Water Quality Monitoring

A water quality monitoring program is a valuable way of getting feedback about the effectiveness of your best management practices. Based on sound, scientific principles, the results can be a powerful tool to help you confirm and communicate that you are employing the correct management strategies. A water quality monitoring program serves three primary purposes:

1. Establishes a baseline of water and sediment quality;
2. Provides data that will establish environmental conditions, thus providing a basis for measuring compliance with environmental regulations and effectively communicating that your course is not having adverse impacts on water quality;
3. Ensures that your IPM program is functioning properly and that no negative impacts have developed.

There are two primary approaches to monitoring. Employing both will help you obtain information upon which to make adjustments in cultural programs and maintain environmental quality.

- **Visual Inspection**—Periodic observation will disclose changes or trends in water quality. As an integral part of the golf course IPM program, spot-checking for problems should be part of the scouting routine. An example of this type of monitoring is associated with an algal bloom. The course personnel constantly spot-check locations that are known problem areas.

- **Objective Monitoring and Data Collection**—Water quality tests conducted to measure dissolved oxygen, pH, nutrients, and other water quality indicators provide data for use in developing or confirming the results of on-going management programs.

Visual Inspection

A visual survey of water quality requires little or no equipment and takes a minimal amount of time. It simply involves surveying the conditions of a golf course water feature, looking at the water and surrounding land, and noting what you see. Despite its simplicity, it is an important aspect of environmental monitoring. By collecting information on a regular basis, you can develop a baseline of normal conditions and record changes over time.

When you visually monitor your water bodies, you should make sure to write down any abnormalities noted, as well as the date, time of day, previous and current weather conditions, previous chemical applications in the area, and any other changes that could be a possible cause of the abnormality.

This simple chart can be carried with you in the field or posted in a central location to provide essential information about water quality conditions that you see.

Objective Monitoring and Data Collection

Baseline water quality data for representative water bodies and water sources that may be affected by golf course management practices can be obtained by testing:

- **Physical characteristics**—Tests for dissolved oxygen, pH, temperature, and specific conductivity;
- **Nutrients**—Tests for nitrogen (nitrate and ammonia) and total phosphorus;
- **Macroinvertebrates**—surveys for aquatic organisms, where water enters and exits the property, to determine water quality in streams. (Contact Audubon International to obtain a guide to sampling for macroinvertebrates or check with your local water resources agency.)

VISUAL INSPECTION

If the water is...	It could be...	You should...
Green or blue-green	Nutrients released into the water causing an algae bloom	Check for possible fertilizer or manure run-off, sewage discharge or septic failure.
Orange-red	Acid drainage or the presence of synthetic dyes	Check for industrial waste or for landfill seepage draining into the water.
Grey/Black	Sewage or livestock waste	Check for sewage discharge or animal populations.
Light brown (muddy or cloudy)	Sediment deposition caused by erosion	Look for disturbed ground left open to rainfall (*e.g.*, construction).
Yellow-brown to dark brown	Acids released from decaying plants. Also common in streams draining from a marsh or swamp	If it's not fall, search upstream for some foreign item in the water.
If you can smell...	**It could be...**	**You should...**
Rotten egg odor	A natural occurrence in swampy or marshy land or sewage pollution	Look for sewage or septic inputs.
Musky odor	Untreated sewage, livestock waste, algae or other conditions	Check your watershed for sewage/septic input and animal populations.
Chlorine	Over-chlorination of sewage input water or swimming pool discharge	Look for sewage input or a recently drained swimming pool.
Fishy Odor	Excess algal growth or presence of dead fish	Search for dead fish or look for cause of excess algae.
If you notice...	**It could be...**	**You should...**
Fish kill	Naturally occurring, (accompanies annual spawning) or toxic dumping/ nutrient overloading	Check upstream for discharges or seepage; check fish lifecycle in your area. Check dissolved oxygen levels in the water. Depressed dissolved oxygen levels are the primary cause for fish kills.
Increase or decrease in wildlife sightings	Many reasons: habitat changes, water quality changes, natural population increases during breeding season or decreases after migration	Have any changes, such as construction or development, occurred since you last monitored? Note the time of year. Can this be correlated with breeding or migration?
Increase or decrease in water flow	Weather-related or possible obstruction or discharge into stream	Note weather conditions such as temperature and recent rainfall. Check upstream for blockage and/or discharge source.
If surface or bottom has...	**It could be...**	**You should...**
Yellow coating (bottom)	Sulfur or natural color	Check for industrial waste.
Multi-color reflection (surface)	Oil or a natural algae	Check for a petroleum smell. If so, look for road runoff or canisters of oil.
White cottony masses	"Sewage fungus"	Check for sewage or septic inputs.
White or cream-colored foam	A natural occurrence (cream-colored) or detergent or industrial waste	If higher than 3 inches and white, check for industrial or residential discharge.

- **Pesticides**—You may wish to test for pesticides used at the golf course. Consider testing for pesticides that are both mobile and toxic. Pick the three most mobile and toxic products and test for these. These pesticides will be a good indicator of the probability of movement for other pesticides as well.

The following information will help you understand the parameters involved in water quality testing and provide direction to assist you in getting started.

- **Testing Frequency**—When starting a water quality monitoring program, testing should be conducted four times per year during the first two years. It is important to sample during different seasons because the environment responds differently during each season. After setting a baseline, sampling twice a year is sufficient, unless problems arise. Problems may include algal blooms, fish kills, or wildlife that acts in a manner inconsistent with normal behavior. Once you have collected baseline data, you will have a starting point from which you can compare the quality of your water from year to year.

- **Sampling Locations**—To determine sample locations, survey the water bodies on the golf course. If there are only a few, you may choose to sample each. Golf courses with many water features may choose to sample representative ponds, as well as those with known problems. How many sample locations you choose is highly site dependent. Three or four sample locations are the minimum number required to assess water quality.

  Sample the same locations over time. This will allow you to compare results and assess environmental conditions over time.

  Potential Locations:

  - Does water from wash pads or irrigation drain into water features or consistently soak into the ground in the same location? If so, these locations may be good candidates for sampling. If the answer to the latter part of the question is yes, you need to test groundwater. At no time should water from a wash pad enter a water feature.

  - Inflow and outflow points on a stream are important locations because they indicate the quality of water coming onto and leaving the course.

  - Effluent water quality should be measured before it reaches the surface water on the course so the impact of this water source can be accurately measured.

- **Conducting and Analyzing the Tests**—Determine whether you want to conduct tests yourself, contract with an independent lab, or partner with a local organization or cooperative extension.

  Do-it-yourself—Several companies offer test kits and instructions. You should develop quality control and quality assurance protocols to make sure your samples are truly representative. Be sure that detection limits are above acceptable measurement levels. Check holding times and preservatives.

  Contract laboratory—If you contract out your water monitoring, use a laboratory to analyze your samples that has a written quality assurance and quality control manual. The lab should be certified by the state to analyze the type of samples that you are requesting. In addition, it's useless to obtain a lot of numbers about water quality with no means to interpret them. Detection limits are critical to interpretation and should always be given with the results.

  Working with local organizations—Because water quality testing requires some technical knowledge, you may wish to partner with your local cooperative extension service, a high school or college biology class, or independent lab to sample and analyze the water. If your area has a local watershed commission or non-profit environmental organization that monitors water quality, it also may be a valuable resource for support and information. Consider working with other golf courses in your area to broaden the scope and share costs of monitoring.

- **Data Storage**—Storage of data should be determined in the beginning of the monitoring program. Storage should be both on a computer diskette and on paper. The computer storage allows you to easily analyze and use the data to help better manage the course.

- **Data Analysis**—Data analysis should be determined in the beginning of the monitoring program. The data should be organized in a way that allows you to determine any problems or trends. Graphing data or arranging them in a table can be very useful in determining environmental conditions over time and allowing comparisons with standards.

- **Criteria for Management Response**—It is vital to set up a management response if samples indicate a problem. Outline specific, step-by-step actions you will take if the results indicate that a non-pesticide or pesticide is increasing in the sample.

  1. **The cause of the increase must be established**—For example, if a sample indicates high phosphorus levels, it may indicate erosion, low dissolved oxygen levels, or nutrient loading. High nitrogen levels may indicate nutrient loading. Was fertilizer inadvertently broadcast directly into a water feature? Was fertilizer applied before a rain event?

  2. **Preventative action must be taken after the cause is established**—Action must be taken to reduce contaminant inputs. Examples of actions include:
     - Make sure that all staff know about and adhere to no-spray zones.
     - Establish no-spray zones around buffer zones in swales or around drainage that enters water features.
     - Change your maintenance practices (*e.g.*, timing of applications, wash pad design or maintenance, etc.).

  3. **Curative action must also be taken**—This will reduce the current level of the contaminant. For example, if there is too much phosphorus in a water feature, planting aquatic vegetation will help to use up nutrients and increase oxygen levels. Aerification will increase dissolved oxygen levels and thus help reduce phosphorus levels.

- **Sampling Parameters**—Parameters refer to the physical and chemical measurements that you will be testing for. Many different parameters can be analyzed in the water. The following parameters are highly recommended. If your water measurements are not within the acceptable range, you need to implement a planned management response to improve water quality.

Sampling Parameters for Water Quality Management

Parameter	Explanation and Importance of the Parameter	Acceptable Range	Possible Effects When Outside the Acceptable Range
Water Temperature	• Determines the suitability of a water body to support aquatic life; fish species and other aquatic life require specific temperatures • Effects the amount of oxygen dissolved in the water	Varies from region to region. Establish the range of your water temperatures by measuring water temperatures over the year.	• Lower temperature, greater dissolved oxygen • Higher temperature, lower dissolved oxygen • Too low or too high will result in a fish kill or damage to other aquatic life and perhaps the aquatic food web.
Dissolved Oxygen (DO)	• Mandatory for aquatic life • Dependent on temperature, time of day (photosynthesis will release oxygen during the day and respiration consumes it at night), and the amount of organic matter in the water (oxygen is essential for decomposition)	6.0—13.0 mg/L	• Below 4.0 mg/L can cause a fish kill • Lower levels (generally below 2 mg/L) can result in anaerobic decomposition, which can release noxious gases, such as hydrogen sulfide, and degrade aesthetics.
pH	• pH measures the level of hydrogen ions in the water and gives an indication as to what reactions are occurring • pH of 7 is neutral • pH above 7 is basic—the greater the pH, the more basic the water • pH below 7 is acidic—the lower the pH, the more acidic the water	6.5–8.5, unless you are in a naturally low pH area (*e.g.*, a blackwater swamp)	• pH outside of the acceptable range may disrupt natural chemical reactions, and cause changes in the naturally occurring biota and their food webs.
Alkalinity	• Measure of the water's ability to neutralize, or buffer, inputs to water • Geology of the underlying bedrock will affect alkalinity (*e.g.,* lakes over limestone have a high alkalinity and therefore a constant pH, whereas lakes over granite are highly susceptible to acidic inputs)	Depends on location	• Low alkalinity will cause the water to have less buffering capacity and the water body may react by exhibiting greater fluctuations.
Conductivity	• Measurement of the ability of water to conduct electricity • Directly related to the amount of mineral salts (*e.g.,* calcium chloride, potassium chloride, sodium hydroxide) present and the temperature of the water	Depends on location	• Outside the acceptable range can disrupt the natural physiology of aquatic life. • In irrigation ponds, increased levels can cause excess corrosion of equipment.

When reviewing the chart, keep in mind that:
1 mg/L = 1 ppm (part per million)
1 ug/L = 1 ppb (part per billion)

(continued next page)

Sampling Parameters for Water Quality Management

Parameter	Explanation and Importance of the Parameter	Acceptable Range	Possible Effects When Outside the Acceptable Range
Visibility and Turbidity	• Water clarity is measured with a secchi disc—the disc is lowered into the water and a measurement of the depth is taken when the secchi disk disappears • Affected by phytoplankton (microscopic algae), suspended inorganic material, silt, and dissolved organic substances, as well as material from the watershed (*e.g.*, sediment from runoff) • These substances impart a color to the lake water and influence the amount of light that can pass through. Can also be affected by cloud cover, reflection from the bottom, presence of rooted aquatic vegetation, and wave action	Should not exceed background	• Decreased clarity implies more suspended solids, which may clog fish gills • Reduced light penetration decreases algae's ability to produce food and oxygen. • Decreased visibility can alter temperature (greater heat absorbance of particulates) and dissolved oxygen concentrations.
Macro-Nutrients	• Aquatic plants, including rooted aquatics and algae have nutritional requirements: micronutrients: required in small quantities macronutrients: required in large amounts • Available nutrients influence plant growth	See specific nutrient levels	• When nutrients are available in abundance (due to fertilization practices, erosion, sewage effluent, etc.) excessive aquatic plant and algae growth can result. An algal bloom may result from the increase in nutrients. • Eutrophication is the term to describe changes in a lake caused by an increased rate of supply of plant nutrients, the resultant ecosystem response to increased plant production, and the changes in biota and the reductions in dissolved oxygen.
Nitrogen	• Present in considerable concentrations as nitrogen gas in the atmosphere • Nitrogen gas is not readily available to plants and most algae. Nitrogen is fixed from the atmosphere by nitrogen fixing bacteria, including blue green algae (which are actually bacteria).	Range varies widely based on water body; see below for specifics	• Nitrogen is a major nutrient that affects the productivity of fresh water. • In coastal waters, nitrogen is often the critical limiting nutrient in eutrophication. Whereas, in freshwater, phosphorus is the limiting nutrient. • Nitrogen exists in many different forms in aquatic systems: dissolved molecular (N2), ammonia nitrogen (NH4+), nitrate (NO2-), nitrate (NO3-), and a large number of organic compounds. • Typical ranges for total nitrogen in waters is from 0.3 to 2 mg/l.
Nitrite/Nitrate Nitrogen	• Common form of nitrogen measured in lakes and ponds • Nitrites are quickly converted to nitrates • Occurs in low concentrations in natural, undisturbed environments • Common reason for excessive concentrations is over fertilization in areas that drain into water bodies	Highly variable, but a goal of < 0.5 mg/L	• Nitrate is the common form of inorganic nitrogen entering water fresh waters from the drainage basin. • Too much nitrite can cause blood diseases in fish; in humans, concentrations greater than 10mg/l in drinking water may cause health problems in infants.

When reviewing the chart, keep in mind that:
1 mg/L = 1 ppm (part per million)
1 ug/L = 1 ppb (part per billion)

(continued next page)

Sampling Parameters for Water Quality Management

Parameter	Explanation and Importance of the Parameter	Acceptable Range	Possible Effects When Outside the Acceptable Range
Ammonia Nitrogen	• Naturally present in surface waters • Toxicity of this nutrient is based on temperature and pH, as these increase, the toxicity increases	Generally low	• Ammonia concentrations are generally low because of plant assimilation. • Ammonia may be toxic to biota. This is a pH dependent relationship, with toxicity increasing with pH. In waters above pH 8, ammonia toxicity may be a concern.
Total Phosphorous	• Total phosphorous includes all chemical forms of phosphorous found in water body • Phosphorous is found in limited quantities naturally • Sources of phosphorous are weathering rocks, decayed plant material, precipitation, sewage, and fertilizers • Phosphorous can attach to bottom sediments and remain there only to be reintroduced into the water column by 1) bottom organisms stirring or burrowing the sediment, water currents, or wind; or 2) depletion of dissolved oxygen at the bottom of the water body allows phosphorus to re-enter the water column.	Goal is < 0.02 mg/l Most freshwater is between 0.01 and 0.05 mg/l	• Phosphorus plays a major role in biological metabolism, is frequently the least abundant nutrient, and commonly, is the first element to limit plant production. • Most high phosphorus levels result from inputs to the water body (*e.g.,* from fertilization, sewage treatment plants, or street runoff.) • It is prudent to keep phosphorus out of water bodies, rather than trying to remove it once it has entered the water.

When reviewing the chart, keep in mind that:
1 mg/L = 1 ppm (part per million)
1 ug/L = 1 ppb (part per billion)