INTERRELATEDNESS BETWEEN LAKE CHARACTERISTICS

80 Overview
80 Area
80 Mean depth
80 Maximum depth
80 Shoreline development factor
81 Color
81 Water clarity
81 Chlorophyll a
81 Chlorides
81 Calcium
82 Magnesium
82 pH
83 Alkalinity
84 Turbidity
84 Organic nitrogen
84 Total nitrogen
84 Inorganic phosphorus
85 Total phosphorus
86 Discussion and Summary
OVERVIEW

General relationships between various water quality parameters have been reported upon extensively in limnology texts (Hutchinson 1975, Wetzel 1975). However, because the large number of lakes sampled in this study spanned a wide range of lake types and conditions, the opportunity exists for a more detailed analysis of these relationships.

It is important to stress that these correlations are not all cause-effect relationships, but perhaps more correctly represent associations. Even in cases where significant correlation coefficients are found between theoretically valid relationships, other unidentified factors may be responsible for the associations.

Reckhow (1979) explicitly describes the weaknesses involved in the use of correlation coefficients and linear regressions; primarily these deal with the assumption that the data are indeed linear and that the data are normally distributed. As will be shown later, these assumptions are not always valid, and even the transformation of the data to compensate for these problems does not always create a totally unbiased relationship.

Relationships between different water quality characteristics are provided in Appendix B. The computer program used to create the correlation matrices from which these figures were drawn did not print the number of matching pairs of data points used in computing the correlation coefficients. In order to make comparisons of significance between matrices (data sets), it was necessary to compute the number of degrees of freedom based on the minimum number of data points for any particular parameter within a given data set. Therefore, the levels of significance presented in Appendix B are somewhat conservatively labeled, but are quite adequate for making comparisons and generalizations between and about the various subsets since the data sets are quite large. The following discussion is based upon the data generated in Appendix B.

Since interrelationships between parameters graphically displayed in Appendix B are readily observable, only major highlights will be specifically mentioned. The following format lists each major characteristic (e.g., Area) and, on the left margin, other characteristics with which it is closely associated, either positively or negatively in almost all of the subsets of lakes analyzed (e.g., mean depth). The characteristics that are indented (e.g., maximum depth) apply only to the restricted groups of lakes indicated in the parentheses (e.g., seepage lakes and impoundments). Some associations important on a regional basis will also be mentioned.

AREA

+ Mean depth
  + Maximum depth (seepage lakes and impoundments)
  + Alkalinity (low alkalinity lakes)
  + Shoreline development factor (seepage lakes, impoundments and low chlorophyll a lakes)

Overall, area showed generally poor correlation with other lake characteristics. In the Northeast, there were positive relationships between area and maximum depth, and area and inorganic and total phosphorus. There was a negative correlation between area and Secchi disc, and positive correlations with inorganic and total phosphorus in the Southeast Region. The Central Region had positive correlations between area and chlorophyll a and total phosphorus. The Southwest Region showed no significant relationship between area and other lake characteristics.

MEAN DEPTH

+ Area
+ Maximum depth
+ Water clarity
  - Turbidity
  - Nutrients
    - Color (drainage lakes)
    - Chlorides, calcium, magnesium (impoundments)
    - Chlorophyll a (seepage lakes and low alkalinity lakes)

The significance of the relationship between mean depth and maximum depth was discussed previously under General Characteristics — Physical Features. The relatively strong negative correlation of mean depth with calcium, magnesium, alkalinity and chlorides in impoundments shows the influence of lake volume and flushing rate on these associations.

The strongest positive correlation of mean depth and water clarity was in the Central Region. Negative correlations between mean depth and color, chlorophyll a, turbidity, and organic and total nitrogen were evident in the Northeast Region. Phosphorus showed little association with mean depth in the Northeast Region, but a weak negative correlation between mean depth and nitrogen and total phosphorus was observed in the Northwest Region.

MAXIMUM DEPTH

+ Mean depth
+ Water clarity
  - Nitrogen
  - Chlorides, inorganic phosphorus (impoundments)
  - Turbidity (seepage lakes, drainage lakes and low alkalinity lakes)
  - Total phosphorus (drainage lakes)
  - Color (drainage lakes)
  - Chlorophyll a (low alkalinity lakes and low chlorophyll a lakes)

The association of maximum depth with nitrogen is generally more pronounced than its association with phosphorus. This may be related to the higher coefficients of variation in the phosphorus concentrations (See Table 33). A rather unusual relationship exists between maximum depth, mean depth and area. As demonstrated earlier, maximum depth and mean depth were often highly related, as were area and mean depth. Yet, where these relationships were the strongest, the relationships between maximum depth and area were at best only weak. The inverse of this situation was also true; the maximum depth-area relationship was strongest where the mean depth-area relationship was weakest. The reasons for, and the significance of, this apparent anomaly are unknown. Both natural lakes and drainage lakes are similar in this respect. The significance of maximum depth as it relates to stratification and the channeling of nutrients in lake systems was discussed earlier (General Characteristics — Lake Morphometry).

Water clarity was positively correlated with maximum depth in all regions except the Central Region. Chlorophyll a, turbidity and nitrogen were all inversely related to maximum depth in the Northeast Region. Nitrogen and phosphorus were weakly related to mean depth in the Northwest and Southeast regions, but such was not the case in the Central and Southwest regions. A positive correlation of pH with mean depth was also found in the latter two regions.

SHORELINE DEVELOPMENT FACTOR

- No overall strong correlations
  + Area (seasonal data, impoundments, seepage lakes and low chlorophyll a lakes)
  + Mean depth (impoundments)
  + Maximum depth
The significance of the shoreline development factor (the ratio of the shoreline perimeter divided by the circumference of a circle with the same area as the lake) and its relationship to other water quality characteristics does not appear to be great. Other factors (mean depth, watershed size, etc.) apparently outweigh the impact of this parameter.

COLOR

- Water clarity
- Mean depth (drainage lakes)
- Maximum depth (drainage lakes)
- pH (drainage lakes)
- Chlorophyll a, chlorides, calcium (low chlorophyll a lakes and low alkalinity lakes)

Strong correlations between color and water clarity were observed in all subsets of data (see also discussions by Anthony and Hayes 1964). A weak association with nitrogen is evident in most subsets (see also Appendix A).

Some regional differences concerning color were noted. Secchi disc and color were strongly related in the Northeast and Northwest regions, but other factors were apparently more important or overriding in the other regions. Color was also strongly associated with chlorophyll a in the Northeast Region and with organic and total nitrogen in both the Northeast and Northwest regions. In the Southeast Region, color was strongly associated with calcium, magnesium and alkalinity, while in the Southwest Region the opposite was true. In both regions, color was inversely related to pH.

WATER CLARITY (SECCHI DISC DEPTH)

+ Mean depth
+ Maximum depth
- Color
- Chlorophyll a
- Turbidity
- Nutrients
+ pH (impoundments)
- chlorides (impoundments)
- chlorides, calcium, magnesium, pH and alkalinity (low color lakes)

The relationship of water clarity to various physical and chemical factors has been discussed elsewhere (see Trophic Classification — Factors Affecting Water Clarity). An unusual association is the relationship of water clarity and pH, which were positively correlated in impoundments and negatively correlated in lakes with measured color levels less than 40 units. Color and pH were negatively correlated in impoundments as were color and water clarity, thus pH and water clarity were directly related. This is the opposite of findings reported by Kwiatkowski and Roff (1976) for northern Ontario lakes that had a pH below 6.0 units, where a strong inverse relationship was noted. While this inverse relationship appeared in the low color lakes, the mean pH for this group of lakes was 7.1 units (Table 13), which is not significantly different than lakes with high color levels. The significance of these differences is uncertain. The fact that water clarity was strongly correlated with all other parameters in the low color data subset indicates that color may severely interfere with the interpretation of results among the other data subsets.

Fairly consistent associations of water clarity and turbidity, nitrogen and phosphorus were common to all regions. Water clarity was negatively correlated with calcium in the Southeast and Central regions and with alkalinity in the Southeast Region. This is consistent with other studies which have demonstrated that excess calcium in the form of colloidal particles may affect the penetration of light in the water column (Hutchinson 1975, Kwiatkowski and El-Shaarawi 1977).

CHLOROPHYLL a

- Water clarity
+ Nutrients
- Chlorides (impoundments, low alkalinity lakes and low color lakes)
- Mean depth (seepage lakes and low alkalinity lakes)
- Turbidity (low alkalinity lakes and low chlorophyll a lakes)
- Maximum depth (low alkalinity lakes and low chlorophyll a lakes)

There are several weaknesses inherent with the use and interpretation of chlorophyll a data. Chlorophyll a cell volume ratios differ among algal genera and species, and among the same species under differing environmental conditions or at different times of the year. Despite these problems, chlorophyll a gives a general indication of the amount of algal biomass present in the lake water at the time of sampling. This value may or may not be representative of a lake's average summer algal concentration due to fluctuations common in phytoplankton biomass. Nevertheless, certain relationships with other parameters (representing existing conditions coincidental to collection of the chlorophyll a sample) are evident. In addition to the Secchi-chlorophyll a and chlorophyll a-total phosphorus relationships which have been previously discussed (Trophic Classification — Factors Affecting Lake Trophic Status), there are a number of other relationships. Among these are the direct correlation of chlorophyll a and chlorides in low alkalinity lakes, low color lakes and impoundments. Nitrogen and turbidity appeared to be better correlated with chlorophyll a than with total phosphorus in low chlorophyll a lakes. A weak association was noted between chlorophyll a and alkalinity in low alkalinity lakes.

Regional comparison of chlorophyll a with other characteristics showed similar relationships, except for the negative correlation of chlorophyll a with magnesium, pH and alkalinity in the Southeast Region. The reason for this difference is unknown but may be related to higher magnesium levels in this region (Fig. 22) or to the impact of the macrophyte communities.

CHLORIDES

+ Calcium
+ Magnesium
+ pH
+ Alkalinity
+ Nutrients
+ Turbidity (seasonal data, impoundments and low color lakes)
- Mean and maximum depth (impoundments)
+ Color (low alkalinity lakes)

Chlorides were generally associated with nutrients and other ions. The association with color in low alkalinity lakes is unexpected and cannot be explained by us. As previously indicated, chlorides were negatively correlated with depth in impoundments.

CALCIUM

+ Chlorides
+ Magnesium
+ pH
+ Alkalinity
+ Nutrients
+ Turbidity (seasonal data)
- Mean depth (impoundments)
+ Color (low alkalinity lakes)
Calcium shows a strong positive correlation with almost all other water quality parameters; a notable exception is in low alkalinity lakes where the relationship of calcium with organic and total nitrogen falls off. However, increasing calcium levels generally accompany increasing levels of inorganic and total nitrogen (Append. A).

The regional comparisons again show the Southeast Region to be slightly different than the others in that calcium and pH were negatively correlated.

**MAGNESIUM**

+ Calcium
+ pH
+ Alkalinity
+ Nutrients
  - Shoreline development factor (seasonal data and impoundments)
  - Turbidity (seasonal data and impoundments)
  - Mean depth (impoundments)
  - Water clarity (low color lakes)

As would be expected, correlations between magnesium and other parameters were similar to those for calcium. Most associations were significantly positive, except where negative correlations with organic and total nitrogen were found in the Southeast Region.

Considerable overlap in mean magnesium content exists between lakes with low and high levels of phosphorus, but lakes with medium phosphorus content have significantly lower mean concentrations of magnesium than high phosphorus lakes (Append. A). This apparent “dip”, which was also noted for calcium, was repeated in the magnesium-inorganic nitrogen relationship. Highest magnesium levels (19 mg/l) were found in lakes with high inorganic nitrogen. Lakes with total nitrogen greater than 1 mg/l had higher magnesium levels than lakes with low total nitrogen.

**pH**

+ Chlorides
+ Calcium
+ Magnesium
+ Alkalinity
+ Turbidity
  + Phosphorus (random lakes)
  - Color (impoundments and drainage lakes).
  + Water clarity (impoundments and low color lakes)

Generally, pH correlations were highly related to alkalinity conditions. A significant difference was found in the pH of lakes which had low levels of total phosphorus and inorganic and to-

**FIGURE 71. Relationship of pH and alkalinity in five Wisconsin regions (random data set).**
tal nitrogen vs those lakes with high levels (Append. A). The correlation of pH with nitrogen and phosphorus was poorer in impoundments and drainage lakes than in seepage lakes. Whether this was influenced by the generally shorter retention time of impoundments and drainage lakes or the differences in other characteristics in these types of lakes is uncertain. The negative correlation of pH and color was previously discussed.

Of regional significance was the relatively poor correlation of pH with nitrogen and phosphorus in the Northeast, Central and Southwest regions, as opposed to the strong correlations evident in the Northwest Region and the slightly negative correlation with total phosphorus in the Southeast Region. Summaries of the regional data (Table 39) and plots of pH vs alkalinity for each of the regions (Fig. 71) provide a clearer picture of the interrelationship of these two parameters. The Southeast Region was different than the others with an apparent negative relationship of pH to alkalinity. The low correlation (negative) between pH and alkalinity in the Southeast Region appears to be a statistical anomaly created by the 8-10 lakes with pH values above 8.5 and the lack of low alkalinity-low pH lakes in the region. The Northwest Region had a similar number of high pH lakes (although at lower alkalinitles) but also had enough low pH-low alkalinity lakes to provide a stronger positive correlation. Most of the high pH lakes in the Northwest Region were located in Polk County where sampling followed a period of warm, humid weather. Algal blooms were evident in many of the lakes, but no correlation was found to link high pH with chlorophyll a or nutrient concentration.

It is quite obvious that the pH-alkalinity relationship is nonlinear in form (Fig. 71); thus, discussion of the relationship based on correlation coefficients alone is of questionable value. The decrease in pH with alkalinity becomes very steep in the lower alkalinity ranges, but scatter in pH values changes very little. This relationship is similar to the findings of other investigators and is important in showing the natural variability between the two parameters.

**ALKALINITY**

+ Chlorides
+ Calcium
+ Magnesium
+ pH
+ Nutrients
  - Shoreline development factor (seasonal data and impoundments)
<table>
<thead>
<tr>
<th>Area</th>
<th>pH-Alk</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast Region</td>
<td>0.679</td>
<td>7.1</td>
<td>22</td>
<td>4.3</td>
<td>1</td>
<td>8.9</td>
<td>224</td>
<td>6.9</td>
</tr>
<tr>
<td>Northwest Region</td>
<td>0.717</td>
<td>7.0</td>
<td>18</td>
<td>5.4</td>
<td>1</td>
<td>9.6</td>
<td>133</td>
<td>7.0</td>
</tr>
<tr>
<td>Central Region</td>
<td>0.491</td>
<td>7.9</td>
<td>124</td>
<td>6.7</td>
<td>12</td>
<td>8.9</td>
<td>190</td>
<td>7.9</td>
</tr>
<tr>
<td>Southeast Region</td>
<td>-0.261</td>
<td>8.0</td>
<td>160</td>
<td>7.1</td>
<td>51</td>
<td>9.4</td>
<td>290</td>
<td>8.1</td>
</tr>
<tr>
<td>Southwest Region</td>
<td>0.738</td>
<td>7.2</td>
<td>42</td>
<td>5.7</td>
<td>2</td>
<td>9.2</td>
<td>202</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Turbidity (seasonal data, impoundments and low alkalinity lakes), Mean depth (impoundments), Area (low alkalinity lakes), Water clarity (low color lakes)

While alkalinity was directly related to nutrients and other ions in Wisconsin lake waters, its relationship with chlorophyll a was weak (best in impoundments where a few very high values had great significance, and in low alkalinity lakes). The relationship between alkalinity and water clarity was best in lakes with low color. Alkalinity is sometimes used as a rough indicator of lake trophic status, but it is not a very accurate or reliable one for Wisconsin lakes.

Statewide, the relationships between alkalinity and chlorophyll a and total phosphorus were not significant in low chlorophyll a lakes. Alkalinity and total nitrogen were significantly related (95% C.I.) in these lakes, and chlorophyll a was more highly related to total nitrogen than to total phosphorus. Extensive evaluation of chlorophyll a and alkalinity relationships (plots) gave no indication as to what factors caused the poor relationships between the two parameters.

Regional distinctions included a strong positive correlation between alkalinity and chlorophyll a in the Northwest and Southeast regions. The reason why these regions are different is not known, but it could be related to higher iron levels in the northern lakes or precipitation of phosphorus with calcium carbonate in the southern lakes (see Gessner 1939).

**ORGANIC NITROGEN**

- Mean depth
- Maximum depth
- Water clarity
- Chlorophyll a
- Chlorides
- Calcium
- Magnesium
- Alkalinity
- Turbidity
- Other nutrients
- pH (natural lakes and low color lakes)

Organic nitrogen was highly related to most other lake characteristics. Organic nitrogen levels were considerably higher in lakes with total phosphorus greater than 0.03 mg/l (Append. A). Low organic nitrogen levels were associated with low inorganic nitrogen and low total nitrogen levels (Append. A). In low alkalinity lakes, the relationships between organic nitrogen and chlorides, calcium, magnesium and pH were weaker, which may be an artifact created by lower variations in these parameters in low alkalinity lakes.

Regional relationships of organic nitrogen showed strong correlations with chlorophyll a in the Northwest, Northeast and Southeast regions, but not in the Central and Southwest regions. The apparent poorer correlations in the latter two regions may not be real and could be caused by the low range of values in the Central Region and high flushing rates and light limitation in the impoundments of the Southwest Region.

**TOTAL NITROGEN**

- Mean depth
- Maximum depth
- Water clarity
- Chlorophyll a
- Chlorides
- Calcium
- Magnesium
- Alkalinity
- Turbidity
- Other nutrients
- pH (low color lakes)

Total nitrogen concentrations in Wisconsin lake waters correspond quite well to other lake characteristics. Some important total nitrogen associations are shown in the comparisons of lakes with differing levels of total phosphorus and organic nitrogen (Append. A). Total nitrogen appears to be a fairly good indicator of overall lake water quality, but variability makes delineations of trophic index levels difficult (Fig. 72).

Total nitrogen was not well related to chlorophyll a levels in either the Central or Southwest Region, but it was related to chloride levels. As would be expected, these relationships are similar to those noted for organic nitrogen.

**INORGANIC PHOSPHORUS**

- Water clarity
- Chlorophyll a
- Chlorides
+ Calcium
+ Magnesium
+ Alkalinity
+ Turbidity
+ Other nutrients
+ Area (random data)
  - Mean depth (seasonal data, drainage lakes and low color lakes)
  - Maximum depth (seasonal data and impoundments)

Inorganic phosphorus was positively correlated with other lake characteristics. The weakest correlation was with pH, particularly in impoundments and drainage lakes. A clear relationship exists between inorganic phosphorus and total phosphorus, and inorganic nitrogen and total nitrogen (Append. A).

Significant correlations with all parameters were evident in the Northwest Region, while in the other regions the relationships between inorganic phosphorus and chlorides, magnesium, pH, and in some cases alkalinity were not as good.

TOTAL PHOSPHORUS

- Mean depth
- Water clarity
- Chlorophyll a
- Chlorides
- Calcium
- Magnesium
- Alkalinity
- Turbidity
- Other nutrients
  - Area (random data)
  - Maximum depth (seasonal data and drainage lakes)

Generally, total phosphorus was directly correlated with other water quality determinants; most of these have been discussed previously under other headings and in the section of the report discussing factors affecting nutrient concentrations (Trophic Classification — Factors Affecting Nutrient Concentrations). Phosphorus and nitrogen appear to be highly co-associated (Append. A). The fact that the weakest total phosphorus correlation appears to be with pH, especially in impoundments and drainage lakes, may support other evidence that a lake's watershed has a significant impact upon lake pH.

Strong positive correlations between total phosphorus and all other characteristics were found in the Northwest Region, while correlations were poorer with magnesium, pH and alkalinity in other regions. A negative correlation between total phosphorus and pH was found in the Southeast Region, indicating possible sedimentation or precipitation of phosphorus with rising levels of alkalinity (primarily due to high magnesium levels). Many of

FIGURE 72. Relationship of chlorophyll a to summer organic nitrogen levels (natural lakes, random data set).

FIGURE 73. Relationship of chlorophyll a to organic phosphorus (lakes and impoundments, random data set).
the lakes in this region are large and deep with high hydraulic loadings. The overall trophic condition or water quality of southeast Wisconsin lakes, in view of the high phosphorus loading from their watersheds, is generally better than might be expected. The reasons for this apparent anomaly are unclear, but may be attributed to a combination of factors including the physical morphometry and higher magnesium levels in southeast Wisconsin lakes.

**DISCUSSION AND SUMMARY**

The interrelationships expressed in Appendix B are undoubtedly masked in many instances by the composition of the lakes in the particular subset (and their associated characteristics). Thus, many relationships may be “hidden” by other overriding factors. Likewise, some of the relationships expressed as significant in Appendix B may purely be the result of their non-random distribution (speaking in terms of parameter values not geographic distribution). The relationships and correlations are based on the assumptions that the data are normally distributed and indeed linear. Figure 72, a plot of chlorophyll \( a \) vs organic nitrogen for the random survey data, shows that while the correlation coefficient \( r = 0.442; R^2 = 19.5\% \) is significant \( (P > 0.001) \), the scatter and skewness in the relationship are great. A plot of chlorophyll \( a \) vs organic phosphorus for the random data set illustrates a similar problem (Fig. 73). Reducing the data base to natural lakes only (Fig. 74) improves the correlation, but does little to improve the value of the relationship in terms of its predictive capabilities. Even associations with higher coefficients of determination \( (R^2) \) display a great deal of scatter. Figures 75 and 45 demonstrate the weaknesses of correlation coefficients for purposes other than gross generalizations concerning the rela-
rionships between characteristics. While \( R^2 \) values were very high, chlorophyll \( a \) ranged from very low to high within different ranges of both inorganic and total phosphorus values. Incorporation of a third factor in the analysis might help explain some of the scatter in many of the relationships. For example, some evidence supporting nitrogen limitation in natural lakes is given in Figure 45. Elimination of low nitrogen:phosphorus ratio lakes would undoubtedly improve this relationship.

A number of the relationships are definitely nonlinear, in which case transformations of the data would probably result in improved correlations (examples are Figs. 76, 77 and 37). Restrictions on data sets also present problems. Particularly noteworthy is the bias introduced by restricting the data set to low chlorophyll \( a \) lakes and the apparent improvement in \( R^2 \) values (Fig. 77). The \( R^2 \) for the same relationship for all data was only 8.7%.

Determining which transformation to use to obtain the highest correlations can be a time-consuming task and quite often is academic, since a great deal of scatter remains regardless of the transformation made and transformations may do little to improve the predictive ability of the resulting linear regression analysis.

Log-log transformations, often used in this effort, reduce the importance of large values and quite often succeed in “normalizing” the data. This method often failed to improve the predictive value of the resulting equations because the basic relationship between the parameters is not affected. Log-log transformations of selected relationships vary in their impact on the correlation coefficients (Table 40). The log transformation had little effect on the total phosphorus-chlorophyll \( a \) and water clarity-color relationships, while \( R^2 \)s increased in other cases. For our data set, the enormous number of possible transformations of the data, combined with the large number of data parameters, prohibits detailed discussion of many of the interrelationships.

### TABLE 40. Correlation coefficients (r) for selected parameters, Log10 transformed (above) and not transformed (below) (random data set, summer data).

<table>
<thead>
<tr>
<th></th>
<th>Log10 Chlorophyll a (µg/l)</th>
<th>Log10 Total P (mg/l)</th>
<th>Log10 Secchi disc depth (m)</th>
<th>Log10 Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log10 Chlorophyll a</td>
<td>0.568</td>
<td>-</td>
<td>-0.570</td>
<td>0.347</td>
</tr>
<tr>
<td>Total P (mg/l)</td>
<td></td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secchi disc depth (m)</td>
<td>-0.731</td>
<td>0.192</td>
<td>-0.540</td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Chlorophyll a (µg/l)</th>
<th>Total P (mg/l)</th>
<th>Secchi disc depth (m)</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log10 Chlorophyll a</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total P (mg/l)</td>
<td>0.582</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secchi disc depth (m)</td>
<td>-0.271</td>
<td>-0.287</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>0.054</td>
<td>0.047</td>
<td>-0.445</td>
<td></td>
</tr>
</tbody>
</table>

![FIGURE 76. Relationship of organic nitrogen to Secchi disc (natural lakes, random data set). (middle)](image)

![FIGURE 77. Relationship of chlorophyll \( a \) to Secchi disc (natural lakes, low chlorophyll \( a \) levels, random data set). (bottom)](image)