2. Water Quality Data Used in This Report

GA DNR CRD Water Quality Monitoring Programs

Data collected by four GA DNR CRD water quality monitoring programs (Shellfish Sanitation, Sounds, Rivers, and Beaches) are analyzed in this report. The purpose, scope, timeframe, and parameters measured for each program are described below. Most of the information about each program is available on the GA DNR CRD website: http://crd.dnr.state.ga.us/. Information about the locations of individual sampling sites included in our analyses can be found in Appendix A.

Shellfish Sanitation Program

GA DNR CRD manages Georgia's Shellfish Sanitation Program for the safe recreational and commercial harvest of oysters and clams. This program is funded by the State of Georgia and carried out in partnership with other agencies, including GA DNR Wildlife Resources Division Law Enforcement Section and the Georgia Dept. of Agriculture. Shellfishing is managed according to U.S. Food and Drug Administration (FDA) National Shellfish Sanitation Program (NSSP) standards. These standards require periodic sanitary surveys and ongoing water quality sampling to ensure that approved shellfish growing areas are not subject to contamination from human or animal fecal matter at levels that, in the judgment of the State Shellfish Control Authority (SSCA, comprised of GA DNR and GA Dept. of Agriculture), presents an actual or potential public health hazard and are not contaminated with pathogenic organisms, toxins, or bacteria concentrations exceeding the standards (NSSP 2007). CRD's specific responsibilities include identifying and maintaining growing area classifications, monitoring waters for fecal bacterial contamination, conducting sanitary surveys, opening and closing harvest areas, managing commercial leases, and issuing permits to shellfish growers and pickers.

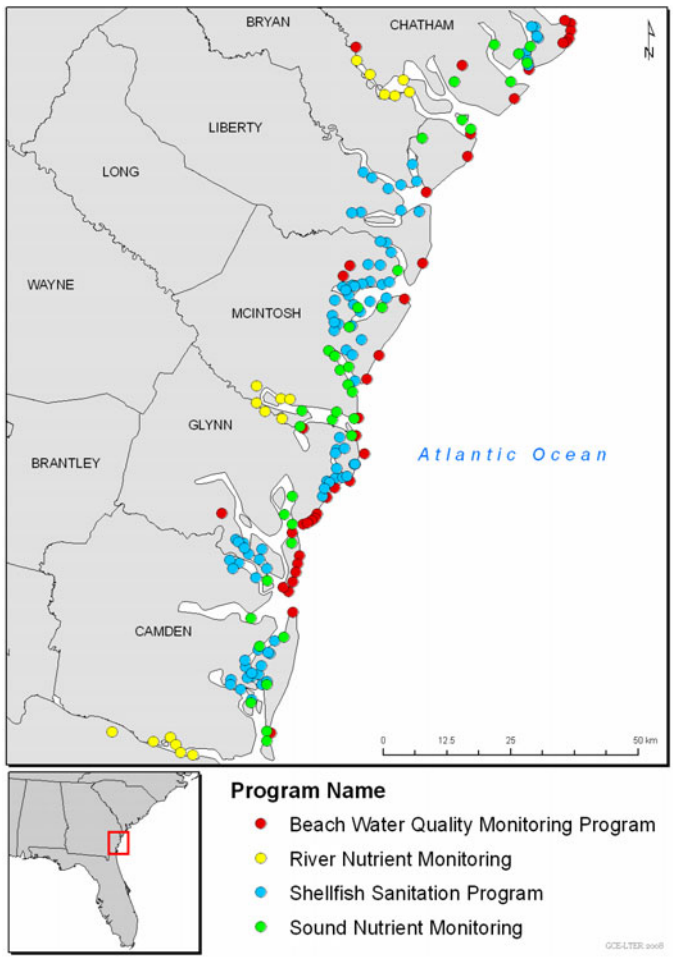

Figure 2-1. Sites monitored by four water quality monitoring programs conducted by GA DNR CRD.

As of 2006, there were over 145,000 acres classified and approved for shellfish harvest on the Georgia coast, adjacent to Chatham, Bryan, Liberty, McIntosh, Glynn, and Camden counties. A total of 89 sites have been monitored by CRD (Figure 2-1), but the number at any given time is less because some sites have been added or discontinued in recent years. One site in the Hampton River area was sampled only once and is not included in these analyses.

The Shellfish Sanitation Program began in 1984, but the data analyzed in this report range from January 1998 through December 2006. 51 sites were being monitored in 1998, 10 more began in July 2002, and 9 more in May 2005, with the remainder of the 88 sites

added a few at a time between these periods. Five sites had been discontinued by the end of 2004, but as of December 2006, 83 were still being monitored. Sites were generally sampled monthly at random tide stages until April 2005, after which sampling shifted to bimonthly at most sites.

One of CRD's main roles in the program is to monitor fecal coliform bacteria levels, so these have been collected throughout. They also routinely collect salinity and water temperature data. Dissolved oxygen and specific conductance were added to the field sampling parameters in 2000. Dissolved nutrient concentrations (nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, total dissolved phosphorus, orthophosphate-phosphorus, and silicate) are available for 66 of the shellfish sites starting in late 2001. These nutrient analyses were cut back due to funding constraints starting in 2003; by December 2006 nutrients were being measured at only 30 sites. pH monitoring was added in late 2003 and continues at all current sites (Figure 2-2).

Sound and River Nutrient Monitoring

These two closely related programs measure nutrients and other water quality parameters in Georgia's estuaries (the Sound program) and the lower reaches of the Ogeechee, Altamaha and St. Marys rivers (the River program). The purpose of these programs, which are funded by the State of Georgia, is to assess trends in nutrient concentrations in Georgia coastal waters and to provide baseline data for resource managers to use in making management decisions.

There are 37 sites in the Sound program and 18 in the River program, 6 each in the Ogeechee, Altamaha, and St. Marys Rivers (Figure 2-1).

Most monitoring began in March 2000, and sampling continued approximately monthly (year-round) at least through the end of the data included here (December 2006). However, some of the early data were discarded due to quality control problems. The nutrient data included in this study generally begin in mid-late 2001 for the sounds and in mid-2002 for the rivers (Figure 2-2).

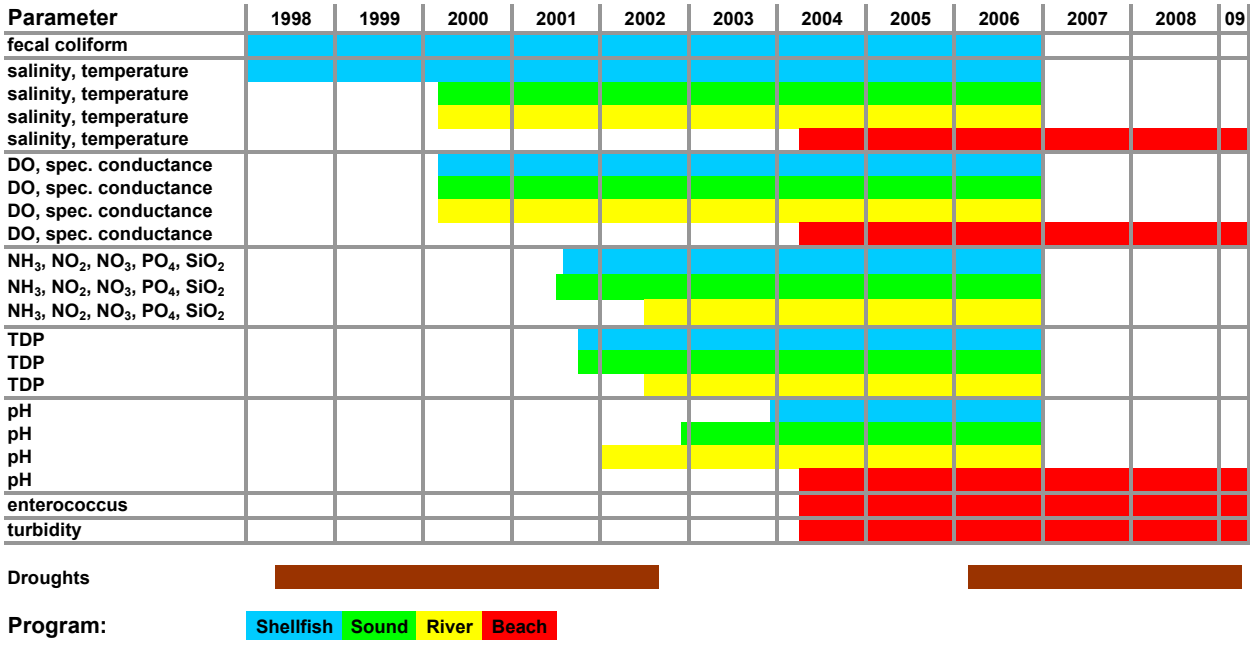

Figure 2-2. Sampling periods included in the database for most sites monitored by GA DNR CRD as part of the Shellfish (blue), Sound (green), River (yellow), and Beach (red) water quality monitoring programs. DO=dissolved oxygen, NH_3=ammonia-nitrogen, NO_2=nitrite-nitrogen, NO_3=nitrate-nitrogen, PO_4=orthophosphate-phosphorus, TDP=total dissolved phosphorus, SiO_2=dissolved silicate.

Dissolved nutrients monitored include nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, total dissolved phosphorus, orthophosphate-phosphorus, and silicate. Other parameters measured in the field include water temperature, salinity, specific conductance, dissolved oxygen, and pH.

Beach Water Quality Monitoring Program

The purpose of this program is to monitor Georgia's recreational marine beaches for conditions that would specifically affect human health through contact with the water. Prior to 1986, fecal coliform bacteria level was the recommended indicator of fecal pollution in marine recreational waters. However, the Beaches Environmental Assessment and Coastal Health (BEACH) Act of 2000 established enterococci as the indicator organisms for marine recreational waters under the current U.S. EPA (1986) water quality standards. Georgia has monitored the beaches according to these rules since April 2004. This program is funded entirely by BEACH Act Implementation Grants. CRD's role is to monitor the *Enterococcus* levels and notify the GA Division of Public Health local district and GA DNR EPD if the standards are exceeded. The local health district issues swimming advisories, and EPD investigates potential sources.

CRD has 41 beach sites listed in its database (Figure 2-1), categorized according to usage. Tier 1 beaches (17 sites) are near large populations, with easy accessibility and amenities that lead to high usage. Tier 2 beaches (9 sites) are less accessible with medium usage. Tier 3 beaches (14 sites) are remote, not easily accessed, and have the least usage. The single Tier 4 beach is under permanent advisory for persistent water quality problems.

Data from April 2004 through April 2009 were analyzed for this report. Tier 1 beaches are monitored weekly year-round, while Tier 2 beaches are monitored monthly April through November. Tier 3 beaches are not currently sampled, although 7 of the 14 sites have some data from 2004. The remaining 7 Tier 3 beaches have no data and were not included in this report. The Tier 4 beach is monitored quarterly.

Water quality parameters measured by CRD at beach sites include *Enterococcus* abundance, water temperature, salinity, specific conductance, pH, dissolved oxygen, and turbidity (Figure 2-2).

Sampling and Analytical Methods

CRD personnel conduct field sampling for all four monitoring programs. Sites are generally sampled during daylight hours at all stages of the tide. Measurements are made on surface waters, with some observations recorded directly in the field and samples for other analyses brought back to the laboratory. Brief descriptions of analytical methods are listed below.

Field Measurements

Water temperature, specific conductance, salinity, pH, dissolved oxygen, and turbidity are measured in the field by CRD personnel using various calibrated handheld multi-parameter water quality instruments sold by YSI or Hydrolab. These in-situ instruments generally measure temperature with a thermistor (EPA Method 170.1) and specific conductance (normalized to 25°C) with a 4-electrode cell (EPA Method 120.1) and then calculate salinity according to Standard Method 2520B. pH is measured using glass electrodes (EPA Method 150.1), and dissolved oxygen (DO) is measured using membrane probes (EPA Method 360.1). Nephelometric turbidity is measured with optical right-angle light scatter sensors (EPA Method 180.1).

Dissolved Nutrients

Surface water samples for nutrients are filtered in the field through 0.45 µm polycarbonate filters before transfer for processing by either the UGA Marine Extension lab, Brunswick, GA or Avery Laboratories and Environmental Services in Savannah, GA.

Silicate

Silicates (as SiO_2) are measured by the UGA Marine Extension lab by colorimetric determination of the blue complex formed after reaction of soluble silicate forms with acid molybdate, oxalic acid, and stannous chloride using a Lachat QuikChem8000 FIA+ nutrient auto-analyzer (method 31-114-27-1-A).

Ammonia

Ammonia/ammonium (NH_3) is measured by the UGA Marine Extension lab by colorimetric determination of indophenol blue formed after the Berthelot reaction with hypochlorite, phenol, and nitroferricyanide using a Lachat QuikChem8000 FIA+ nutrient auto-analyzer (method 31-107-06-1-E).

Nitrite

Nitrite (NO_2) is measured by the UGA Marine Extension lab by colorimetric determination of azo dye following reaction with sulfanilamide and N-(1-napthyl)-ethylenediamine dihydrochloride using a Lachat QuikChem8000 FIA+ nutrient auto-analyzer (method 31-107-04-1-C).

Nitrate

Nitrate+nitrite (NO_x) is measured by the UGA Marine Extension lab by Cu-Cd reduction followed by nitrite analysis (above). Nitrate (NO_3) is obtained by difference from the non-reduced nitrite-only analysis.

DIN

Dissolved inorganic nitrogen (DIN) is the sum of ammonia, nitrite, and nitrate, all expressed as mg N L^{-1}.

Orthophosphate

Orthophosphate (PO_4) is measured by the UGA Marine Extension lab by colorimetric determination of the blue complex formed after reaction with ammonium molybdate and antimony potassium tartrate under acidic conditions, followed by ascorbic acid reduction, using a Lachat QuikChem8000 FIA+ nutrient auto-analyzer (method 31-115-01-3-A).

Total Dissolved Phosphorus

Total dissolved phosphorus (TDP) is measured by Avery Laboratories & Environmental Services, by persulfate digestion followed by the ascorbic acid-molybdenum blue method for PO_4 (see above) according to Standard Method 4500P B-E using a Konelab AquaKem instrument.

Bacterial Samples

Fecal Coliform Bacteria

Sampling by the Shellfish Program follows the procedure described by the NSSP Manual of Operations, Systematic Random Sampling. Classification of Georgia shellfish waters is based upon estimation of fecal coliform group density by multi-tube fermentation techniques in A-1 broth according to Standard Method 9221 E.2. The 3-tube decimal dilution method was used by CRD from January 1998-February 2003, and the 5-tube method has been used since March 2003 for greater precision. Both of these methods yield a Most Probable Number (MPN) per 100 mL.

Fecal coliform abundance is analyzed for CRD by an outside laboratory. From January 1998-February 2003, fecal coliforms were measured by Altamaha Laboratories, Blackshear, GA using the 3-tube method. The same lab used the 5-tube method from March 2003-June 2007. CRD then used the Alabama Department of Public Health, Mobile, AL for this analysis for an interim period of July-October 2007 before switching to the Chatham County Health Department Laboratory, Savannah, GA in November 2007.

Fecal coliform levels are monitored using a running geometric mean of the last 30 samples collected at each site. Acceptable levels for shellfish harvest, as determined by the SSCA, are a geometric mean of less than 14 MPN per 100 mL water, and a single-sample 90th percentile (5-tube dilution) less than 43. However, raw data were analyzed for this report.

Enterococci Bacteria

Beach water samples for *Enterococcus* analyses are taken to the processing lab within 6 hours, maintaining chain of custody. Altamaha Laboratories, Blackshear, GA analyzed samples from April 2004-May 2006. Since May 2006, CRD has used the Chatham County Health Department Laboratory, Savannah, GA.

Abundance of fecal enterococci is determined by membrane filtration using membrane-enterococcus indoxyl-ß-D-glucoside agar (mEI) followed by direct count of colony-forming units (CFU) (EPA Method 1600). Results are expressed as CFU per 100 mL. Public health status is monitored using a running geometric mean over the last 30 days for Tier 1 beaches and an annual geometric mean over the recreational season (May-October) for Tier 2 beaches, with swimming advisories posted if the geometric mean is 35 or greater, or if a single sample measures 104 or greater. However, raw data were analyzed for this report.

Database

We used a SQL Server database to organize CRD's water quality data for the analyses presented in this report. The SQL database tables and schema (Figure 2-3) were designed with a goal of flexible querying across all four sampling programs while retaining as much detail as possible about the program affiliation, the identification of the analytical laboratory, and the methodology associated with each observation. We distinguish between the terms "sites" and "stations" as follows: Sampling sites are locations identified by their geographical coordinates (latitude/longitude), with associated information about the county, river, sound, and/or beach where the site is located. Even though each site is currently associated with only one sampling program, we allowed for the possibility that a site could be used for more than one program and may have a different site name in each case: therefore, the site name used by CRD is stored separately in a table that links sites with programs. A station is an individual instance when a site was sampled: a station links a site with a date and time. The data taken during a station are stored in two tables: the values of the main parameters listed above are stored in the observations table, while ancillary data about sampling conditions (tide stage, wind direction, weather) are stored in the conditions table.

Parameter observations are further characterized by analytical method information in order to track any potential changes due to methods. The entries in the calibrations table define the start and end dates for periods when a set of consistent analytical conditions were in force. Any change in processing laboratory, analytical method, equipment calibration, or minimum detection limit results in a new calibration ID. Information for data validation such as minimum and maximum valid values and regulatory limits are also stored here even though they are not strictly related to methodology. Association of a calibration ID with a data observation (parameter value) links the observation to the methodology that was in use at the time of sampling.

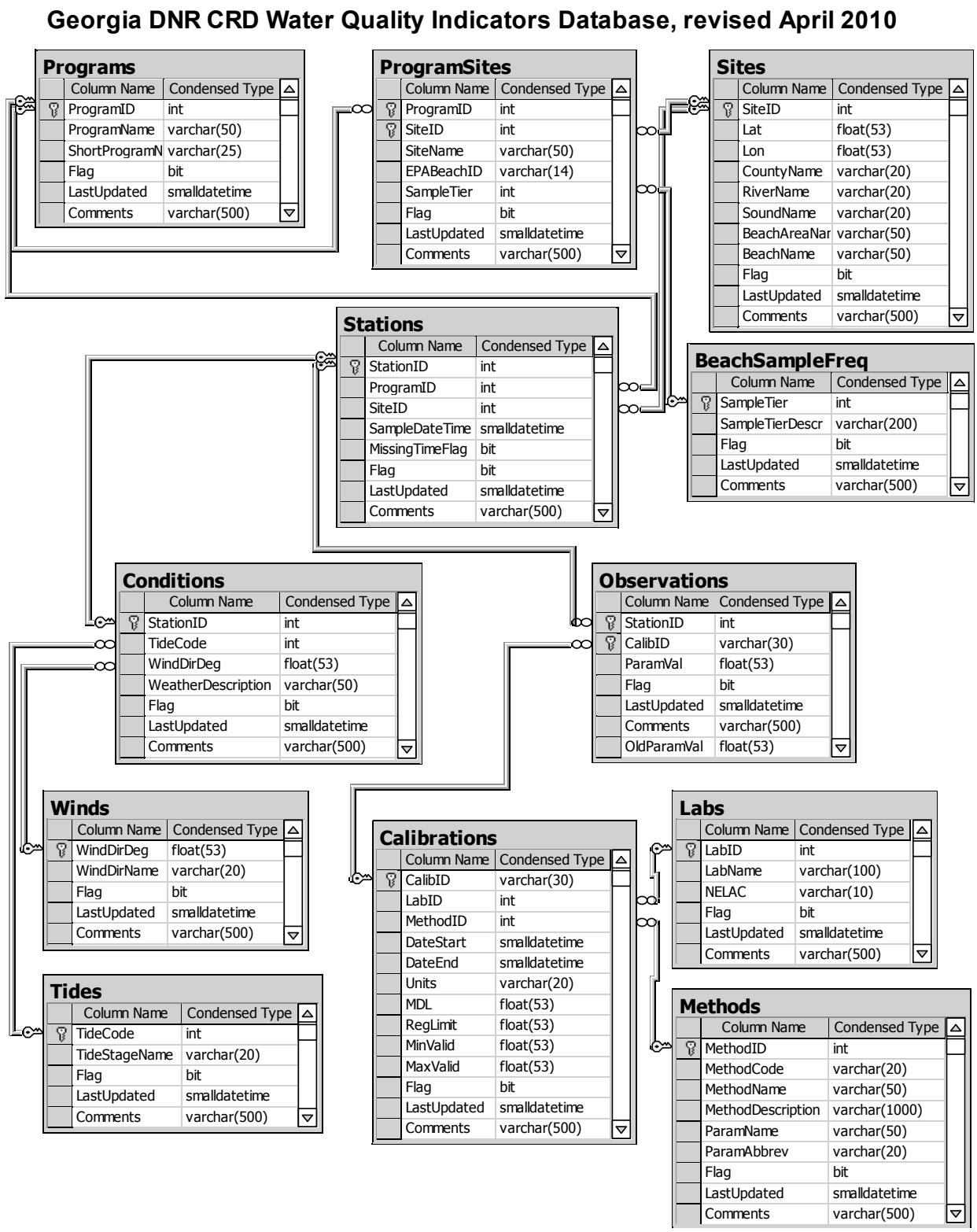

Figure 2-3. Database schema for the water quality indicators database, showing tables in the database and relationships among them.

The data from all four CRD water quality monitoring programs were compiled into this common database, which was then extensively cross-checked for potential errors. This included ensuring that location information associated with sampling events was consistent both within and across programs; evaluating the reported values against expected relationships (e.g. conductivity should be well-correlated with salinity); and checking to be sure that values for component constituents were less than values for totals. Our check on spatial information revealed that five sites had been misclassified in the wrong sounds, and these were corrected. In addition, there were two borderline areas (St. Andrew/Cumberland and St. Simons/Hampton) where sites near each other were not associated with the same sound, especially where more than one program was involved. We used maps to decide how to standardize locations across programs and changed some sound designations as a result. We also assigned sound designations to beach sites where possible in order to maximize the ability to combine data across programs. Corrections to erroneous values that were discovered during diagnostics and analysis were made in the database, with notes to indicate the correction.

The database can be queried and analyzed by a variety of software packages including Microsoft Access (database software) and Matlab (general purpose analytical and graphing software). It can also be readily updated to incorporate additional water quality observations.