages.
26. Measurement error (sum of sampling and lab error sources) from 8 paired duplicates in recent years is 7 ug/L (in other words, to be 95% sure that two values are different, one must be more than 7 ug/L different from the other. Based on 4 field blanks, values <9 ug/L may not be differentiable from 0, roughly consistent with the 7 ug/L measurement error estimate. So small shifts cannot be reliably detected. TP values in Onota Lake are mostly <20 ug/L (Fig 21), so frequent measurement does not provide any great insights to lake condition.
27. The primary interest now is on any big spikes in TP values or any shifts outside the typical surface range over the last decade. This can be accomplished with strategic timing of sampling. Given the long term pattern of low surface TP values, and the cost of the testing, it is reasonable to assess TP in spring (April/May) early summer (late June/early July) and late summer (late August/early September). This will bracket the times of expected highest and lowest values and the period of main interest for users.
28. Deep TP has greater potential to attain high values (Fig 21), and these are of definite interest in the long term health of the lake. These values occur during mid- to late summer, as a function of release of P from the sediment during stratification, so sampling for TP in deep water during the early and late summer samplings should be sufficient to bracket any build-up of TP. For consistency, sampling in spring is desirable if affordable.
29. Chl values exhibit temporal variability, but not a wide range (Fig 22). Chl could be sampled with TP, but is more likely to be estimated from SDT data.

Figure 20. SDT over time at Lake Onota stations.

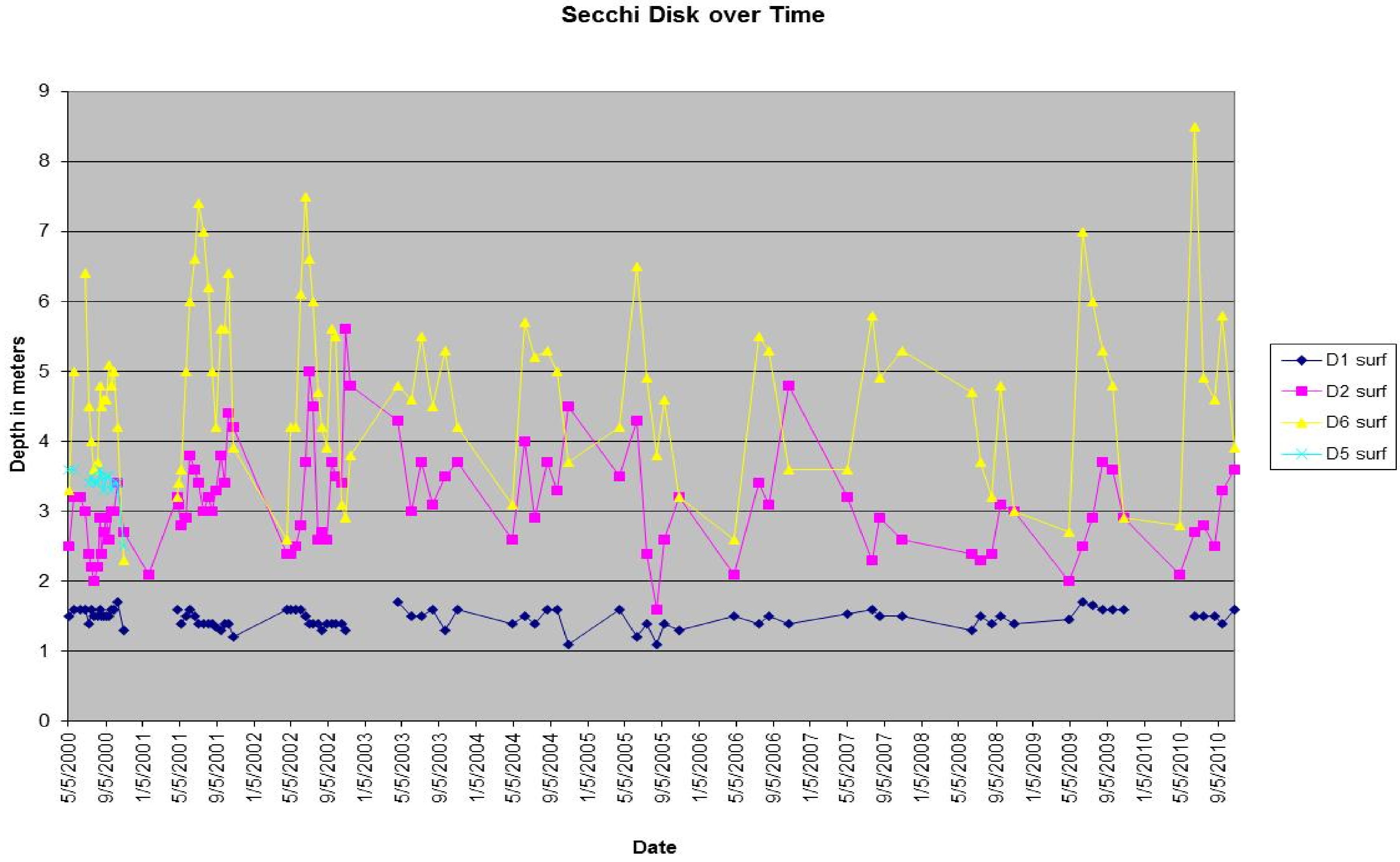


Figure 21. TP over time at Lake Onota stations.

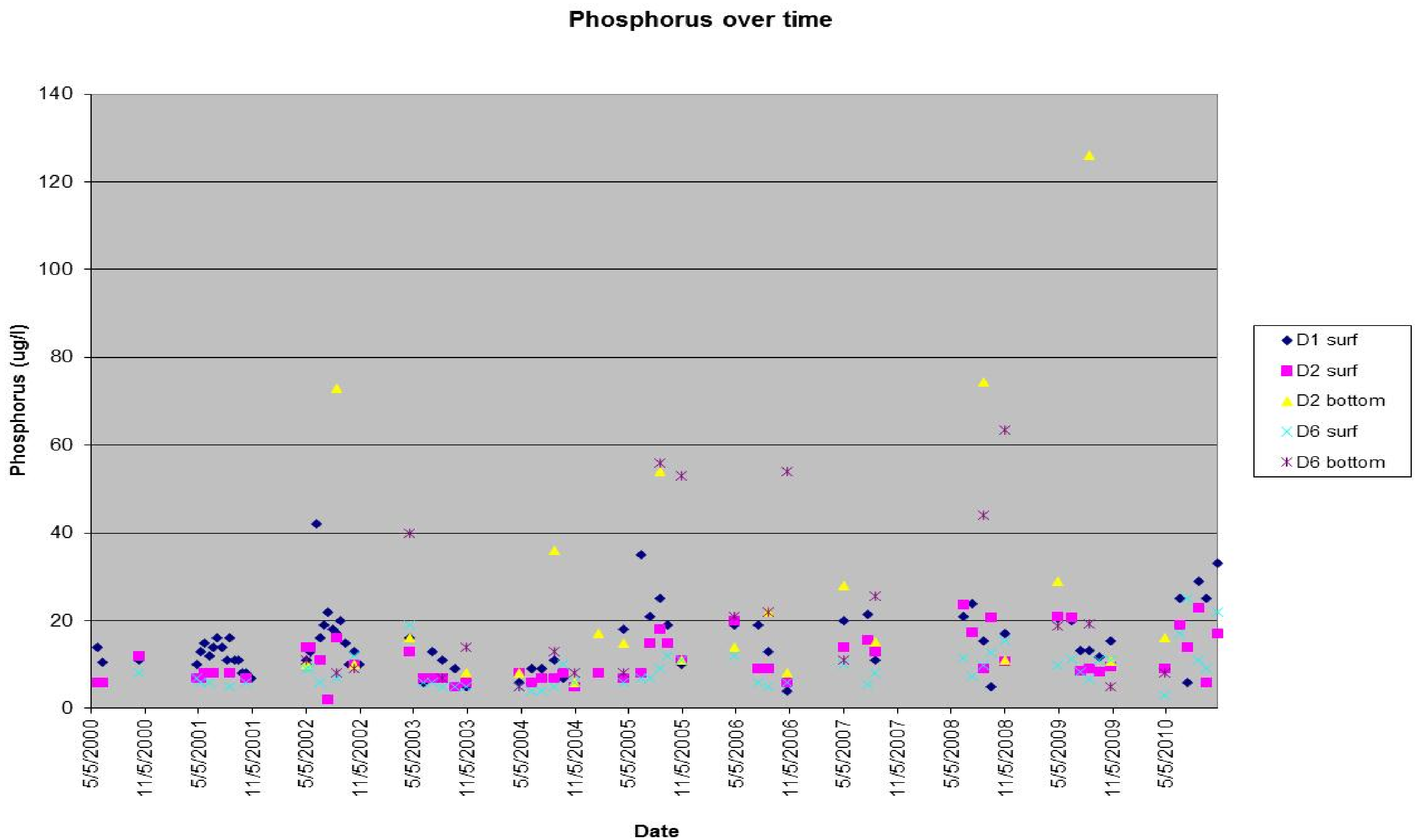
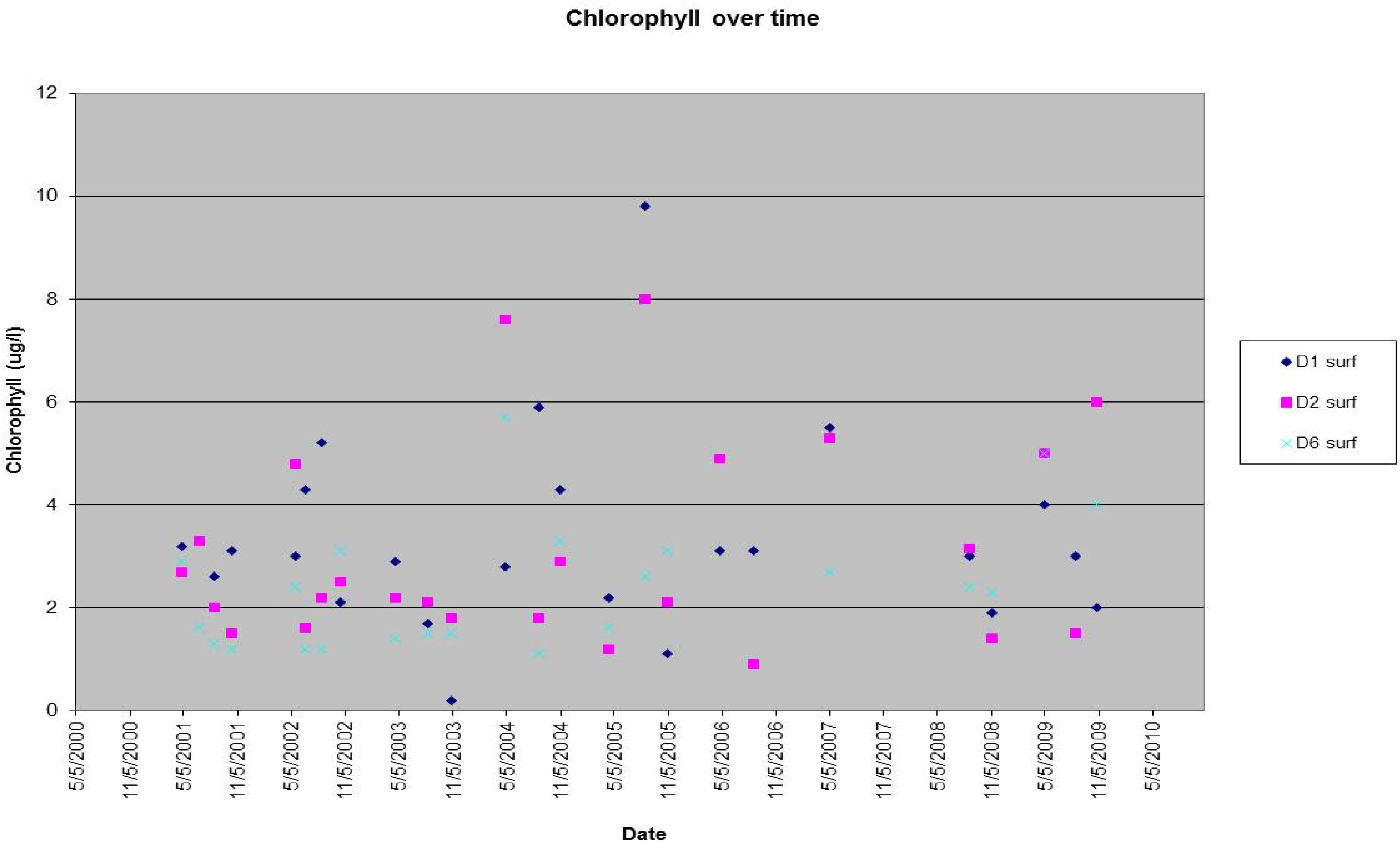


Figure 22. Chlorophyll over time at Lake Onota stations.



30. Tributaries can provide valuable data for nutrient inputs, but mainly during wet weather, which has not been properly represented in past tributary sampling. Tributaries should be sampled during the first flush of storms, which can be accomplished with passive samplers (Fig 23, specialized caps provided to R. Race). One sampling a year is reasonable, more if affordable, and over a period of years the range of wet weather inputs can be characterized. Spring storms tend to have the most influence on summer conditions, but any storm will provide useful information. Sampling for TP, dissolved P, nitrate N and total Kjeldahl N (includes ammonium N and particulate organic N) would be desirable.
31. The only further outlet sampling that might provide valuable data would be during drawdown, as this represents a major output of water and TP. One sample during peak drawdown outflows each year would be helpful for a few years, to assess this major discharge and aid consideration of mass balance of TP for Lake Onota.

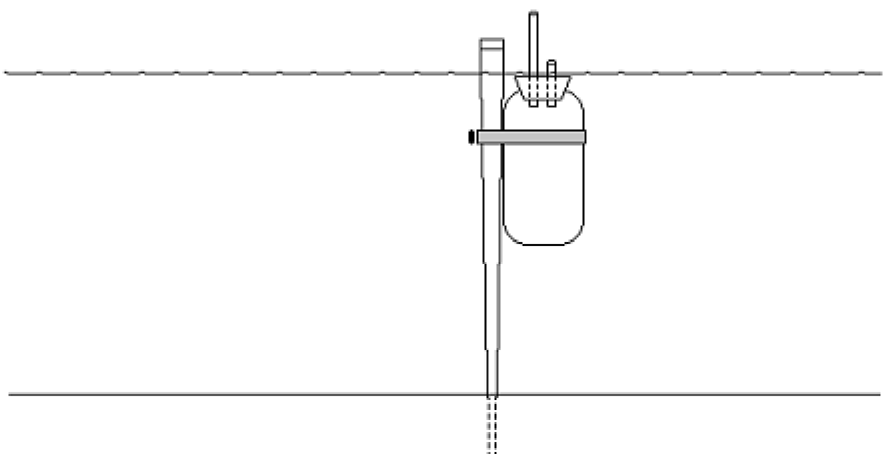


Fig. 23. Passive storm water sampler design

Condition Summary
Lake Onota has exhibited relatively low TP and Chl and moderately high SDT for over a decade, suggesting desirable conditions. Water is clear enough for enjoyable and safe contact recreation but fertile enough to support fish and wildlife. Oxygen is adequate everywhere except deep water during summer thermal stratification, a very common feature in many lakes; while oxygen is potentially lowered by human inputs to the lake, having low deep oxygen during summer is a natural phenomenon. Eliminating it may be very beneficial to lake condition and ecology, but is not essential to maintain current uses. The pH is slightly basic, which is natural for the Berkshire region; no extremely elevated pH values have been encountered that would harm fish or wildlife. Little is known about quantity of forms of nitrogen, and there are few data wet weather inputs, the likely major mode of loading to the lake; wet weather data would be helpful in establishing watershed management priorities and algal bloom threats in the future.

Recommendations
- Assess T, DO, pH, SDT and TP in Lake Onota.
- Measure T/DO as a profile at D2 and D6 at 6 ft or 2 m intervals.
- Measure pH at D2 and/or D6; a surface measurement should be sufficient, but additional bottom measurement would be useful if convenient.
- Measure SDT at D2 and D6 and any other deep stations as convenient.
- Measure TP at the surface and near bottom of D6.
- Measure SDT as often as possible, with once per 2 weeks suggested as optimal.
- Measure T/DO, pH and surface and bottom TP three times per year, in April/May, late June/early July, and late August/early September.
- Measure actual inlet TP in the four main tributaries during wet weather at least once per year to evaluate actual inputs via the main entry mode for water to the lake. Also assess dissolved P, nitrate nitrogen and total Kjeldahl nitrogen in the wet weather samples if affordable.
- Consider assessing TP in the actual outlet water during peak drawdown flows if any modeling is to be conducted on P loads and processing in the lake.
- Consider assessing surface and deep water nitrate nitrogen and total Kjeldahl nitrogen at D6 for the early and late summer samplings, to provide data for this other important nutrient.

The basis of the monitoring program would therefore be measurements of SDT about every two weeks at two or more deep locations, with three samplings at D2 and D6 (spring, early summer, late summer) that include T and DO profiles at 2 m intervals, surface pH, and surface and bottom TP measures. Additional nitrogen measures might be considered at D2 and D6 if affordable. At least one wet weather sampling of the four tributaries is recommended, at least for TP, and possibly also for dissolved P, nitrate N and total Kjeldahl N. Sampling of the outlet for TP during peak drawdown flows would aid any future modeling efforts.