Appendix H

Limnology, Water Quality Parameters, and Conditions and Ecoregions

Water Quality Parameters

Nutrients are important parameters because phosphorous and nitrogen are major nutrients required for the growth of algae and rooted vegetation in lakes. Certain forms of nutrients that are readily available to support growth of aquatic plants are soluble orthophosphate, nitrate and nitrite, and ammonia nitrogen. Total phosphorus concentrations in conjunction with total Kjeldahl nitrogen concentrations provide an indication of the maximum growth that can be achieved in an aquatic system. These nutrients can enter the aquatic environment externally through the use of fertilizers, septic leachate, sewage effluents, detergents and soaps, particulate material transported by storm water, or precipitation. Highly organic or mucky lake sediments can serve as an internal source of nutrients under certain chemical conditions (i.e. if the overlying waters become devoid of oxygen). The decomposition of dead algal cells or aquatic weed tissue can also provide another internal source of nutrients.

Phosphorus is an essential nutrient for growth of aquatic organisms in lakes but often is a factor limiting growth because of low concentrations within the water column. Total phosphorus (TP) represents the sum of all forms of phosphorus: dissolved and particulate organic phosphates from algae and other organisms; inorganic particulate phosphorus from soil particles and other solids; polyphosphates from detergents; and dissolved orthophosphates. The phosphorus loads that enter the lake affect total phosphorus concentrations. Soluble orthophosphate levels, however, are more likely to be affected by algal consumption during the growing season.

The nitrogen cycle in lakes is considerably more complicated than the phosphorus cycle. Nitrogen can exist in either oxidized forms, usually nitrate (NO_3^-) or nitrite (NO_2^-), or reduced forms, including ammonia (NH_3) and organic nitrogen. Atmospheric nitrogen (N_2) can also be used as a nutrient source by some species of algae, and decomposition processes can produce various other reduced forms of nitrogen. The form of nitrogen present depends primarily on dissolved oxygen concentrations and plant growth. Extensive algal blooms can deplete concentrations of the inorganic nitrogen forms, nitrate and ammonia, as nitrogen is converted into organic nitrogen in the form of algal cells. Total Kjeldahl nitrogen (TKN) provides a measure of ammonia plus organic nitrogen, including organic nitrogen in particulate forms. Total nitrogen (TN) is the sum of TKN and nitrate + nitrite-N. Nitrate is the most common form of nitrogen in surface waters, while ammonia is predominant in low oxygen environments. Low concentrations of ammonia-N are common in the aerobic surface waters of most lakes, since this form of nitrogen is the easiest for phytoplankton to assimilate (Coastal Environmental, Inc., 1996).

Other water quality parameters were assessed in the determination of the water quality of Navajo Reservoir. These parameters included temperature, dissolved oxygen, conductivity, turbidity, pH, and Secchi disk transparency profiles. These parameters are described as follows and are important in determining overall lake "health."

Temperature affects a number of physical, chemical, and biological processes in natural aquatic systems. The temperature regime of a lake is a function of seasonal/diurnal ambient air temperatures and the morphometry and setting of the lake. Biologically, one of the most important effects of temperature is the decrease in oxygen solubility as the temperature increases. As a result, the increase in temperature can also increase the oxygen demand of biological organisms such as aquatic plants and fish. In addition, chemical compounds tend to become more soluble as a response to higher temperatures. Temperature is controlled primarily by climatic conditions, but human activity can also influence temperature. Thermal or chemical pollution could adversely alter the distribution and species composition of aquatic communities.

The dissolved oxygen (DO) concentration of a lake is an important indicator for determining the conditions of a lake. A great amount of information can be obtained solely through the analysis of this parameter. Among the information that can be obtained is: the determination of lake productivity through the photosynthetic activity of algae and weeds; an indication of mixing patterns and the effectiveness of mixing processes in a lake through DO gradients; and the physical-chemical properties of lakes and the composition of a lake's biota through DO concentrations. Typically, the solubility of dissolved oxygen in natural surface waters ranges from 15 mg/L at 0 ° C to 8 mg/L at 25 °C. Dissolved oxygen concentrations are dependent upon temperature, salinity, wind mixing, and atmospheric pressure. Reductions in DO concentrations can also be caused by the decomposition of organic wastes and the oxidation of inorganic wastes (McNeely, R.N., et al., 1979).

Conductivity is a measure of the ability of water to conduct an electric current and is dependent on the number of dissolved ions in solution. Conductivity is closely related to, and highly correlated with, the concentration of dissolved solids within the water column. The conductivity of lake water is influenced by the geology and soils present in the watershed. However, conductivity varies significantly with temperature. Temperature has a relatively large effect on conductivity so conductivity is typically corrected to 25 °C and reported as specific conductance (µS/cm at 25 °C) to allow direct comparison of samples collected at different temperatures. Specific conductance has been found to range from 50 to 1500 µS/cm in natural surface waters.

Turbidity is the measure of suspended particles within the water column. These particles can consist of plankton, microscopic organisms, silt, clay, and/or organic matter held in suspension through Brownian movement or water flow. The suspension of these solid particles in the water column can be attributed to erosion, runoff, and/or algal blooms. Turbidity is measured by comparing the optical interferences of suspended particles against light transmission in the water column as measured by water sampling instruments that have been standardized with known samples of standard turbidity units. Turbidity is important because it can influence biological communities such as submerged aquatic vegetation and algae and affect their ability to photosynthesize.

The hydrogen ion activity in water provides an indication of the balance between acids and bases in solution. Hydrogen ion activity in water is usually reported as its negative logarithm, or pH. The pH of lake water is an important general water quality indicator because pH is a major factor in most chemical and biological reactions. Accepted water quality criteria (U.S. EPA, 1980) indicate a pH of less than 6.5 units may be harmful to many species of fish. Therefore, the pH range of 6.5 to 9.0 units would be suitable for the protection of aquatic habitats. Observed pH is determined by a number of complex interactions and provides an overall measure of the intensity of the various acid/base interactions occurring.

The transparency, or clarity, of water is most often reported in lakes as the Secchi depth. This measurement is taken by lowering a circular white or black-and-white disk, 20 cm in diameter, into the water until it is no longer visible. Observed Secchi depths range from a few centimeters in very turbid lakes to over 40 meters in the clearest known lakes (Wetzel, 1983). Although somewhat simplistic and subjective, this testing method probably best represents the conditions that are most readily apparent to the typical lake user. Lakes with Secchi depths of less than 1 meter (3 feet) are often judged undesirable for many recreational uses.

Reference Conditions and Ecoregions

1 – Reference conditions were derived by the EPA using the following criteria: the evaluation of all the available evidence and the selection of values appropriate for nutrient control by a body of qualified regional specialists; the evaluation of historical data and/or anecdotal information that gives an enrichment trend and aids in establishing a perspective of the resource base; the selection of reference sites that represent the least culturally-impacted waters and represent the most natural condition of the resource base at the time (reference condition); the use of theoretical or empirical models of the historical and reference condition data; and lastly, the assessment of downstream impacts.

2 – The EPA has developed a new classification for ecological regions and nutrient enrichment problems across the United States. EPA describes this classification as follows:

"Eutrophication of surface waters in the United States is a long standing problem. As much as half of the Nation's waters surveyed by states and tribes do not adequately support aquatic life because of excess nutrients. Nitrogen and phosphorus are the primary causes of eutrophication and resulting algal blooms. Chronic symptoms of over-enrichment include low dissolved oxygen, fish kills, cloudy murky water, and depletion of desirable flora and fauna. Nutrient levels that lead to these problems vary from region to region due to geographical variations in geology and soil types. In order to "better protect water quality, states and tribes need to take ecoregional variations into account when setting water quality criteria for a particular waterbody.

"To better assist states and tribes in setting regional-specific water quality criteria, EPA is publishing national nutrient criteria for seventeen ecoregions across the country - criteria for eight ecoregions for lakes and reservoirs; eight ecoregions for rivers and streams; and one ecoregion for wetlands. These recommended criteria will be used to support the development of more localized, waterbody specific state and tribal nutrient criteria."

Navajo Reservoir falls within the Ecoregion II – Western Forested Mountain's category. The sublevel within this category is Level III – 21, The Southern Rockies. (U.S. EPA, 2000)

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