2006

Water Quality Monitoring Program

Volunteer Manual

Welcome Volunteer Monitors!

This year marks the first year of RappFLOW's water quality monitoring program! Thank you for joining us on this new endeavor! Your participation and commitment will be an example to everyone who cares about our natural environment. The data obtained from analyzing the samples you collect will provide vital information on the ongoing health of the Rappahannock rivers and streams. We look forward to a great season on the water. Thanks to all of you.

-RappFLOW Staff and Board

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1. General Monitoring Information:

1.1 2006 Sampling Dates and Time

Your team leader will contact you about specific sampling dates. Depending on the number of teams, volunteers will sample every month or every other month. Since water quality changes throughout the day, sampling must begin as close to sunrise as possible, preferably starting at 6:30am.

1.2 Contacting RappFLOW

Any questions and comments can be directed to your team leader or RappFLOW staff.

Kenny Giles, Water Testing Volunteer Team Leader
kengiles@starpower.net
Kenny's home phone: 540-937-7224

Water Testing Volunteer Team Leader
To be announced

Christina Bird Loock, Director
christina@rappflow.org
Christina's cell phone (540) 522-4237

Jean Pfefferkorn, Outreach and Volunteer Coordinator
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Jean's home phone: (540) 937-2603

Rappahannock Friends and Lovers of Our Watershed
Office Address- coming soon
Office Phone number- coming soon

1.3 Use of this data

RappFLOW has been working with the Virginia Department of Environmental Quality (DEQ) to assure that, when feasible, the data collected by RappFLOW volunteers meets the highest level of DEQ specifications (level III). Of the parameters being tested, the methodology for dissolved oxygen, pH, and temperature meet level III standards. To test bacteria, RappFLOW is using a method called Coliscan, which was recommended by the DEQ. Although it does not meet level III standards, it is valuable as an accurate indicator of bacteria concentrations. Level III data for bacteria is only attainable by contracting with a professional laboratory, a method which RappFLOW will use to verify results with bacteria counts above allowable limits. All transparency/turbidity methods, including use of a professional lab, only meet the lowest level of standards (level I). RappFLOW had chosen to use a transparency tube.

2. Safety Considerations when Sampling at the River

Please make safety your top priority!

1. Always sample with at least one partner. Do not sample alone.

2. Before you leave, please let someone know where you are going and when you expect to be back.

3. Park in a safe location away from traffic.

4. Be aware of the presence of others nearby - do not go a remote section of the river or stream alone.

5. Listen to weather reports and check river conditions. Be aware of your own physical limitations and the difficulty collecting water at certain locations under certain conditions. High flows can turn even the most placid water into a raging torrent. Avoid dangerous situations.

6. Do not wade into the water above the knee, even with waders.

7. Carefully make your way to the river. Watch for steep banks and poison ivy!

8. Carry a first aid kit with you and let your partners know of any allergies or medical conditions you may have.

9. **Please, do not attempt to collect a sample if you feel the least bit of risk of any kind.**

3. Checklist of Equipment and Supplies

Before going out in the field, make sure someone your team has the following:

- ☐ Sample Containers.
  - E. coli plastic bottles (enough to run a duplicate at each site)
  - sample bottles from ESS laboratory (if asked to collect)

- ☐ Black waterproof marker for writing site numbers on bottles.

- ☐ A pencil for filling out data sheet

- ☐ A clipboard

- ☐ A hand-held calculator

- ☐ Folder containing
  - ☐ A list of the site numbers and descriptions
  - ☐ Calibration form for pH meter
  - ☐ Calibration form for DO meter
  - ☐ Field data sheets (enough for each site plus a few extra)
  - ☐ This handbook with written procedures
  - ☐ Sheet for calculating theoretical DO

- ☐ Dissolved oxygen meter

- ☐ pH meter

- ☐ Buffer solutions for pH meter

- ☐ Containers to pour the buffer solutions into.

- ☐ Distilled water for calibrating and cleaning pH and DO probes

- ☐ Cooler with ice to keep E. coli samples cool. So that samples are not submerged in water that may have accumulated in the bottom of the cooler from melting ice, pack the ice in plastic bags or plastic jars, or use sealed ice packs. *It is very important to use a cooler since the samples must be stored in a **cool, dark** place.*

- ☐ Turbidity tube and bucket for pouring sample into tube.

- ☐ Waders or footwear that can get wet. Don't sample barefoot! Do not enter stream deeper than just above the knee.

- ☐ Rubber gloves if sampling below a wastewater treatment plant or in waters suspected to be polluted. Hand sanitizer.

- ☐ First aid kit.

4. Filling out Field Data Sheets

Use one field data sheet for each site.

Site Name and #: Record the name and number of the sampling site. Refer to site spreadsheet.

Site Description: Brief description of sampling location. Refer to site spreadsheet for site descriptions.

GPS Waypoint: If this is a new site, take a GPS waypoint reading and record the waypoint.

Monitoring Names: Fill in the first and last name of all monitors present.

Weather and Site Observations:

Weather: Record the wind and weather at the site. Report the weather for the three days previous to sampling as best you can remember. Estimate the last day of rainfall 1/4 inch or more previous to the sampling day.

Site observations are very important for understanding possible causes of unusual results. For each site sampled, record the relative height of the water (use your memory of previous visits as well as the bank vegetation/debris as an indicator of average flows), the speed, water clarity, water color.

Water Color: Use the clear container used to collect E.coli for determining water color observed in sample container.

Indicators: Note everything you observe that might affect water quality or that is unusual about the site. If you're not sure if it's important, write it down.

Samples collected for laboratory analysis: If you are asked to collect any samples to send to the lab, please check the appropriate boxes. For phosphorous and nitrogen, write the type of test.

Field Measures: For each parameter, follow the instructions in this handbook under the heading "Sampling protocols" and record in the appropriate spaces.

E. coli bacteria Measurements: This portion of the data sheet is to be filled out by the volunteer that completes the coliscan bacteria plating, incubation, and counting. This is done immediately on return from collecting the samples in the field.

5. Sampling Protocols

5. 1 Information on Collecting Samples

In general, sample away from the streambank in the main current. Never sample stagnant water. The outside curve of the stream is often a good place to sample, since the main current tends to hug this bank. In shallow stretches, carefully wade into the center current to collect the sample. Always enter the stream downstream of where you are going to sample and walk upstream to the sampling location. **If you bring a dog with you, please do not let him/her enter the water until you have finished sampling.**

Each team will collect the following:

1. Two E. coli bacteria water samples from each site
2. Water temperature (displayed on pH and dissolved oxygen meters)
3. Dissolved oxygen (using YSI meter and probe)
4. pH (using YSI meter and probe)
5. Water clarity (using a transparency tube)

Occasionally a team may be asked to collect the following to send to the lab:

6. E. coli water sample for lab analysis
7. Total suspended solids water sample
8. Phosphorus water sample
9. Nitrogen water sample

IMPORTANT: Before taking any samples, calibrate the DO and pH meters

Please see specific instructions under DO and pH headings.

5.2 E. coli Bacteria Protocol

To collect bacteria samples use the smallest plastic bottle. Take two samples at each site.

1. Collect bacteria samples before any other samples. Take several precautions to ensure good samples: avoid agitating the bottom sediments; stay clear of algal blooms, surface debris, oil slicks, and congregations of waterfowl. **Mark down on your data sheet if any of the above is present.** Do not allow your dog into the water upstream of you.
2. With a waterproof pen, write the site number on the outside of the bottle and on the top.
3. Put on your gloves.
4. *Wading.* Try to disturb as little bottom sediment as possible. Be careful not to collect water that contains bottom sediment. **Stand facing upstream. Collect the water sample in front of you.**
5. Remove the cap of the bottle. Avoid touching the inside of the bottle or cap.
6. Hold the bottle near its base and plunge it (opening downward) below the water surface. Collect a water sample 8 to 12 inches beneath the surface or mid-way between the surface and the bottom if the stream reach is shallow.
7. Turn the bottle underwater into the current and away from you. In slow-moving stream reaches, push the bottle underneath the surface and away from you in an upstream direction.
8. Fill the bottle 2/3rds full.
9. Replace cap and place samples in cooler.

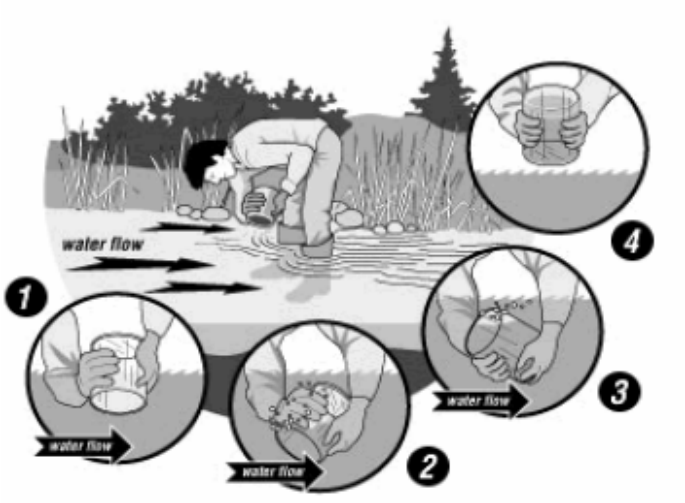

Figure 5.1. Collecting a water sample (from Volunteer Estuary Monitoring: A Methods Manual, Second Edition)

5. 3 Dissolved Oxygen (DO) Protocol

A dissolved oxygen meter is an electronic device that converts signals from a probe that is placed in the water into units of DO in milligrams per liter. The probe is filled with a salt solution and has a selectively permeable membrane that allows DO to pass from the stream water into the salt solution. The DO that has diffused into the salt solution changes the electric potential of the salt solution and this change is sent by electric cable to the meter, which converts the signal to milligrams per liter. Adapted from EPA Monitoring and Assessing Water Quality; http://www.epa.gov/owow/monitoring/volunteer/stream/.

5.3.1 Before Sampling

The dissolved oxygen (DO) meter is easy to use, but to maintain accuracy it must be calibrated at the beginning of each sampling day before it is used. The calibration is then checked again at the end of the sampling day. The following instructions are adapted from the Virginia Department of Environmental Quality and the YSI EcoSense DO200 manual. Read through the entire instructions before beginning the calibration. Record your calibration data on the DO calibration sheet provided.

The first worksheet of the DEQ supplied calibration log sheet is to perform the calibration procedure for dissolved oxygen (DO) probes. The DO calibration process can be the most complicated of the three probes covered in this document. With practice, the user can complete the entire DO probe calibration process within 5-10 minutes.

5.3.2 Calibration instructions:

1. Before going out in the field, find the local barometric pressure reading. Some sources are www.weatherchannel.com or www.noaa.gov. Convert inches of mercury (InHg) to millibars (mBar) using the following equation:

   InHg * 33.8639 = mBar
2. Record the date of calibration on the probe calibration form. Calibration must be done each day you perform samples.
3. Place 5-6 drops of distilled water into the sponge inside the calibration bottle. Turn the bottle over and allow excess water to drain out of the bottle. The wet sponge creates a 100% water-saturation air environment for the probe, which is ideal for calibration, transport, and storage. For calibration, the probe remains in the water saturated air environment and is not submersed.
4. Slide the probe into the calibration bottle. Be sure the membrane does not touch the sponge.
5. Turn the DO meter on. Wait 10-15 minutes for the dissolved oxygen and temperature reading to stabilize.
6. Record the temperature of the DO probe just before calibration.
7. Use the DO theoretical calibration chart (in appendix) to calculate the DO theoretical value.
   a. On the DO theoretical calibration chart, you will notice two separate tables. The large top table is composed of two major areas. The first column and row of the table is to find the temperature of the probe during the calibration. The center of the table shows the DO readings for that temperature. When you intersect the temperature readings, you will find the DO value of the probe. For example, I have grayed out the row for 18 and the column for 0.4. This means that if it the probe was reading a temperature of 18.4 C, the DO readout would be 9.37 mg/L (or ppm). This value is true if you were calibrating at sea level BP.

   b. Because most calibrations do not occur at sea level, you have to compensate for barometric pressure (BP). The bottom table of the calibration chart addresses

pressure compensation. The YSI probes you are using calibrate BP using millibars (mBar). When you download the BP from the weather station, they report this value in inches of mercury (inHg). You can use the formulas at the bottom of the page to calculate mBar from inHg. Once you have the mBar value, compare it with the bottom table to find your BP correction factor. For example, if you had a BP of 970 millibars you would use a correction factor of 0.96 (found at the third column, bottom row).

c. To find your theoretical DO level, you will take the value you obtained from the top table and multiply it by the correction factor that you found on the bottom table. Using the example above, your probe temperature is at 18.4 C and the BP is at 970 mBar. The theoretical DO value would be 9.00 mg/L (9.37mg/L x 0.96 correction factor).

8. Calibrate the meter. Press **CAL**.

9. The LCD prompts for the local pressure in mBar. Use the arrow keys to increase or decrease the pressure value respectively.

10. When the proper pressure displays, press return arrow once to view the calibration value in the lower right of the display. Once the value in the main display stabilizes, press the return arrow again to move to the salinity compensation procedure.

11. The display prompts for the approximate salinity of the water to be analyzed. Keep this at zero.

12. The meter is now calibrated. Record the mg/L reading of the calibrated DO level under **DO Level After Cal** on the probe calibration form. If everything is working properly, the probe should display the saturation DO level based on the altitude and temperature you are calibrating at. The theoretical DO value and the probes calibrated readout should be within 0.2 ppm (or mg/L)

13. Record the % saturation displayed on the DO probe under the **% Sat after Cal** column. This will be important later when you do the midday calibration check.

14. After calibration, please keep the probe on at all times while you are taking it out to the field and performing your field samples. The unit should hold the calibration even if it is powered off. However, it is recommended that you perform the calibration again if the probe is turned off.

5.3.3 Taking DO Measurements in the Field:

1. Remove the calibration bottle from the probe
2. Place the probe in the water to be measured. Be careful not to get the meter wet since it is not waterproof.
3. **Stir the probe continuously** in the water.
4. Allow the DO and temperature to stabilize.
5. **Record** the DO (in mg/L and % Saturation) and temperature readings on your **field data sheet**.
6. Rinse the DO probe with distilled water.
7. Return the DO probe to the calibration bottle.
8. **Midday % Sat Check-** Midway though the sample run, (especially if it is more than 2 hours) the user should check for probe drift. The check will determine if the probe needs recalibration. The midday check consists of placing the probe in the calibration chamber with a moist sponge. Switch the mode of the probe to display % saturation. Record the value on the log sheet.

9. **% Sat Difference (do not overwrite)-**This column will automatically calculate the difference between your midday % saturation and the mornings results. If the difference is more than 5.0%, you should recalibrate the probe and flag data collected in the morning since the probe did not hold the proper calibration.

5.3.4 Dissolved Oxygen End of Day Calibration Check:

After the sample run is complete, return the probe to the calibration station to perform a quick end of day calibration check.

1. Place the probe in the DO calibration chamber and let it equalize. This may take between 2 to 10 minutes depending on the condition of the probe.
2. After you have placed the probe in the calibration chamber to equalize, note the temperature. The probe temperature should be roughly close to the same as the morning calibration if you did the calibration indoors. If you are calibrating the probe outside, the temperature may be different from the earlier reading, but this will not affect the calibration check. Record this under **Temp C End of Day** on the probe calibration form.
3. Record the pressure reading of the probe under **Pressure End of Day (mBar or mmHg)** on the probe calibration form. This may have changed from the morning reading due to a change in the weather. You can get current local barometric pressure readings from www.weatherchannel.com or www.noaa.gov. If you not in a place with internet access, record this as close to the end of the day as possible.
4. As in the morning calibration, use the DEQ DO Saturation Table.doc to determine your theoretical DO level. Record it under **Theoretical DO Level End of Day (ppm or mg/L)** on the probe calibration form.
5. Record the reading of the probe (ppm or mg/L) under **DO Level End of Day** on the probe calibration form. **DO NOT** recalibrate the probe. The purpose of this check is to see if the probe has drifted out of acceptable limits during the day.
6. When the calibration data is entered into the probe calibration form excel worksheet, it will automatically calculate the mg/L difference from the afternoon theoretical DO level and the readout of the probe. Do not overwrite this column. If the probe is functioning properly there should be a difference of less than 0.60 mg/L from the afternoon theoretical DO level and the probe readout. The color scale signifies the following:
    a. **Red**- Displayed to show if the calibration difference is greater than 0.60 mg/L. The probe needs service and you must flag the data because the probe did not hold onto the calibration.
    b. **Yellow**- Displayed to show a calibration difference of 0.41 to 0.60 mg/L. The calibration of the probe is approaching the limits of accuracy and preventative maintenance may be required. It may be wise to clean the probe or replace the probe membrane when this occurs.
    c. **Green-** Displayed to show if the calibration difference of 0.00 to 0.40 mg/L. The probe is functioning properly and no action is necessary except for general housekeeping according to manufacturer directions.
7. The person calibrating and using the probe should initial the probe calibration form.
8. Use the **notes** space for any notes or comments regarding the probe.

5.4 pH Protocol

RappFLOW uses a YSI meter and probe to measure pH. A pH meter measures the electric potential (millivolts) across an electrode when immersed in water. This electric potential is a function of the hydrogen ion activity in the sample.

A pH meter consists of a *potentiometer,* which measures electric current; a glass electrode, which senses the electric potential where it meets the water sample; a reference electrode, which provides a constant electric potential; and a temperature compensating device, which adjusts the readings according to the temperature of the sample (since pH varies with temperature). The reference and glass electrodes are frequently combined into a single probe called a combination electrode.

Adapted from EPA Monitoring and Assessing Water Quality;
http://www.epa.gov/owow/monitoring/volunteer/stream/vms54.html

5.4.1 Before Sampling:

The pH meter is easy to use, but to maintain accuracy it must be calibrated at the beginning of each sampling day before it is used. The calibration is then checked again at the end of the sampling day. The following are instructions adapted from the Virginia Department of Environmental Quality. Read through the entire instructions before beginning the calibration. Record your calibration data on the pH calibration sheet provided.

5.4.2 Calibration Instructions:

Most probes allow calibrating the pH probe using two different buffers. In most cases the use the 7.00 and 4.00 pH buffer solutions is suitable and reflects the pH found in the majority of Virginia waterways. If you are experiencing pH values above 7.00, DEQ strongly recommends calibration using 7.00 and 10.00 buffer solution.

You should use fresh buffer solution when you calibrate the probe and check the readings at the end of the day. Please record the probe readings to the nearest hundredth unit place (Ex. 7.01) when performing the calibration.

1. Record the date of calibration on the probe calibration form. Calibration must be done each day you perform samples.
2. Carefully remove the probe from its plastic soaker bottle by first unscrewing plastic top on bottle and pulling the probe out. Cap plastic bottle with second top (the one without the hole.) Slide cap and o-ring off probe.
3. As a rinse solution, use a part of the next sample or buffer which is to be measured (in this case pH 7 buffer). This will minimize contamination from carryover. Vigorously stir probe in the rinse solution. This action will bring solution to the electrode's surface more quickly and improve speed of response. Shake the electrode with a snap motion to remove residual drops.
4. Place the probe in a cup of pH 7 buffer solution. Stir.
5. **Record** the temperature of the pH 7 buffer. Write this under **Temp C in Morning** on the field probe pH calibration form.
6. Press **MODE** until "pH" displays. Swirl the buffer or the probe to obtain an accurate reading. Record the probe reading of the 7.00 buffer solution under **Pre Cal pH 7**.
7. While the pH probe is in the 7.00 buffer solution, allow the temperature to stabilize, then press "STAND" to calibrate. If AUTOLOCK is on, "WAIT" flashes until the unit detects a stable reading. Once the unit calibrates the first point, "STAND" displays steadily, and

"SLOPE" flashes. The probe should now read a value close to 7.00 pH units. Record the pH value displayed under **Cal to 7 Buffer**.

8. . Then immerse the probe in the 4.00 (or 10.00) buffer solution, record the stabilized value under **Pre Cal to pH 4 (or 10)**.
9. While the probe is in the pH 4 (or 10) buffer, allow the temperature to stabilize, then press "SLOPE" to calibrate. If AUTOLOCK is on, "WAIT" flashes until the unit detects a stable reading. Once the unit calibrates the second point, "STAND" and "SLOPE" display steadily. The probe should now read a value close to 4.00 (or 10.00) pH units. Record the pH value displayed under **Cal to pH 4 (or 10) Buffer**.
10. The probe is now calibrated. Clean the probe with distilled water and shake electrode with a snap motion to dry.
11. Return the probe to the plastic soaker bottle for transport to your first site. Keep the probe in this solution at all times when you are not using it. If it should spill or need replacement for some reason, refill the bottle with pH 4 buffer solution.
12. Remember to keep the probe on at all times while taking the probe out into the field and when returning to perform the end of the day check.

5.4.3 Taking pH Measurements in the Field:

To take pH measurements, "STAND" and "SLOPE" must display steadily, indicating the unit is dual-point calibrated and ready for measurements.

1. Carefully remove the probe from its plastic soaker bottle by first unscrewing plastic top on bottle and pulling the probe out. Cap plastic bottle with second top (the one without the hole.) Slide cap and o-ring off probe.
2. Shake the electrode with a snap motion to remove residual drops of the storage solution.
3. Press MODE to enter pH mode.
4. Place the probe in the water to be measured. Be careful not to get the meter wet since it is not waterproof.
5. Remove any air bubbles trapped around the probe by stirring the probe.
6. Allow the pH and temperature to stabilize. Continue stirring the probe to speed response time.
7. **Record** the pH and temperature readings on your **field data sheet**.
8. Rinse pH probe with distilled water and hake the electrode with a snap motion to remove residual drops of the storage solution.
9. Return the pH probe to the plastic soaker bottle solution.

5.4.4 pH End of Day Calibration Check:

1. Place the probe into the pH 7 buffer and ensure adequate mixing. Record the pH and temperature values the probe displays when it equalizes on the probe calibration form under **pH 7 Check End of Day** and **Temp C at End of Day**. DO NOT recalibrate the probe. The purpose of this end of day check is to detect unacceptable probe drift.
2. Place the probe in the pH 4 (or 10) buffer and ensure adequate mixing. Again, record the value when it equalizes under **pH 4 (or 10) Check End of Day**. DO NOT recalibrate the probe.
3. When the calibration data is entered into the probe calibration form excel worksheet, it will automatically calculate the differences between the beginning and end of day calibrations. Do not overwrite these columns. They uses the following color system:

a. **Red**- The pH difference is greater than 0.2 SU. Flag the data and repair/replace the probe.
b. **Yellow**- The pH is between 0.15 and 0.2 SU. The probe may need servicing soon.
c. **Green**- The pH difference is between 0.00 and 0.15 SU. The probe is functioning properly and no further action is necessary. Follow general housekeeping as outlined by the manufacturer.

4. The person calibrating and using the probe should initial the probe calibration form.
5. Use the **notes** space for any notes or comments regarding the probe.

5.5 Water Clarity Protocol

To measure water clarity, use the transparency tube:

1. Collect a surface water sample in a bucket.
2. Stand with your back to the sun so that the transparency tube is shaded.
3. Close the drain tube by squeezing the crimp
4. Fill the tube with the water sample.
5. While looking down the opening of the tube, partially open the drain crimp and slowly drain off sample.
6. When the black and white pattern at the bottom of the tube faintly begins to appear, immediately close off the drain crimp and note the amount of water remaining via the centimeter ruler on the side of the tube.
7. Record the depth of water in the tube on you field data sheet under water clarity. Note: If you can still see the disk on the bottom of the tube after the tube is filled, check the box that states “actual transparency reading was greater than the value entered”.
8. Pour the water from the tube back into the sample bucket or mix up the remaining sample.
9. Repeat the measurement.

(From Lawrence Enterprises Inc. http://www.watermonitoringequip.com/pages/home.html)

6. Why You Are Performing These Tests

6.1 BACTERIA (E. coli)

Members of two bacteria groups, coliforms and fecal streptococci, are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in streams suggests that pathogenic microorganisms might also be present and that swimming and eating shellfish might be a health risk. Since it is difficult, time-consuming, and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for coliforms and fecal streptococci instead. Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and storm runoff. In addition to the possible health risk associated with the presence of elevated levels of fecal bacteria, they can also cause cloudy water, unpleasant odors, and an increased oxygen demand.

E. coli is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. EPA recommends E. coli as the best indicator of health risk from water contact in recreational waters. E.coli is the standard in Virginia for swimming beaches and will soon be the standard for all Virginia waters.

(From Volunteer Stream Monitoring: a methods manual, chapter 5 water quality conditions, http://www.epa.gov/owow/monitoring/volunteer/stream/vms511.html)

6.2 DISSOLVED OXYGEN

Dissolved oxygen (DO) is one of the most important indicators of the quality of water for aquatic life. It is essential for all plants and animals. Oxygen availability throughout the year is influenced by other chemicals present in the water, biological processes, and temperature.
A dissolved oxygen test measures the amount of oxygen dissolved in the water. A dissolved oxygen measurement, however, does not measure the amount of dissolved oxygen the water is capable of holding at the temperature at which it was tested. Warmer water is capable of holding less dissolved oxygen than colder water. When water holds the entire DO it can hold at a given temperature, it is said to be 100 percent saturated with oxygen. If water holds half as much oxygen as it can hold at a given temperature, it is 50 percent saturated.

Most living organisms require oxygen for their basic metabolic processes. Since the existence of plants also depends on the availability of light, the oxygen-producing processes occur only near the surface or in shallow waters. Photosynthesis of aquatic plants releases oxygen into the water. Oxygen is also dissolved in water through diffusion and surface turbulence. Oxygen is poorly soluble in water, roughly 10 ppm (parts per million) at 0-2 ºC compared to almost 1700 ppm for carbon dioxide at the same temperature. When oxygen levels in the water fall below 3-5 ppm, most fish and marine organisms are stressed and cannot survive.

In general, oxygen levels during mid-day at the surface are near saturation (the maximum level sustained at the temperature), and drop as the water depth increases. Dissolved oxygen levels are an indicator of water quality. Oxygen levels may be reduced because of warm water temperatures and poor flushing. Run-off from farms or lawns containing fertilizers and other

nutrients can overfertilize aquatic plants. At first aquatic vegetation will flourish and raise dissolved oxygen levels found in the water. As the plants begin to die, the process of decomposition will deplete the oxygen content of the water. *Eutrophication* is the term used when high nutrient levels cause an excess of phytoplankton.
(From: Chesapeake Bay Citizen Monitoring Program Manual, 2002. Alliance for the Chesapeake Bay. Richmond, Virginia. www.acb-online.org)

6.3 pH

pH is a measure of how acidic or basic (alkaline) a solution is. In any given solution some atoms of water dissociate to form hydrogen ions (H+) and hydroxyl ions (OH-). The pH scale is a means of showing which ion has the greater concentration. At a pH of 7.0, the concentrations of hydrogen ions and hydroxyl ions are equal and the water is said to be neutral. Pure water has a pH of 7.0. When the pH is less than 7.0, there are more hydrogen ions than hydroxyl ions and the water is said to be acidic. When the pH is greater than 7.0, there are more hydroxyl ions than hydrogen ions and the water is said to be basic or alkaline.

pH is defined as the negative logarithm of the hydrogen ion concentration which means that the concentration of hydrogen ions does not increase or decrease in a linear fashion. Increases are in powers of 10. At pH of 5 there are 10 times more hydrogen ions than at a pH of 6. A pH of 3 is not just twice as acid as a pH of 6, it is 100 times more acidic. A change in pH of one whole number is therefore quite a large change.

Water dissolves mineral substances it contacts, picks up aerosols and dust from the air, receives man-made wastes, and supports photosynthetic organisms, all of which affect pH. Photosynthesis by aquatic plants removes carbon dioxide from the water, which can significantly increase pH. Therefore, in waters with plant life (including planktonic algae), especially low-velocity or still waters, an increase in pH can be expected during the growing season.

The turbulence of flowing water promotes gaseous interchange between the atmosphere and water. The carbon dioxide content of water in rivers and streams is less likely to change; but activities in the watershed may affect pH. Increased leaching of soils or mineral outcrops during snowmelt or heavy precipitation affects pH downstream. Human activities such as accidental spills, agricultural runoff (pesticides, fertilizers, soil leachates), and sewer overflow may also change pH.

pH affects many biological and chemical processes in the water. For example, different organisms flourish within different ranges of pH. Most aquatic animals prefer a pH range of 6.5-8.0. pH outside this range reduces the diversity in the stream because it stresses the physiological systems of most organisms and can reduce reproduction. Low pH can also allow toxic elements and compounds to become mobile and "available" for uptake by aquatic plants and animals. This can produce conditions that are toxic to aquatic life, particularly to sensitive species like rainbow trout.
(From: Volunteer Stream Monitoring: a methods manual, chapter 5 water quality conditions, http://www.epa.gov/owow/monitoring/volunteer/stream/vms54.html and Chesapeake Bay Citizen Monitoring Program Manual, 2002. Alliance for the Chesapeake Bay. Richmond, Virginia. www.acb-online.org)

6.4 TEMPERATURE

Although water temperature may be one of the easiest measurements to perform, it is probably one of the most important parameters to be considered. It dramatically affects the rates of chemical and biochemical reaction within the water. Many biological, physical, and chemical principles are temperature dependent. Among the most common of these are the distribution and abundance of organisms living in the rivers and streams, rates of chemical reactions, density, inversions and mixing, and current movements.

Temperature affects feeding, reproduction, and metabolism of aquatic animals; even a week or two of high temperatures may make stream unsuitable for sensitive aquatic organisms, even though temperatures are within tolerable levels throughout the rest of the year. Not only do different species have different requirements, but optimum habitat temperatures may change depending on the stage of life. Fish larvae and eggs usually have narrower temperature requirements than adult fish.

Causes of temperature change include: weather changes, removal of shading streambank vegetation, construction of dams and other impoundments, discharge of heated water from industry, urban storm water, and groundwater flows to streams.
(From: Chesapeake Bay Citizen Monitoring Program Manual, 2002. Alliance for the Chesapeake Bay. Richmond, Virginia. www.acb-online.org)

6.5 WATER CLARITY

Material that becomes mixed and suspended in water will reduce its clarity and make the water *turbid* (dirty). In summer, plankton are growing and multiplying rapidly in the warm, nutrient-rich water. During periods of heavy rain, run-off from land can carry large amounts of silt into streams. Silt is often related to nutrient enrichment of a river because nutrients such as phosphorus cling to soil particles. Fine sediment can become re-suspended in more shallow waters during heavy winds and tidal action. In addition, unprotected shoreline will erode and contribute suspended particles to the water. In shallow areas, wind-generated waves and boat wakes stir up sediments. Wind and boat generated waves breaking on shore also contribute to turbidity.

Turbidity affects fish and aquatic life by:

- Interfering with the penetration of sunlight. Submerged aquatic vegetation (SAV) needs light for photosynthesis. If suspended particles "block out" light, photosynthesis, which produces oxygen for fish and aquatic life, will be reduced. SAV provides essential food, nursery areas, shelter and habitat for diverse communities of shellfish, waterfowl and fish. If light levels become too low, photosynthesis may stop altogether and algae will die.
- Sediment buries eggs and benthic (bottom dwelling) organisms' habitat
- Large amounts of suspended matter may clog the gills of fish and shellfish and kill them directly.
- Fish cannot see very well in turbid water and so may have difficulty finding food.

(From: Chesapeake Bay Citizen Monitoring Program Manual, 2002. Alliance for the Chesapeake Bay. Richmond, Virginia. www.acb-online.org)

6.6 Total Suspended Solids (TSS) and Nutrients (Sampled in select locations)

Total suspended solids (TSS). TSS measures the amount of suspended solids in the water. TSS measures the actual weight of suspended material per volume of water. Total volumes of material entering a stream can be calculated from TSS values.

Total phosphorous (TP). Phosphorous is a rate–limiting nutrient; only a small amount in the water can cause rapid algae and aquatic plant growth. Total phosphorus is the measure of all forms of phosphorus present in water.

Orthophosphate. Soluble reactive phosphate or orthophosphate is the fraction of TP that is soluble or available to organisms for growth.

Total kjeldhal nitrogen (TKN). TKN represents the fraction of Total Nitrogen that is unavailable for growth or bound up in organic from.

Nitrate nitrogen, Nitrate nitrogen and Ammonia nitrogen. Nitrate nitrogen (NO_3), Nitrate nitrogen (NO_2) and Ammonia nitrogen (NH_4) represent the bioavailable forms of nitrogen.

Although nutrients are beneficial to both terrestrial and aquatic plants, they can become water contaminants if present in excessive amounts. Since phosphorus is the nutrient in short supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events in a stream. Such evens include accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

There are many sources of phosphorus and nitrogen, both natural and human. These include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations.

Phosphorus cycles through the environment, changing form as it does. Aquatic plants take in dissolved inorganic phosphorus and convert it to organic phosphorus as it becomes part of their tissues. Animals get the organic phosphorus they need by eating either aquatic plants, other animals, or decomposing plant and animal material.

As plants and animals excrete wastes or die, the organic phosphorus they contain sinks to the bottom, where bacterial decomposition converts it back to inorganic phosphorus, both dissolved and attached to particles. This inorganic phosphorus gets back into the water column when the bottom is stirred up by animals, human activity, chemical interactions, or water currents. Then it is taken up by plants and the cycle begins again.

In a stream system, the phosphorus cycle tends to move phosphorus downstream as the current carries decomposing plant and animal tissue and dissolved phosphorus. It becomes stationary only when it is taken up by plants or is bound to particles that settle to the bottom of pools.

Monitoring phosphorus and nitrogen is challenging because it involves measuring very low concentrations down to 0.01 milligram per liter (mg/L) or even lower. Even such very low concentrations of phosphorus can have a dramatic impact on streams.
(From Volunteer Stream Monitoring: a methods manual, chapter 5 water quality conditions, http://www.epa.gov/owow/monitoring/volunteer/stream/vms56.html)

7. Virginia Water Quality Standards

Dissolved oxygen: Minimum of 4 mg/L, Daily average of 5 mg/L

pH: 6.0-9.0 standard units

Temperature: Minimum of 31^{o}C

E. coli: Maximum geometric mean of 126 colonies/100 mL or
a single sample of less than 235 colonies/100 mL

Water clarity/ transparency: No numerical state water quality standards currently exist.

Nutrients: No numerical state water quality standards exist for phosphorus and nitrogen. Standards are currently being developed.