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U.S. Geological Survey Quality-Assurance Plan for Continuous Water-Quality Monitoring in Kansas, 2014

Open-File Report 2014–1151

U.S. Department of the Interior
U.S. Geological Survey

Cover. Little Arkansas River near Sedgwick, Kansas. Photograph by John Rosendale, U.S. Geological Survey.

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Conversion Factors

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Volume	
milliliter (mL)	0.0338	ounce, fluid (oz)
milligram per liter (mg/L)	1	parts per million (ppm)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

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Abstract

A quality-assurance plan for use in conducting continuous water-quality monitoring activities has been developed for the Kansas Water Science Center in accordance with guidelines set forth by the U.S. Geological Survey. This quality-assurance plan documents the standards, policies, and procedures used by the U.S. Geological Survey in Kansas for activities related to the collection, processing, storage, analysis, and release of continuous water-quality monitoring data. The policies and procedures that are documented in this quality-assurance plan for continuous water-quality monitoring activities complement quality-assurance plans for surface-water and groundwater activities in Kansas.

Introduction

The U.S. Geological Survey (USGS) is the Nation's principal water-resources information agency. The objectives of the USGS Basic Hydrologic Data Program are to collect and provide unbiased, scientifically based information that describes the quantity and quality of water in the Nation's streams, lakes, reservoirs, and aquifers. Water-quality monitoring activities in Kansas are part of the USGS's overall mission of appraising the Nation's water resources.

To address quality-control issues related to continuous water-quality monitoring activities, the USGS has implemented policies and procedures designed to ensure that all scientific work conducted by or for the USGS is consistent with the objectives set by the Office of Water Quality in Reston, Virginia. A quality-assurance (QA) plan is a formal document that describes the management policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation procedures for guaranteeing data quality.

Purpose and Scope

The purpose of this report is to document the standards, policies, and procedures used by the USGS in Kansas for activities related to the collection, processing, storage, analysis, and release of continuous water-quality monitoring data. This report identifies responsibilities for ensuring that stated policies and procedures are carried out. The report also serves as a guide for all Kansas Water Science Center (KSWSC) personnel involved in continuous water-quality monitoring activities and as a resource for identifying memoranda; publications, such as Wagner and others (2006); and other pertinent literature that describe techniques and requirements in more detail.

The scope of this report includes discussions of the policies and procedures followed by the USGS in Kansas for the collection, processing, analysis, storage, and release of continuous water-quality monitoring data. In addition, issues related to employee safety and training are presented. The policies and procedures documented in this report on continuous water-quality monitoring activities are intended to complement the USGS QA plans for surface-water, groundwater, and discrete water-quality activities in Kansas. This report is reviewed and revised at least once every 3 years to ensure that responsibilities and methodologies remain current and that the ongoing procedural improvements are effectively documented.

Responsibilities

Quality-assurance practices are used to achieve and maintain high integrity water-quality data. Good QA requires that specific actions be carried out systematically in accordance with established protocols. Errors and deficiencies result when individuals fail to carry out their responsibilities. Clear and specific responsibility statements promote an understanding of duties in the process of collecting reliable water-quality data.

Following is a list of responsibilities for KSWSC personnel who are involved in the collection, processing, storage, analysis, and release of continuous water-quality data.

The data collector is responsible for:

1. Day-to-day operation of assigned water-quality monitors in accordance with USGS standards and procedures.
2. Troubleshooting instrument errors and malfunctions and documenting maintenance activities.
3. Using the Continuous Hydrologic Instrumentation Monitoring Program (CHIMP) or standardized field forms to document all field measurements and field observations at the water-quality monitoring station.
4. Proper instrument storage, care, use, and calibration.
5. Familiarity with manufacturer equipment manuals, calibration procedures, Techniques and Methods Report 1–D3 by Wagner and others (2006), and the USGS National Field Manual (Wilde, variously dated) herein referred to as the USGS NFM.
6. Daily data review and timely equipment servicing and maintenance.
7. Continuous water-quality records being computed and processed in a rational and timely manner.
8. Following USGS safety policies regarding operation and maintenance of water-quality monitoring stations, traffic control, personal floatation devices (PFDs), laboratory use, boat operation, and other related procedures.

The Supervisory/Lead Hydrologic Technician or designated person is responsible for:

1. Maintaining operation of all water-quality monitoring stations in area of responsibility.
2. Assigning staff workloads.
3. Reviewing real-time data in their area of responsibility.
4. Maintaining familiarity with manufacturer equipment manuals, calibration procedures, Techniques and Methods Report 1–D3 by Wagner and others (2006), and the USGS NFM (Wilde, variously dated).
5. Training personnel in protocols for servicing and maintaining continuous water-quality monitors.
6. Reviewing all field forms for correctness and completeness.
7. Monitoring status of continuous water-quality monitoring records throughout the record-working cycle.
8. Reviewing continuous water-quality monitoring records for their area of responsibility and meeting deadlines set by the Chief of the Hydrologic Data Management Section or the Chief of the Hydrologic Section.
9. Participating in review of continuous water-quality monitoring records.
10. Following USGS safety policies regarding operation and maintenance of water-quality monitoring stations, traffic control, PFDs, laboratory use, boat operation, and other related procedures, and ensuring that personnel are doing the same.
11. Working with the Chief of the Hydrologic Investigations Section, Water-Quality Specialist, and Project Chiefs to ensure that personnel are available for data-collection activities and ensuring that water-quality monitoring project objectives and requirements are met.

The Project Chiefs are responsible for:

1. Reviewing continuous water-quality data-collection activities.
2. Ensuring that continuous water-quality data collected, computed, or interpreted as part of their project are done in accordance with all applicable QA protocols and guidelines.
3. Providing technical assistance for continuous water-quality data collection and data interpretation.
4. Training and participating in workshops related to continuous water-quality data collection.
5. Following USGS safety policies regarding operation and maintenance of water-quality monitoring stations, traffic control, PFDs, laboratory use, boat operation, other related procedures, and ensuring that personnel are doing the same.

The Kansas Water-Quality Specialist is responsible for:

1. Participating in review of continuous water-quality monitoring records.
2. Maintaining familiarity with manufacturer equipment manuals, calibration procedures, and the USGS NFM (Wilde, variously dated).
3. Providing technical assistance for continuous water-quality data collection and data interpretation.

4. Participating in and assisting with workshop training related to continuous water-quality data collection.
5. Reviewing continuous water-quality fact sheets and reports.
6. Reviewing proposals for new continuous water-quality data collection or interpretive projects.
7. Following USGS safety policies regarding traffic control, PFDs, laboratory use, boat operation, other related procedures, and ensuring that personnel are doing the same.

The Chief of the Hydrologic Investigations Section and Director are responsible for:

1. Overall operation of the USGS water-quality monitoring network in the KSWSC.
2. Working with Project Chiefs, the KSWSC Water-Quality Specialist and Supervisory/Lead Hydrologic Technician to ensure that all continuous water-quality data are collected to meet the needs of the cooperators and processed according to USGS standards and procedures.
3. Reviewing and revising the Kansas Water-Quality Monitoring QA Plan.
4. Ensuring that employees receive the necessary training for safe and proper data collection and water-quality monitoring-record processing.
5. Working with the Chief of the Hydrologic Data Management Section to release water-quality monitoring data for Kansas, and more importantly, ensuring that unit values are worked and maintained in the National Water Information System (NWIS) Web site.
6. Ensuring that KSWSC water-quality personnel are following safety policies regarding traffic control, PFDs, laboratory use, boat operation, and other related procedures.

Transition to Electronic Data Management

The KSWSC began transitioning to electronic data management of all hydrologic data and records on October 2013, corresponding with the beginning of the Federal fiscal and water year 2014. Before that, data were stored in either paper or electronic format. The ultimate goal is to move to a “paperless” system where all data are collected electronically and stored in digital format. When additional practical data-storage capabilities are available in national databases and applications, the KSWSC will use those resources for appropriate data storage and archiving (Putnam and Hansen, 2014).

Various computer directories where water-quality monitoring information may be stored are mentioned throughout this report. As the transition to complete electronic data management progresses, these locations may change as the process is developed more fully.

Collection of Continuous Water-Quality Monitoring Data

Public water-supply use, industry, agriculture, energy production, waste disposal, and recreation are closely linked to streamflow and water availability. Land use in Kansas is dominated by agriculture, which includes production of livestock (confined feeding and free roaming) and crops (wheat, corn, grain sorghum, and soybeans). Agricultural chemicals applied include fertilizers (phosphorus, nitrogen, and ammonia), pesticides and herbicides (such as atrazine, alachlor, glyphosate, and picloram). Agricultural chemicals, bacteria, and other contaminants adhere to sediment particles, can be carried by runoff into streams and lakes and may have detrimental effects on aquatic ecosystems, wildlife, fish, waterfowl, recreational use, and treatment of water for public consumption.

Nutrient enrichment can cause increased algal growth in streams and reservoirs. Algal blooms may cause taste-and-odor or toxicity problems for water suppliers and consumers. Nutrient enrichment also can adversely affect food sources and reproduction in fish and waterfowl. Therefore, reliable continuous water-quality data are necessary for planning and resource management.

Collection of continuous water-quality data is a major component of KSWSC water-resource studies. A common practice for quantifying chemical concentrations in water is to collect discrete samples and do laboratory analysis. However, these methods leave temporal gaps in data between samples. Fluctuations in water-quality occur hourly, daily, seasonally, and with changes in the environment. Physical, chemical, and biological properties such as specific conductance (SC), pH, water temperature, dissolved oxygen (DO), turbidity, nitrate, oxidation-reduction potential (ORP), solar irradiance, and fluorescence (chlorophyll and phycocyanin) are commonly measured continuously and in real time.

Continuous (measurements taken every 5 to 60 minutes) in-situ water-quality monitors have been installed at several sites in Kansas (*http://waterdata.usgs.gov/ks/nwis/current?type=qw*; *http://nrtwq.usgs.gov/ks/*) to quantify water-quality conditions at a temporal resolution that cannot be achieved through discrete sample collection. Water-quality measurements can be used in conjunction with discrete water-quality sampling to characterize the dynamic physical and biological conditions of a body of water.

The primary objective of operating a continuous in-situ water-quality monitor is to obtain a continuous record of SC, pH, water temperature, DO, turbidity, nitrate, ORP, solar irradiance, fluorescence (chlorophyll and phycocyanin), or other physical, chemical, and biological properties. Continuous data can be used to develop statistical relations between discrete samples and sensor data, making it possible to compute estimated concentrations and loads for additional water-quality constituents. These data can be transmitted in near-real time when the water-quality monitor is connected to a data collection platform (DCP, fig. 1). Continuous real-time water-quality data can help identify temporal changes in selected water-quality constituents, thereby enhancing the existing streamflow-gaging or groundwater network and potentially providing an alert system (for example, increased sediment concentrations or unsafe levels of fecal bacteria or blue-green algae) for regulators, water users, and the public. The real-time water-quality monitoring network also is used to optimize sample collection over a range of physical conditions. Without continuous water-quality monitors located in streams, reservoirs, or wells, incorrect conclusions may be made about relations among stage, streamflow, groundwater elevation data, physical, chemical, or biological water properties and processes.

Figure 1. Continuous water-quality monitoring station installed with data-collection platform for real-time data transmissions located at Cheney Reservoir near Cheney, Kansas.

Water-quality sensors that are used to measure the physical, chemical, and biological properties require careful inspection, maintenance, and calibration procedures. This QA plan, along with the water-quality monitor user’s manual, publications for water-quality monitoring, such as Wagner and others (2006), and the USGS NFM (Wilde, variously dated), provide protocols and guidelines for those procedures. The protocols described in this plan apply to water-quality monitors deployed directly in streams, reservoirs, and wells used to collect continuous data for any length of time, and to field monitors used to verify measurements from the continuous in-situ monitor, to collect stream cross-section surveys or depth profiles associated with continuous water-quality monitoring, and to collect discrete measurements associated with discrete water-quality samples. All personnel involved in continuous water-quality monitoring activities follow the protocols established in this plan.

Site Selection

Selection of the deployment location for a continuous water-quality monitoring station is related to data-collection objectives. The ideal location for a water-quality monitor is often at a site with an existing streamgage where an infrastructure for surface-water or groundwater data collection is already in place. Site-selection considerations for a water-quality monitoring station are listed in Wagner and others (2006). These considerations include, but are not limited to: the ability to install the continuous water-quality monitor so that measurements are representative of the location being monitored; the degree of cross-sectional and verticial variability; feasibility of water-quality data collection over the range of stage conditions; means for efficient and safe access to the site; ability to safely access and service equipment under all weather and flow conditions; and the ability to protect instrumentation from high stream velocities, floating debris, and vandalism.

Equipment Installation

Proper equipment installation is critical for obtaining reliable data. Each water-quality monitoring station generally has unique conditions that dictate installation plans. For example, a reservoir or well installation requires different considerations from a stream water-quality monitor installation. Factors such as water environment (streams, reservoir, groundwater), placement, site accessibility, and safety vary at each water-quality monitoring station. When first installing a water-quality monitor at a site, it is prudent to install equipment such as brackets, a temporary water-quality monitor, monitor field cable, and communication wires that can be moved efficiently while evaluating the range of conditions before deciding on a final installation. Equipment that is permanently fixed to bridge railings or other fixtures may be difficult and costly to move if conditions at the site change substantially. It is the responsibility of the Supervisory/Lead Hydrologic Technician and the

Project Chief to inspect water-quality monitoring stations to ensure that installations promote the collection of reliable data, that equipment has not fallen into disrepair, and that employees are not exposed to unnecessary safety concerns.

Site Documentation

Thorough documentation of qualitative and quantitative information describing each water-quality monitoring station is required. Documentation includes a station description, a job hazard analysis, and photographs. Documentation provides a permanent record of site characteristics, structures, equipment, instrumentation, altitudes, location, safety considerations, and changes in conditions at the site.

Station Descriptions

A station description is prepared for each streamgage, reservoir, and groundwater station in the KSWSC and becomes part of the permanent record for each site. If a water-quality monitor is installed at an active streamgage, the same station description is to be used for both elements. The station description includes the water-quality monitor installation location and a historical record of ongoing water-quality activities at the station. Station descriptions are written and updated by station data collection personnel. Station descriptions are reviewed annually by the Supervisory/Lead Hydrologic Technician, or Project Chief; updates are made when appropriate.

Currently (2014), KSWSC station descriptions are available to KSWSC personnel on the Site Information Management System (SIMS). Cooperators may obtain a hard copy of the station description upon request from the KSWSC database administrator (appendix 1). Additional information that cannot be stored in SIMS such as maps and sketches are scanned and stored in KSWSC internal station-specific folders.

Job Hazard Analysis

Job hazard analyses (JHAs) provide additional safety guidelines to prevent unnecessary exposure to job-related hazards. Every streamgage, reservoir, well, and water-quality monitoring station is required to have a current JHA as part of the permanent record for each site. JHAs are written and updated by station data collection personnel and reviewed annually by the Supervisory/Lead Hydrologic Technician, or Project Chief, and updates are made when appropriate (appendix 2). The KSWSC Safety Officer ensures that JHAs are prepared promptly and correctly. KSWSC JHAs may be accessed by KSWSC personnel in KSWSC internal station-specific safety folders.

Photographs

Photographs of gage houses, monitoring equipment, controls, reference marks, and debris piles are taken by field data collectors to document site operations, supplement written descriptions, and use in publications. Photographs include monitoring equipment location and are available for low-, medium-, and high-flow conditions. Cameras are available to data collectors to document changes over time at monitoring stations. Digital photographs are archived in KSWSC internal station-specific folders. Older paper photographs are archived in existing office files.

Flood Conditions

Flood conditions present problems that otherwise do not occur on a regular basis. These problems can include difficulties in gaining access to a water-quality monitoring station because roads and bridges are flooded, closed, or destroyed. Debris in the stream can damage equipment (fig. 2) and presents dangers to data collection personnel.

The USGS KSWSC maintains a communication plan (Kansas Water Science Center Plan of Operations During Floods) for flood events on the KSWSC internal home page located under the Hydrologic Information section so high-priority surface-water data associated with flood conditions are collected promptly and correctly. The flood plan describes responsibilities before, during, and after a flood; informational-reporting procedures; and field-activity priorities. The flood plan is a central reference for emergency communications, personnel telephone numbers, lists of available

Figure 2. Occurrence of the in-situ water-quality monitor and protective polyvinyl chloride pipe getting caught in floating debris during high flow on the Little Arkansas River near Sedgwick, Kansas.

equipment, and instructions for determining priority sites for measurement. The Kansas flood plan includes information for safe traffic control during bridge measurements, sampling activities, and instrument maintenance. The USGS National Flood Plan is available at *http://water.usgs.gov/floods/usgs/FloodPlans.html* and serves as a companion document to the KSWSC flood plan.

The Kansas flood plan addresses streamgaging issues but does not specifically address water-quality monitoring plans during flood conditions. The Supervisory/Lead Hydrologic Technician, Project Chief, or Chief of Hydrologic Investigations/Data Section coordinates water-quality monitoring activities during flood conditions and communicates plans to field personnel. The Kansas flood plan is used in conjunction with project objectives and staff availability to establish project-specific plans for water-quality monitoring activities during flood conditions. The Flood Coordinator, Field Office Flood Coordinator, Supervisory/Lead Hydrologic Technician, and Project Chiefs work together to balance priorities for field personnel with responsibilities that include streamgaging and water-quality monitoring.

Kansas Water Science Center personnel take all practical actions to ensure that all streamflow- and monitoring-station equipment remains in operation during flood events. This includes water-quality monitors, unless damage to the instrument is imminent, making removal necessary. Several continuous water-quality monitors operated by the KSWSC are suspended from bridges to hang at a location in the stream that is best suited for low-flow conditions. Water-quality monitors can be relocated on the bridge to reduce the risk of damage (generally on the downstream side of a pier) allowing for continuous data collection during high-flow conditions. The water-quality monitor can be relocated to its original position after water levels have receded. Because many cooperators make daily decisions on water-management issues using real-time data, it is a high priority for water-quality monitors to remain operational during all streamflow conditions wherever possible. It is the responsibility of the Supervisory/Lead Hydrologic Technician, or designated person to ensure spare equipment is available when repairs are needed.

Low-Flow Conditions

Streamflow conditions during periods of low flow typically differ from those periods of medium and high flow. Low flows often are associated with factors that affect the sensors in the stream. These factors include algal growth (fig. 3), larvae and debris accumulation, and insufficient stream depth to keep sensors under water. Water-quality monitor relocation may be necessary to improve performance during low-flow conditions. If streamflow or stream depths are substantially reduced, data reliability decreases, and the water-quality monitor may need to be removed from the stream until sufficient streamflow returns.

Figure 3. Occurrence of excessive algal growth at Cheney Reservoir near Cheney, Kansas, July 2007.

Field data collectors, the Supervisory/Lead Hydrologic Technician, and Project Chiefs are responsible for ensuring that appropriate equipment and procedures are used during low-flow periods. Field notes are to be reviewed by the Supervisory/Lead Hydrologic Technician, or Project Chief immediately following each field trip to verify that appropriate procedures were used for low-flow data-collection activities.

Data recorded from the continuous in-situ water-quality monitor or field monitor while servicing the monitoring station may not be reliable when assessing fouling corrections during extreme low-flow conditions. If sediment near the streambottom is disturbed, it may take several hours for the silts and clays to settle. Several data points recorded after servicing the water-quality monitor may need to be deleted. In these instances, to determine whether data points are deleted, the time-series data can be assessed in the NWIS database by comparing data recorded before servicing the water-quality monitor to data recorded after servicing the water-quality monitor.

Zero-Flow Conditions

During periods of zero flow when the stream is dry and the in-situ water-quality monitor or sensors are not in water or when the in-situ water-quality monitor is situated in a pool of stagnant water, the water-quality monitor is removed from the site. Some sensors on the water-quality monitor, such as the pH and DO sensors, will be damaged irreparably when the sensors are out of water. The optical window of optical sensors, such as the turbidity sensor, may become scratched after dust, dirt, sand, or dried mud accumulates on the optical window while the monitor is still programmed to wipe the optical window before every measurement.

Data recorded from the continuous in-situ water-quality monitor while the water-quality monitor sits in a pool of stagnant water are not reliable. Additionally, algae growth and larvae will accumulate more quickly while the sensors are wet. If the sensors eventually go out of water, the algae will dry on the sensors. When the sensors go back into water, the excessive algae accumulation on the sensors will prevent reliable readings from the water-quality monitor until the monitor and sensors are cleaned. Data collected from the water-quality monitor while the monitor is located at a site during zero-flow conditions are deleted from the database, and readings are blocked from the NWIS Web site.

Cold-Weather Conditions

Water-quality activities in Kansas include collecting water-quality samples during cold-weather conditions. Cold temperatures, wind, snow, and ice can create data collection difficulties. These factors also can create dangers to data collectors. Employee safety is the highest priority in collecting streamflow and water-quality data during winter periods.

Safety is extremely important during discrete water-quality sample collections and using water-quality monitors to measure water parameters under icy conditions. Multiple data collectors are used on the larger rivers, such as the Kansas River. Questions concerning how to safely make discharge measurements, collect water-quality samples, or access water-quality monitors during icy conditions are discussed with the KSWSC Safety Officer prior to visiting the site. All data collectors should refer to the site JHA before servicing the water-quality monitor if unfamiliar with the site.

Water temperatures are monitored daily. When water temperatures are approaching zero and air temperatures are expected to remain near freezing for a long period of time, the in-situ water-quality monitor is removed before ice becomes too thick around the water-quality monitor and protective polyvinyl chloride unless the installation was designed to withstand icy conditions. Water-quality monitors and field cables trapped in thick or floating ice (fig. 4) may be damaged. The Supervisory/Lead Hydrologic Technician, or Project Chief determines removal of the water-quality monitor during ice conditions and re-installation after the ice has thawed. In some cases, anchoring a water-quality monitor in a deep pool set to self-log can be a technique used to maintain winter water-quality record. This method has been used successfully, but requires careful consideration of site characteristics, project needs, and risk to the water-quality monitor. When water-quality monitors become trapped in or below ice, removal attempts are carefully considered because of potential dangers to personnel.

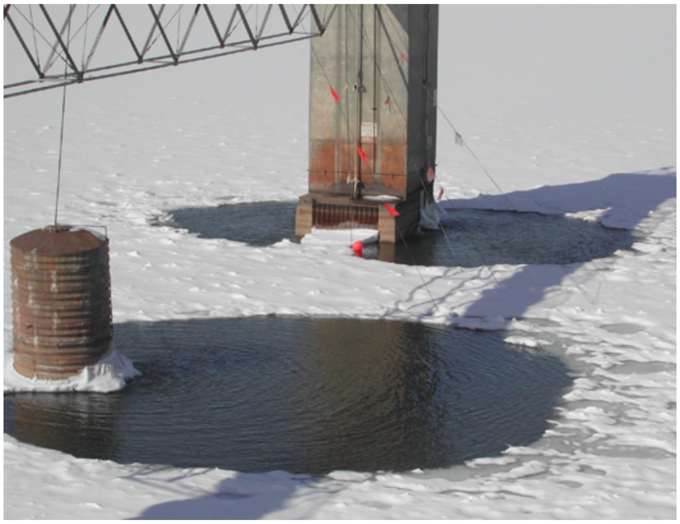


Figure 4. Occurrence of four continuous in-situ water-quality monitors (with flagging on the field cables) trapped below ice at Cheney Reservoir near Cheney, Kansas, January 2007.

Groundwater Monitoring

The KSWSC currently (2014) has continuous in-situ water-quality monitors installed in several wells. The biggest advantage of groundwater monitoring over stream monitoring is the ability to measure year-round without concerns of floating debris or ice, and the reduction of bio-fouling. It is recommended that a well installed with a continuous water-quality monitor be routinely purged at least once a year. Purging helps keep the well screen clear of sediment accumulation and chemical fouling, such as iron or sulfate build-up. While the well is being purged, the in-situ water-quality monitor is removed from the well and placed in a protected location. The water-quality sensors also are protected from damage or from drying out by installing a protective calibration cup filled with tap water over the sensors. During continuous operations, the water-quality monitor is located in the well screen for reliable operation. Protocols are still being developed to ensure that in-situ water quality monitors in wells are measuring groundwater quality. Before and after pumping measurements are part of the documentation that are used to document that the water-quality monitor is measuring groundwater quality and not well water quality of stagnant water.

Standard water-quality monitors used by many USGS science centers are not rated for water depths greater than 66 meters because the pressure from extreme water depths may damage equipment. Newer water-quality monitors are available and are more durable and reliable in water depths beyond 66 meters, for example the Xylem EXO1. Water-quality monitors installed in the KSWSC wells are to be placed at depths that do not exceed the manufacturer's recommendations.

Submersible pressure transducers used in the KSWSC wells include a water temperature thermistor that provides temperature correction data to the pressure transducer. In the KSWSC, these temperature data are used as ancillary information for internal use only. Additional details related to these data are described by Putnam and Hansen (2014).

Water-Quality Monitoring Instruments

The KSWSC currently (2014) maintains several multiparameter water-quality monitors, all of which were manufactured by YSI or Xylem. Models include YSI 6600s (EDS and V2) and Xylem EXO2s, which generally are used with multiple sensors for stream and reservoir deployments, and YSI 600s (XL, XLM–V2) and Xylem EXO1s, which are smaller and regularly used for well deployments. The five most commonly used water-quality sensors are specific conductance, pH, water temperature, dissolved oxygen, and turbidity. Of these five sensors, turbidity and optical dissolved oxygen are described in more detail in a later section because improved sensor technologies have necessitated changes in operation procedures. In addition, other sensors operated by the KSWSC including fluorescence, sunlight, nitrate, colored dissolved organic matter (CDOM), and oxidation-reduction potential sensors also are discussed in a later section.

Instruments used on water-quality projects in Kansas (fig. 5) are selected on the basis of the specifications described in the USGS NFM (Wilde, variously dated) and the project requirements. The USGS Hydrologic Instrumentation Facility (HIF) at the Stennis Space Center in Mississippi provides analyses and tests of precision and bias for some water-quality instruments and provides equipment consultations upon request; nevertheless, all water-quality monitors used by the KSWSC are tested by KSWSC personnel before deployment at a monitoring station.

Figure 5. Water-quality monitor equipped with fluorescence chlorophyll , conductivity and temperature, turbidity, luminescent dissolved oxygen, and pH and oxidation-reduction potential sensors.

All water-quality instruments are properly tested, calibrated, operated, maintained, and stored. The manufacturer’s operating guidelines are carefully followed for correct operation of equipment. Backup water-quality monitors and sensors are to be readily available and in good working condition to avoid loss of data because of instrumentation malfunction.

It is critical to maintain a system that documents calibrations and maintenance of water-quality monitor records. It has become a high priority for the KSWSC to maintain all records electronically. CHIMP is used by KSWSC personnel to document water-quality monitoring activities in the field and in the laboratory. Calibration and maintenance records for water-quality monitoring equipment, including the manufacturer, make, model, and serial number, are kept in KSWSC internal monitor-specific folders. CHIMP creates electronic files for site inspections of water-quality monitors and for calibration of field monitors. Information required in calibration and maintenance records includes the date, initials of the data collector, results of calibration or equipment check, and any other actions taken (such as monitor repairs, monitor changes, or sensor changes). CHIMP files created to document site activities are imported into the Site Visit database and also are archived in KSWSC internal station-specific folders in the permanent electronic file directory. CHIMP files created to document calibration for field monitors also are archived in KSWSC internal monitor-specific folders in the permanent electronic file directory. Calibration and maintenance records are checked for completeness and accuracy.

Under rare circumstances when CHIMP is not used (for example, when the electronic tablet or other device is not working), a paper form or a spreadsheet program may be used to document calibration for field monitors. The paper form will be digitally scanned and archived in station-specific or monitor-specific folders. The spreadsheet will maintain separate “tabs” for each field monitor and also be archived in station-specific or monitor-specific folders.

Methods and Frequency for Servicing Continuous Water-Quality Monitors

Algae, larvae, and sediment often accumulate on water-quality monitors in surface-water environments (fig. 6). Iron, hydrogen sulfate, or other chemical buildup also can collect on water-quality monitors in groundwater environments. Cleaning trips are scheduled when algal growth, larval accumulation, or sediment deposition diminish the accuracy of transmitted data. Excessive accumulation is generally most noticeable on SC, turbidity, chlorophyll, and phycocyanin sensors. For example, a gradual decline or a dramatic drop in SC values with no runoff event may indicate fouling in the SC port. Data spikes or erratic data may indicate excessive fouling on the turbidity, fluorescence chlorophyll (fig. 7), or phycocyanin sensors. Nonroutine visits may be necessary after storm runoff to remove debris and sediment buildup on the sensors. Every 3 months during a cleaning trip, calibration checks are performed on all

Figure 6. Water-quality monitor with algal fouling accumulated during long-term deployment.

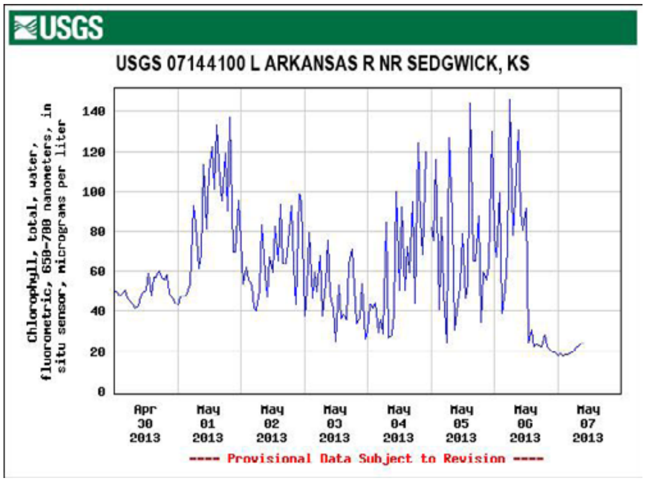


Figure 7. National Water Information System Web page showing continuous fluorescence chlorophyll data collected by a water-quality monitor displaying effects of excessive sediment and algae buildup.

of the sensors on the continuous in-situ water-quality monitor. However, calibration checks may be performed at any time during cleaning trips if continuous in-situ sensor readings are significantly different from the field monitor.

The data collector in consultation with the Supervisory/Lead Hydrologic Technician, Project Chief, or designated person is responsible for scheduling site visits at an appropriate frequency and also for daily review of all real-time data to identify erroneous data or operational problems. The data collector servicing the water-quality monitoring station is responsible for corrective field actions. Failure to monitor data, service equipment, or allowing equipment to fall into disrepair results in unreliable data. Routine inspections of monitoring stations and equipment are made by the Supervisory/Lead Hydrologic Technician, or Project Chief. Deficiencies are communicated to the data collector.

If it is not possible to rectify a monitoring station that is transmitting erroneous data within 48 hours, the data are temporarily blocked from the NWIS Web site using appropriate NWIS Web site commands. The water-quality monitor should be back in service within 5 calendar days of when the problem was first reported.

Maintenance and Calibration of Continuous Water-Quality Monitors

Routine water-quality monitor maintenance activities include cleaning and inspecting the continuous in-situ water-quality sensors, verifying sensor performance by checking sensor readings against known standards, recalibrating the sensor if sensor readings exceed acceptance criteria (table 1), and corroborating data from the continuous in-situ water-quality monitor against a calibrated field monitor (appendix 3).

Water-quality sensor inspection and comparison against known standards are performed in the field every 3 months during a cleaning visit. More frequent checks are made for new or problematic equipment. Failure of the sensor to check within the acceptance criteria in table 1 against known standards can be an indication of calibration drift, water-quality monitor or sensor malfunction, mislabeled standards, or contaminated standards. Water-quality sensors are recalibrated only when it is determined that the sensor is out of calibration beyond calibration criteria in table 1 and no other factors are affecting calibration check readings. This determination may need to be made with multiple standards checks to ensure the performance of the water-quality monitor sensor. If sensors are recalibrated because of sensor malfunction, mislabeled standards, or contaminated standards, recalibration of the water-quality sensor will result in poor water-quality records as well as a return trip to the monitoring site to correct the problem. The data collector is responsible for following correct sensor calibration protocols and documenting any problems encountered during the procedures. If there are concerns about the performance of the water-quality sensor or the quality of the calibration check, the sensor is not recalibrated.

Environmental and site factors also are assessed for their potential impact on sensor calibration. If calibration checks or sensor recalibrations cannot be effectively completed onsite, an alternative location should be selected. For example, sensor calibration checks or sensor recalibrations performed during windy days could result in inaccurate readings. It would be better to perform sensor calibration checks in an enclosed vehicle, under the bridge where it might not be windy, or on another day.

An alternative to field calibration checks is to routinely exchange (swap) the continuous in-situ water-quality monitor with a water-quality monitor that has been calibrated in the office laboratory. For some projects, this method is preferred over field calibrations, especially when optical sensors such as the turbidity sensor can be adversely affected by sunlight during field calibrations. When a water-quality monitor exchange

Table 1. Summary of calibration criteria for water-quality monitors used to measure selected physical properties in the Kansas Water Science Center.

[NIST, National Institute of Standards and Technology; ±, plus or minus; ºC, degrees Celsius; ≥, greater than or equal; SC, specific conductance; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ≤, less than or equal; DO, dissolved oxygen; mg/L, milligrams per liter; FNU, formazin nephelometric units; NWQL, National Water Quality Laboratory; ORP, oxidation-reduction potential]

Physical property	Calibration method used	Acceptance criteria	Calibration frequency and location	Reference for calibration and use	Sample analyzed at laboratory
Temperature	NIST-certified or traceable thermometer	Within ± 0.2 ºC	5-point annual check in the office. 2-point quarterly check in the field	Wilde, 2006; See manufacturer's instructions	No.
Specific conductance	1-point calibration with known standard ≥ 1000 µS and 1-point check that brackets the expected values of the stream If needed, 1-midpoint check to verify the linearity of the sensor	Calibration point within ± 3 percent of the expected standard value, in µS/cm	Every 3 months in the field and after replacement of the temperature/conductivity sensor	Radtke and others, 2005; See manufacturer's instructions	Yes, at least 6 times per year.
	Air SC check	Air SC check ≤ 5 µS/cm			
pH	2-point calibration, bracketing the expected values of the stream	Within ± 0.2 pH units of the expected temperature compensated value of the buffers	Every 3 months in the field and after replacement of the pH or temperature sensor	Ritz and Collins, 2008; See manufacturer's instructions	Yes, at least 6 times per year.
Dissolved oxygen (optical)	1-point air saturated water or water saturated air calibration in conjunction with temperature and barometric pressure	Within ± 0.3 mg/L or 5 percent of the expected DO milligrams per liter value	Every 3 months in the field and after replacement of the DO membrane cap, DO sensor or temperature sensor	Rounds and others, 2013; See manufacturer's instructions	No.
	Zero DO check.	Zero DO ≤ 0.2 mg/L within 5–10 minutes			
Turbidity	2-point calibration (sensor specific values). Use YSI polymer standards or Hach Stablcal standards	0 point within ± 0.5 FNUs using turbidity-free deionized water and (or) ± 5 percent of expected value of the standard value	Every 3 months and after replacement of the sensor	Anderson, 2005; See manufacturer's instructions	Yes, at least 6 times per year with multiple analysis to cooperator laboratory and NWQL.
Fluorescence (chlorophyll or phycocyanin)	2-point calibration. See manufacturer's instructions	0 point within ± 0.5 units using turbidity-free deionized water and (or) ± 5 percent of expected value of the standard value	Every 3 months and after replacement of the sensor or temperature sensor	See manufacturer's instructions	Yes, Determined by project's objectives.
Color dissolved organic matter	2-point calibration. See manufacturer's instructions	0 point within ± 0.5 units using organic blank water and (or) ± 5 percent of expected value of the standard value	Every 3 months and after replacement of the sensor or temperature sensor	See manufacturer's instructions	Determined by project's objectives.
Nitrate	2-point calibration. See manufacturer's instructions	0 point within ± 0.3 mg/L using inorganic blank water and (or) ± 5 percent of expected value of the standard value	Every 3 months	See manufacturer's instructions	Yes, at least 6 times per year with multiple analysis to cooperator laboratory and NWQL.
Oxidation-reduction potential	1-point calibration. See manufacturer's instructions	Within ± 5 percent of temperature compensated standard value, in millivolts	Every 3 months and after replacement of the ORP sensor or temperature sensor	Nordstrom and Wilde, 2005; See manufacturer's instructions	No.
Barometric pressure	Mercury barometer	Within 1 millimeter of mercury of local station pressure at National Weather Service	Quarterly in the office	Rounds and others, 2013; See manufacturer's instructions	No.

is performed at the monitoring station, cleaning protocols are to be followed onsite by collecting "before cleaning" and "after cleaning" readings from both the in-situ monitor and the field monitor. After the water-quality monitor exchange, "final readings" are again recorded from the "new" in-situ water-quality monitor and the field monitor before leaving the monitoring station.

Calibration checks on water-quality sensors and sensor recalibrations for any continuous water-quality monitor being installed or exchanged at a water-quality monitoring station are performed within 1 day prior to installing or exchanging a water-quality monitor and are documented in CHIMP or a spreadsheet program. After the "old" (swapped) in-situ water-quality monitor is brought back to the office laboratory, calibration checks are performed within 1 day to determine sensor calibration drift and also are documented in CHIMP or a spreadsheet program.

Cleaning or calibration steps can be avoided in a few instances: (1) the continuous in-situ water-quality monitor or sensor has malfunctioned and sensor readings cannot be obtained, and (2) the continuous in-situ water-quality monitor is being removed for the winter and the stream or lake is iced over. Reinstalling the water-quality monitor into the stream under icy conditions may damage the water-quality monitor or the sensors. Although the ice scenario may prevent cleaning protocols from being followed, it does not preclude sensor calibration checks from being performed at the office laboratory. Under most conditions when the continuous in-situ water-quality monitor is working, standard cleaning and calibration protocols are to followed.

Protocols for maintenance and calibration of water-quality monitors used in wells have been modified from protocols used for water-quality monitors in surface-water environments. Well water is disturbed during monitor removal. For that reason, "after cleaning" readings cannot be done with reasonable accuracy, and a field monitor cannot be installed in the well to obtain accurate field readings. Initial readings are obtained before removing the water-quality monitor from the well. After cleaning the water-quality monitor, sensor calibration checks and recalibration are performed. Final readings are obtained after reinstalling the water-quality monitor in the well to ensure that the water-quality monitor is still working.

Currently (2014), new water-quality monitors manufactured by Xylem, the EXO models, have been deployed at some Kansas water-quality monitoring stations. The EXO water-quality monitor features "smart sensor" technology that allows an individual EXO sensor to store calibration data (YSI, 2012). Once a calibration is performed on a smart sensor, the sensor can be detached from the EXO water-quality monitor on which it was calibrated and placed on another EXO water-quality monitor without loss of calibration. Until the EXO sensor is ready to use, the sensor is tagged with the serial number of the sensor, date of calibration or calibration check, and results of the calibration. If an EXO sensor is recalibrated, a calibration file is created on the computer that also includes the sensor's serial number and results of the calibration. These files can be printed out and attached to the tag.

Several smart sensors (conductivity, pH, DO, turbidity, chlorophyll fluorescence, and dissolved organic matter) have an internal reference temperature required for calibration. Calibration checks of the reference temperature for individual sensors are verified periodically as described in table 1. If enough spare sensors are available, sensor "exchange" instead of field calibrations can be performed similar to the water-quality monitor exchanges described earlier in this section. This also has the potential to save on calibration standards, as several sensors of the same model can be calibrated simultaneously. As more experience is gained in the KSWSC in deploying EXO water-quality monitors and smart sensors, more specific guidance will be added to the QA plan. Until such guidance is available, Project Chiefs in coordination with the Water Quality Specialist and Supervisory/Lead Hydrologic Technician set specific calibration policy for EXOs as needed.

Types of Water-Quality Sensors

The KSWSC currently (2014) is using several different types of sensors for measuring physical, chemical, and biological properties of streams, reservoirs, or groundwater. Sensors are used to measure SC, pH, water temperature, DO, turbidity, fluorescence (chlorophyll and phycocyanin), solar irradiance, nitrate, CDOM, or ORP. The five most commonly used sensors are specific conductance, pH, water temperature, dissolved oxygen, and turbidity. Of these five sensors, only turbidity and optical DO are described in more detail in this section because improved sensor technologies have necessitated changes in operation procedures. Details related to the other three common sensors can be found in appendix 3 and are described by Wagner and others (2006), chapter 6 of the USGS NFM (Wilde, variously dated), and manufacturer recommendations.

Turbidity Sensors

Turbidity measurements from different instruments are not equivalent because of differences in instrument design. For example, a 100-formazin nephelometric unit (FNU) reading obtained from one turbidity sensor does not necessarily correspond to a 100-FNU reading made by a turbidity sensor from a different manufacturer or even a different sensor model made by the same manufacturer (Anderson, 2005). Thus, it is important to use the same instrument with the same standards throughout the lifetime of a project or to the extent possible. Two different types of turbidity sensors used to measure turbidity are described in this section.

YSI Model 6136

The most common turbidity sensors used by the KSWSC measure turbidity ranging from 0 to 1,000 FNUs according to manufacturer's specifications. Some sensors exceed the manufacturer's specifications and measure higher values. Nevertheless, most sensors have maximum reporting limitations and may truncate in highly turbid waters.

Sensor calibration is checked using deionized (DI) water for the 0 FNU standard and known standards such as 100 FNU and 1,000 FNU. If determined to be necessary, a 2-point or 3-point calibration is made. Sensors used where turbidity is likely to exceed 1,000 FNU are checked and calibrated using standards of higher turbidity. There are many turbidity standards available to calibrate turbidity sensors. Inorganic blank water (IBW) from USGS One Stop Shopping (item number Q378FLD) can be used for calibration of the zero-point standard if the water science center does not have the capabilities to make DI water. Stabilized formazin (such as StablCal) and styrene divinylbenzene polymer standards (such as Amco AEPA–1) are acceptable turbidity calibration standards (Wagner and others, 2006). Because turbidity standards are physically different, turbidity sensors calibrated with formazin will not measure the same value using an Amco AEPA-1 standard. The same turbidity standard should be used throughout a project instead of alternating between formazin and Amco AEPA–1 standards. Turbidity standards are well mixed before each use by gently inverting the solution several times because particles in solution settle out; standards should not be vigororously shaken as this will entrain bubbles in the standard. The Supervisory/Lead Hydrologic Technician, Project Chief, or Water-Quality Specialist evaluates which standards give the most consistent readings and are most appropriate for the sensor being used.

Deionized water used as the zero-point standard should be turbidity-free (such as IBW) or filtered through a 0.2-micron filter to eliminate all particles that may cause poor calibration checks or calibration errors. Air bubbles also can cause poor calibration checks. If air bubbles are a common occurrence in the DI water, the water should be collected the day before it is needed, so air bubbles are degassed.

When a different type of sensor must be used to replace an existing sensor it is important to deploy both sensors side-by-side for a period of time over a wide range of conditions from low flow to high flow, cold weather to hot weather, and clear water to highly turbid waters to quantify differences in measurements. For example, when the outdated YSI model 6026 turbidity sensors were replaced with YSI model 6136 turbidity sensors, data from the two sensors were collected concurrently at the same location to develop a quantifiable relation as illustrated in figures 8 and 9. This relation allows measurements before the sensor change to be compared to those made after the change.

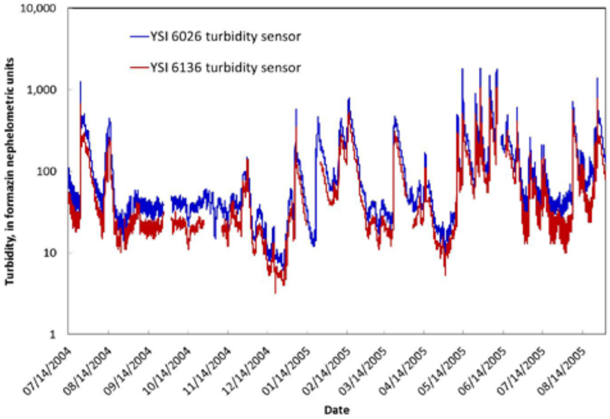


Figure 8. Comparison of continuous in-situ turbidity data collected from YSI model 6026 and YSI model 6136 turbidity sensors located at Little Arkansas River near Sedgwick, Kansas, July 2004–August 2005.

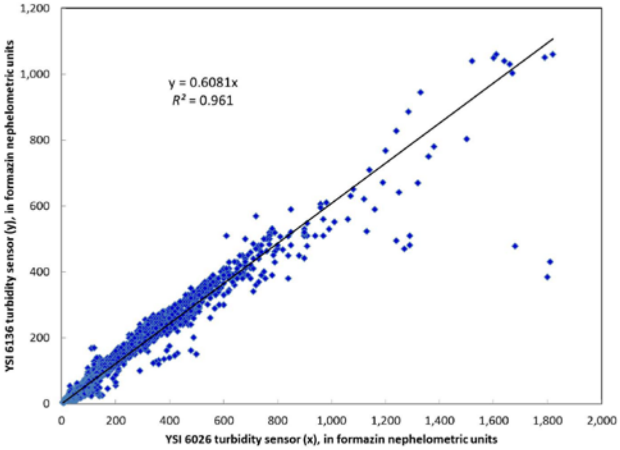


Figure 9. Relation between concurrent turbidity measurements using YSI model 6026 and YSI model 6136 turbidity sensors located at Little Arkansas River near Sedgwick, Kansas, July 2004–August 2005.

Hach Solitax Turbidity Sensor

A Hach Solitax sensor (fig. 10) is capable of recording turbidity values up to 4,000 formazin backscatter units (FBU) in the turbidity operating mode or 50,000 milligrams per liter (mg/L) in the total solids (TS) operating mode according to manufacturer's specifications. The Hach Solitax sensor has a much larger optical window than other turbidity sensors (fig. 11). These sensors are being used by the KSWSC at several sites to measure sediment concentrations or to augment sediment information when other turbidity sensors have reached their maximum reporting limits. The Solitax sensor in the TS operating mode is still a turbidity sensor, but operates at different light wavelengths. Therefore, TS data are stored as turbidity in formazin backscatter ratio units instead of total solids in milligrams per liter.

Figure 10. Hach Solitax turbidity sensor.

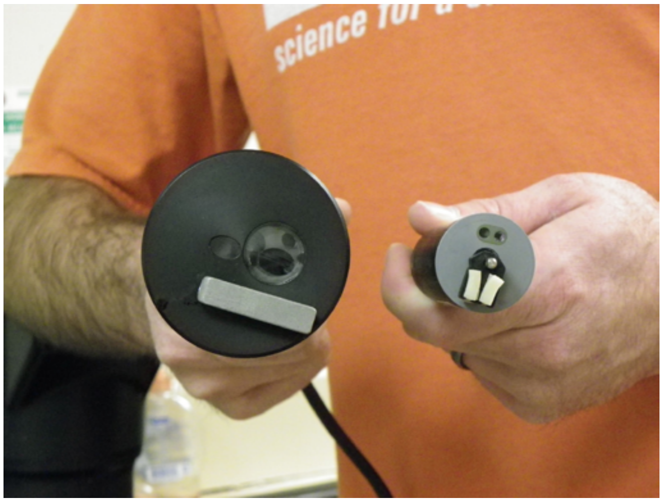


Figure 11. Comparison of optical windows of Hach Solitax (left) and YSI model 6136 (right) turbidity sensors.

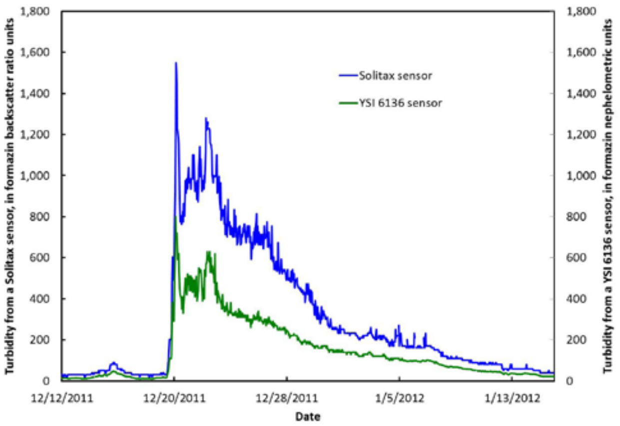


Figure 12. Comparison of continuous in-situ turbidity data collected from Hach Solitax (total solids operating mode) and YSI model 6136 turbidity sensors located at Little Arkansas River upstream from Aquifer Storage and Recovery Facility near Sedgwick, Kansas, December 2011–January 2012.

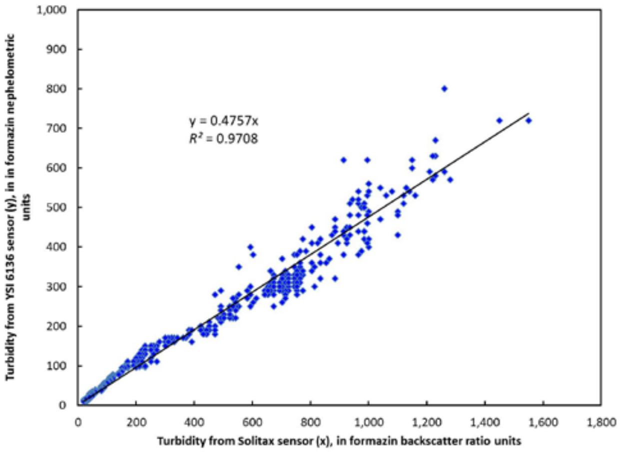


Figure 13. Relation between concurrent turbidity measurements collected from Hach Solitax (total solids operating mode) and YSI model 6136 turbidity sensors located at Little Arkansas River upstream from Aquifer Storage and Recovery Facility near Sedgwick, Kansas, December 2011–January 2012.

Figure 12 shows a hydrograph of concurrent turbidity data collected from a YSI model 6136 turbidity sensor and a Hach Solitax turbidity sensor in the TS operating mode. The R-squared (R^2) value of the relation between the two concurrent turbidity measurements is 0.97 (fig. 13). The Solitax data in TS operating mode can be used to augment sediment information when other turbidity sensors have reached their maximum reporting limits. Because of high purchase and operating costs associated with the Hach Solitax sensors, an evaluation of the frequency and duration of turbidity truncation at a water-quality monitoring station is prudent before deploying a Solitax sensor.

There are four major components of the Hach Solitax sensor: power supply, the controller, data output, and calibration. The controller is used to display readings from the sensor, log data, and set programming options and requires a 24-volt power supply instead of the standard 12 volts that most field equipment uses. The optimal power system is one 24-volt solar panel (or two 12-volt solar panels) and two 12-volt batteries wired for a 24-volt system. The less preferred method is to use one 12-volt solar panel and one 12-volt deep cycle battery with a 12- to 24-volt direct current (DC) boost converter. Keeping the battery fully charged for the Solitax sensor and controller for long periods of time during cloudy weather or colder periods can be difficult using the latter method. Battery swaps are routinely done in order to minimize the amount of lost data.

A sc100 or sc200 controller controls the operations of the Hach Solitax sensor and can be programmed for a variety of tasks. The most common tasks include programming the data output to turbidity or total solids, the controller's date and time, the logging interval, and the Solitax sensor's wiper interval, and entering calibration information for the Solitax sensor. While servicing the Hach Solitax sensor in the field, data collectors are to always check the controller's internal time against clock time and programmed settings to verify correct settings have not been accidentally changed or reset back to factory defaults because of power failure.

The Solitax sensor communicates with a DCP using a serial data interface (SDI) analog-to-digital interface. The sensor's analog output in milliamps is converted to a voltage reading by using the interface equipment. The voltage reading recorded by the DCP is then converted to original units by entering a slope adjustment in the DCP, and then transmitted in real time. A second method for Solitax data collection is to routinely download data logged in the controller instead of transmitting data in real time. This method eliminates analog errors caused by background electronic interference, which are recorded in voltage readings. The preferred method is to transmit Solitax data in real time and also routinely download logged data from the controller. As long as the controller's data and time have been correctly set, real-time data can be compared to logged data to determine if electronic noise is problematic.

Calibration verification of the Hach Solitax sensor is performed with the calibration kit provided by Hach for the Solitax sensor. Because data output in the TS operating mode is not analogous to known turbidity standard values, the purpose of the calibration check is solely to evaluate potential calibration drift. The sensor is checked using 0, 100, 1,000, and possibly 4,000 FNU standards at the beginning of deployment and during any subsequent calibration checks. Initial readings at the beginning of deployment from the Solitax in TS mode are documented in CHIMP. During future calibration checks, if TS readings drift more than 5 percent from the initial deployment readings, a drift correction can be prorated over time so that the original deployment calibration check value is maintained.

Fluorescence Sensors for Measuring Chlorophyll and Phycocyanin

The KSWSC has several water-quality monitors equipped with two types of fluorescence sensors: chlorophyll and phycocyanin (also called blue-green algae). Chlorophyll and phycocyanin are algal pigments used to gather light for photosynthesis. All algae have chlorophyll, but only cyanobacteria (blue-green algae) have phycocyanin. The chlorophyll sensor gives an indication of total algal abundance, and the phycocyanin sensor gives an indication of cyanobacterial abundance. Although phycocyanin does have strong fluorescent signatures, it does not interfere significantly with the fluorescence of chlorophyll. Most fluorescence sensors have a wiping mechanism that reduces biofouling. Chlorophyll is reported in micrograms per liter. Phycocyanin is reported in cells per milliliter.

The KSWSC uses a 2-point calibration method to calibrate fluorescence sensors. The first point is a 0 standard using turbidity-free DI water and the second point is standard made from rhodamine fluorescent tracer dye. Although the standards do not directly correlate to known concentrations of chlorophyll or blue-green algae, this method allows for the 0 point and the slope of the sensor to be set, and then calibration drift can be measured fairly accurately over time.

An alternative method for calibration is to compare fluorescence readings from the in-situ water-quality monitor against environmental samples analyzed in the laboratory for chlorophyll concentrations or cyanobacteria cell counts. However, there are several challenges associated with this approach. There is a lag time between when discrete samples are collected and when laboratory results are received, resulting in an inherent lag in the ability to correct a fluorescence record when calibrating fluorescence sensors with laboratory-measured samples. In addition, fluorescence by chlorophyll and phycocyanin is strongly affected by temperature and solar irradiance and may change by orders of magnitude over a 24-hour period; there may be large changes in fluorescence values without associated changes in fluorescence chlorophyll concentration (fig. 14) or blue-green cyanobacteria values depending on environmental conditions. Therefore, the KSWSC does not calibrate fluorescence sensors using laboratory-measured data from environmental samples.

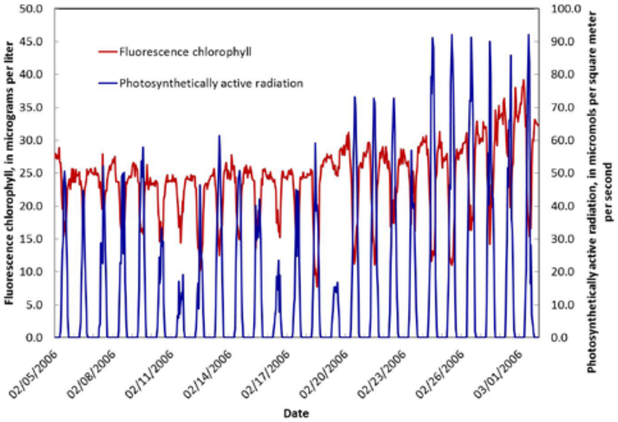


Figure 14. Comparison of continuous in-situ fluorescence chlorophyll and in-situ photosynthetically active radiation collected from two separate water-quality monitors located at Cheney Reservoir, Kansas, February 5–20, 2006.

Sensors for Measuring Sunlight

Additional sensors are being used for collecting sunlight data in conjunction with water-quality monitoring. Continuous light measurements lead to better understanding of photosynthesis, primary production, and other biological processes that may contribute to nutrient loading and algae blooms. The wavelength of the photosynthetically active radiation sensor manufactured by YSI is 400 to

700 nanometers and was attached to the in-situ water-quality monitor to measure solar light (fig. 15). Other instruments used for recording ambient light data are the HOBO Data Logger and the LI–COR Quantum radiation sensor. Both sensors measure relative light intensity and are placed in suitable stream locations. Data from the HOBO sensor are routinely downloaded rather than being transmitted in real time, while data from the LI–COR sensor, used with a millivolt adapter connected to the DCP, are transmitted in real time. Sunlight instruments are used and maintained according to manufacturer's recommendations.

Figure 15. Hach Nitratax plus sc nitrate sensor.

Luminescent Dissolved Oxygen Sensors

All continuous in-situ water-quality monitors and most field monitors used in the KSWSC for collecting DO concentrations use luminescent or optical DO sensors. DO is reported in milligrams per liter and in percent saturation. A 1-point calibration is used to calibrate an optical DO sensor by using either the air-saturated water method or the water-saturated air method. To verify that the DO sensor can record readings near zero mg/L (commonly referred to as a zero-DO check), the DO sensor is completely submersed in a sodium sulfite solution. The DO sensor should read less than 0.2 mg/L within 5 minutes.

When a zero-DO check is performed in a sodium sulfite solution, wiper pads on all optical sensors (not just the pad for the optical DO sensor) are removed. The wiper pads absorb the sodium sulfite solution and slowly release the solution back into the water, thereby causing erroneously low DO readings. If the data collector is not aware of the potential problems that might incur when performing a zero-DO check with the sodium sulfite solution, calibration errors after sensor recalibration will result in erroneous readings. This was demonstrated by an in-house experiment in the Wichita, Kans., field office when the optical DO sensor was checked in a sodium sulfite solution. For several hours, the water-quality monitor was allowed to sit in a bucket of water using an air stone to saturate the water. After the air-saturated measurement was recorded, the optical DO sensor was then checked in the sodium sulfite solution. The optical DO sensor measured less than 0.2 mg/L within 5 minutes. After the measurement was recorded again, the water-quality monitor was then rinsed 2 minutes under running tap water to remove the sodium sulfite residue and then returned to the bucket of water using an air stone to saturate the water. It took approximately 45 minutes for measured DO values from the optical DO sensor to return to values recorded before the zero-DO check.

Optical DO sensors have a membrane assembly that needs to be replaced yearly. Changes in the construction of optical DO sensors or the membrane assembly have been made by many manufacturers. In particular, YSI, Inc. has made at least two changes to the optical DO membrane assembly since their first optical DO sensor was manufactured. As a result, a new temperature coefficient needs to be reprogrammed in the water-quality monitor. An incorrect temperature coefficient will result in DO concentrations not being reported correctly. The changing of the membrane assembly and new temperature coefficient is documented in CHIMP or the spreadsheet program as maintenance.

More discussion on how luminescent DO sensors work is available from manufacturers. Additional information and other comparisons also were done by the Oregon Water Science Center (Johnston and Williams, 2006).

Nitrate Sensors

The KSWSC is currently (2014) using Hach Nitratax *plus* sc nitrate sensors (fig. 15) to measure nitrate concentrations at several water-quality monitoring stations. The sensors generally are operated and maintained as described by Pellerin and others (2013). The Hach Nitratax sensor uses two-beam technology and has a 5-millimeter path length with a measuring range of 0.1–25 mg/L in the NOx (nitrate plus nitrite as nitrogen in milligrams per liter) operating mode or 0.1–100 mg/L in the NO3 (nitrate plus nitrite in milligrams per liter as nitrate) operating mode. Readings from Nitratax sensors are being stored under parameter code 99133, nitrate plus nitrite as nitrogen in milligrams per liter. When nitrate plus nitrite concentrations as nitrogen exceed 10 mg/L (the maximum contaminant level for drinking water), field personnel will try to collect a sample for laboratory verification.

Similar to the Solitax sensor, the Nitratax sensor also uses analog features with data output in milliamps in order for the DCP to transmit nitrate readings in real time. As nitrate concentrations increase or decrease, analog milliamp readings increase or decrease, respectively. The Hach Nitratax sensor also uses the same controller as the Hach Solitax sensor to collect and output the data to a DCP. The Nitratax sensor's analog data output in milliamps is converted to a voltage reading by using a SDI analog-to-digital interface. The end result is a milliamp measurement from the controller that is converted to a voltage reading recorded by the DCP, reconverted to original units by entering a slope adjustment in the DCP, and then transmitted in real time. To obtain actual measured concentration values, the controller can be set to internally log with data routinely downloaded into the NWIS database.

In the NO3 operating mode, nitrate plus nitrite concentrations in milligrams per liter as nitrate are collected as molecular weight. To convert NO3 molecular weight readings to nitrate plus nitrite as nitrogen in milligrams per liter, NO3 readings are multiplied by 0.226. For example, a 50 mg/L reading in the NO3 operating mode is multiplied by 0.226 to equal a nitrate plus nitrite as nitrogen concentration of 11.3 mg/L.

Historically, monitoring sites in the KSWSC transmitted data from the in-situ Hach Nitratax sensor in the NO3 operating mode and used a 0.226 multiplier in the USGS automated data processing system (ADAPS) to convert its readings to nitrate plus nitrite as nitrogen concentrations in milligrams per liter for display on the NWIS Web site. Currently (2014), monitoring stations operating Nitratax sensors are operating the sensors in the NOx operating mode, and data are transmitted in real time as nitrate plus nitrite as nitrogen in milligrams per liter.

The Hach Nitratax sensor is equipped with a self-cleaning wiper to keep the detection window free of sediment particles or algal buildup. However, if stream sediment concentrations are too high, the Hach Nitratax sensor may not be able to accurately measure nitrate concentrations because the measuring window becomes obstructed by sediment. After a runoff event, an additional cleaning site visit may be needed.

A 2-point calibration is performed with DI water as the zero point and a nitrate standard of known concentration as the second point. The KSWSC uses nitrate standards made by Hach (stock number LCW825 and stock number LCW828) with nitrate concentration of 11.3 mg/L and 5.56 mg/L, respectively in the NOx operating mode. If a higher range nitrate standard is needed, it can be purchased from several companies. Additional calibration checks on the Hach Nitratax sensor can be made with nitrate dilution standards to check the linearity of the sensor (appendix 4). The sensor can be calibrated or checked in the NO3 or NOx operating mode. However, since the KSWSC is now operating the Nitratax sensors in the NOx operating mode, field collectors are to perform calibration checks in the NOx operating mode. All calibration checks and sensor recalibrations are documented in CHIMP. Dilution standards are made with DI water. IBW is not recommended for making dilution standards. Laboratory analysis of the blank water has found small quantities of nitrate in the solution. Laboratory equipment, such as a graduated cylinder, used to make the dilution standards are cleaned and free of nitrate residue. Open bottles of standards are stored in the laboratory refrigerator while unopened bottles are stored in laboratory cabinets. Nitrate standards taken to the field are transported in coolers with a small quantity of ice and not exposed to direct sunlight.

A KSWSC test on the Hach Nitratax sensor in nitrate standards at various concentrations showed that the relation between nitrate calibration standards and measured nitrate concentrations is linear (fig. 16). The concentration of the standard used to measure and make dilution solutions was analyzed by the National Water Quality Laboratory (NWQL) and was found to be within 0.1 mg/L of the value noted on the bottle's label. In addition to calibration checks, a sample of the concentrated nitrate standard is sent to the NWQL to obtain an accurate standard concentration. The nitrate standard is analyzed for nitrate plus nitrite as nitrogen using laboratory code (LC) 3156. Results of the laboratory analysis are documented in the USGS water-quality database program and also archived in the continuous in-situ Hach Nitratax's calibration file. If the concentration of the nitrate standard solution is more than 0.2 mg/L from the standard solution value, a correction factor is applied to continuous data collected by the Hach Nitratax sensor. Another quality control procedure is to collect routine samples in the stream near the sensor, have the samples analyzed for nitrate or nitrate plus nitrite concentrations, and then compare the sample data to readings measured by the nitrate sensor. Water samples sent to the NWQL generally are analyzed for nitrate plus nitrite as nitrogen, such as LC 3156 or LC 3157. A second analysis can be requested to measure nitrite as nitrogen, such as LC 3117, so that actual nitrate concentrations can be determined. If there are additional concerns about nitrate or nitrite levels in DI water used for the zero-point standard or for making dilution standards, samples of the DI water are sent to the NWQL also to be analyzed for LC 3156 (or LC 3157) and LC 3117.

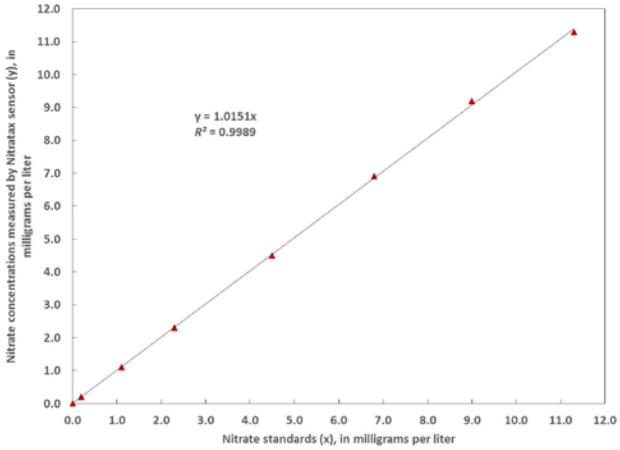


Figure 16. Relation between nitrate standards and nitrate concentrations measured by a Hach Nitratax plus sc nitrate sensor.

The Hach Nitratax sensors have shown good results in measuring nitrate plus nitrite concentrations while deployed in stream environments. Figure 17 displays the results of in-situ measured nitrate plus nitrite concentrations against laboratory measured nitrate and laboratory measured nitrate plus nitrite concentrations September 2012 through December 2012 from the Little Arkansas River near Sedgwick, Kansas. The peak nitrate plus nitrite concentration measured by the in-situ nitrate sensor on October 15 was 11.3 mg/L as nitrogen while the measured laboratory nitrate plus nitrite concentration was 11.7 mg/L as nitrogen. A nitrite sample was not collected at that time.

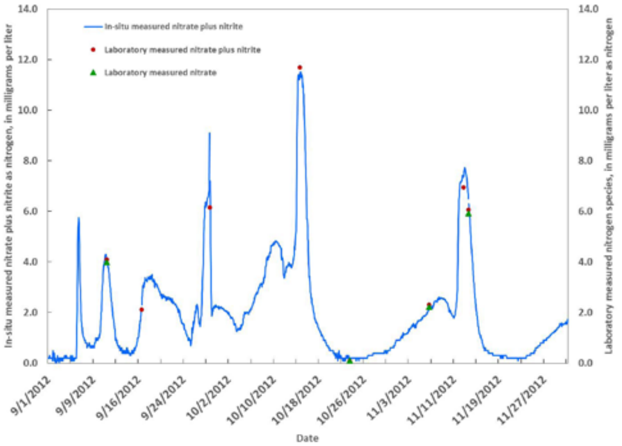


Figure 17. Laboratory measured nitrate plus nitrite concentrations, laboratory measured nitrate concentrations, and in-situ measured nitrate plus nitrite readings collected from a Hach Nitratax plus sc sensor located at Little Arkansas River near Sedgwick, Kansas, September 2012–December 2012.

Colored Dissolved Organic Matter Sensors

Colored dissolved organic matter occurs naturally primarily as a result of tannins released from decaying matter in the water. Activities from agriculture and wastewater discharge also can affect dissolved organic measurements in stream environments. The sensor can be used to optically measure dissolved organic matter in streams or reservoirs.

The Turner Designs CDOM sensor (fig. 18) is attached to a YSI water-quality monitor using the YSI sensor adapter kit to attach third party sensors to YSI equipment. YSI, Inc., in conjunction with Turner Designs, developed an analog-to-digital adapter in order to use the CDOM sensor on a YSI water-quality monitor. Measured values, in parts per billion (ppb), can be transmitted in real time. The KSWSC is displaying these sensor data on the NWIS Web site in ppb, quinine sulfate equivalents.

A wiper unit also is used with the CDOM sensor in order to keep the detection window free of sediment and algal buildup. The wiper unit attached to the CDOM sensor in figure 18 is unique to Turner Designs.

Figure 18. Colored Dissolved Organic Matter sensor installed on a YSI water-quality monitor with a wiper unit and wiper battery pack.

A 2-point calibration is performed using organic blank water (available from USGS One Stop Shopping, item number N1590) for the zero calibration point and 100 ppb or 400 ppb pyrenetetrasulfonic acid (PTSA) solution for the second calibration point. The 100 ppb and 400 ppb PTSA calibration standards are purchased from Turner Designs, stock numbers 10–608 and 10–609, respectively. Operation and performance of the CDOM sensor at the water-quality monitoring station (Little Arkansas River near Sedgwick, Kansas) is still (2014) being tested by the KSWSC.

Small quantities of the PTSA solution may be washed down the drain while flushing with large amounts of water. Personnel are to wash hands thoroughly with soap and water after use.

Oxidation-Reduction Potential Sensors

Oxidation-reduction potential, also referred to as redox, is the measurement of the tendency of a solution to gain or lose electrons. Reduction potentials of aqueous solutions are determined by measuring the potential difference between an inert indicator electrode in contact with the solution and a stable reference electrode connected to the solution by a salt bridge (vanLoon and Duffy, 2011). The most common materials used to manufacture reference electrodes are silver/

silver chloride or calomel. Zobell solution is used to calibrate ORP sensors to verify the performance of the sensor. Although Zobell solution can be used for the silver/silver chloride or calomel sensor, millivolt outputs at the same solution temperature for each type of sensor are not equal. Data collectors need to be aware of the type of ORP sensor being used and use the correct calibration table when calibrating the sensor or making calibration checks.

Currently (2014), the KSWSC has six real-time groundwater monitoring stations and one reservoir monitoring station equipped with combination pH/ORP sensors. Additionally, ORP is measured when collecting discrete groundwater samples. A 1-point calibration is performed on the ORP sensor using Zobell solution. A second point check can be performed made by placing the pH/ORP sensor in the monitor's calibration cup filled with Zobell solution and sealing the cup so that the Zobell solution will not leak out. The sealed calibration cup is then immersed in a bucket of cold water. This second point check at a different temperature verifies that the temperature compensator is working. Although the millivolt output is positive when the sensor is immersed in Zobell solution, measurements in stream, reservoir, or groundwater environments can report negative values. This has been seen numerous times at monitoring stations and also when collecting discrete groundwater samples in the KSWSC.

Small quantities of Zobell solution may be disposed in the drain and flushed with copious amounts of water. As with all chemicals, personnel are to wash hands thoroughly after handling the solution.

New Sensor Technologies

The KSWSC places a high priority on using appropriate emerging technologies and newly developed instruments for continuous water-quality monitoring. Advances in the field of water-quality monitoring can greatly enhance data collection. Evaluation of new instrument technologies in the laboratory and field is necessary to determine their utility for future projects.

Instruments obtained by the KSWSC using new or inadequately documented technologies are tested and evaluated prior to being used as a sole source of water-quality data. The testing procedure is planned in advance and tailored to specific instruments. The evaluation process generally includes tests in the KSWSC laboratories, side-by-side deployments with other instruments in the field and in the laboratory, and verification of data with laboratory-analyzed samples. Data collected at monitoring stations are stored in ADAPS.

New instruments are evaluated on the basis of data accuracy, monitor reliability, and user friendliness. The evaluation of data accuracy includes an assessment of calibration drift, frequency of spikes, and ability of the instrument to measure the full range of conditions that occur in the targeted field locations. Monitor reliability includes resilience to fouling conditions, required maintenance frequency, durability, and quality of technical support from the manufacturer. Factors related to user friendliness include ease of installation and efficient operation, communication interface, power or battery life, and internal logging capabilities.

At the end of the monitor or sensor test, a decision is made by the testing group on how to report the finding of the monitor or sensor test, for example in an internal KSWSC document, a journal article, or at a conference presentation.

Supplies

Specific conductance standards, pH buffers, and miscellaneous water-quality monitor supplies used by the USGS can be ordered from One-Stop Shopping. Other standards, for example, nitrate standards, can be ordered from open-market vendors. Appropriate standards are used for each sensor. Consistent use of the same vendor for open market supplies is a must without documenting the effects of changing vendors on the calibration of the instrument and related field readings.

Supplies are stored according to manufacturer recommendations. Standards and buffers are not kept in vehicles where they may be exposed to extreme heat and cold. Standards and buffers are transported to water-quality monitoring stations in insulated coolers during periods of hot or cold weather. Expired standards and buffers are not used for calibration, but may be used for rinsing sensors.

Troubleshooting

Unstable or inaccurate water-quality sensor measurements may be caused by several factors including sensor fouling (algae, sediment, or debris), calibration drift, sensor malfunction, or water and corrosion in the sensor. Data collectors follow manufacturer's guidelines and recommendations for troubleshooting water-quality monitors and sensors noted in appendix 5.

Field Notes

Thorough documentation of field observations and data-collection activities is a necessary component of data collection and analysis for water-quality monitoring. To ensure that clear, thorough, and systematic notations are made during field visits, information is recorded in CHIMP. Monitoring station specific CHIMP files are imported into Site Visit. Files also are archived in the KSWSC internal station specific folders. On rare occasions when CHIMP is not available (for example, when the personal digital assistant is not working), paper field forms may be used. Paper forms are scanned and stored in digital form in the KSWSC permanent file directory. CHIMP provides an efficient method of importing water-quality monitor data into Site Visit. If paper forms are used, the data collector manually enters field information into Site Visit. Paper forms are digitally scanned and stored in monitor specific folders.

Field notes must include continuous in-situ sensor readings before and after cleaning, calibration check results, and recalibration information from the continuous in-situ water-quality monitor (appendix 6). Comments about the condition of the water-quality monitor, sensors, field cables, and other significant site conditions, such as weather, precipitation, and channel conditions, also are noted in the appropriate comment fields. Field notes also include in-situ readings from a field water-quality monitor throughout the inspection process of the continuous in-situ water-quality monitor. Field notes must have sufficient information for a record reviewer or Project Chief to understand the purpose of the field visit and rationale for any actions or data recorded during the field visit.

Calibration information for the field water-quality monitor is recorded in CHIMP or a spreadsheet program and is archived in the KSWSC internal monitor specific folders. A copy of the CHIMP file for the field water-quality monitor is stored in a binder in the field laboratory and filed under the field monitor's serial number. For the field offices that use a spreadsheet program, a copy of the spreadsheet is available on a laptop in the laboratory.

The data collector must transfer all field notes into Site Visit within 3 working days after servicing the continuous in-situ water-quality monitor. The Supervisory/Lead Hydrologic Technician, or Project Chief inspects field notes within 3 working days of data entry into Site Visit. Deficiencies found in the methodology, content, accuracy, clarity, or thoroughness of field notes are identified and communicated to the data collector. The deficiencies are remedied by providing specific instructions to individuals who fail to record notations that meet USGS standards.

Water-Quality Field Monitors

Water-quality field monitors (or field monitors) are separate water-quality instruments used to provide additional information about ongoing stream conditions while the continuous in-situ water-quality monitor is being serviced. Field monitors also can be used to verify the performance of the in-situ water-quality monitor and possibly provide replacement sensors if a sensor on the in-situ water-quality monitor is malfunctioning and no backup sensor is readily available. These instruments are stored in the field office, calibrated in the field office, and transported to the monitoring station for comparison with the in-situ instruments. Field measurements should represent the natural conditions of the hydrologic system at the time of data collection. Sensor calibration checks or recalibrations of the field monitor are performed in the office, within the range of onsite conditions at each monitoring station, and are required for most instruments to guarantee measurement quality. USGS procedures for collecting in-situ measurements in streams, reservoirs, and wells are provided in chapter A6 of the USGS NFM (Wilde, variously dated).

The calibrated field monitor is taken into the field to monitor changes in the stream before, during, and after in-situ water-quality monitor cleaning and calibration. The field monitor is rinsed multiple times with native water to remove calibration solutions from the sensors. The field monitor is allowed to equilibrate in the stream for 5–10 minutes before measured values are recorded. Measured values from the continuous in-situ water-quality monitors and the field monitor are recorded at approximately the same location in the stream and at the same time (within 5 minutes).

Calibration methods and criteria for the field water-quality monitor are the same as those provided in table 1 for the in-situ water-quality monitor except for calibration frequency. The field water-quality monitor is checked for calibration drift prior to use (not to exceed 7 calendar days since the last calibration check) and recalibrated as needed. As with the continuous in-situ monitor, calibration checks and adjustments are thoroughly documented by the data collector in CHIMP (appendix 7). CHIMP files created to document field monitor calibrations are archived in KSWSC internal field monitor-specific folders. A copy of the CHIMP file also is maintained in a binder in the field laboratory for easy reference. As an alternative to CHIMP, a calibration spreadsheet (appendix 8) or the water-quality monitor's logbook can be used. Calibration spreadsheets also are stored in field monitor-specific folders. If bound paper logbooks are used to record the results of the field monitor, the records must be digitally scanned and archived in KSWSC internal field monitor-specific folders.

Cross-Sectional and Depth-Integrated Surveys

Cross-sectional surveys are performed with a calibrated field monitor to determine how readings from the continuous in-situ water-quality monitor located at a single point in the stream compare with cross-sectional values that are representative of the entire stream. Depth-integrated surveys are completed to quantify how well readings from the continuous in-situ water-quality monitor located at a set depth level in a stream or reservoir compare with the variability in the water column. A water-quality monitor installed in a reservoir cannot be representative of the entire reservoir but may be representative of the water column at a particular location in the reservoir based on project objectives.

Stream cross-sectional surveys at water-quality monitoring stations in the KSWSC generally are performed during every discrete water-quality sampling visit. Cross-sectional surveys are done over various flow conditions throughout the year and during seasonal variations, especially for a monitoring station with a new in-situ water-quality monitor. Comparisons between data collected by the continuous in-situ water-quality monitor and cross-section measured values are used to determine the best placement of the continuous in-situ water-quality monitor and to document differences in the horizontal profile of the stream.

The most common method used to make cross-section measurements is an equal-width increment survey for narrow and well-mixed streams. For streams that are wide and not as well mixed, the equal-discharge increment method is recommended. Surveys also should be representative of the water-column mixing in the stream. For streams that are too deep to wade, a depth-integrated, cross-sectional survey should be considered. This method measures sensor values at various depth intervals in the water column. Sensor measurements can be made at equal-depth increments or by using the 0.2 and 0.8 methods that data collectors use to measure stream velocity.

Depth-integrated surveys also are done on a regular basis during reservoir discrete water-quality sampling visits. Surveys are done more frequently when noticeable differences occur between measured sensor values from near the water surface and measured sensor near the bottom of the reservoir. Two continuous in-situ water-quality monitors are installed at Cheney Reservoir near Cheney, Kans., for measurement of SC, pH, water temperature, and DO at two depth levels. The first water-quality monitor, installed at a depth of approximately 6–7 feet below the water surface, also measures turbidity and fluorescence. Table 2 and figure 19 show the results of a depth-integrated survey from July 2007. DO concentrations displayed more variation between readings from near the surface of the lake to readings near the bottom of the lake on this sample date, but such extreme variability with depth is rare in Cheney Reservoir.

Depth-integrated surveys also can be done in wells. Surveys should be done before the continuous in-situ water-quality monitor is installed in the well. It is critical that the water-quality monitor be lowered very slowly down the well because movement of the monitor up or down the well stirs water in the water column and results in erroneous data.

National Water Information System Data Review

The National Water Information System Web site has significantly increased the visibility of real-time water-quality data (U.S. Geological Survey, 1999a) to users. Real-time water-quality monitoring stations in the KSWSC can be viewed at *http://waterdata.usgs.gov/ks/nwis/current/?type=quality*. All water-quality monitoring stations available nationally can be viewed at *http://waterwatch.usgs.gov/wqwatch/*. The National Real-Time Water Quality Web site located at *http://nrtwq.usgs.gov* provides streamflow, computed constituent concentrations and loads, and other information for several states across the Nation.

Inaccuracies in transmitted water-quality data may be caused by instrument malfunctions or physical changes at the monitoring station. Data collectors are to review water-quality data daily on the NWIS Web site and to rectify any problems caused by fouling, calibration drift, or water-quality monitor or sensor malfunction at the water-quality monitoring station within 3 working days. If problems exist at a water-quality monitoring station and it is not possible to service the monitoring station within 3 working days, sensor data are temporarily turned off on the NWIS Web site by the Supervisory/Lead Hydrologic Technician, data collector, or a designated individual.

Table 2. Results of a depth-integrated survey made with a field water-quality monitor at Cheney Reservoir near Cheney, Kansas, July 27, 2007.

[°C, degrees Celsius; uS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; FNU, Formazin nephelometric units]

Depth below water surface, in feet	pH, units	Temperature, °C	Specific conductance, µS/cm	Dissolved oxygen, mg/L	Turbidity, FNU
1	8.71	26.84	746	8.15	20.1
2	8.70	26.84	746	8.08	20.3
3	8.70	26.84	746	8.06	20.0
4	8.69	26.83	746	7.95	20.1
5	8.69	26.83	746	7.95	20.3
6	8.69	26.83	746	7.93	20.1
7	8.69	26.83	746	7.97	20.0
8	8.68	26.83	746	7.92	20.2
9	8.68	26.83	746	7.92	20.2
10	8.68	26.83	746	7.93	20.0
11	8.68	26.83	746	7.92	19.4
12	8.68	26.83	746	7.89	19.8
13	8.68	26.83	746	7.93	19.9
14	8.68	26.83	746	7.91	19.8
15	8.68	26.83	746	7.91	19.9
16	8.68	26.82	745	7.90	20.1
17	8.66	26.77	745	7.20	22.3
18	8.22	25.94	750	4.75	22.8
19	7.96	25.60	748	3.36	24.2
20	7.90	25.53	748	2.91	24.3
21	7.89	25.52	747	2.85	25.0
22	7.84	25.46	747	2.47	25.1
23	7.82	25.39	747	2.31	28.7
24	7.81	25.36	747	2.24	30.4
25	7.80	25.31	747	2.10	32.5
26	7.78	25.27	747	1.90	35.1
27	7.75	25.19	747	1.74	33.0
28	7.72	25.10	746	1.42	34.1
29	7.71	25.06	746	1.34	34.4
30	7.70	25.03	746	1.18	34.4
31	7.64	24.38	748	0.58	29.7
32	7.59	24.26	747	0.26	30.5
33	7.59	24.26	747	0.23	32.1
34	7.58	24.18	747	0.20	38.4
35		Bottom of reservoir			

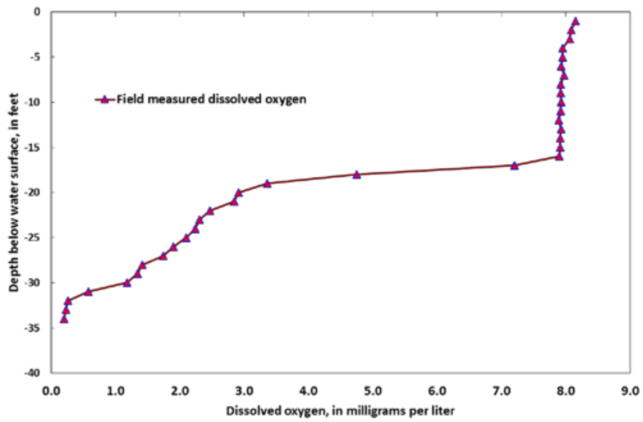


Figure 19. In-situ dissolved oxygen readings measured at various depths with a field water-quality monitor during a depth-integrated survey at Cheney Reservoir near Cheney, Kansas, July 27, 2007.

Continuous water-quality data sometimes have spikes (fig. 20). To avoid most erroneous data spikes, data descriptor thresholds are set in ADAPS to screen erroneous data on the NWIS Web site from the public. Original data are retained in ADAPS, but when data exceeds very high, very low, or rate-of-change thresholds set in ADAPS, the data are not seen on the NWIS Web site (fig. 21); instead, symbols and notations are displayed.

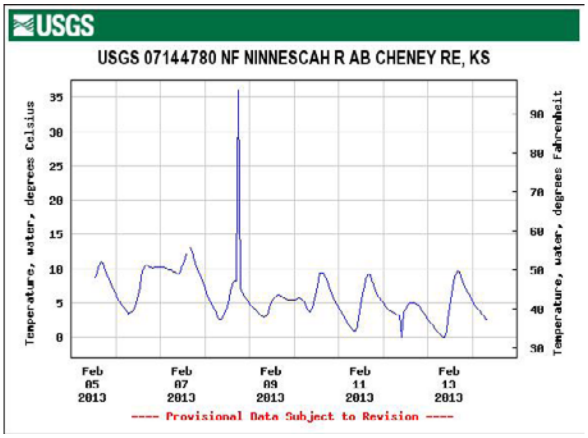


Figure 20. National Water Information System Web page showing continuous in-situ water temperature data collected by a water-quality monitor displaying data that has not been screened for erroneous values.

Thresholds are station specific. A threshold set for one water-quality monitoring station may not be an appropriate threshold for other stations. Additionally, after thresholds have been set, they are occasionally reviewed. A very low threshold of zero set for water temperature during the spring to fall months will not work for the winter months when water temperatures drop to zero (fig. 22).

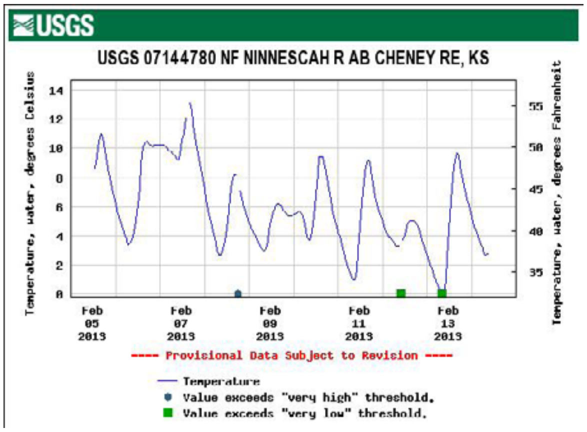


Figure 21. National Water Information System Web page showing continuous in-situ water temperature data collected by a water-quality monitor with erroneous data deleted from public viewing.

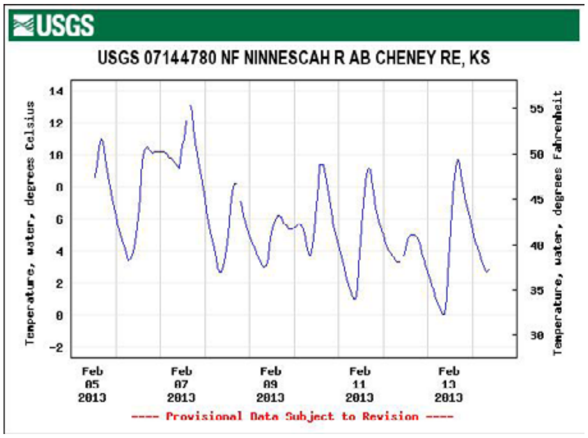


Figure 22. National Water Information System Web page showing continuous in-situ water temperature data collected by a water-quality monitor displaying the effects of deleted erroneous data and a very low threshold set appropriately for colder winter months.

Rate-of-change thresholds for SC and turbidity are the most difficult to accurately set. Rapid declines or rises in data can occur in a matter of a few minutes. It is not uncommon for rate-of-change thresholds to be changed for seasonal variance. In small flashy runoff watersheds, an inappropriate rate-of-change threshold could result in data collectors being unable to view rapidly changing data during storm events on the NWIS Web site, resulting in missed sampling opportunities. In these cases, the data collector, Supervisory/Lead Hydrologic Technician, or Project Chief should evaluate and discuss the necessity of setting rate-of-change thresholds for small watersheds.

Corrective actions are required when erroneous data are viewed on the NWIS Web site. Erroneous data are immediately deleted from ADAPS. At times, a site visit may be necessary to verify data are erroneous. Instead of deleting data, suspicious data can be flagged in the record processing system so that data do not display on the NWIS Web site. After data are verified as correct or bad from a site visit, the flagged data can be deleted or left as appropriate.

Appropriate corrections to NWIS Web data are made within 3 working days of the in-situ water-quality monitor inspection by either deleting the erroneous data, applying data corrections to compensate for fouling or calibration drift, or changing thresholds to more appropriate settings. It is important to have complete and accurate data during critical periods and at critical monitoring stations. It is the responsibility of the Supervisory/Lead Hydrologic Technician, or Project Chief to assign an individual to review data on a daily basis, on weekends, and possibly holidays and to delete erroneous data that is being displayed on the NWIS Web site.

Quality Assurance of Water-Quality Monitoring Data

The USGS water-quality personnel involved in the collection of water-quality monitoring data are required to participate in the annual National Field Quality Assurance (NFQA) Project (Stanley and others, 1998). The objectives of the NFQA program are to ensure the proficiency of field personnel and field water-quality monitors and to identify personnel who need more training.

Required documentation in the NFQA project includes participant’s name, control code number, serial number of water-quality monitor being used to perform the tests, and results of the tests. The Kansas Water-Quality Specialist or designated individual is responsible for ordering NFQA samples, reviewing results, and notifying personnel of errors and deficiencies. Personnel receiving an unsatisfactory rating will receive additional training by the KSWSC Supervisory/Lead Technician in the calibration of water-quality equipment. Additional NFQA samples may be reordered by the KSWSC for personnel with unsatisfactory ratings.

Training

Employee training is an integral part of water-quality activities allowing current employees to maintain and enhance their technical knowledge and new employees to gain the specific skills needed to adequately perform their job. A well-documented training program not only ensures that data are collected correctly by technically competent personnel but also lends legal credibility to data and interpretations.

The supervisor and employee develop individual training plans at least annually as part of the employee’s performance review process. The Kansas Training Officer is responsible for informing USGS staff about the availability of training that includes in-house training opportunities, USGS courses, and webinars. The Kansas Water-Quality Specialist provides recommendations and advice to supervisors and their staff as needed. Primary sources of water-quality training are USGS courses, usually held at the National Training Center in Lakewood, Colorado, and USGS webinars or in-house training courses. Training documents are maintained by the Kansas Training Officer in KSWSC personnel files and by the Personnel Office in the Central Region. Periodic reviews of data-collection procedures by the Supervisory/Lead Hydrologic Technician, Kansas Water Quality Specialist, and Project Chief are used to evaluate the effectiveness of training programs and to determine if technical work is being conducted correctly. Reviews also are used to identify and resolve problems before they become widespread and potentially compromise data quality.

Safety

The safety of personnel and others is the highest priority for the USGS. The collection of streamflow and water-quality data can be hazardous. Data collectors often work in areas of high traffic, remote locations, and under extreme environmental conditions. Fieldwork involves transportation and use of equipment and chemicals. Data collectors also may come in contact with waterborne or airborne chemicals, pathogens, and toxins while servicing water-quality monitors or collecting discrete water-quality samples. The quality of data also may be compromised when personnel are exposed to dangerous conditions.

So that personnel follow established procedures and protocols that promote all aspects of safety, the USGS communicates safety information and directives to all personnel by memorandums, in-house training classes, videos, and safety posters. Specific policies and procedures related to safety can be found on the internal KSWSC Safety Page, in the Kansas Hygiene Plan, the Kansas Traffic Control Handbook, the Kansas Flood Plan, and the site-specific “Job Hazard Analysis.” Additional guidelines pertaining to safety for field activities are provided in Lane and Fay (1997). It is the responsibility of each employee to attend scheduled safety training, read all assigned safety material, and practice safe work habits at all times. Copies of the Kansas Traffic Control Plan are kept in the field office, field vehicles, and gage houses. Copies of JHAs are kept in safety books in the servicing vehicles, in the field office, and in gage houses.

The USGS in Kansas has a designated Safety Officer. Personnel who have questions or concerns pertaining to safety, or who have suggestions for improving some aspects of safety, should direct those questions, concerns, and suggestions to the Kansas Safety Officer, Supervisory/Lead Hydrologic Technician, Project Chief, or Field Office Safety Officer. Personnel are encouraged to strive to improve safety at all sites and for all activities.

Material safety data sheets (MSDS) are maintained in the laboratory and in all water-quality field vehicles for all chemicals used by the KSWSC. MSDS notebooks are updated with new sheets when new chemicals are purchased by the KSWSC.

Processing and Analysis of Continuous Water-Quality Monitoring Data

The computation of water-quality monitoring records involves the analysis of field observations, notes and measurements, adjustment and application of those relations, and systematic documentation of the methods and decisions that were applied. Continuous water-quality monitoring records are worked in ADAPS, discussed in the station analysis in Record Management System (RMS), and are ready for checking within 40 days from a complete cleaning and calibration inspection. Records are checked and ready for review within 20 days of the date the record is logged as worked in RMS. Records are reviewed and approved in ADAPS and RMS no more than 150 days from date of last approved daily value in ADAPS. The Continuous Records Processing (CRP) status report, found in SIMS, is used to view the status of record work.

This section of the QA plan provides guidelines and descriptions for protocols pertaining to the processing and analysis of data associated with the computation of water-quality monitoring records. The procedures followed by the KSWSC are similar to streamflow records in that all data are reviewed thoroughly for accuracy, and hydrologic comparisons are made to other data at the water-quality monitoring station as well as other monitoring stations. The overall process for working a water-quality monitor record is summarized in appendix 9.

Water-Quality Field Monitor Notes and Measurements

Water-quality monitoring data such as SC, pH, water temperature, DO, turbidity, fluorescence, CDOM, and nitrate and onsite observations are recorded in CHIMP. Sensor values from the continuous in-situ water-quality monitor and the field water-quality monitor are recorded before and after cleaning the in-situ water-quality monitor. Calibration checks and recalibration data for the in-situ water-quality monitor also are recorded in CHIMP. After reinstalling the in-situ water-quality monitor, final values are documented again from the continuous in-situ water-quality monitor and the field water-quality monitor.

Water-quality monitoring information documented in CHIMP is electronically transferred and imported into the Site Visit database program by the data collector. Although CHIMP can be set up to document onsite information for all water-quality sensors; however, at this time (2014), data from only water temperature, pH, SC, turbidity, and DO sensors can be uploaded into Site Visit and retrieved from Site Visit for reports or plotting programs. CHIMP files created for water-quality monitors that record other types of sensor readings, such as nitrate or fluorescence, also can be imported into Site Visit, but data will not be stored in specific locations, and the data can not be retrieved for reports or plotting programs. However, the CHIMP file can be retrieved by users for quick reference.

All data and procedures are checked and evaluated for accuracy. Numbers can be easily misread, transposed, or incorrectly recorded. Suspicious data are flagged as questionable and not necessarily used in the record computation process. Reasons for not using information from the field notes in the record process must be documented in the station analysis. It is the responsibility of the data collector assigned to the water-quality monitor to follow proper operation and maintenance procedures and to ensure that field notes are recorded and transferred to Site Visit accurately and completely.

Continuous Water-Quality Monitoring Record

Real-time water-quality monitoring data are measured and logged as a continuous record (60-minute, 30-minute, or 15-minute intervals, for example) by the DCP, then transmitted in real time and relayed to USGS offices. Real-time data are reviewed daily in the NWIS Web site to identify erroneous data or operational problems. Water-quality monitors are programmed to internally log data wherever possible. Although most water-quality monitoring stations in the KSWSC are real time with DCPs for collection and transmission of data, logged data from water-quality monitors serve as a backup and can be used when the DCP malfunctions or when communication problems occur between the DCP and the water-quality monitor. In the event that data are not transmitted from the DCP, internally logged data from the DCP or the water-quality monitor can be manually entered into ADAPS for short periods of record or entered into the ADAPS database using the device conversion and delivery system decoding wizard (DECWIZ) software for long periods of record. Whatever method is used to fill in missing data, the method used must be clearly described in the station analysis.

Real-time data are not available for a few water-quality monitoring stations in the KSWSC. Data collectors must program the water-quality monitor to internally log data. The logged data file is downloaded from the continuous in-situ water-quality monitor every site visit, reviewed to verify that the water-quality monitor is operating properly, entered into ADAPS using DECWIZ, and erroneous data deleted as soon as possible. The electronic data log is archived in KSWSC internal station-specific folders.

Continuous Water-Quality Monitoring Records Computation

The application of data corrections to water-quality monitoring data allows data from water-quality sensors to be corrected for environmental effects and instrument calibration drift. Ensuring the accuracy of field notes and proper calibration procedures is therefore a necessary component of safeguarding the accuracy of the computed record. Record computation includes examination of water-quality monitoring data to determine if the record accurately represents the body of water being monitored; additionally, it includes identifying periods of time during which inaccuracies have occurred and determining their cause.

When fouling corrections are not possible because fouling is too extreme, erroneous water-quality monitor data are removed from the database. Within ADAPS, original data are always retained in the database as "raw measured unit values." A duplicate set of values are stored as "edited unit values." Edited unit values are data values that can be edited, deleted, corrected, and processed to obtain a "computed unit value" used for record computation.

The KSWSC uses the automated correction loader (ACL) program for several water-quality monitoring stations. The program will automatically enter data corrections into ADAPS eliminating the need for manual data entry. After the CHIMP file is imported or manually entered into Site Visit, ACL evaluates the data and computes fouling and calibration drift corrections based on the sensor values recorded in the CHIMP file, and enters the correction into ADAPS. For more information about the ACL program, the online user's manual may be downloaded by USGS personnel at *https://redmineks.cr.usgs.gov/attachments/215/.*

Generally, ACL simplifies data correction entry, but record workers are to review the results of this automated step. Incorrect corrections may occur because field data recorded into CHIMP were erroneous. If this occurs and the automated correction was not reviewed and corrected, the NWIS Web data may not be accurate.

Currently (2014), Site Visit will only accept continuous in-situ sensor data from water temperature, SC, pH, turbidity, or DO sensors, and the ACL program does not process data corrections for water temperature. Consequently, automated data corrections are only applied to SC, pH, turbidity, or DO readings. After valid corrections have been applied to the readings, computed readings that exceed the maximum allowable data correction ("maximum allowable limits") defined by Wagner and others (2006) or the KSWSC (table 3) are not released. Exceptions to the maximum allowable limits are allowed on a case-by-case exception and reviewed by the Supervisory/Lead Technician or Project Chief. Data beyond Wagner and others' maximum allowable limits may still be usable and preferred to no data when analyzing data for reports. Exceptions to Wagner and others (2006) are documented in the station analysis.

Records are worked, checked, and reviewed on a continual basis in ADAPS as the water year progresses to improve the accuracy of provisional records shown on the NWIS Web site and to minimize computations needed at the end of the water year. The data collector responsible for the water-quality monitoring station generally does all initial record computations for that station unless a designated record worker has been assigned to work the water-quality record. Experienced personnel review records while noting any modifications made by the checker and maintaining consistency among similar water-quality monitoring stations. The KSWSC does not require three separate record workers to work, check, or review records. An experienced record worker may combine the check and review process into one step. However, RMS requires that each step be signed off. If one person checks and reviews a record, that person will need to sign off as both the record checker and the record reviewer.

Although three individual record workers are not required to complete the record cycle, inexperienced personnel will gain skills and knowledge if they are incorporated into the record process and are assigned as the record worker or the record checker to gain experience.

Table 3. Maximum allowable data corrections ("maximum allowable limits") for continuous in-situ water-quality monitors (modified from Wagner and others, 2006).

[± plus or minus; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; <, less than; FNU, formazin nephelometric units; ≥, greater than or equal; QSE, quinine sulfate equivalence]

Physical property	Maximum allowable limits
Specific conductance	± 30 percent µS/cm
pH	± 2 standard units
Water temperature	± 2.0 degrees Celsius
Dissolved oxygen (luminescent)	± 30 percent mg/L
Turbidity	Turbidity < 100 FNUs, greater of 30 FNUs or 30 percent FNUs Turbidity ≥ 100 FNUs, ± 30 percent FNUs
Fluorescence chlorophyll	± 30 micrograms per liter
Color dissolved organic matter	± 30 percent parts per billion, QSE
Nitrate	± 30 percent mg/L
Oxidation reduction potential	± 30 percent millivolts

Procedures for Records Computation and Checking

Procedures for assuring thoroughness, consistency, and accuracy of continuous water-quality monitoring records are described in this section of the QA plan. The goals, procedures, and policies presented in this section are grouped in association with the separate components that are included in the records-computation process. Three types of data corrections normally applied to water-quality sensor data are fouling, calibration drift, and cross-sectional corrections (Wagner and others, 2006) depending on the degree of correction needed.

In 2015, testing for a replacement for ADAPS will begin. Some of the processes and components of record processing described in the following sections will change. Also, during the transition to electronic data management, the documentation of record work may change. The following sections will be updated when the procedures for processing records are better defined.

Fouling Corrections

Diel fluctuations are typical of many of the water-quality parameters, such as water temperature, pH, DO, and nitrate. SC and turbidity also can display these types of fluctuations. In addition, measurements can vary substantially during a hydrologic event. Before applying a fouling correction to the data of record, consideration must be given to the environmental changes that are occurring naturally in the stream during the period that the in-situ water-quality monitor is being cleaned. Measurements made from a field water-quality monitor while the in-situ water-quality monitor is being serviced are used to evaluate these natural changes.

Sensor fouling occurs on any continuous water-quality instrument left in a stream, reservoir, or well for an extended period of time because of biological or chemical particles accumulating on sensors (fig. 6). A site visit to clean water-quality sensors often results in an obvious change in sensor values. Differences in sensor values before and after the cleaning process and allowance for environmental stream change determine a fouling correction. Modified from Wagner and others (2006), the equations used to calculate fouling in units and in percent are:

$$\textit{Fouling, in units} = (I_A - I_B) - (S_A - S_B), \qquad (1)$$

$$\textit{Fouling, in percent} = [(I_A - I_B) - (S_A - S_B)]/I_B \times 100, \qquad (2)$$

where

I are readings from the continuous in-situ water-quality monitor,

S are values from the separate field monitor, and

$_A$ and $_B$ are after and before cleaning, respectively.

By converting the fouling correction in units to a percentage, a linear data correction is applied to the data record if needed (table 4). Differences between sensor values before and after cleaning should have a physical basis. A water-quality sensor must have a visual indication of fouling before a fouling correction is applied. Sensor values from both the in-situ and field water-quality monitors are made at approximately the same location and at the same time (within 5 minutes) and need to be fairly stable and equilibrated. If sensor values from the field monitor are changing as a result of slow or poor sensor performance and less likely as a result of environmental stream change, values from the field monitor are not used to calculate the fouling correction.

Data corrections are entered in ADAPS in paired sets defining the beginning and ending of the applied data correction. Sensor values affected by fouling are corrected in ADAPS by applying a 1- or 2-point data correction in correction set number 1. Figure 23 is an example of a 2-point fouling correction applied in ADAPS using the information from table 4. Fouling corrections are started from the previous site visit when the water-quality monitor was last cleaned, from an inconsistent decrease or increase in sensor values, or during environmental events with increased stream levels, increased sensor values, or decreased sensor values, depending on the water-quality monitoring station and conditions since the last visit. The correction is generally prorated over time to the next inspection when the water-quality sensor is cleaned.

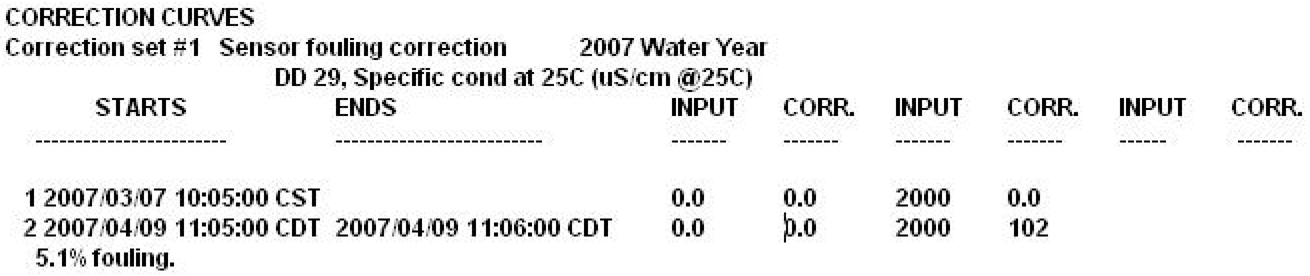
Generally, fouling is assumed to begin as soon as the water-quality instrument is deployed in a stream, reservoir, or groundwater environment. Changing conditions can have an impact on the quantity and type of fouling that may accumulate on water-quality sensors. Low-flow or low velocity stream conditions generally encourage the accumulation of material on water-quality monitors, whereas higher streamflow or higher velocities generally help reduce the buildup of material. Concentrations of suspended sediment and chemical and biological material can increase or decrease during runoff events. As stream levels and velocities begin to decrease after a runoff event, more sediment, silt, and other particles are deposited on the streambed and onto water-quality monitors and sensors.

Fouling hinders the water-quality sensor's ability to accurately record values. Routine site visits can eliminate much of the fouling. However, there are periods during the year when excessive algal growth, larvae accumulation, or shifting sand is problematic for the water-quality monitor. Long-term buildup on the sensors may require soaking the sensors in solutions such as vinegar (weak acid) to remove the buildup. Other problems are related to seasonal effects such as falling leaves being trapped in the water-quality monitor's sensor guard. When severe fouling occurs, data cannot be corrected with any reasonable degree of accuracy. Applying a correction for extreme fouling is ineffective and data should be deleted. Antifouling paints around sensors can be used to reduce fouling, but only if exact manufacturer's recommendations are followed. HIF does not allow any water-quality rental instrument to be coated with antifouling agents.

Table 4. Computation of a fouling correction for specific conductance with allowance for environmental stream change.

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; SC, specific conductance; I, reading from in-situ monitor; A, after cleaning reading; B, before cleaning reading; S, reading from a separate field monitor; %, percent]

On-site reading	Specific conductance reading (µS/cm)
In-situ monitor: SC reading after cleaning	495
In-situ monitor: SC reading before cleaning	470
Fouling ($I_A - I_B$)	25
Field monitor: SC reading after cleaning	501
Field monitor: SC reading before cleaning	500
Environmental stream change ($S_A - S_B$)	1
Overall fouling ($I_A - I_B$) – ($S_A - S_B$)	24
Overall percentage fouling [($I_A - I_B$) – ($S_A - S_B$)] / x 100	5.1
Specific conductance reading (µS/cm)	**5.1% fouling correction on SC reading (µS/cm)**
0	0
2,000	102



```
CORRECTION CURVES
Correction set #1   Sensor fouling correction        2007 Water Year
                         DD 29, Specific cond at 25C (uS/cm @25C)
       STARTS                  ENDS                  INPUT    CORR.    INPUT    CORR.    INPUT    CORR.
  -----------------------  -------------------------  -------  -------  -------  -------  ------  -------

 1 2007/03/07 10:05:00 CST                           0.0      0.0      2000     0.0
 2 2007/04/09 11:05:00 CDT  2007/04/09 11:06:00 CDT  0.0      0.0      2000     102
  5.1% fouling.
```

Figure 23. Example of a 2-point fouling correction table displaying data corrections applied for a specific conductance record.

Calibration Drift Corrections

A calibration drift is an electronic drift in the equipment from the last time the sensor was calibrated and is determined by differences in values between the standard value and what a clean sensor is reporting when immersed in the standard solution. It is essential for record computations that correct protocols for calibration checks be completed before recalibrating the sensor in order to accurately determine a calibration drift. If the sensor is recalibrated after the first checkpoint and before the second or third checkpoints are made for that sensor, sensor drift measurements will be unreliable in determining an accurate calibration drift correction for the data recorded by the water-quality sensor. The sensor is recalibrated only after all calibration checks have been performed on that sensor, and sensor values do not exceed the calibration criteria (table 1) during the inspection process.

The sensors in use by the KSWSC are made to respond linearly and should exhibit minimal calibration drift. Before assuming the sensor is the source of drift, ensure that proper techniques are being used, calibration standards are free from contamination, sensors are clean, and site conditions are favorable for doing calibration checks.

Minimally, two standards are used to check or calibrate many water-quality sensors. A third checkpoint can be used if needed. Calibration drift corrections can be applied using a 1-, 2- or 3-point data correction in correction set number 2 in ADAPS. If the sensor is responding linearly, a 2-point data correction is generally used for applying a calibration drift correction (table 5). However, there are times when a sensor does not respond linearly. This nonlinear response may be detected when the sensor is checked in a third standard. Modified from Wagner and others (2006), the equations used to calculate drift in units and in percent are:

$$\text{Drift, in units} = (S - I), \qquad (3)$$

$$\text{Drift, in percent} = [(S - I)]/I \times 100, \qquad (4)$$

where

S is the standard value, and
I are readings from the continuous in-situ water-quality monitor.

Table 5. Computation of a calibration drift correction for specific conductance.

[Computation of drift: S–I; Percentage computation of drift: (S–I) / I x 100, in percent; S, value of specific conductance standard; I, reading from in-situ monitor; µS/cm, microsiemens per centimeter at 25 degrees Celsius; SC, specific conductance; na, not available]

Specific conductance standard	Specific conductance (µS/cm)			
	Standard	In-situ monitor	Drift	Drift, in percent
Standard 1	500	480	20	4.17
Standard 2	1,000	970	30	3.09
Standard 3	2,500	2,450	50	2.04
Average	na	na	na	3.10

Specific conductance reading (µS/cm)	3.1% fouling correction on SC reading (µS/cm)
0	0
3,000	93

Table 6 is an example of a turbidity sensor with a nonlinear response when checked in three turbidity standards. Figure 24 displays how the calibration drift correction is applied in ADAPS. A calibration drift correction (if applied) begins from the last date the water-quality sensor was recalibrated or had a calibration check value that did not require the sensor to be recalibrated. The drift correction is prorated over time to the inspection when the sensor is cleaned and checked again for calibration drift. Calibration drift should be minimal if the instrument is well maintained and water-quality sensors are recalibrated on a routine basis when they exceed the calibration criteria (table 1).

Table 6. Computation of a calibration drift correction for turbidity.

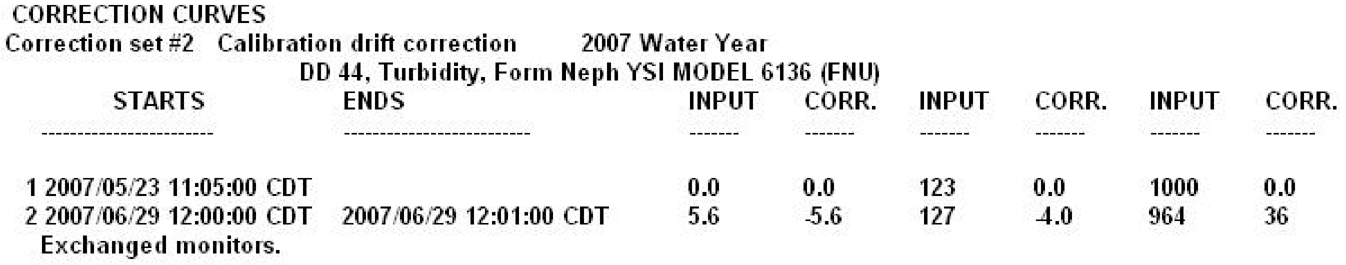
[Computation of drift: S–I; Percentage computation of drift: (S–I) / I x 100, in percent; S, value of turbidity standards; I, reading from in-situ monitor; FNU, formazin nephelometric unit; na, not available]

Turbidity standard	Turbidity (FNU)			
	Standard	In-situ monitor	Drift	Drift, in percent
Standard 1	0	5.6	-5.6	na
Standard 2	123	127	-4	-3.1
Standard 3	1,000	964	36	3.7

Turbidity reading (FNU)	Drift correction on turbidity reading (FNU)
5.6	-5.6
127	-4
964	36

Cross-Sectional Corrections

As previously discussed, stream cross-sectional surveys at water-quality monitoring stations in the KSWSC are generally done during every discrete water-quality sampling visit. Several cross-section measurements must be made over a wide range of water-surface elevations and seasonal changes throughout the year to establish an accurate cross-sectional correction. A correction determined during low-flow conditions might not be the same correction determined under moderate to high-flow conditions. Likewise, a correction made for warmer summer conditions may not be the same as one made for colder winter conditions even with the same water-surface elevations. Because of wide variance in cross-section measurements in water-surface elevations over time, cross-sectional corrections are generally not made in KSWSC water-quality monitor record processing. However, Project Chiefs can decide whether or not to apply a cross-sectional correction during data interpretation. If an extreme difference exists between the cross-section mean and the concurrent in-situ measurement, the water-quality monitor should be relocated.



```
 CORRECTION CURVES
Correction set #2   Calibration drift correction        2007 Water Year
                                 DD 44, Turbidity, Form Neph YSI MODEL 6136 (FNU)
          STARTS                    ENDS                       INPUT    CORR.    INPUT    CORR.    INPUT    CORR.
   -----------------------     -------------------------      -------  -------  -------  -------  -------  -------

 1 2007/05/23 11:05:00 CDT                                    0.0      0.0      123      0.0      1000     0.0
 2 2007/06/29 12:00:00 CDT   2007/06/29 12:01:00 CDT          5.6      -5.6     127      -4.0     964      36
   Exchanged monitors.
```

Figure 24. Example of a 3-point calibration drift correction table displaying data corrections applied for a turbidity record.

Graphs

A hydrograph is a plot of water flow or gage height data readings over time. Graphs are a useful tool in identifying periods of erroneous information, such as incorrect data corrections, when compared to hydrographs from other sensors or hydrologic record from upstream or downstream sites. Graphic comparison to other water-quality sensor data or to discharge record (fig. 25) when computing the water-quality record is useful when evaluating water-quality records. For example SC and turbidity data are often compared to discharge data. During a runoff event, discharge and turbidity values generally increase while SC values decrease. Although this does not occur during every event, discharge, turbidity, and SC often have a direct or inverse relation with each other. When this relation is not observed on the NWIS Web site, fouling may have occurred and a site inspection may be needed to clean the water-quality monitor.

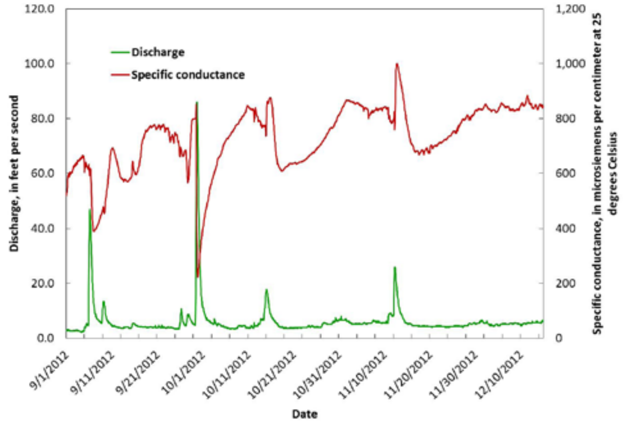


Figure 25. Comparison between discharge and continuous in-situ specific conductance data located at Little Arkansas River near Sedgwick, Kansas, September 2012–December 2012.

Plotting programs in ADAPS used by record workers during the record process allows the record worker to zoom in on suspect data, delete erroneous data, and copy electronic data log (EDL) from the DCP or the water-quality monitor data into “edited unit values” tables when original transmitted data are missing. Other available tools, such as Water Quality Monitor Review, are used for producing graphs and other useful information when reviewing records.

The National Water Information System Web site also has many output formats to view water-quality monitoring data. These tools are extremely useful during daily review to also identify problems at a water-quality monitoring station when up to three water-quality sensor data, such as discharge, turbidity, and SC, are plotted on the same graph. Another viewing option on the NWIS Web site is to view a graph for one water-quality sensor from three water-quality stations. Comparing water-quality sensor data from two or three water-quality monitoring stations in the same basin also can help identify potential problems.

Primary Records

A primary record is a daily summary of computed unit values stored in the ADAPS database for a water-quality sensor. Day-to-day information on the primary record includes daily maximum, minimum, mean or median values, time of occurrence, and daily maximum and minimum corrections applied to the record for the day. The primary record is used to identify partial or missing data and is useful in verifying the validity of daily values for partial days generated by the processing program. Two formats are available, a standard record primary and a historical record primary. The most commonly used primary record for water-quality characteristics is a historical primary record (appendix 10). Notations are made on the paper report, thus allowing the record checker or reviewer to verify that daily values for partial days have been reviewed by the record worker. The paper report is used as a verification tool and is not archived as part of the permanent record.

Daily Value Tables and Graphs

Daily maximum, minimum, and mean or median values are computed by ADAPS and stored automatically in daily value tables for a complete daily record. If needed, a specific daily table can be generated (appendix 11) by the record worker. The record worker is responsible for identifying periods of erroneous data, records affected by severe fouling, or data recorded from out of calibration sensors. If erroneous data exist in the “edited unit values” tables, daily values generated by the record primary may not be accurate. The erroneous data are deleted and the primary record is reprocessed to update the daily values tables. Daily values graphs are a graphical output of daily values stored in the ADAPS database. These graphs are easily viewed using the Hydra plotting program in ADAPS and are useful for recognizing errors in the daily values; for example, the record worker will recognize if the maximum daily value was entered as a value lower than the minimum daily value.

Partial Records

The continuous in-situ water-quality monitor is disconnected from the DCP for a period of 1–3 hours while servicing the water-quality monitor for cleaning and calibration and can result in missing record. Other periods of missing record may result from equipment malfunction or vandalism. Daily maximum, minimum, and mean or median values are generated by the primary record, but are not stored in the daily values tables for partial days of record. The daily values reported in the primary record may not be accurate for the day. The actual maximum or minimum value for the day may have occurred during a period when data were missing. The record worker is responsible for verifying the validity of the daily values generated by the primary record for partial days.

Graphical analysis using Hydra is helpful to verify the accuracy of daily maximum and minimum values determined on the primary record. The record worker graphically reviews the daily values in Hydra and checks the validity of the daily value for partial days reported on the primary record.

If a value is determined to be accurate, the daily value for the partial day is manually entered in the daily values tables. If a daily value for a partial day is considered invalid, then the daily value is left blank in the database. Wagner and others (2006) describe additional publishing criteria for specific water-quality sensors.

Based on Wagner and others (2006), the KSWSC uses the following guidelines for releasing daily values for partial days of continuous water-quality monitoring record:

1. The maximum or minimum daily unit values from the primary record can be reported if they occur at their expected times and are verified to be accurate by graphic analysis for days with less than 25 percent missing values. Mean and median values may be reported if both maximum and minimum daily values are recorded, if the mean or median values appear to be reasonable for the day, and water-surface elevations are stable or minimally changing.

2. The maximum and minimum daily unit values from the primary record can be reported if they occur at their expected times and are verified to be accurate by graphic analysis for days with 25 to 50 percent missing unit values. Computed mean or median values become questionable as more daily data are missing. Mean or median values can be reported if both maximum and minimum daily values are reported, if adjacent water-quality sensor data before and after missing unit values are stable or minimally changing, and water-surface elevations are also stable or minimally changing.

3. Generally, if more than 50 percent of the unit values are missing, daily maximum and minimum values are only reported if retained data are stable for the day. This judgment is left up to the record processor. If conditions are not stable and a clear trend does not exist, daily values are not reported.

4. Daily mean or median values are not reported if the expected maximum or minimum daily value is not recorded.

5. Diel fluctuations are typical of water-quality characteristics even under stable stage conditions. Additionally, sensor data can display an opposite response to what may be expected during runoff. For example, SC values generally decline with a rise in water-surface elevations; however, there are times when SC values increase during a rise in water-surface elevations, for example in the winter because of road salt running off roads into streams. Because of the complex nature between water-quality characteristics and streamflow data, unit values or daily values are not estimated for missing or deleted water-quality monitoring data.

End-of-Year Summary

The National Water Information System computation software creates an end-of-year summary (appendix 12) of the maximum and minimum instantaneous unit values recorded by the continuous water-quality monitor for the water year (October 1 to September 30). These values are verified by the data collector as accurate. The end-of-year summary is compared to computed continuous record and hydrographs so that the maximum or minimum daily values for the year are correct. Instantaneous maximum or minimum unit values generated by the end-of-year summary may not be correct if erroneous values, such as spikes or zeroes, were not removed from the database. If the instantaneous maximum or minimum unit value cannot be reported as a valid maximum or minimum daily value for the day of occurrence, it cannot be reported as the instantaneous maximum or minimum unit value for the year. After the water year record has been approved, the KSWSC database administrator updates the section “extremes for period of daily record (WQ)” in the station manuscript (appendix 13) if the instantaneous maximum or minimum unit values from the end-of-year summary exceed historical unit values reported in the station manuscript.

Water-Quality Monitor Review

Water-quality monitor review is a Portable Document Format (PDF) viewer program initiated by the Unix command “wqmreview” in the Unix window. It is a useful tool for reviewing water-quality monitoring records. The program is intiated by typing the “wqmreview” command in the Unix window, then enter the station number, and then enter “AL” (update all monitor parameter electronic record materials) at the command line. The script takes approximately 15 minutes to run and creates graphs, primaries, unit value inventory tables, daily value tables, end-of-year summaries, Site Visit reports, and tables of laboratory results for discrete water-quality samples for only water temperature, SC, pH, turbidity, and DO readings. Upon completion of the script, updated PDF files can be viewed by KSWSC personnel at *http://swr.cr.usgs.gov.* Record workers, checkers, or reviewers are not required to use “wqmreview.” Nevertheless, the program goes beyond Hydra’s capabilities in producing various types of graphs for water temperature, SC, pH, DO, and turbidity and is more efficient than personnel trying to reproduce all the graphs and tables that the program does automatically.

Rating the Quality of Continuous Water-Quality Monitoring Records

Rating the quality of water-quality monitoring records is similar to rating streamflow records. A rating of excellent, good, fair, or poor is assigned to the record for the year or for periods of record throughout the year. Wagner and others (2006) describe criteria for the primary five sensors on a water-quality monitor (water temperature, SC, pH, turbidity, and DO) based solely on the absolute value of applied data corrections. Table 7, similar to Wagner and others (2006), also includes ratings for other water-quality sensors, such as fluorescence chlorophyll and nitrate. An automated data-quality rating program can be installed on the user's Unix window that is initiated by the Unix command in the Unix window such as:

```
dq_rating.pl nwisks 1 07144100 28 20130101 20140221        (5)
```

where

07144100	is the station identification number,
28	is the data descriptor number, and
20130101 20140221	is the date frame of the record that is to be rated.

The results of the data-quality rating are determined solely on the basis of the data correction values in ADAPS (appendix 14). In the KSWSC, rating the quality of water-quality records also includes evaluating the quantity and quality of original data, the number of applied data corrections, magnitude of data corrections, whether correct protocols for servicing the water-quality monitor were followed, amount of data deleted or missing because of fouling or equipment failure, or if maximum allowable limits were exceeded (table 3).

Turbidity and nitrate sensors can record very small values. Rating criteria and maximum allowable limits may not be appropriate for these sensors when readings are low. For example, a 0.5-unit fouling correction for in-situ readings of 10 units is 5 percent, but when in-situ readings are at 2 units, the 0.5-unit correction computes to 25 percent. A 0.5-unit correction for these sensors is not unusual and is an acceptable correction for the water-quality sensors when fouling occurs at very low values.

Station Analysis

Data analysis, data processing procedures, and computation rationale are documented for each water-quality monitoring station to provide a review basis and to serve as a reference (Rantz and others, 1982). Station analyses are written for each period of record as defined by a cleaning and calibration check service inspection. KSWSC personnel use RMS on the SIMS Web site to create an ongoing station analysis (appendix 15) to document water-quality record processing and dates when the record was worked, checked, and reviewed. Station analysis topics include water-quality monitoring equipment and sensors, missing or deleted periods of record, applied data corrections, special computations of records, and remarks. The analysis is stamped with the beginning and ending dates of the period of computed record, the record worker's name, and the date that the record was worked. After the station analysis is saved and completed in RMS by the record worker, an e-mail is sent to the assigned record checker that the record and station analysis are ready to be checked. Similarly, after the station analysis is saved and completed in RMS by the record checker, an e-mail is sent to the assigned record reviewer stating that the record and station analysis are ready

Table 7. Criteria for rating a continuous in-situ water-quality monitoring record based on the magnitude of the applied data corrections (modified from Wagner and others, 2006).

[≤, less than or equal; ±, plus or minus; %, percent; µS/cm, microsiemens per centimeter at 25 degrees Celsius; >, greater than; °C, degrees Celsius; mg/L, milligrams per liter; FNU, Formazin nephlometric units; µg/L, micrograms per liter; ppb, parts per billion; mV, millivolts]

Water-quality characteristics	Rating			
	Excellent	Good	Fair	Poor
Specific conductance	≤ ± 3% µS/cm	> ± 3 to 10% µS/cm	> ± 10 to 15% µS/cm	> ± 15% µS/cm
pH	≤ ± 0.2 standard units	> ± 0.2 to 0.5 standard units	> ± 0.5 to 0.8 standard units	> ± 0.8 standard units
Temperature	≤ ± 0.2 °C	> ± 0.2 to 0.5 °C	> ± 0.5 to 0.8 °C	> ± 0.8 °C
Dissolved oxygen (optical)	≤ ± 5% mg/L	> ± 5 to 10% mg/L	> ± 10 to 15% mg/L	> ± 15% mg/L
Turbidity	≤ ± 5% FNU	> ± 5 to 10% FNU	> ± 10 to 15% FNU	> ± 15% FNU
Fluorescence chlorophyll	≤ ± 5% µg/L	> ± 5 to 10% µg/L	> ± 10 to 15% µg/L	> ± 15% µg/L
Colored dissolved organic matter	≤ ± 5% ppb	> ± 5 to 10% ppb	> ± 10 to 15% ppb	> ± 15% ppb
Nitrate	≤ ± 5% mg/L	> ± 5 to 10% mg/L	> ± 10 to 15% mg/L	> ± 15% mg/L
Oxidation reduction potential	≤ ± 5% mV	> ± 5 to 10% mV	> ± 10 to 15% mV	> ± 15% mV

to be reviewed. An e-mail also is sent to the record worker and includes comments from the record checker about the record and the station analysis. RMS requires that each step of record work be signed off when completed. If the same person acts as the record checker and reviewer, then they will need to sign off as both.

Using RMS, a record checker or reviewer may send the record back for rework or updates prior to submitting the record for review or approval. An e-mail is sent to the record worker with the checker's or reviewer's comments. All changes and modifications are discussed with the record worker and the Supervisory/Lead Hydrologic Technician or Project Chief to resolve any disputes. The record worker keeps the station analysis current after every site inspection. The Supervisory/Lead Hydrologic Technician or Project Chief is responsible for reviewing the status of records in order to keep the record computing and the checking process current throughout the year.

Data Aging Records

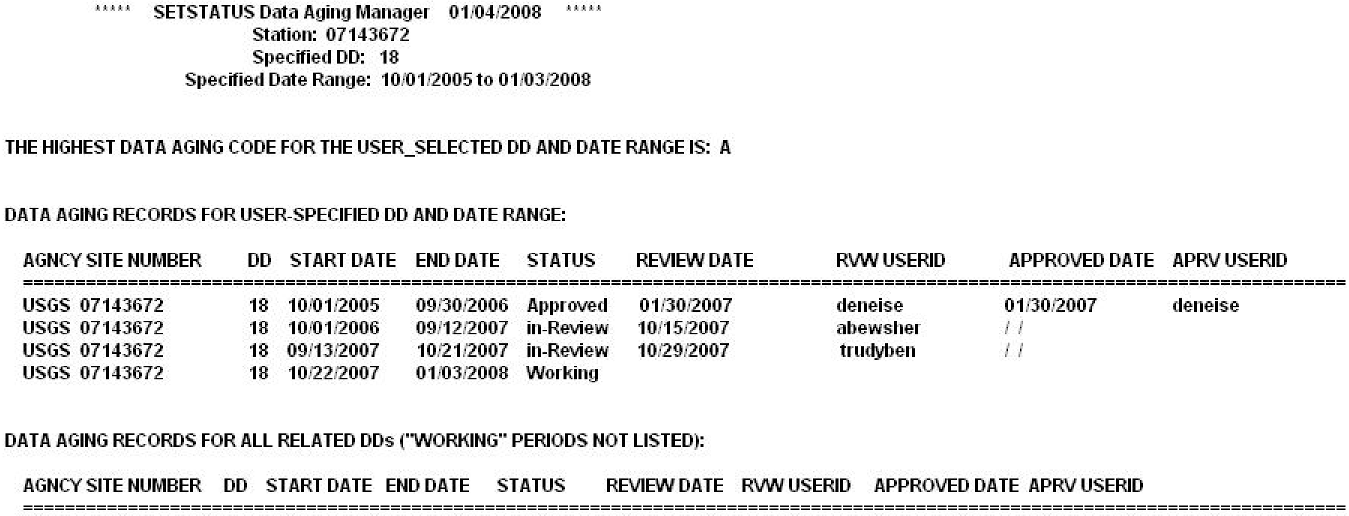
"Edited unit values" are values that can be deleted, have applied data corrections, and are processed to obtain "computed unit values." As a result of processing, computed unit values and daily values are updated in primary records, unit value tables, and daily value tables. All of these values, corrections, primaries and tables are considered "Working" records. Changes can be made to them at any time. The "Working" record is set to "in-Review" status to prevent accidental changes in the record after the water-quality monitoring record has been worked. Once the record has been finalized, the record is set to "Approved" status by the record reviewer. Figure 26 is an example of a data aging record that has various set data-aging levels.

If mistakes are found during the record checking and review process and the record needs to be reworked, the record is set from "in-Review" back to "Working" status. The record is updated as needed, reprocessed, then reset to "in-Review." However, once a record has been set to "Approved" status, only the KSWSC database administrator can set the record back to "Working" status. If this happens, any significant revised record is documented in the station analysis and the data sheet manuscript is included with the final record.

When the record has been set to "Approved" status, the last approved valid daily value for the record period for a specific water-quality sensor will be flagged in the CRP status report and the date will be noted in the report. The CRP status report is often used by supervisors, project chiefs, or other personnel to review the status of water-quality monitoring records at any time. Records in which the last approved daily value exceeds record working criteria can be examined in greater detail. The CRP status report is often used for performance evaluations.

Review of Continuous Water-Quality Monitoring Records

After a water-quality monitoring record has been worked and checked, the Supervisory/Lead Hydrologic Technician, Project Chief, or other experienced hydrographers review the record for accuracy and completeness. The goal of the review process is to ensure that proper methods were applied and documented throughout the water-quality data collection and record computation process. During the record review, emphasis is placed on checking data that were changed or corrected by the record checker. The record reviewer also may use the same steps used by the record worker for working a continuous water-quality monitor record (appendix 9) or the



```
   *****    SETSTATUS Data Aging Manager    01/04/2008    *****
                         Station:  07143672
                         Specified DD:   18
                 Specified Date Range:  10/01/2005 to 01/03/2008


THE HIGHEST DATA AGING CODE FOR THE USER_SELECTED DD AND DATE RANGE IS:  A


DATA AGING RECORDS FOR USER-SPECIFIED DD AND DATE RANGE:

  AGNCY SITE NUMBER      DD   START DATE   END DATE    STATUS      REVIEW DATE         RVW USERID        APPROVED DATE   APRV USERID
  ======================================================================================================================================
  USGS  07143672         18   10/01/2005   09/30/2006  Approved     01/30/2007         deneise           01/30/2007      deneise
  USGS  07143672         18   10/01/2006   09/12/2007  in-Review   10/15/2007          abewsher          / /
  USGS  07143672         18   09/13/2007   10/21/2007  in-Review   10/29/2007           trudyben         / /
  USGS  07143672         18   10/22/2007   01/03/2008  Working


DATA AGING RECORDS FOR ALL RELATED DDs ("WORKING" PERIODS NOT LISTED):

  AGNCY SITE NUMBER    DD   START DATE  END DATE     STATUS      REVIEW DATE   RVW USERID    APPROVED DATE  APRV USERID
  ======================================================================================================================================
```

Figure 26. Example of a data-aging table displaying the status of a specific conductance record set at various data-aging levels.

PDF viewer program “Water-Quality Monitor Review.” The record reviewer also may use a hydrographic comparison with similar water-quality monitoring stations to ensure consistency of water-quality monitoring records. Deficiencies and errors in the water-quality monitoring record are documented in RMS and may be corrected by the record reviewer after discussions with the record worker or returned to the record worker for rework. Upon approval of the record by the reviewer, the record is set to “Approved” status in ADAPS and RMS. Continuous water-quality monitoring data on the NWIS Web site will change from “Provisional” data to “Approved” data.

Archiving Water-Quality Monitoring Data

All USGS personnel are directed to preserve all original unaltered field data containing hydrologic measurements and observations (U.S. Geological Survey, 1999b). Original water-quality monitoring data include paper or electronic field notes and observations, field inspection values, and calibration notes for water-quality monitors. The NWIS database retains original transmitted DCP data from water-quality monitoring stations. EDL files downloaded from DCPs or continuous water-quality monitors may be uploaded into the NWIS database as needed to fill in missing record. However, EDL files not uploaded into the NWIS database are digitally retained for future reference in KSWSC internal station-specific folders. Files created by CHIMP to document water-quality monitoring station activities are imported into Site Visit and also are archived in KSWSC internal station-specific folders. Files created by CHIMP or a spreadsheet program to document field monitor calibrations are archived in KSWSC internal field monitor-specific folders. Handwritten logs are digitally copied and also retained in monitor-specific folders.

Release of Continuous Water-Quality Monitoring Data

In most instances, the KSWSC transmits continuous water-quality data in near real time and makes the information immediately available to the public on the USGS’s NWIS Web site (*http://waterdata.usgs.gov/nwis*), the National Real-Time Water Quality Web site (*http://nrtwq.usgs.gov/),* and the Water Quality Watch Web site (*http://waterwatch.usgs.gov/wqwatch).* Provisional continuous water-quality monitoring data are immediately released to the public on a continuous basis. Because of increasing availability and use of time-series data, the USGS established the national Continuous Records Processing policy (U.S. Geological Survey, 2010) which requires that all continuous data records including water-quality data be processed on a continuous basis. Continuous records processing is the collection, analysis, review, and approval of time-series hydrologic data. This policy requires that all category one time-series data are finalized within the National Water Information System within 150 days of collection.

Summary

Continuous water-quality measurements of specific conductance, pH, water temperature, dissolved oxygen, turbidity, fluorescence (chlorophyll and phycocyanin), solar irradiance, nitrate, colored dissolved organic matter, oxidation reduction potential, and other physical, chemical, and biological properties can be used in conjunction with discrete water-quality sampling to characterize physical and biological conditions of a body of water and to identify temporal changes in selected water-quality constituents. Water-quality sensors that are used to measure the physical, chemical, and biological properties require careful inspection, maintenance, and calibration procedures.

This report provides information and documents the policies and procedures for Kansas Water Science Center personnel in the collection of continuous water-quality monitoring data, in the servicing of continuous in-situ water-quality monitors and sensors, in the assessment of water-quality monitoring data, in the archiving of continuous water-quality monitor field notes, in the review of data on the National Water Information System Web site, and in record working and review to ensure high-quality, continuous water-quality monitoring data for use by regulators, water users, and the public.

References Cited

Anderson, C.W., 2005, Turbidity, (version 2.1): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, section 6.7; accessed May 22, 2014, at *http://water.usgs.gov/owq/FieldManual/Chapter6/6.7_contents.html*.

Johnston, M.W. and Williams, J.S., 2006, Field comparison of optical and Clark cell dissolved oxygen sensors in the Tualatin River, Oregon, 2005: U.S. Geological Survey Open-File Report 2006–1047; accessed May 19, 2014, at *http://pubs.usgs.gov/of/2006/1047/*.

Lane, S.L., and Fay, R.G., 1997, Safety in field activities: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A9, Ocober 1997; accessed May 14, 2014, at *http://water.usgs.gov/owq/Field Manual/Chap9/content.html*.

Nordstrom, D.K. and Wilde, F.D., Reduction-oxidation potential (electrode method), (version 1.2): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, section 6.5; accessed May 22, 2014, at *http://water.usgs.gov/owq/FieldManual/Chapter6/6.5_contents.html*.

Pellerin, B.A., Bergamaschi, B.A., Downing, B.D., Saraceno, J.F., Garrett, J.A., and Olsen, L.D., 2013, Optical techniques for the determination of nitrate in environmental waters—Guidelines for instrument selection, operation, deployment, maintenance, quality assurance, and data reporting: U.S. Geological Survey Techniques and Methods 1–D5, 37 p. (Also available at *http://pubs.usgs.gov/tm/01/d5/.)*

Putnam, J.E., and Hansen, C.V., 2014, Quality-assurance and data management plan for groundwater activities by the USGS in Kansas, 2014: U.S. Geological Survey Open-File Report 2014–1060, variously paged.

Radtke, D.B., Davis, J.V., and Wilde, F.D., Specific electrical conductance, (version 1.2): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, section 6.3; accessed May 22, 2014, at *http://water.usgs.gov/owq/FieldManual/Chapter6/6.3_contents.html*.

Ritz, G.F. and Collins, J.A., pH, (version 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, section 6.4; accessed May 22, 2014, at *http://water.usgs.gov/owq/FieldManual/Chapter6/6.4_contents.html*.

Rounds, S.A., Wilde, F.D., and Ritz, G.F., Dissolved oxygen, (version 3.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, section 6.2; accessed May 22, 2014, at *http://water.usgs.gov/owq/FieldManual/Chapter6/6.2_contents.html*.

Stanley, D.L., Boozer, T.M., and Schroder, L.J., 1998, Summary of the U.S. Geological Survey National Field Quality-Assurance Program from 1979 through 1997: U.S. Geological Survey Open-File Report 98–392, 11 p. (Also available at *http://pubs.water.usgs.gov/ofr98392*.)

U.S. Geological Survey, 1999a, Quality assurance measures for serving real-time water data on the World Wide Web: Water Resources Division Memorandum No. 99.34, accessed May 15, 2014, at *http://water.usgs.gov/admin/memo/policy/wrdpolicy99.34.html*.

U.S. Geological Survey, 1999b, Preservation of original digital field-recorded time-series data: Water Resources Division Memorandum No. 99.33, accessed May 15, 2014, at *http://water.usgs.gov/admin/memo/policy/wrdpolicy99.33.html*.

U.S. Geological Survey, 2010, Continuous records processing of all water time series data: Water Resources Division Policy Numbered Memorandum No. 2010.02, accessed May 15, 2014, at *http://water.usgs.gov/admin/memo/policy/wrdpolicy10.02.html*.

vanLoon, Gary, and Duffy, Stephen, 2011, Environmental chemistry—A global perspective (3d ed.): USA, Oxford University Press. p. 235–248.

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51p. (Also available at *http://pubs.usgs.gov/tm/2006/tm1D3.*)

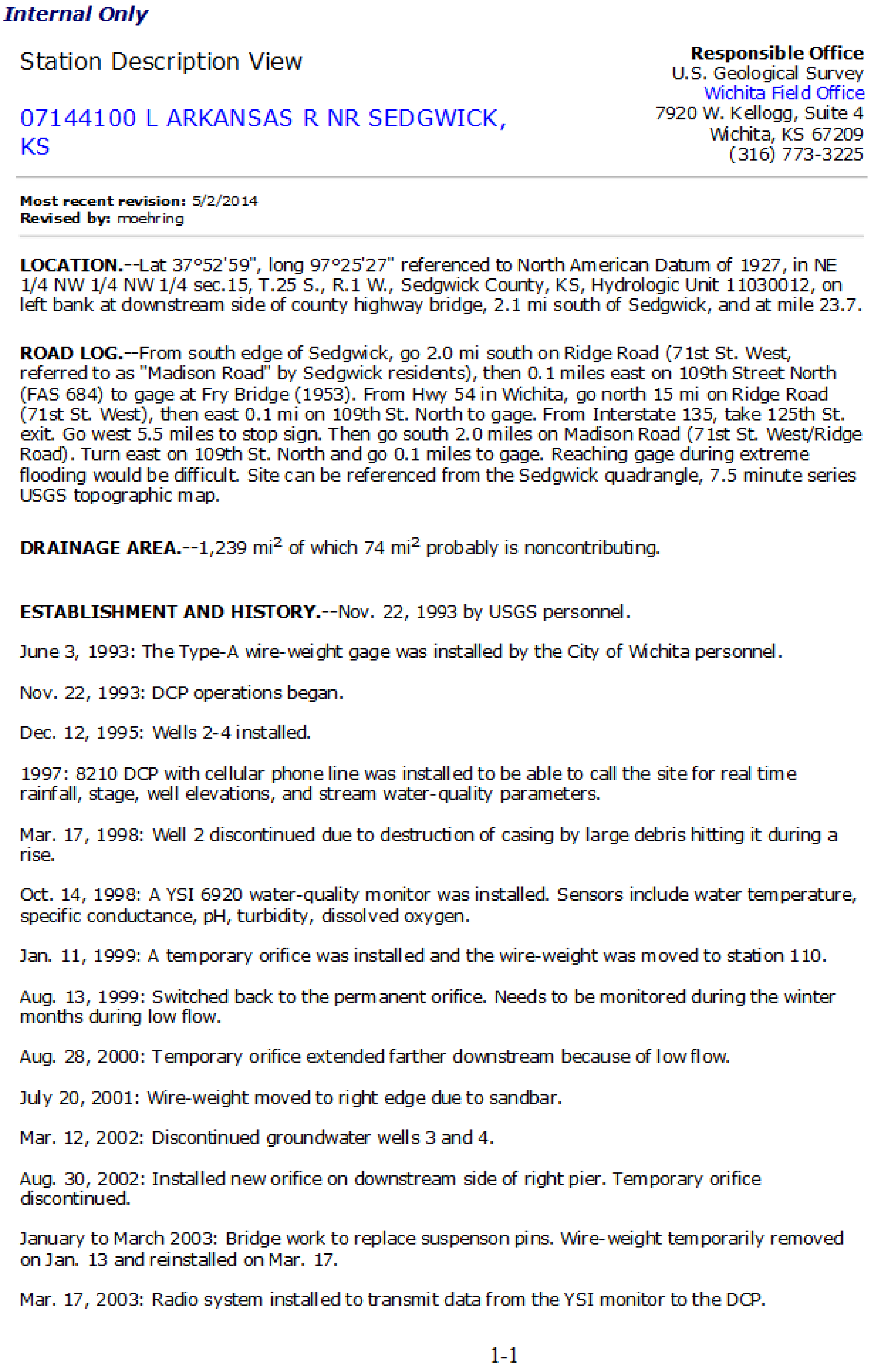
Wilde, F.D., e.d., variously dated, Field measurements: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6 with sec. 6.0–6.8, accessed May 22, 2014, at *http://water.usgs.gov/owq/FieldManual/Chapter6/Ch6_contents.html*.

Wilde, F.D., Temperature, (version 2): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, section 6.1; accessed May 22, 2014, at *http://water.usgs.gov/owq/FieldManual/Chapter6/6.1_contents.html*.

YSI, 2012, EXO User Manual Revision C: Advanced Water Quality Monitoring Platform. Yellow Springs, OH: YSI Inc., 2012. Print.

Appendixes 1–15

Appendix 1. Example of a station description for Little Arkansas River near Sedgwick, Kansas



Internal Only

Station Description View

07144100 L ARKANSAS R NR SEDGWICK, KS

Responsible Office
U.S. Geological Survey
Wichita Field Office
7920 W. Kellogg, Suite 4
Wichita, KS 67209
(316) 773-3225

Most recent revision: 5/2/2014
Revised by: moehring

LOCATION.--Lat 37°52'59", long 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, KS, Hydrologic Unit 11030012, on left bank at downstream side of county highway bridge, 2.1 mi south of Sedgwick, and at mile 23.7.

ROAD LOG.--From south edge of Sedgwick, go 2.0 mi south on Ridge Road (71st St. West, referred to as "Madison Road" by Sedgwick residents), then 0.1 miles east on 109th Street North (FAS 684) to gage at Fry Bridge (1953). From Hwy 54 in Wichita, go north 15 mi on Ridge Road (71st St. West), then east 0.1 mi on 109th St. North to gage. From Interstate 135, take 125th St. exit. Go west 5.5 miles to stop sign. Then go south 2.0 miles on Madison Road (71st St. West/Ridge Road). Turn east on 109th St. North and go 0.1 miles to gage. Reaching gage during extreme flooding would be difficult. Site can be referenced from the Sedgwick quadrangle, 7.5 minute series USGS topographic map.

DRAINAGE AREA.--1,239 mi^2 of which 74 mi^2 probably is noncontributing.

ESTABLISHMENT AND HISTORY.--Nov. 22, 1993 by USGS personnel.

June 3, 1993: The Type-A wire-weight gage was installed by the City of Wichita personnel.

Nov. 22, 1993: DCP operations began.

Dec. 12, 1995: Wells 2-4 installed.

1997: 8210 DCP with cellular phone line was installed to be able to call the site for real time rainfall, stage, well elevations, and stream water-quality parameters.

Mar. 17, 1998: Well 2 discontinued due to destruction of casing by large debris hitting it during a rise.

Oct. 14, 1998: A YSI 6920 water-quality monitor was installed. Sensors include water temperature, specific conductance, pH, turbidity, dissolved oxygen.

Jan. 11, 1999: A temporary orifice was installed and the wire-weight was moved to station 110.

Aug. 13, 1999: Switched back to the permanent orifice. Needs to be monitored during the winter months during low flow.

Aug. 28, 2000: Temporary orifice extended farther downstream because of low flow.

July 20, 2001: Wire-weight moved to right edge due to sandbar.

Mar. 12, 2002: Discontinued groundwater wells 3 and 4.

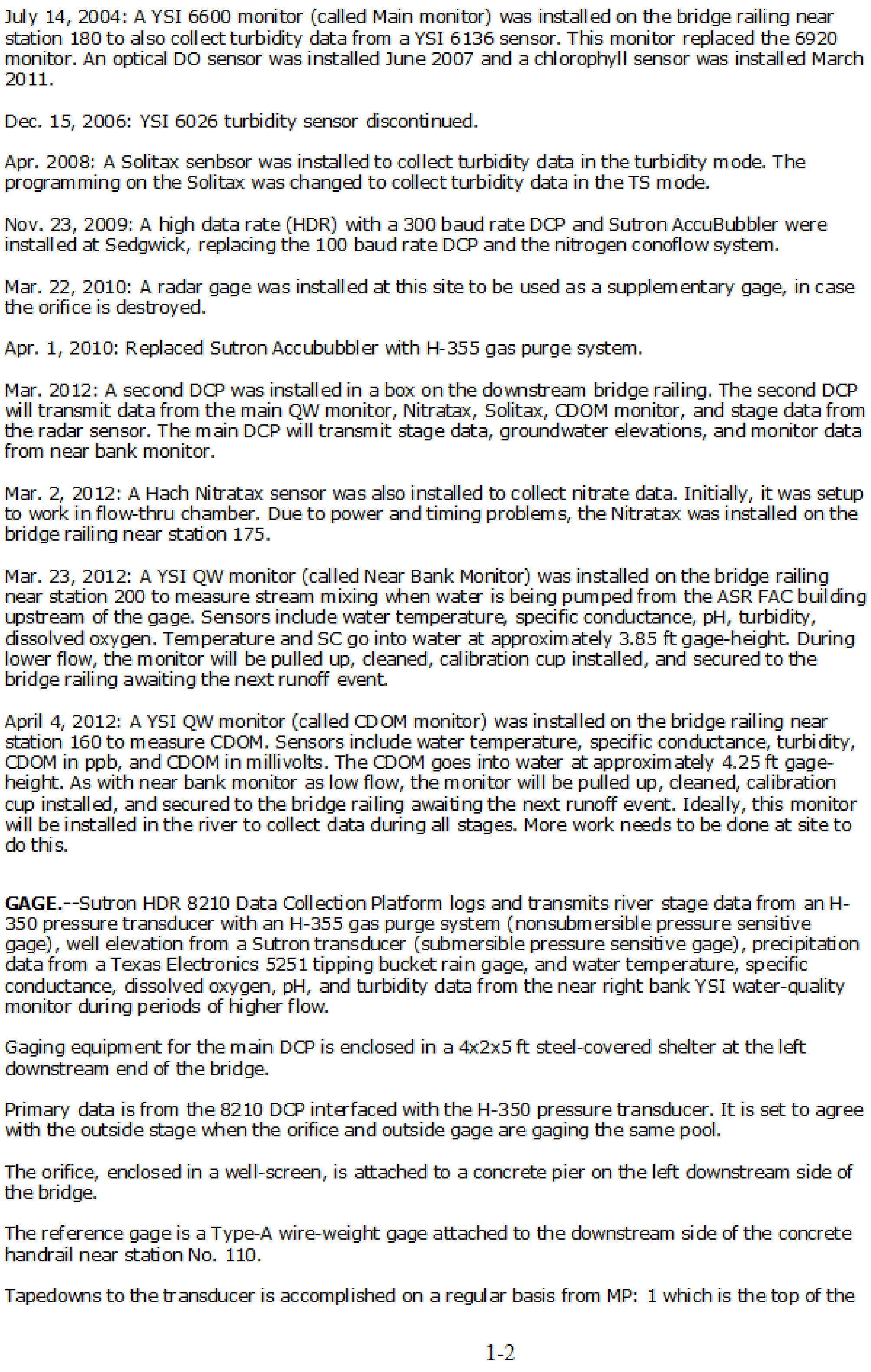
Aug. 30, 2002: Installed new orifice on downstream side of right pier. Temporary orifice discontinued.

January to March 2003: Bridge work to replace suspenson pins. Wire-weight temporarily removed on Jan. 13 and reinstalled on Mar. 17.

Mar. 17, 2003: Radio system installed to transmit data from the YSI monitor to the DCP.

1-1

Appendix 1. Example of a station description for Little Arkansas River near Sedgwick, Kansas



July 14, 2004: A YSI 6600 monitor (called Main monitor) was installed on the bridge railing near station 180 to also collect turbidity data from a YSI 6136 sensor. This monitor replaced the 6920 monitor. An optical DO sensor was installed June 2007 and a chlorophyll sensor was installed March 2011.

Dec. 15, 2006: YSI 6026 turbidity sensor discontinued.

Apr. 2008: A Solitax senbsor was installed to collect turbidity data in the turbidity mode. The programming on the Solitax was changed to collect turbidity data in the TS mode.

Nov. 23, 2009: A high data rate (HDR) with a 300 baud rate DCP and Sutron AccuBubbler were installed at Sedgwick, replacing the 100 baud rate DCP and the nitrogen conoflow system.

Mar. 22, 2010: A radar gage was installed at this site to be used as a supplementary gage, in case the orifice is destroyed.

Apr. 1, 2010: Replaced Sutron Accububbler with H-355 gas purge system.

Mar. 2012: A second DCP was installed in a box on the downstream bridge railing. The second DCP will transmit data from the main QW monitor, Nitratax, Solitax, CDOM monitor, and stage data from the radar sensor. The main DCP will transmit stage data, groundwater elevations, and monitor data from near bank monitor.

Mar. 2, 2012: A Hach Nitratax sensor was also installed to collect nitrate data. Initially, it was setup to work in flow-thru chamber. Due to power and timing problems, the Nitratax was installed on the bridge railing near station 175.

Mar. 23, 2012: A YSI QW monitor (called Near Bank Monitor) was installed on the bridge railing near station 200 to measure stream mixing when water is being pumped from the ASR FAC building upstream of the gage. Sensors include water temperature, specific conductance, pH, turbidity, dissolved oxygen. Temperature and SC go into water at approximately 3.85 ft gage-height. During lower flow, the monitor will be pulled up, cleaned, calibration cup installed, and secured to the bridge railing awaiting the next runoff event.

April 4, 2012: A YSI QW monitor (called CDOM monitor) was installed on the bridge railing near station 160 to measure CDOM. Sensors include water temperature, specific conductance, turbidity, CDOM in ppb, and CDOM in millivolts. The CDOM goes into water at approximately 4.25 ft gage-height. As with near bank monitor as low flow, the monitor will be pulled up, cleaned, calibration cup installed, and secured to the bridge railing awaiting the next runoff event. Ideally, this monitor will be installed in the river to collect data during all stages. More work needs to be done at site to do this.

GAGE.--Sutron HDR 8210 Data Collection Platform logs and transmits river stage data from an H-350 pressure transducer with an H-355 gas purge system (nonsubmersible pressure sensitive gage), well elevation from a Sutron transducer (submersible pressure sensitive gage), precipitation data from a Texas Electronics 5251 tipping bucket rain gage, and water temperature, specific conductance, dissolved oxygen, pH, and turbidity data from the near right bank YSI water-quality monitor during periods of higher flow.

Gaging equipment for the main DCP is enclosed in a 4x2x5 ft steel-covered shelter at the left downstream end of the bridge.

Primary data is from the 8210 DCP interfaced with the H-350 pressure transducer. It is set to agree with the outside stage when the orifice and outside gage are gaging the same pool.

The orifice, enclosed in a well-screen, is attached to a concrete pier on the left downstream side of the bridge.

The reference gage is a Type-A wire-weight gage attached to the downstream side of the concrete handrail near station No. 110.

Tapedowns to the transducer is accomplished on a regular basis from MP: 1 which is the top of the

Appendix 1. Example of a station description for Little Arkansas River near Sedgwick, Kansas

2" PVC well casing.

Datum of gage is 1,340.00 ft above sea level.

A 2nd DCP enclosed in a tool type box is located near 170 on the downstream side of the concrete rail houses equipment for the main YSI water-quality monitor, Hach Solitax and Nitratax sensors, CDOM monitor, and radar stage sensor. The second DCP transmit water temperature, specific conductance, dissolved oxygen, pH, turbidity, and chlorophyll from the YSI main water-quality monitor, turbidity data from the Solitax sensor, nitrate data from the Nitratax sensor, CDOM data from another YSI QW monitor, and gage-height data from the radar stage sensor. The water-quality monitors and sensors are attached to a chain/plastic coated wire on the downstream side of the bridge.

The radar gage is used as a supplementary gage, in case the orifice is destroyed. The radar gage is located near Station 190 ft on the downstream side of the concrete bridge rail.

Equipment for the right bank monitor is housed in a 2x3x1 stainless box on the downstream side of the concrete rail near Station 230. Data is transmitted from the monitor to the main DCP via a radio system.

CONTROL.--The streambed is silty sand, subject to severe shifting. The right bank is gradually sloping in the vicinity of the gage. The right bank is mostly dirt and mud and is subject to washing out during higher flow. The left bank is a levee which is considerably higher than the right bank. Trees are abundant along both banks. The narrow channel meanders upstream and downstream from bridge. At extreme high flow, the very wide, relatively flat floodplain predominates as control.

At very high flow conditions, water is diverted into the Floodway at Little Arkansas River at Valley Center, KS (07144201).

DISCHARGE MEASUREMENTS.--Wading measurements can be made in the vicinity of the gage. Higher flow is measured on the downstream side of the bridge.

FLOODS.--According to a Flood Control/City of Wichita employee, a peak of 25.90 ft occurred Oct. 1973.

On July 17, 1993 a peak of 26.28 ft occurred.

On or about Nov. 1, 1998, peak gage-height and flow was determined to be 25.8 ft from a HWM with an estimated discharge of 17,500 cfs. Water from the Little Arkansas River was out of its banks in several areas. The site was inaccessible from all roads for 3-4 days. An electrical short occurred in well 4 when the well was under water causing the gage to go down during this time.

The highest measurement made by USGS personnel at this site was Oct 10, 2003 with a gage-height of 23.60 with a measured discharge of 14,000 cfs. High-water mark at 24.3 ft, computed discharge of 15,000 cfs.

On June 9, 2010, a gage-height of 23.64 ft was recorded with a computed discharge of 15,200 cfs.

POINT OR GAGE HEIGHT OF ZERO FLOW.--About 1.91 ft gage height, Aug. 31, 2011.

WINTER FLOW.--Ice effect may be moderate during cold periods.

REGULATION AND DIVERSIONS.--Natural flow of stream affected by ground-water withdrawals, diversions for irrigation, and return flow from irrigated areas.

ACCURACY.--Records should be good.

COOPERATION.--City of Wichita and Groundwater Management District No. 2, Halstead.

REFERENCE MARKS.--RM-1: Bronze tablet set in concrete hubguard on left upstream wingwall

Appendix 1. Example of a station description for Little Arkansas River near Sedgwick, Kansas

stamped 1371.55 by City of Wichita. Elevation 31.550 ft, gage datum. Use as base.

RM-2: Top of 3/8" bolt in phillips shell on right downstream wingwall. Elevation 31.358 ft, gage datum.

C.B.: Wire-weight check-bar. Elevation 33.606 ft, gage datum.

MP-1: Top of PVC inside protective well casing at well #1 (Sedgwick Well), located directly behind the gagehouse. Elevation 30.356 ft, gage datum.

MP-6: 3/8 inch bolt in left pier on west side. Elevation 13.566 ft, gage datum. Upper CSI.

MP-7: 3/8 inch bolt in pier that has orifice attached to it. Elevation 6.435 ft, gage datum. Lower CSI.

Sta. No. 110: Elevation 34.338 ft, gage datum. Sta. No. 250: Elevation 34.568 ft, gage datum.

DESTROYED REFERENCE AND BENCH MARKS:

MP-2: The top of the inside PVC well casing at well #2 (EB-142-A1). Elevation 11.138 ft, gage datum. Protective casing and pvc well casing destroyed due to a floating tree hitting them on or about Mar. 17, 1998. Well discontinued.

Well 5 was destroyed by Burns and McDonald and replaced with nearby Index Well-34.

MP-3: The top of the inside PVC well casing at well #3 (EB-142-A2). Elevation 15.173 ft, gage datum. (Well discontiued.)

MP-4: The top of the inside PVC well casing at well #4 (EB-142-A3). Elevation 23.651 ft, gage datum. (Well discontinued.)

MP-5: The top of the inside PVC well casing at well #5 (EB-142-A4). Elevation 25.921 ft, gage datum. (Well destroyed.)

RM-4: A painted mark on left downstream bridge abutment, directly below the bridge gap at station 0. Elevation 26.717 ft, gage datum.

WATER QUALITY.--
QW MONITORS.--A YSI 6600 monitor (called Main monitor) is attached to a plastic coated cable located at Station 180 on the downstream side of the bridge. The monitor collects water temperature, SC, pH, DO, DO% saturation, turbidity and chlorophyll data.

Throughout the year, the monitor may have to be moved, lowered, or raised based on the flow conditions and sand shifting in the channel.

If monitor can no longer be lowered and streamflow is insufficient to cover the sensors, then the monitor should be removed from the site.

A 2nd YSI QW monitor (called CDOM monitor) is attached to a plastic coated cable located at Station 173 on the downstream side of the bridge. The monitor collects CDOM data in ppb and in millivolts.

A Hach Nitratax sensor is attached to a plastic coated cable (enclosed in blue and white tubing) located at Station 176 on the downstream side of the bridge. The Nitratax sensor collects nitrate data in the NO3 operating mode.

A Hach Solitax sensor is attached to a plastic coated cable (enclosed in black tubing) located at Station 183 on the downstream side of the bridge. The Solitax sensor collects turbidity data in the TS operating mode.

A 3rd YSI QW monitor (called Near Bank Monitor) is installed on the downstream bridge railing near station 200. The monitor collects water temperature, SC, pH, turbidity, and dissolved oxygen data. The monitor is lowered into the river during periods of high flows. During low flow, the monitor is

pulled up, cleaned, calibration cup installed, and secured to the bridge railing waiting for the next runoff event.

QW SAMPLING.--During high flow,discrete water-quality samples are collected from the downstream side of the bridge when the river is too deep to wade.

During medium flow,sampling is done approximately 20-30 ft upstream of the gage.

During low flow, sampling is done approximately 30-50 ft downstream of the gage.

Grab samples, generally for IMA grabs, are collected from the bridge near the centroid using a weighted basket.

DATE OF LAST LEVELS.--
Last run: May 02, 2014; Next run: May 01, 2017; Frequency: 3 years; Status: OPEN

No Remarks

back to top

U.S. Geological Survey Intranet
URL: http://sims.water.usgs.gov/SIMSClassic/
Page Contact Information: GS-W_Help_SIMS@usgs.gov
Page Last Updated: August 28, 2013

Appendix 2. Example of a Job Hazard Analysis for Little Arkansas River near Sedgwick, Kansas

Site Specific Job Hazard Analyses
Surface Water Discharge, Ground Water Elevations, and Water Quality Site

Station Name: Little Arkansas River nr Sedgwick, KS **Station Number:** 07144100

Maximum Wading Stage: **About 5 ft.** Subject to Change

Most Used Cross-Section: Downstream about 20-100 ft. A PFD must be worn if depth exceeds 1.0 ft. in any portion of the channel traveled by the employee, if the stream bottom isn't visible to the employee, if the channel bank and/or stream bottom is slippery or of uneven material, if ice is present on the stream, or if the conditions of the channel are unknown.

Streambed Characteristics Soft shifting sand.

Bridge Measurements and QW activity: Low volume traffic, personnel are visible to traffic. Refer to traffic Plan Diagram 3 (MUTCD TA 1).
Large farm implements use this road in the spring and fall.

Potential Unsafe Condition

The following is a list of Potential Hazards relative to this specific site:

Bridge stations: Avoid station 170 ± 10 ft as debris tends to accumulate around pier. Debris will not be seen during high flow.

Scour of the channel: Test the bottom with the wading rod as sand can get quite soft. Proceed across slowly. Use the same path once a good section is established.

Ice Measurements: Ice rarely covers across the whole cross section, but thin shore ice can develop along the banks. ***Two workers must be present during ice measurements.***

Insects: It is common for ants and spiders to be present in the gage house. Ticks and mosquitoes will be found in tall grass around the gage house and down the path to the river.

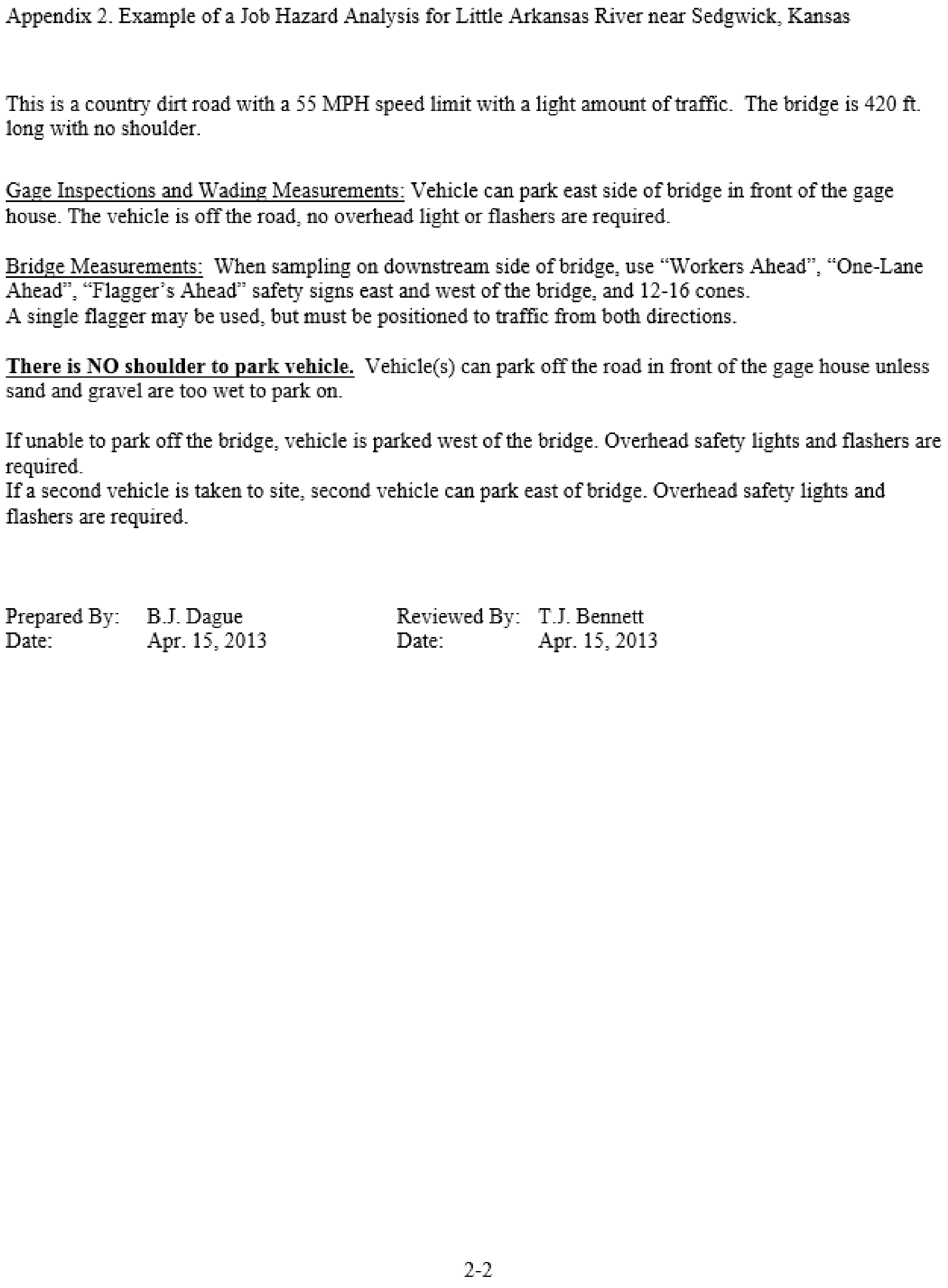
Gage Cleaning: Follow NE Hantavirus gage cleaning protocols for personal protection associated with rodents.

QW Processing: Keep electrical connections from getting wet. Be careful with generator and gasoline.
Wear gloves and eye protection as required for sampling and using acids.

Sheriff Sedgwick County
141 West Elm St.
Wichita, KS 67203
316-383-7264

Wesley West Emergency Center
8714 West 13th St. N.
Wichita, KS 67214
316-962-9900

Hospital Directions: Travel south on Ridge Road to 13th St. in Wichita. Go west on 13th St. to Tyler St., then north on Tyler about ½ block to the emergency entrance of Wesley Medical Center.



Appendix 2. Example of a Job Hazard Analysis for Little Arkansas River near Sedgwick, Kansas

This is a country dirt road with a 55 MPH speed limit with a light amount of traffic. The bridge is 420 ft. long with no shoulder.

Gage Inspections and Wading Measurements: Vehicle can park east side of bridge in front of the gage house. The vehicle is off the road, no overhead light or flashers are required.

Bridge Measurements: When sampling on downstream side of bridge, use “Workers Ahead”, “One-Lane Ahead”, “Flagger’s Ahead” safety signs east and west of the bridge, and 12-16 cones.
A single flagger may be used, but must be positioned to traffic from both directions.

There is NO shoulder to park vehicle. Vehicle(s) can park off the road in front of the gage house unless sand and gravel are too wet to park on.

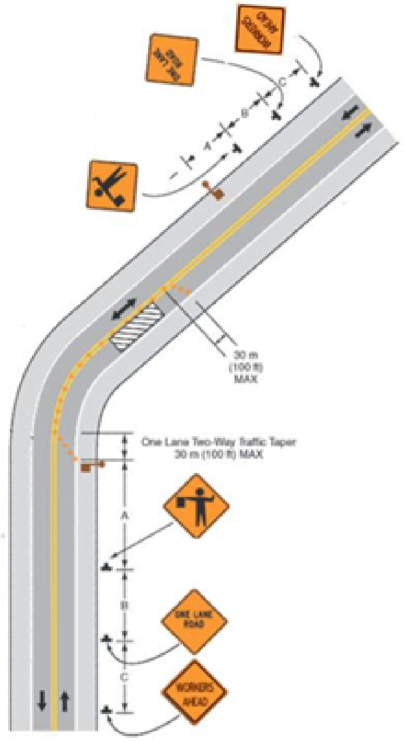
If unable to park off the bridge, vehicle is parked west of the bridge. Overhead safety lights and flashers are required.
If a second vehicle is taken to site, second vehicle can park east of bridge. Overhead safety lights and flashers are required.

Prepared By: B.J. Dague
Date: Apr. 15, 2013

Reviewed By: T.J. Bennett
Date: Apr. 15, 2013

Appendix 2. Example of a Job Hazard Analysis for Little Arkansas River near Sedgwick, Kansas

Diagram 3 (MUTCD TA 10)



Cleaning and calibration protocols for a continuous *in-situ* water-quality monitor

Before and after cleaning readings

1. Perform calibration checks and recalibrate water-quality sensors (if needed) on a field water-quality monitor (field monitor) in the office.
2. At the water-quality monitoring station, rinse the sensors on the field monitor with native water before placing it in the stream or reservoir. This will remove residual standards from the sensors.
3. Place the field monitor in the stream or reservoir as close to the continuous *in-situ* water-quality monitor as possible. After both units have sufficiently equilibrated, record "before Cleaning" readings from both the *in-situ* monitor and the field monitor. Readings from both units should be within 5 minutes of each other.
4. After cleaning the *in-situ* monitor and sensors, place the *in-situ* monitor back in the stream and record "after cleaning" readings from both the *in-situ* monitor and the field monitor once the water-quality monitor has equilibrated. Upon completion of field readings, disconnect the *in-situ* monitor and secure the end of the cable so that it won't get dirty or wet.
5. If calibration checks are scheduled for the *in-situ* monitor, do an in-depth cleaning on the *in-situ* water-quality monitor and sensors before performing calibration checks. Be careful about getting anything more than a gentle detergent on the optical (luminescent) DO sensor. Use lint free or soft wipes. Do not use abrasive cleaners, harsh detergents or chemicals, such as hydrochloric acid or alcohol. For other optical sensors, such as the turbidity sensor, also use lint free or soft wipes. Do not use abrasive cleaners that may scratch the sensor window.

6. Stop the current log file and download the logged data from the continuous water-quality monitor. Remove the battery port cover and clean off fine sediment accumulated on the battery cap and O-rings. Replace batteries with new "like" batteries. Do not mix batteries from different manufacturers. Replace the battery port cover and start a new log file.

Specific conductance sensor calibration check

1. Record pre-calibration check readings from two or three standards before recalibrating the sensor. The highest and lowest SC standards need to bracket the range of recorded readings from the last time the SC sensor was checked. A third mid-point check, if used, will check the linearity of the sensor.
2. After all checks have been completed, if any standard is off more than 3%, recalibrate the SC sensor. Calibrate the sensor to the highest standard and check only with one or two lower value standards.

pH sensor calibration check

1. Record pre-calibration check readings from 7 and 10 pH buffers (4 buffer if needed) before recalibrating the sensor.
2. After all checks have been completed, if either the 7 or 10 buffer is off more than 0.2 units, recalibrate the pH sensor. Recalibrate the sensor using the 2-point method with 7 buffer always as the first calibration point and 10 buffer as the second calibration point. Check only with 4 buffer if needed.

Turbidity sensor calibration check

1. Remove the wiper unit from the turbidity sensor and replace the old dirty pad with a new clean pad. Clean the tip of the optical window with a soft alcohol wipe and reinstall the wiper unit on the turbidity sensor. It is critical that a new clean wiper pad is used when performing calibration checks. A dirty pad will result in erroneous checks readings.
2. Record pre-calibration check readings from two or three turbidity standards (avoid direct sunlight) before recalibrating the sensor. Use fresh deionized water (DI) for the 0-point standard and one or two other known standards. If the 0 standard is off more than 2 FNUs, recheck the sensor with fresh DI water.
    - Do not rush this procedure. The "clean optics" command needs to be activated with each standard change to remove bubbles. After the cleaning cycle is complete, allow sufficient time (15-20 seconds) for readings to change. Readings will NOT change instantaneously after the cleaning cycle is complete.
3. After all checks have been completed, if the 0 standard is still off more than 2 FNUs or if the second or third standard is off more than 5%, recalibrate the turbidity sensor (avoid direct sunlight). Calibrate low to high, using the 2- or 3- point method. The 0 FNU standard is always the first calibration point when calibrating a turbidity sensor.
    - Again, do not rush this procedure. The "clean optics" command needs to be activated with each standard change to remove bubbles. After the cleaning cycle is complete, allow sufficient time (15-20 seconds) for readings to change. Readings will NOT change instantaneously after the cleaning cycle is complete.

Appendix 3. Cleaning and calibration protocols for a continuous *in-situ* water-quality monitor

Optical dissolved oxygen sensor calibration check

1. Remove the wiper unit from the optical DO sensor and replace the old dirty pad with a new clean pad. Clean the tip of the optical window with a soft wipe and mild detergent. Reinstall the wiper unit on the DO sensor.
2. Prepare the DO sensor for a calibration check using the air-saturated water method with the portable pump and air stone or the water-saturated air method using a wet towel (referred to as the "wet towel" method).
3. With the water-quality monitor inverted, fill the calibration cup full of water so that the DO and water temperature sensors are completely covered with water. Set the air stone in the bottom of the calibration cup and set the lid on top of the calibration cup to prevent the hose and stone from slipping out of the cup. Run the air system 10-15 minutes looking for stabilization of DO values.
4. If the "wet towel" method is used for calibration checks, remove the wiper unit from the DO sensor and gently tap dry the sensors and monitor guard. Install the monitor guard on the monitor and wrap a wet medium thickness terry cloth towel around the guard. Place the wrapped end of the monitor in a plastic bag to increase a water-saturated air environment and sit in a shaded area. If air temperatures are extremely hot, the unit is placed in a cooler with cooler water in the bottom of the cooler. Set in shaded area. Let the monitor set 10-15 minutes looking for stabilization of DO values.
5. Record a pre-calibration check value for the DO sensor before recalibrating the sensor. If the sensor if off more than the greater of 0.3 units or 5 percent from the DO saturation table chart, recalibrate the sensor. Replace the wiper unit if it was removed for the calibration check.

- If the optical DO sensor was removed from a low DO or zero DO environment, do NOT recalibrate the sensor, especially if the calibration check reading is off quite a bit. A DO sensor exchange may be needed instead of recalibrating the sensor. If a DO sensor exchange is done, allow the exchanged DO sensor to sit in tap water for a day to equilibrate to normal pressure before performing a calibration check.

Fluorescence chlorophyll sensor calibration check

1. Remove the wiper unit from the chlorophyll sensor and replace the pad with a new clean pad. Clean the tip of the optical window with a soft alcohol wipe and reinstall the wiper unit on the turbidity sensor. It is critical that a new clean wiper pad is used when performing calibration checks. A dirty pad will result in erroneous checks readings.
2. Record pre-calibration check readings from two chlorophyll standards (avoid direct sunlight) before recalibrating the sensor. Use fresh DI for the 0-point standard and one other prepared standard of known value. If the 0 standard is off more than 2 units, recheck with fresh DI water.
    - Do not rush this procedure. The “clean optics” command needs to be activated with each standard change to remove bubbles. After the cleaning cycle is complete, allow sufficient time (15-20 seconds) for readings to change. Readings will NOT change instantaneously after the cleaning cycle is complete.
3. After all checks have been completed, if the 0 standard is still off more than 2 units or if the second standard is off more than 5%, recalibrate the chlorophyll sensor (avoid direct sunlight). Calibrate low to high, using the 2-point method with the 0 standard always being the first calibration point.

- Again, do not rush this procedure. The "clean optics" command needs to be activated with each standard change to remove bubbles. After the cleaning cycle is complete, allow sufficient time (15-20 seconds) for readings to change. Readings will NOT change instantaneously after the cleaning cycle is complete.

Final readings

1. Rinse all sensors on the continuous *in-situ* monitor extremely well with native water. This will remove residual standard from the sensors.
2. Reconnect the *in-situ* monitor correctly to the monitor's field cable making sure the cable is tightly screwed into the monitor as recommendation by the manufacturer. Redeploy the *in-situ* monitor back into the stream or reservoir. Record "final readings" from both the *in-situ* monitor and field monitor after both instruments have sufficiently equilibrated to current environmental conditions.

Cleaning and calibration protocols for a continuous *in-situ* water-quality monitor in a well

The protocols for cleaning and servicing a continuous water-quality monitor installed in a groundwater well are slightly different than the protocols for a stream or reservoir. Two major differences are discussed here. The first major difference is the construction of the well. Many wells monitored by the KSWSC are 2 inch diameter wells. A field water-quality monitor, even the smaller diameter water-quality monitors used for wells, cannot be placed in the well while the continuous *in-situ* water-quality monitor is still located in the well. The 2 inch diameter space is not large enough for the continuous *in-situ* monitor, the field monitor, and both monitor field cables. Therefore, a field monitor is not used to obtain field readings.

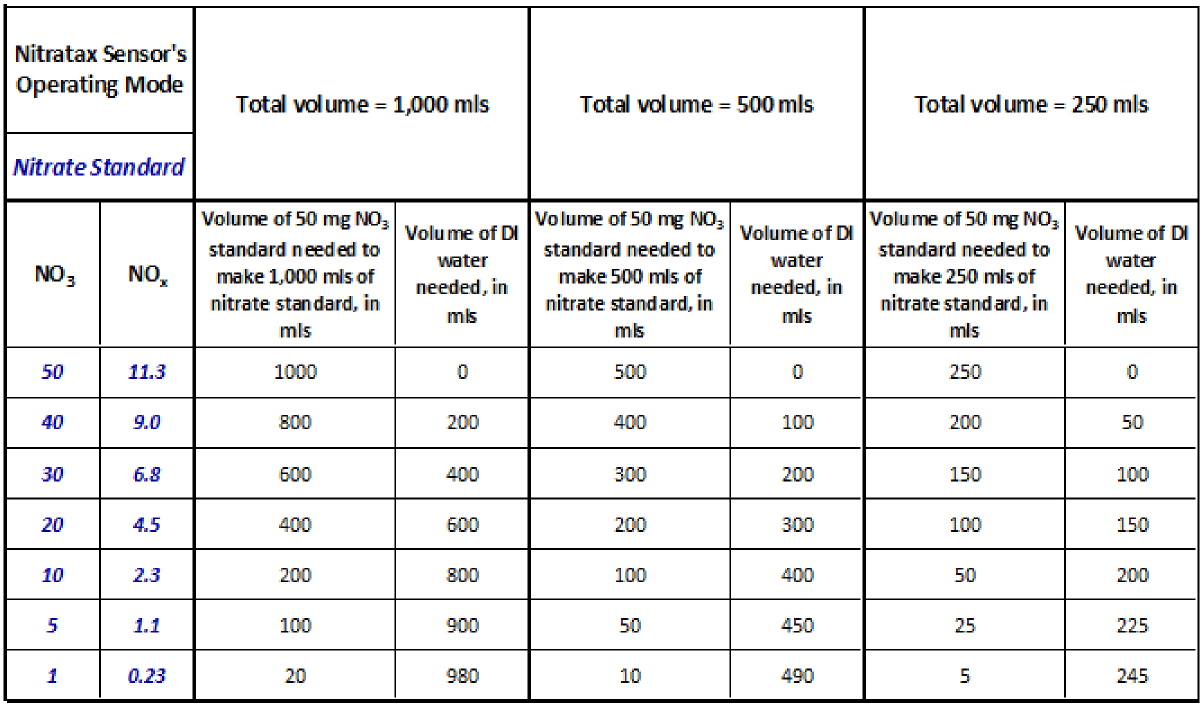
The second major difference results when the continuous *in-situ* water-quality monitor is removed from the well. The fresher well water near the well screen is mixed up with the older stagnant water in the upper sections of the well. Due to the mixing, initial "before cleaning" readings will not agree with "after cleaning" readings. Therefore, "after cleaning" readings are not obtained. "Final readings" are recorded to verify that the continuous *in-situ* monitor is working when reinstalled in a well.

The protocols for cleaning the monitor and sensors, stopping and starting log files, performing calibration checks, and recalibrating sensors are the same as noted in the previous sections, except for the luminescent DO sensor. Deep wells and some shallow wells have little to no DO in the water. As a general rule, the KSWSC does a DO sensor exchange when servicing an *in-situ* monitor in a well. A luminescent DO sensor is prepared one to two days before the planned site visit. At the water-quality monitoring station, the older DO sensor is removed and tagged with information from the monitoring station and water-quality monitor it was removed. The newly prepared DO sensor is installed on the continuous *in-situ* monitor and recalibrated.

The exchanged DO sensor is brought back to the office and set in tap water for at least one day to equilibrate back to normal pressure. After the DO sensor has equilibrated back to normal pressure, the sensor is installed on a water-quality monitor in the office and a calibration check is performed on the DO sensor. Results are recorded in the existing CHIMP file created the day of the site visit. The DO sensor is then prepared for another well or stored properly for future use.

The ability to remove an optical DO sensor from one water-quality monitor, install it on another "like" water-quality monitor, perform a calibration check, and obtain a valid and accurate reading is a result of “smart sensor” technology (YSI, 2012). Calibration information for the optical DO sensor is stored internally in the DO sensor’s software rather than on the water-quality monitor’s software.

Appendix 4. Dilution chart for making nitrate standards for a Hach Nitratax nitrate sensor



Nitratax Sensor's Operating Mode *Nitrate Standard*		Total volume = 1,000 mls		Total volume = 500 mls		Total volume = 250 mls	
NO_3	NO_x	Volume of 50 mg NO_3 standard needed to make 1,000 mls of nitrate standard, in mls	Volume of DI water needed, in mls	Volume of 50 mg NO_3 standard needed to make 500 mls of nitrate standard, in mls	Volume of DI water needed, in mls	Volume of 50 mg NO_3 standard needed to make 250 mls of nitrate standard, in mls	Volume of DI water needed, in mls
50	*11.3*	1000	0	500	0	250	0
40	*9.0*	800	200	400	100	200	50
30	*6.8*	600	400	300	200	150	100
20	*4.5*	400	600	200	300	100	150
10	*2.3*	200	800	100	400	50	200
5	*1.1*	100	900	50	450	25	225
1	*0.23*	20	980	10	490	5	245

Equipment troubleshooting

This appendix is meant to briefly discuss a few of the common problems associated with YSI water-quality monitors, which are predominantly used in the Kansas Water Science Center. It also discusses potential problems associated with DCPs and radios to transmit data. This appendix is by no means a replacement for the manufacturer's operating guidelines. Additional troubleshooting problems are referred to as well as consulting the manufacturer's technicians for unresolved problems.

Temperature/Specific conductance sensors

Typically these sensors perform with relative consistency. Rapid declines or jumpy SC values generally are associated with either sediment or bio-fouling inside of the openings of the conductivity sensor. Cleaning these openings with small brushes or a pipe cleaner will usually remove sediment or bio-fouling.

pH sensors

pH sensors generally perform with few problems. It is important to take extreme caution when cleaning the pH sensor so as not to break the glass bulb. Bio-fouling on the bulb can result in abnormally low values and can be fixed by careful cleaning or rinsing with water.

Optical dissolved oxygen sensors

Unlike the older Clark cell DO sensors, calibration drift on optical (luminescent) DO sensors are minimal. Most luminescent DO sensors or water-quality monitors are equipped with a wiping mechanism that will activate just before a reading and will wipe of bio-matter off the window of the DO sensor. Bio-fouling still can occur during periods of high algal accumulation or when cleaning visits are extended too long. The window of the sensor accumulates too much bio-matter for the wiper pad to keep the window of the DO sensor clean. When servicing the sensor, replace the wiper pad and gently wipe the DO membrane assembly with a lint free or soft wipe and mild soapy water. Do not use harsh detergents or chemicals, such as hydrochloric acid or alcohol.

The DO membrane assembly generally needs replaced once a year. Some membrane assemblies last longer, while others may not even last a year due to aging of the luminescent window or removal of the luminescent window by sand particles in the stream. Routine calibration checks are recommended. If calibration drift is noted during each check, requiring recalibration of the sensor each visit, then the luminescent DO sensor is exchanged with another DO sensor.

The membrane assembly can be replaced by field personnel or sent to the manufacturer, which is the preferred method. The service technicians will look at other items on the sensor that may need serviced, such as the O-rings. Depending on the manufacturer, a new DO membrane assembly may need to have updates made to the water-quality monitor’s programming. The data collector needs to be aware of all programming updates when a new membrane is installed on the DO sensor. All servicing needs are documented in CHIMP or the spreadsheet program.

Turbidity sensors

Turbidity sensors use a wiper mechanism to clean sediment or bio-matter from the sensor’s optical window. If the turbidity sensor does not properly locate the wiper, erroneous readings are collected and transmitted in real time. When operating properly, the wiper parks 180 degrees from the optical window. Mud or bioaccumulation on the wiper itself can lead to improper parking, which will affect sensor readings. The wiper may get in the way of the optical window, causing artificially high and erratic readings. The optical window also needs about an inch of water to collect accurate readings. Dirt accumulation in the bottom of the water-quality monitor’s sensor guard can be read by the optic, generating artificially high readings. Cleaning the guard and making sure the water-quality monitor is not located too near bed sediment are good solutions to this problem.

Fluorescence sensors

Fluorescence sensors use the same wiping mechanism as turbidity sensors. Making sure that the fluorescent wiper and pad are clean and recognizable by the optical window is of utmost importance. All problems associated with the turbidity sensor also apply to fluorescence sensors.

The fluorescence red dye solution used for calibration has been found to degrade in higher air temperatures. Thus taking the calibration solution to the water-quality monitoring station in a cooler with ice provides more accurate readings during calibration checks.

Continuous water-quality monitor deployment

Continuous *in-situ* water-quality monitors are deployed in surface water, reservoirs, or wells. With any installation, the SC sensor is used as an indication that the water-quality monitor is in or out of the water. If SC values decreases to zero, the water-quality monitor is out of the water. In surface water or reservoirs environments, turbidity readings that are extremely high or erratic are an indication that the water-quality monitor is either located too close to the water surface where too much natural light interferes with readings or too near the streambed or bottom of the reservoir where sand, sediment, or silt also interferes with turbidity readings. The turbidity sensor's wiper is activated allowing for all wipers on optical sensors to complete their rotations before observing values.

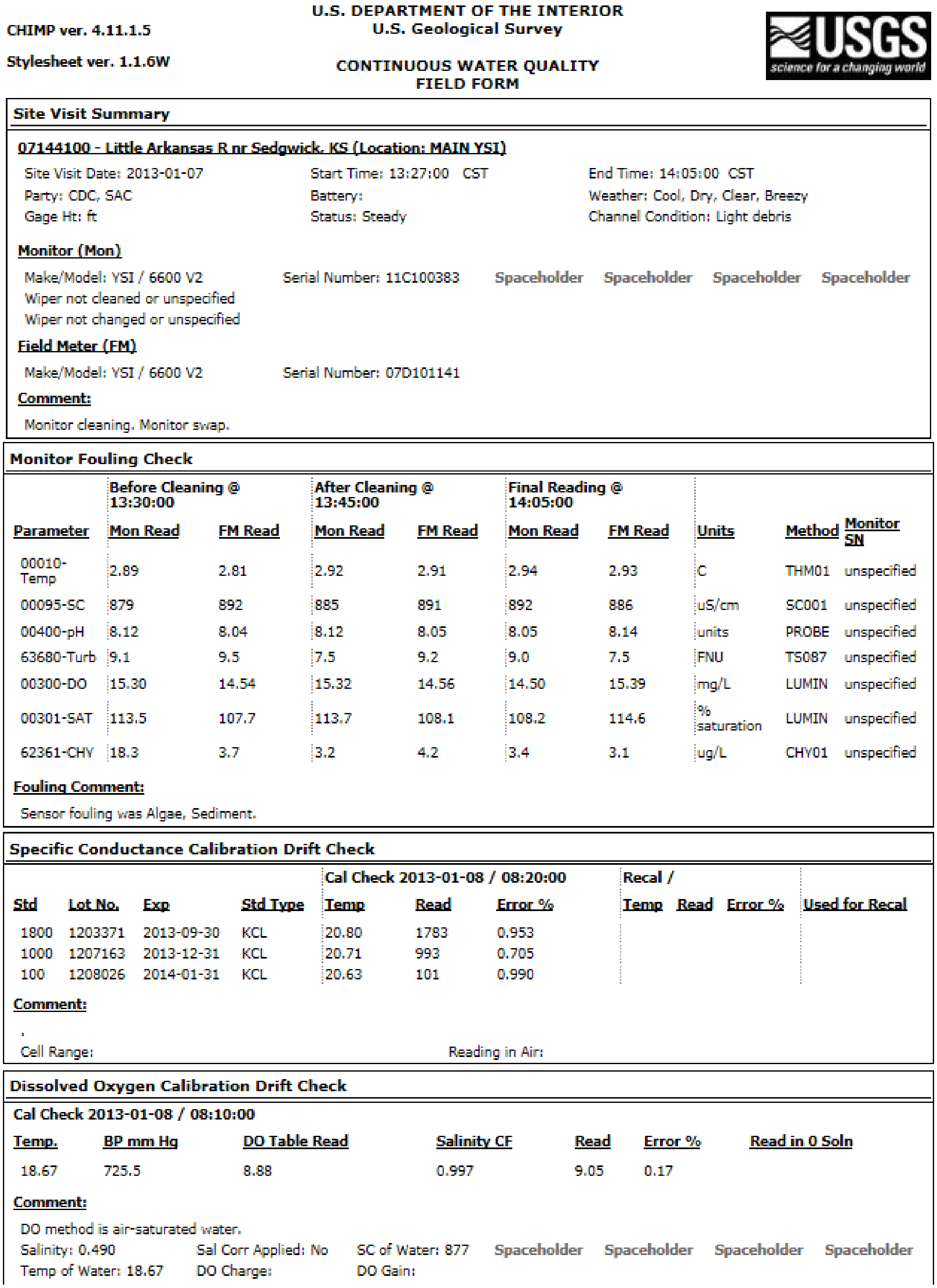
Radio/Data Collection Platform operation

For specific problems with radios or the DCP, refer to their respective operation manuals. When a water-quality monitor is installed, the standard data interface address is programmed correctly in the

DCP, the water-quality monitor, and the “master” radio. Consult the DCP manual to setup the platform specific to the instruments installed at the water-quality monitoring station.

The following is a general guide to fixing a water-quality monitoring station that was previously set up correctly, but has stopped transmitting. Ensure that the continuous *in-situ* water-quality monitor is communicating with the water-quality monitor handheld reader. Check the “slave” radio to make sure that the light emitting diode (LED) is oscillating on and off roughly every 15 seconds. If the “slave” radio is correctly interacting with the “master” radio, the LED light should remain on for the programmed activity time during each scheduled measurement. If both radios and the water-quality monitor are working correctly, check the DCP’s battery voltage, the “slave” radio’s battery voltage, and all wire connections.

Appendix 6. Example of a continuous in-situ water-quality monitor field form



CHIMP ver. 4.11.1.5

Stylesheet ver. 1.1.6W

U.S. DEPARTMENT OF THE INTERIOR
U.S. Geological Survey

CONTINUOUS WATER QUALITY
FIELD FORM

Site Visit Summary

07144100 - Little Arkansas R nr Sedgwick, KS (Location: MAIN YSI)

Site Visit Date: 2013-01-07	Start Time: 13:27:00 CST	End Time: 14:05:00 CST
Party: CDC, SAC	Battery:	Weather: Cool, Dry, Clear, Breezy
Gage Ht: ft	Status: Steady	Channel Condition: Light debris

Monitor (Mon)

Make/Model: YSI / 6600 V2 Serial Number: 11C100383 Spaceholder Spaceholder Spaceholder Spaceholder
Wiper not cleaned or unspecified
Wiper not changed or unspecified

Field Meter (FM)

Make/Model: YSI / 6600 V2 Serial Number: 07D101141

Comment:

Monitor cleaning. Monitor swap.

Monitor Fouling Check

	Before Cleaning @ 13:30:00		After Cleaning @ 13:45:00		Final Reading @ 14:05:00				
Parameter	**Mon Read**	**FM Read**	**Mon Read**	**FM Read**	**Mon Read**	**FM Read**	**Units**	**Method**	**Monitor SN**
00010-Temp	2.89	2.81	2.92	2.91	2.94	2.93	C	THM01	unspecified
00095-SC	879	892	885	891	892	886	uS/cm	SC001	unspecified
00400-pH	8.12	8.04	8.12	8.05	8.05	8.14	units	PROBE	unspecified
63680-Turb	9.1	9.5	7.5	9.2	9.0	7.5	FNU	TS087	unspecified
00300-DO	15.30	14.54	15.32	14.56	14.50	15.39	mg/L	LUMIN	unspecified
00301-SAT	113.5	107.7	113.7	108.1	108.2	114.6	% saturation	LUMIN	unspecified
62361-CHY	18.3	3.7	3.2	4.2	3.4	3.1	ug/L	CHY01	unspecified

Fouling Comment:

Sensor fouling was Algae, Sediment.

Specific Conductance Calibration Drift Check

				Cal Check 2013-01-08 / 08:20:00			Recal /			
Std	**Lot No.**	**Exp**	**Std Type**	**Temp**	**Read**	**Error %**	**Temp**	**Read**	**Error %**	**Used for Recal**
1800	1203371	2013-09-30	KCL	20.80	1783	0.953				
1000	1207163	2013-12-31	KCL	20.71	993	0.705				
100	1208026	2014-01-31	KCL	20.63	101	0.990				

Comment:

.

Cell Range: Reading in Air:

Dissolved Oxygen Calibration Drift Check

Cal Check 2013-01-08 / 08:10:00

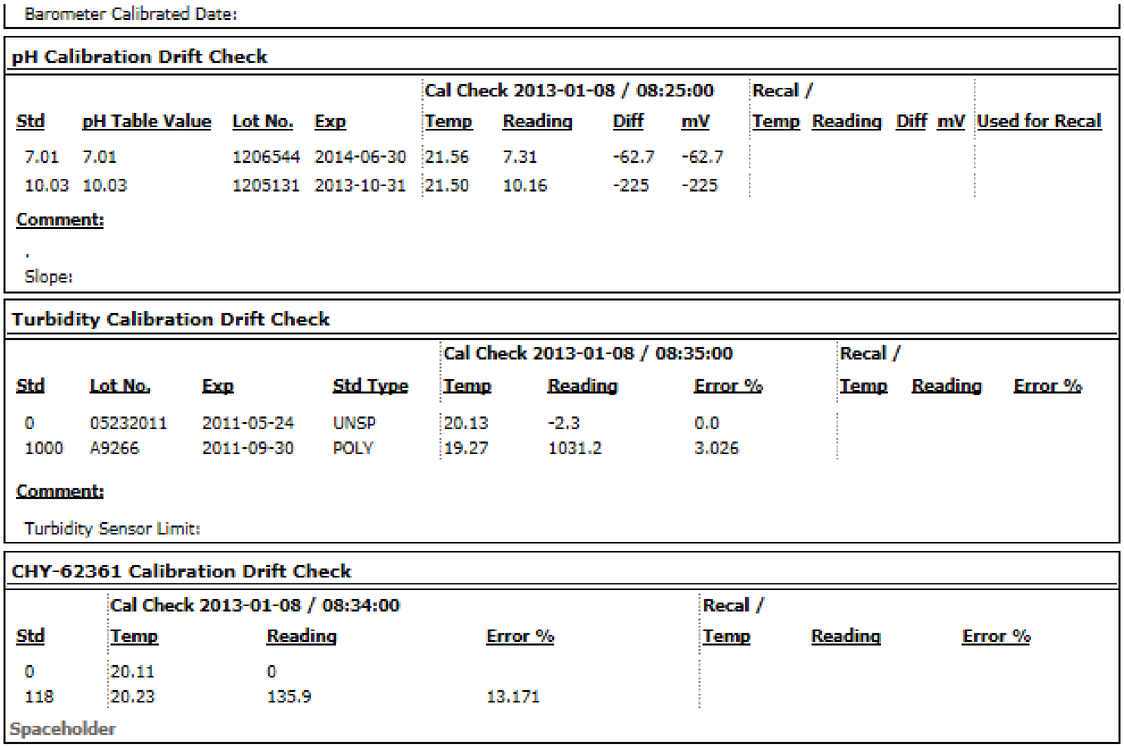
Temp.	**BP mm Hg**	**DO Table Read**	**Salinity CF**	**Read**	**Error %**	**Read in 0 Soln**
18.67	725.5	8.88	0.997	9.05	0.17	

Comment:

DO method is air-saturated water.

Salinity: 0.490	Sal Corr Applied: No	SC of Water: 877	Spaceholder	Spaceholder	Spaceholder	Spaceholder
Temp of Water: 18.67	DO Charge:	DO Gain:				

Appendix 6. Example of a continuous in-situ water-quality monitor field form



Barometer Calibrated Date:

pH Calibration Drift Check

				Cal Check 2013-01-08 / 08:25:00				Recal /				
Std	**pH Table Value**	**Lot No.**	**Exp**	**Temp**	**Reading**	**Diff**	**mV**	**Temp**	**Reading**	**Diff**	**mV**	**Used for Recal**
7.01	7.01	1206544	2014-06-30	21.56	7.31	-62.7	-62.7					
10.03	10.03	1205131	2013-10-31	21.50	10.16	-225	-225					

Comment:

.

Slope:

Turbidity Calibration Drift Check

				Cal Check 2013-01-08 / 08:35:00			Recal /		
Std	**Lot No.**	**Exp**	**Std Type**	**Temp**	**Reading**	**Error %**	**Temp**	**Reading**	**Error %**
0	05232011	2011-05-24	UNSP	20.13	-2.3	0.0			
1000	A9266	2011-09-30	POLY	19.27	1031.2	3.026			

Comment:

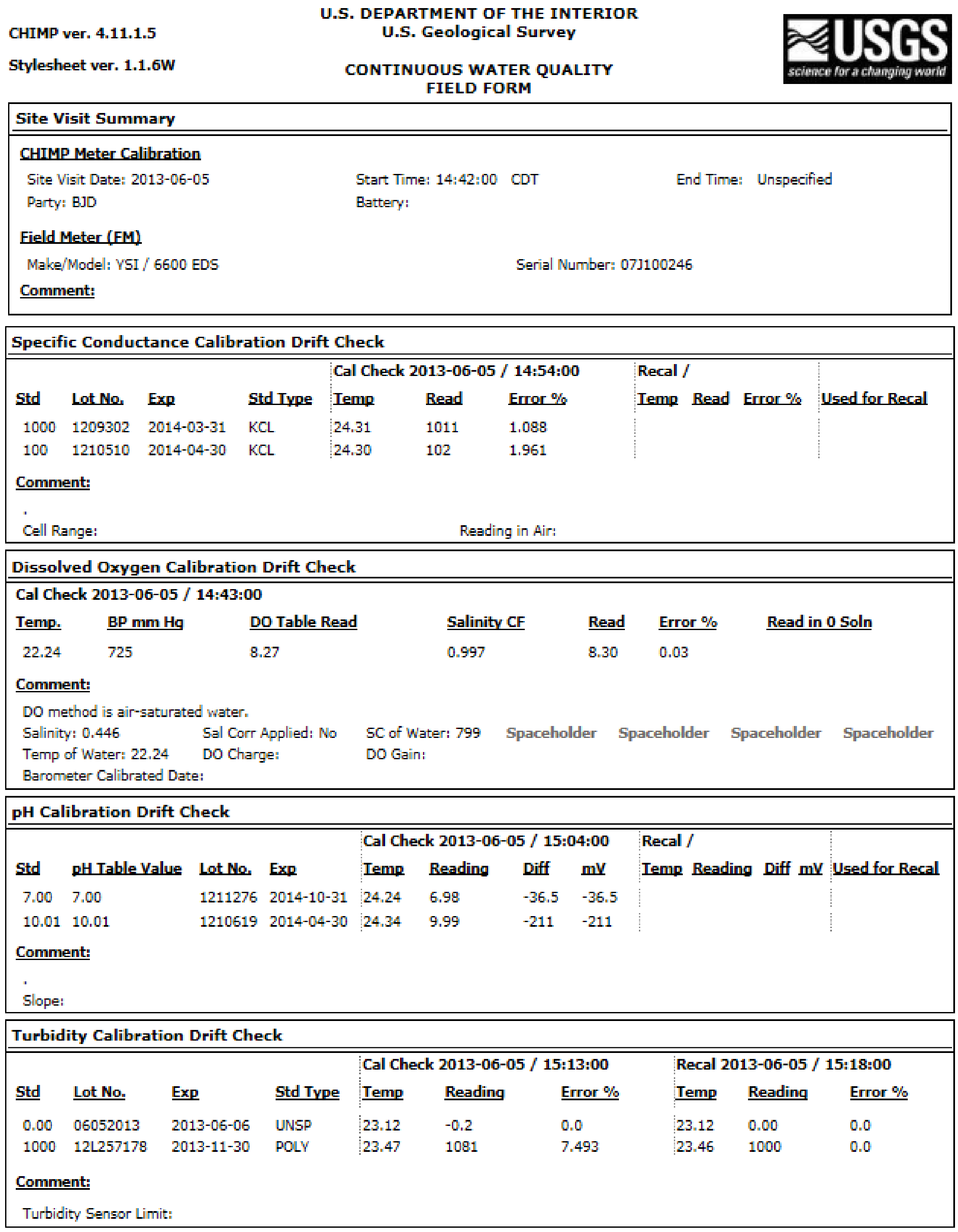
Turbidity Sensor Limit:

CHY-62361 Calibration Drift Check

	Cal Check 2013-01-08 / 08:34:00			Recal /		
Std	**Temp**	**Reading**	**Error %**	**Temp**	**Reading**	**Error %**
0	20.11	0				
118	20.23	135.9	13.171			

Spaceholder

Appendix 7. Example of a water-quality field monitor field form



CHIMP ver. 4.11.1.5

Stylesheet ver. 1.1.6W

U.S. DEPARTMENT OF THE INTERIOR
U.S. Geological Survey

CONTINUOUS WATER QUALITY
FIELD FORM

Site Visit Summary

CHIMP Meter Calibration

Site Visit Date: 2013-06-05   Start Time: 14:42:00 CDT   End Time: Unspecified
Party: BJD   Battery:

Field Meter (FM)

Make/Model: YSI / 6600 EDS   Serial Number: 07J100246

Comment:

Specific Conductance Calibration Drift Check

				Cal Check 2013-06-05 / 14:54:00			Recal /			
Std	**Lot No.**	**Exp**	**Std Type**	**Temp**	**Read**	**Error %**	**Temp**	**Read**	**Error %**	**Used for Recal**
1000	1209302	2014-03-31	KCL	24.31	1011	1.088				
100	1210510	2014-04-30	KCL	24.30	102	1.961				

Comment:

.

Cell Range: Reading in Air:

Dissolved Oxygen Calibration Drift Check

Cal Check 2013-06-05 / 14:43:00

Temp.	**BP mm Hg**	**DO Table Read**	**Salinity CF**	**Read**	**Error %**	**Read in 0 Soln**
22.24	725	8.27	0.997	8.30	0.03	

Comment:

DO method is air-saturated water.
Salinity: 0.446   Sal Corr Applied: No   SC of Water: 799   Spaceholder   Spaceholder   Spaceholder   Spaceholder
Temp of Water: 22.24   DO Charge: DO Gain:
Barometer Calibrated Date:

pH Calibration Drift Check

				Cal Check 2013-06-05 / 15:04:00				Recal /				
Std	**pH Table Value**	**Lot No.**	**Exp**	**Temp**	**Reading**	**Diff**	**mV**	**Temp**	**Reading**	**Diff**	**mV**	**Used for Recal**
7.00	7.00	1211276	2014-10-31	24.24	6.98	-36.5	-36.5					
10.01	10.01	1210619	2014-04-30	24.34	9.99	-211	-211					

Comment:

.

Slope:

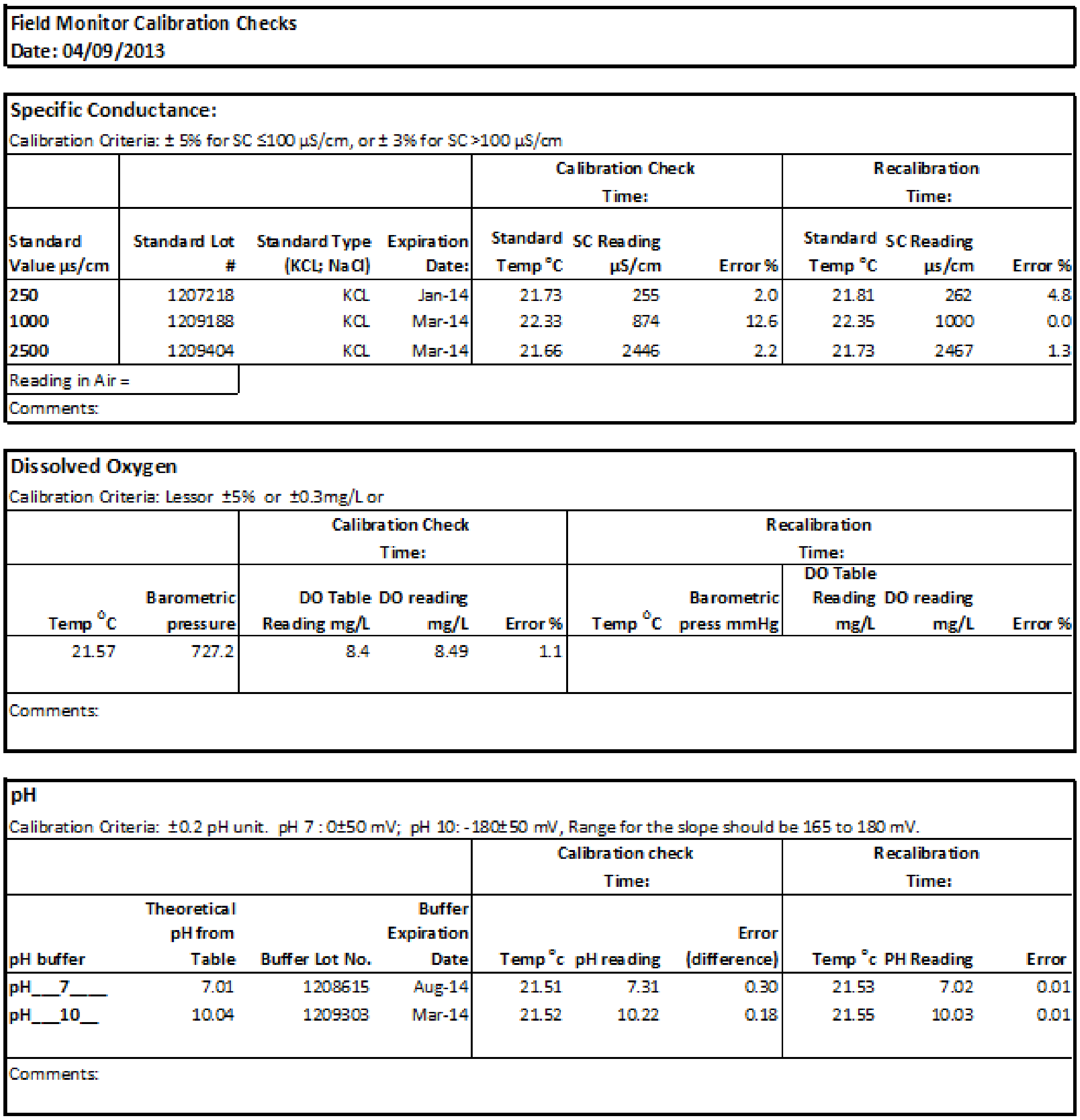
Turbidity Calibration Drift Check

				Cal Check 2013-06-05 / 15:13:00			Recal 2013-06-05 / 15:18:00		
Std	**Lot No.**	**Exp**	**Std Type**	**Temp**	**Reading**	**Error %**	**Temp**	**Reading**	**Error %**
0.00	06052013	2013-06-06	UNSP	23.12	-0.2	0.0	23.12	0.00	0.0
1000	12L257178	2013-11-30	POLY	23.47	1081	7.493	23.46	1000	0.0

Comment:

Turbidity Sensor Limit:

Appendix 8. Example of a water-quality field monitor spreadsheet form



Field Monitor Calibration Checks
Date: 04/09/2013

Specific Conductance:

Calibration Criteria: ± 5% for SC ≤100 µS/cm, or ± 3% for SC >100 µS/cm

				Calibration Check Time:			Recalibration Time:		
Standard Value µs/cm	Standard Lot #	Standard Type (KCL; NaCl)	Expiration Date:	Standard Temp °C	SC Reading µS/cm	Error %	Standard Temp °C	SC Reading µs/cm	Error %
250	1207218	KCL	Jan-14	21.73	255	2.0	21.81	262	4.8
1000	1209188	KCL	Mar-14	22.33	874	12.6	22.35	1000	0.0
2500	1209404	KCL	Mar-14	21.66	2446	2.2	21.73	2467	1.3

Reading in Air =

Comments:

Dissolved Oxygen

Calibration Criteria: Lessor ±5% or ±0.3mg/L or

		Calibration Check Time:			Recalibration Time:				
Temp °C	Barometric pressure	DO Table Reading mg/L	DO reading mg/L	Error %	Temp °C	Barometric press mmHg	DO Table Reading mg/L	DO reading mg/L	Error %
21.57	727.2	8.4	8.49	1.1					

Comments:

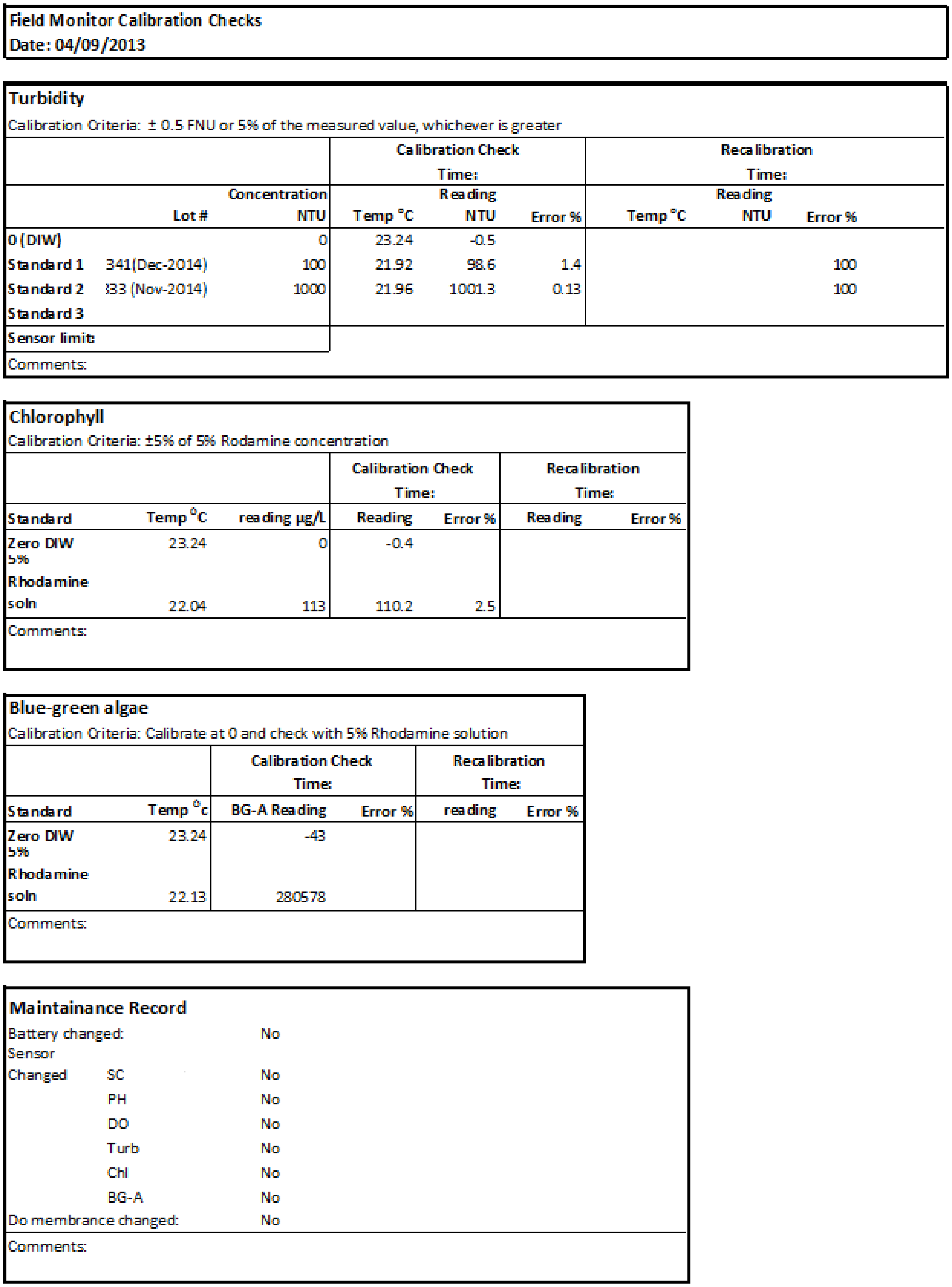
pH

Calibration Criteria: ±0.2 pH unit. pH 7 : 0±50 mV; pH 10: -180±50 mV, Range for the slope should be 165 to 180 mV.

				Calibration check Time:			Recalibration Time:		
pH buffer	Theoretical pH from Table	Buffer Lot No.	Buffer Expiration Date	Temp °c	pH reading	Error (difference)	Temp °c	PH Reading	Error
pH___7___	7.01	1208615	Aug-14	21.51	7.31	0.30	21.53	7.02	0.01
pH___10__	10.04	1209303	Mar-14	21.52	10.22	0.18	21.55	10.03	0.01

Comments:

Appendix 8. Example of a water-quality field monitor spreadsheet form



Field Monitor Calibration Checks
Date: 04/09/2013

Turbidity

Calibration Criteria: ± 0.5 FNU or 5% of the measured value, whichever is greater

			Calibration Check Time:			Recalibration Time:		
	Lot #	Concentration NTU	Temp °C	Reading NTU	Error %	Temp °C	Reading NTU	Error %
0 (DIW)		0	23.24	-0.5				
Standard 1	341(Dec-2014)	100	21.92	98.6	1.4			100
Standard 2	333 (Nov-2014)	1000	21.96	1001.3	0.13			100
Standard 3								
Sensor limit:								

Comments:

Chlorophyll

Calibration Criteria: ±5% of 5% Rodamine concentration

			Calibration Check Time:		Recalibration Time:	
Standard	**Temp °C**	**reading µg/L**	**Reading**	**Error %**	**Reading**	**Error %**
Zero DIW	23.24	0	-0.4			
5% Rhodamine soln	22.04	113	110.2	2.5		

Comments:

Blue-green algae

Calibration Criteria: Calibrate at 0 and check with 5% Rhodamine solution

		Calibration Check Time:		Recalibration Time:	
Standard	**Temp °c**	**BG-A Reading**	**Error %**	**reading**	**Error %**
Zero DIW	23.24	-43			
5% Rhodamine soln	22.13	280578			

Comments:

Maintainance Record

Battery changed:		No
Sensor Changed	SC	No
	PH	No
	DO	No
	Turb	No
	Chl	No
	BG-A	No
Do membrance changed:		No

Comments:

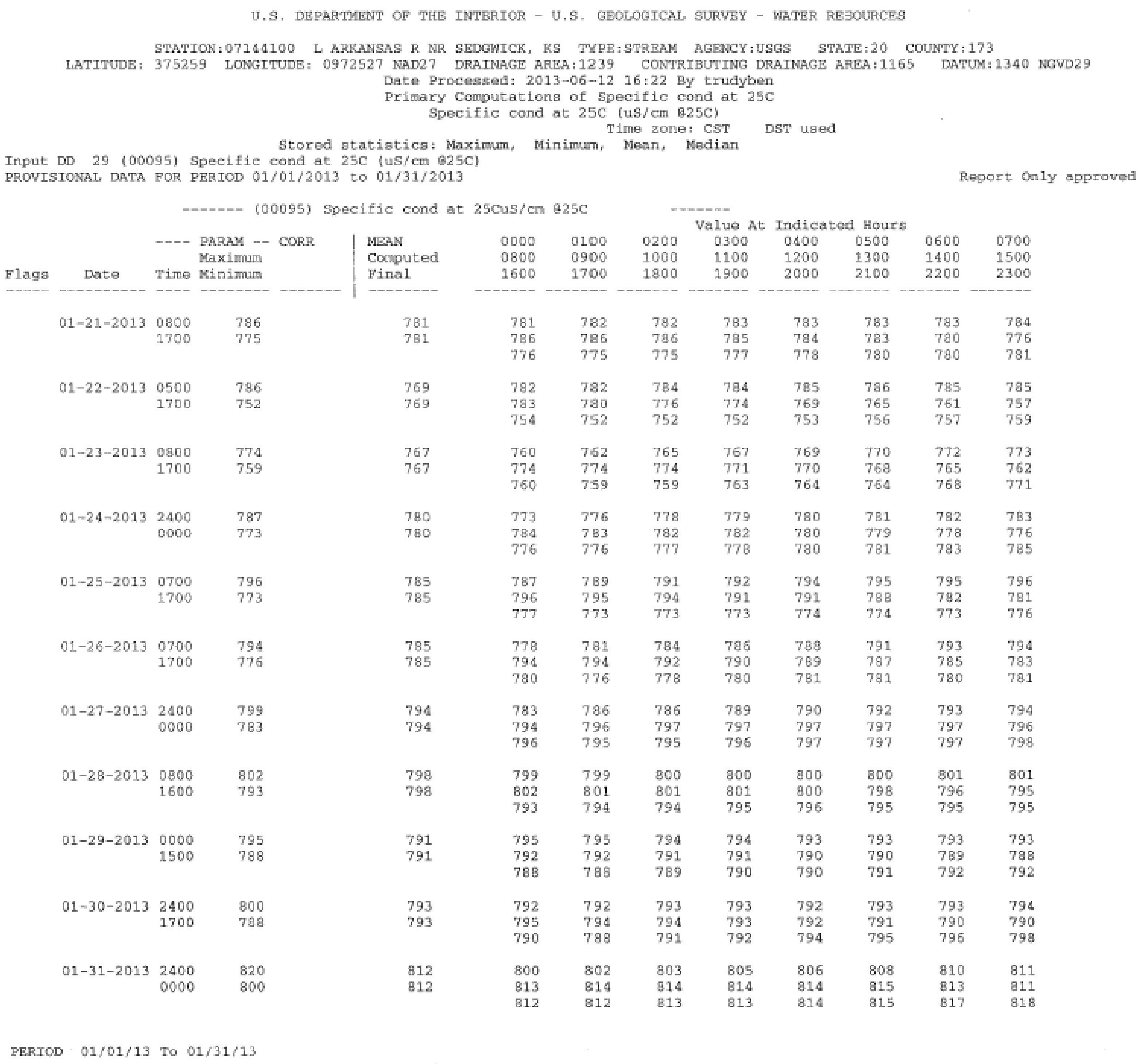
Appendix 9. Steps for working a continuous *in-situ* water-quality monitor record

Steps for working a continuous *in-situ* water-quality monitor record

1. Review the continuous water-quality monitor field notes for accuracy or questionable readings.
2. Import the CHIMP file created at the water-quality monitoring station into the Site Visit database or manually enter the data into Site Visit.
3. If available, download EDL data into ADAPS to fill in missing record.
4. Graphically review "edited" unit values in Hydra.
    a) Delete erroneous values.
    b) Remove the "X" code on good unit values.
5. Apply data corrections for fouling or calibration drift by manually entering them into ADAPS or verify the accuracy of data corrections entered into ADAPS by the ACL program.
6. Run a historical primary.
7. Graphically review "edited" vs. "computed" unit values in Hydra to verify accuracy of data corrections.
8. Verify accuracy of daily values for partial days listed on the primary.
9. Update valid maximum, minimum, mean or median daily values for partial days into appropriate daily values tables using Hydra.
10. Set "Data Aging Status" to "In-Review" when the record is complete.

Appendix 9. Steps for working a continuous *in-situ* water-quality monitor record

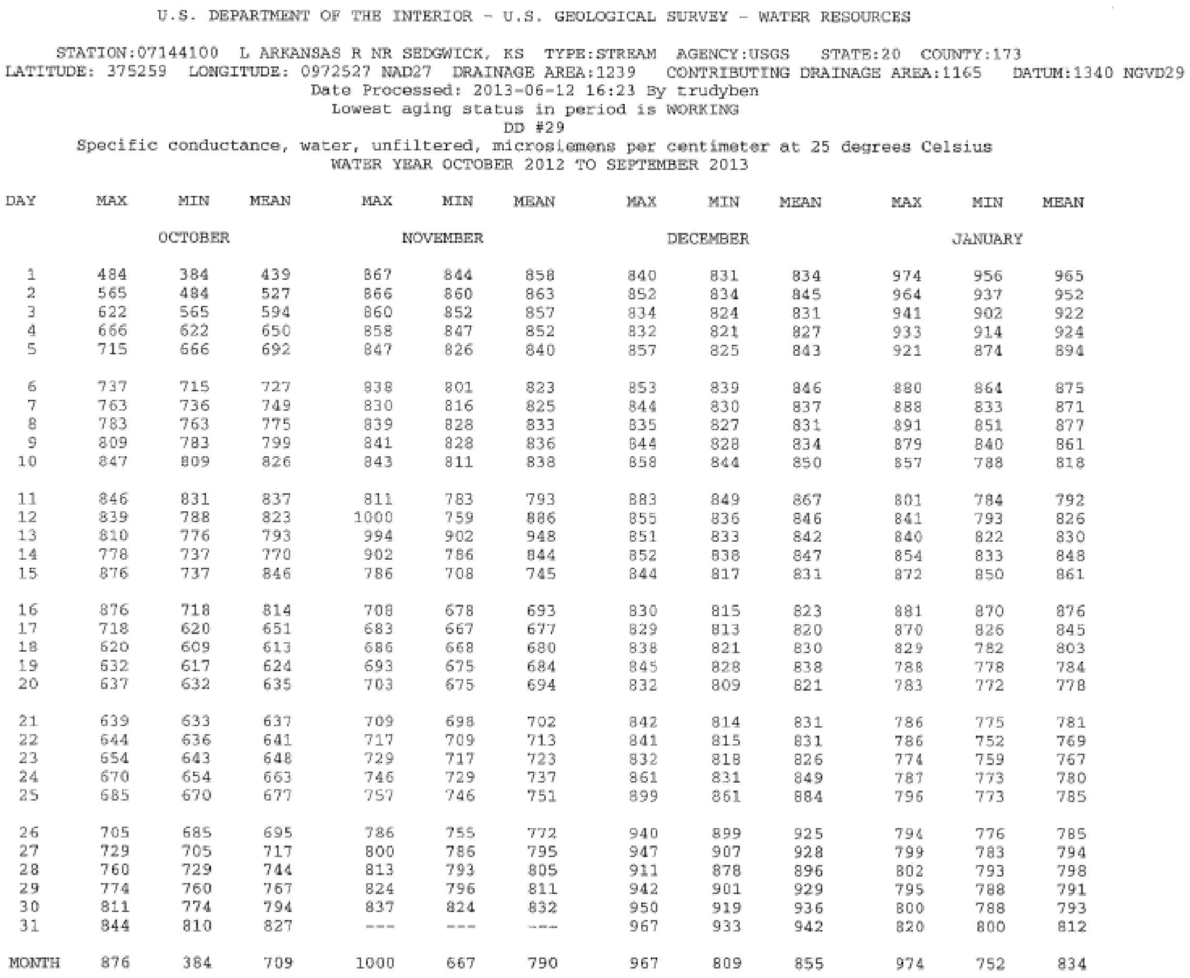
11. Write the station analysis using RMS. The station analysis is written while working the record. It is much easier to write the analysis while working the record rather than to wait until the end and have to remember what was done.
12. Save the station analysis and submit the analysis to the record checker by clicking on the "Finished" button.



Appendix 10. Example of a historical primary record for specific conductance record, January 21-31, 2013.

```
                U.S. DEPARTMENT OF THE INTERIOR - U.S. GEOLOGICAL SURVEY - WATER RESOURCES

          STATION:07144100  L ARKANSAS R NR SEDGWICK, KS  TYPE:STREAM  AGENCY:USGS   STATE:20  COUNTY:173
     LATITUDE: 375259  LONGITUDE: 0972527 NAD27  DRAINAGE AREA:1239   CONTRIBUTING DRAINAGE AREA:1165   DATUM:1340 NGVD29
                                  Date Processed: 2013-06-12 16:22 By trudyben
                                  Primary Computations of Specific cond at 25C
                                       Specific cond at 25C (uS/cm @25C)
                                                         Time zone: CST    DST used
                         Stored statistics: Maximum,  Minimum,  Mean,  Median
Input DD  29 (00095) Specific cond at 25C (uS/cm @25C)
PROVISIONAL DATA FOR PERIOD 01/01/2013 to 01/31/2013                                                 Report Only approved

             ------- (00095) Specific cond at 25CuS/cm @25C          -------
                                                             Value At Indicated Hours
                ---- PARAM -- CORR     | MEAN          0000    0100    0200    0300    0400    0500    0600    0700
                     Maximum           | Computed      0800    0900    1000    1100    1200    1300    1400    1500
Flags    Date   Time Minimum           | Final         1600    1700    1800    1900    2000    2100    2200    2300
----- ---------- ---- -------- ------- | --------     ------- ------- ------- ------- ------- ------- ------- -------

      01-21-2013 0800      786               781        781     782     782     783     783     783     783     784
                 1700      775               781        786     786     786     785     784     783     780     776
                                                        776     775     775     777     778     780     780     781

      01-22-2013 0500      786               769        782     782     784     784     785     786     785     785
                 1700      752               769        783     780     776     774     769     765     761     757
                                                        754     752     752     752     753     756     757     759

      01-23-2013 0800      774               767        760     762     765     767     769     770     772     773
                 1700      759               767        774     774     774     771     770     768     765     762
                                                        760     759     759     763     764     764     768     771

      01-24-2013 2400      787               780        773     776     778     779     780     781     782     783
                 0000      773               780        784     783     782     782     780     779     778     776
                                                        776     776     777     778     780     781     783     785

      01-25-2013 0700      796               785        787     789     791     792     794     795     795     796
                 1700      773               785        796     795     794     791     791     788     782     781
                                                        777     773     773     773     774     774     773     776

      01-26-2013 0700      794               785        778     781     784     786     788     791     793     794
                 1700      776               785        794     794     792     790     789     787     785     783
                                                        780     776     778     780     781     781     780     781

      01-27-2013 2400      799               794        783     786     786     789     790     792     793     794
                 0000      783               794        794     796     797     797     797     797     797     796
                                                        796     795     795     796     797     797     797     798

      01-28-2013 0800      802               798        799     799     800     800     800     800     801     801
                 1600      793               798        802     801     801     801     800     798     796     795
                                                        793     794     794     795     796     795     795     795

      01-29-2013 0000      795               791        795     795     794     794     793     793     793     793
                 1500      788               791        792     792     791     791     790     790     789     788
                                                        788     788     789     790     790     791     792     792

      01-30-2013 2400      800               793        792     792     793     793     792     793     793     794
                 1700      788               793        795     794     794     793     792     791     790     790
                                                        790     788     791     792     794     795     796     798

      01-31-2013 2400      820               812        800     802     803     805     806     808     810     811
                 0000      800               812        813     814     814     814     814     815     813     811
                                                        812     812     813     813     814     815     817     818

PERIOD  01/01/13 To 01/31/13
```

10-1

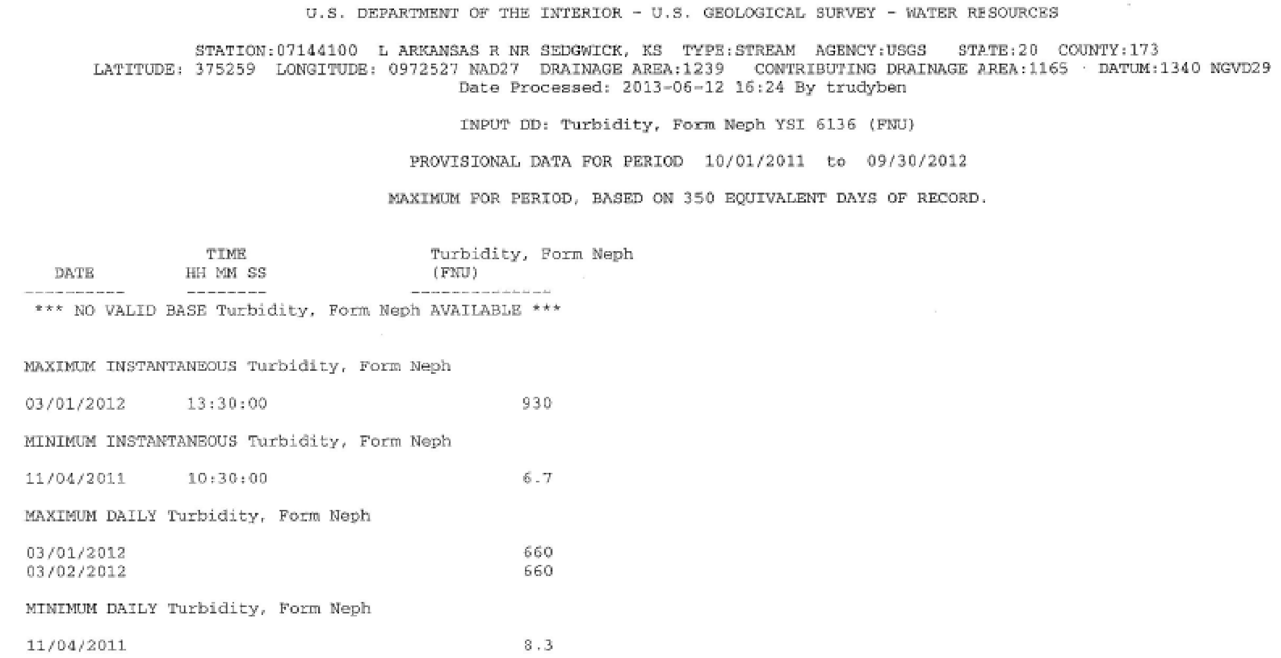


```
               U.S. DEPARTMENT OF THE INTERIOR - U.S. GEOLOGICAL SURVEY - WATER RESOURCES

      STATION:07144100  L ARKANSAS R NR SEDGWICK, KS  TYPE:STREAM  AGENCY:USGS   STATE:20  COUNTY:173
LATITUDE: 375259  LONGITUDE: 0972527 NAD27  DRAINAGE AREA:1239   CONTRIBUTING DRAINAGE AREA:1165   DATUM:1340 NGVD29
                             Date Processed: 2013-06-12 16:23 By trudyben
                              Lowest aging status in period is WORKING
                                            DD #29
        Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius
                              WATER YEAR OCTOBER 2012 TO SEPTEMBER 2013

DAY      MAX     MIN    MEAN      MAX     MIN    MEAN      MAX     MIN    MEAN      MAX     MIN    MEAN

               OCTOBER                 NOVEMBER                  DECEMBER                  JANUARY

  1      484     384     439      867     844     858      840     831     834      974     956     965
  2      565     484     527      866     860     863      852     834     845      964     937     952
  3      622     565     594      860     852     857      834     824     831      941     902     922
  4      666     622     650      858     847     852      832     821     827      933     914     924
  5      715     666     692      847     826     840      857     825     843      921     874     894

  6      737     715     727      838     801     823      853     839     846      880     864     875
  7      763     736     749      830     816     825      844     830     837      888     833     871
  8      783     763     775      839     828     833      835     827     831      891     851     877
  9      809     783     799      841     828     836      844     828     834      879     840     861
 10      847     809     826      843     811     838      858     844     850      857     788     818

 11      846     831     837      811     783     793      883     849     867      801     784     792
 12      839     788     823     1000     759     886      855     836     846      841     793     826
 13      810     776     793      994     902     948      851     833     842      840     822     830
 14      778     737     770      902     786     844      852     838     847      854     833     848
 15      876     737     846      786     708     745      844     817     831      872     850     861

 16      876     718     814      708     678     693      830     815     823      881     870     876
 17      718     620     651      683     667     677      829     813     820      870     826     845
 18      620     609     613      686     668     680      838     821     830      829     782     803
 19      632     617     624      693     675     684      845     828     838      788     778     784
 20      637     632     635      703     675     694      832     809     821      783     772     778

 21      639     633     637      709     698     702      842     814     831      786     775     781
 22      644     636     641      717     709     713      841     815     831      786     752     769
 23      654     643     648      729     717     723      832     818     826      774     759     767
 24      670     654     663      746     729     737      861     831     849      787     773     780
 25      685     670     677      757     746     751      899     861     884      796     773     785

 26      705     685     695      786     755     772      940     899     925      794     776     785
 27      729     705     717      800     786     795      947     907     928      799     783     794
 28      760     729     744      813     793     805      911     878     896      802     793     798
 29      774     760     767      824     796     811      942     901     929      795     788     791
 30      811     774     794      837     824     832      950     919     936      800     788     793
 31      844     810     827      ---     ---     ---      967     933     942      820     800     812

MONTH    876     384     709     1000     667     790      967     809     855      974     752     834
```

11-1

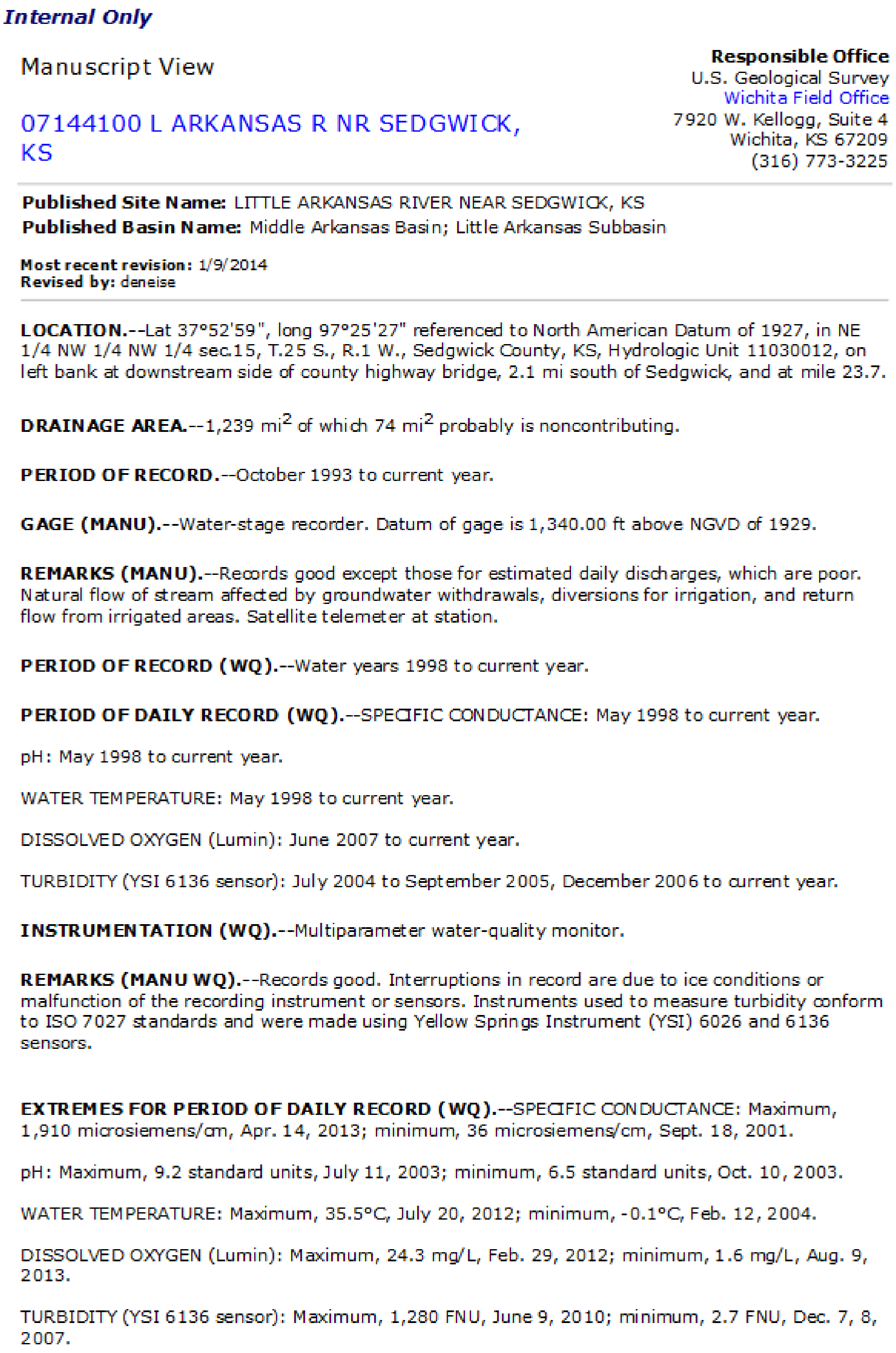
Appendix 11. Example of a daily values table for specific conductance record, October 1, 2012-January 21, 2013

Appendix 12. Example of an end-of-year summary for turbidity record, 2012 water year



```
                    U.S. DEPARTMENT OF THE INTERIOR - U.S. GEOLOGICAL SURVEY - WATER RESOURCES

              STATION:07144100  L ARKANSAS R NR SEDGWICK, KS  TYPE:STREAM  AGENCY:USGS   STATE:20  COUNTY:173
    LATITUDE: 375259  LONGITUDE: 0972527 NAD27  DRAINAGE AREA:1239   CONTRIBUTING DRAINAGE AREA:1165 · DATUM:1340 NGVD29
                                     Date Processed: 2013-06-12 16:24 By trudyben

                                     INPUT DD: Turbidity, Form Neph YSI 6136 (FNU)

                                  PROVISIONAL DATA FOR PERIOD  10/01/2011  to  09/30/2012

                                 MAXIMUM FOR PERIOD, BASED ON 350 EQUIVALENT DAYS OF RECORD.

                  TIME                   Turbidity, Form Neph
   DATE         HH MM SS                 (FNU)
-----------     --------               --------------
 *** NO VALID BASE Turbidity, Form Neph AVAILABLE ***


MAXIMUM INSTANTANEOUS Turbidity, Form Neph

03/01/2012      13:30:00                          930

MINIMUM INSTANTANEOUS Turbidity, Form Neph

11/04/2011      10:30:00                          6.7

MAXIMUM DAILY Turbidity, Form Neph

03/01/2012                                        660
03/02/2012                                        660

MINIMUM DAILY Turbidity, Form Neph

11/04/2011                                        8.3
```

Appendix 13. Example of a station manuscript for Little Arkansas River near Sedgwick, Kansas



Internal Only

Manuscript View

07144100 L ARKANSAS R NR SEDGWICK, KS

Responsible Office
U.S. Geological Survey
Wichita Field Office
7920 W. Kellogg, Suite 4
Wichita, KS 67209
(316) 773-3225

Published Site Name: LITTLE ARKANSAS RIVER NEAR SEDGWICK, KS
Published Basin Name: Middle Arkansas Basin; Little Arkansas Subbasin

Most recent revision: 1/9/2014
Revised by: deneise

LOCATION.--Lat 37°52'59", long 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, KS, Hydrologic Unit 11030012, on left bank at downstream side of county highway bridge, 2.1 mi south of Sedgwick, and at mile 23.7.

DRAINAGE AREA.--1,239 mi^2 of which 74 mi^2 probably is noncontributing.

PERIOD OF RECORD.--October 1993 to current year.

GAGE (MANU).--Water-stage recorder. Datum of gage is 1,340.00 ft above NGVD of 1929.

REMARKS (MANU).--Records good except those for estimated daily discharges, which are poor. Natural flow of stream affected by groundwater withdrawals, diversions for irrigation, and return flow from irrigated areas. Satellite telemeter at station.

PERIOD OF RECORD (WQ).--Water years 1998 to current year.

PERIOD OF DAILY RECORD (WQ).--SPECIFIC CONDUCTANCE: May 1998 to current year.

pH: May 1998 to current year.

WATER TEMPERATURE: May 1998 to current year.

DISSOLVED OXYGEN (Lumin): June 2007 to current year.

TURBIDITY (YSI 6136 sensor): July 2004 to September 2005, December 2006 to current year.

INSTRUMENTATION (WQ).--Multiparameter water-quality monitor.

REMARKS (MANU WQ).--Records good. Interruptions in record are due to ice conditions or malfunction of the recording instrument or sensors. Instruments used to measure turbidity conform to ISO 7027 standards and were made using Yellow Springs Instrument (YSI) 6026 and 6136 sensors.

EXTREMES FOR PERIOD OF DAILY RECORD (WQ).--SPECIFIC CONDUCTANCE: Maximum, 1,910 microsiemens/cm, Apr. 14, 2013; minimum, 36 microsiemens/cm, Sept. 18, 2001.

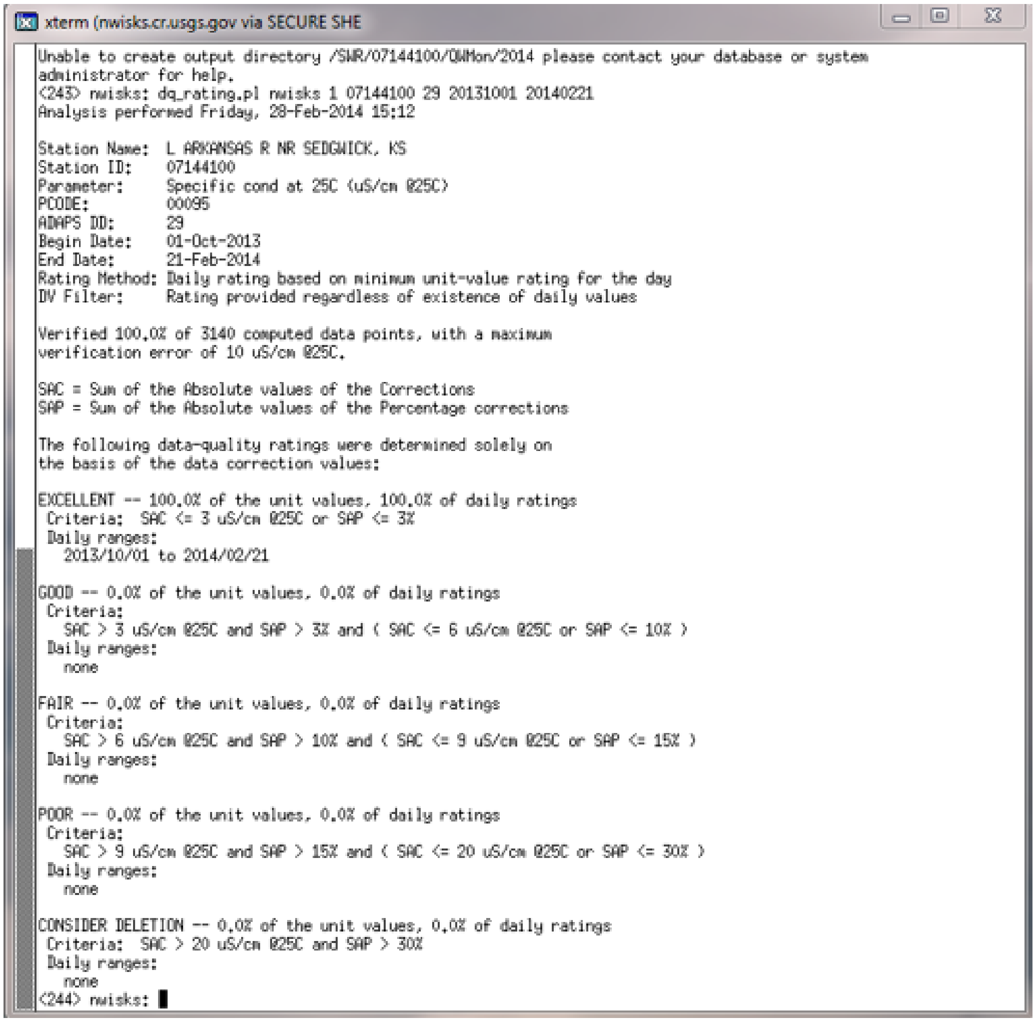
pH: Maximum, 9.2 standard units, July 11, 2003; minimum, 6.5 standard units, Oct. 10, 2003.

WATER TEMPERATURE: Maximum, 35.5°C, July 20, 2012; minimum, -0.1°C, Feb. 12, 2004.

DISSOLVED OXYGEN (Lumin): Maximum, 24.3 mg/L, Feb. 29, 2012; minimum, 1.6 mg/L, Aug. 9, 2013.

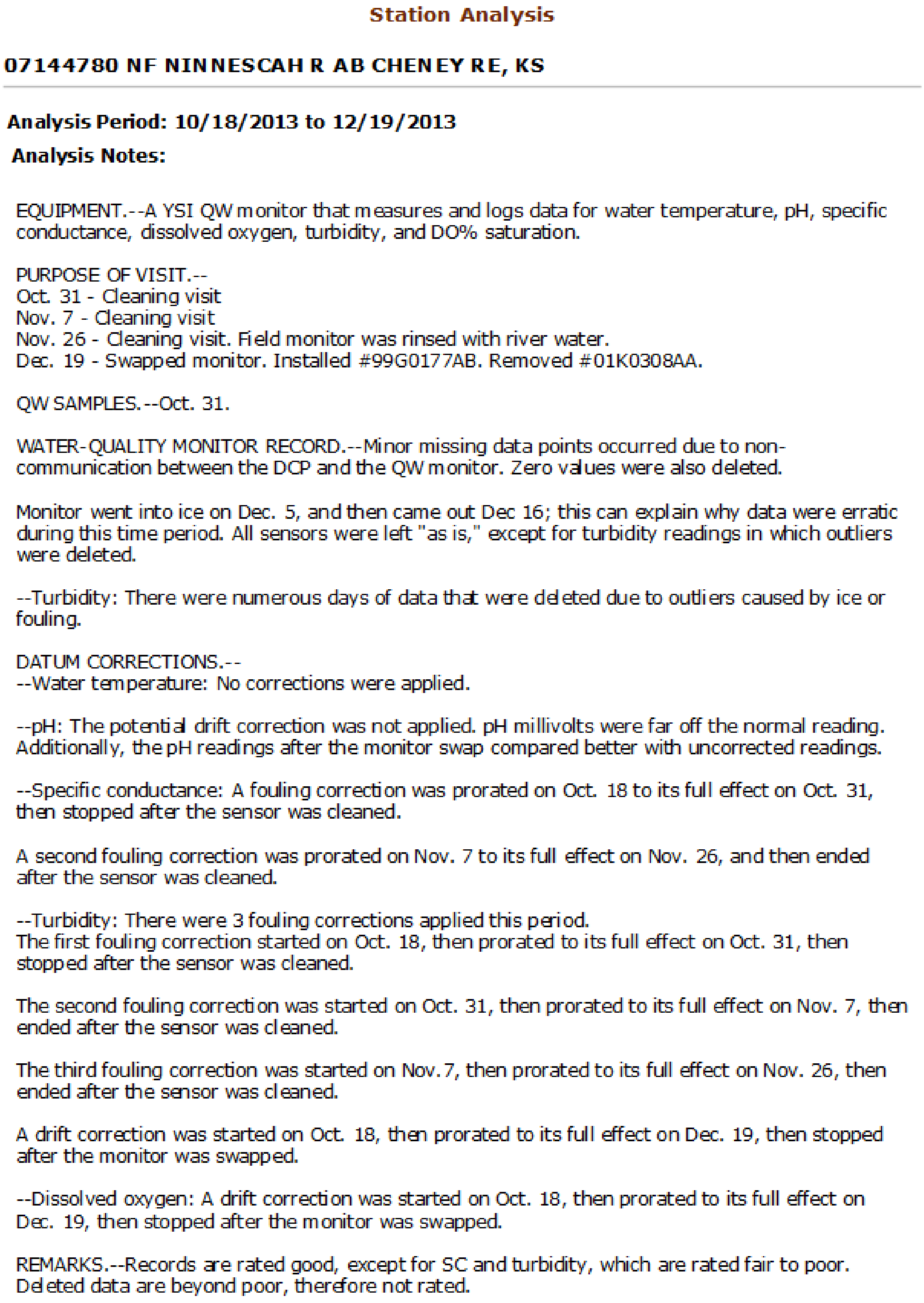
TURBIDITY (YSI 6136 sensor): Maximum, 1,280 FNU, June 9, 2010; minimum, 2.7 FNU, Dec. 7, 8, 2007.

Appendix 14. Example of the Data-Quality Ratings output for specific conductance record, October 1, 2013-February 21, 2014



```
Unable to create output directory /SWR/07144100/QWMon/2014 please contact your database or system
administrator for help.
<243> nwisks: dq_rating.pl nwisks 1 07144100 29 20131001 20140221
Analysis performed Friday, 28-Feb-2014 15:12

Station Name:  L ARKANSAS R NR SEDGWICK, KS
Station ID:    07144100
Parameter:     Specific cond at 25C (uS/cm @25C)
PCODE:         00095
ADAPS DD:      29
Begin Date:    01-Oct-2013
End Date:      21-Feb-2014
Rating Method: Daily rating based on minimum unit-value rating for the day
DV Filter:     Rating provided regardless of existence of daily values

Verified 100.0% of 3140 computed data points, with a maximum
verification error of 10 uS/cm @25C.

SAC = Sum of the Absolute values of the Corrections
SAP = Sum of the Absolute values of the Percentage corrections

The following data-quality ratings were determined solely on
the basis of the data correction values:

EXCELLENT -- 100.0% of the unit values, 100.0% of daily ratings
 Criteria:  SAC <= 3 uS/cm @25C or SAP <= 3%
 Daily ranges:
   2013/10/01 to 2014/02/21

GOOD -- 0.0% of the unit values, 0.0% of daily ratings
 Criteria:
   SAC > 3 uS/cm @25C and SAP > 3% and ( SAC <= 6 uS/cm @25C or SAP <= 10% )
 Daily ranges:
   none

FAIR -- 0.0% of the unit values, 0.0% of daily ratings
 Criteria:
   SAC > 6 uS/cm @25C and SAP > 10% and ( SAC <= 9 uS/cm @25C or SAP <= 15% )
 Daily ranges:
   none

POOR -- 0.0% of the unit values, 0.0% of daily ratings
 Criteria:
   SAC > 9 uS/cm @25C and SAP > 15% and ( SAC <= 20 uS/cm @25C or SAP <= 30% )
 Daily ranges:
   none

CONSIDER DELETION -- 0.0% of the unit values, 0.0% of daily ratings
 Criteria:  SAC > 20 uS/cm @25C and SAP > 30%
 Daily ranges:
   none
<244> nwisks: █
```

Appendix 15. Example of a station analysis for NF Ninnescah River above Cheney Reservoir, Kansas



Station Analysis

07144780 NF NINNESCAH R AB CHENEY RE, KS

Analysis Period: 10/18/2013 to 12/19/2013

Analysis Notes:

EQUIPMENT.--A YSI QW monitor that measures and logs data for water temperature, pH, specific conductance, dissolved oxygen, turbidity, and DO% saturation.

PURPOSE OF VISIT.--
Oct. 31 - Cleaning visit
Nov. 7 - Cleaning visit
Nov. 26 - Cleaning visit. Field monitor was rinsed with river water.
Dec. 19 - Swapped monitor. Installed #99G0177AB. Removed #01K0308AA.

QW SAMPLES.--Oct. 31.

WATER-QUALITY MONITOR RECORD.--Minor missing data points occurred due to non-communication between the DCP and the QW monitor. Zero values were also deleted.

Monitor went into ice on Dec. 5, and then came out Dec 16; this can explain why data were erratic during this time period. All sensors were left "as is," except for turbidity readings in which outliers were deleted.

--Turbidity: There were numerous days of data that were deleted due to outliers caused by ice or fouling.

DATUM CORRECTIONS.--
--Water temperature: No corrections were applied.

--pH: The potential drift correction was not applied. pH millivolts were far off the normal reading. Additionally, the pH readings after the monitor swap compared better with uncorrected readings.

--Specific conductance: A fouling correction was prorated on Oct. 18 to its full effect on Oct. 31, then stopped after the sensor was cleaned.

A second fouling correction was prorated on Nov. 7 to its full effect on Nov. 26, and then ended after the sensor was cleaned.

--Turbidity: There were 3 fouling corrections applied this period.
The first fouling correction started on Oct. 18, then prorated to its full effect on Oct. 31, then stopped after the sensor was cleaned.

The second fouling correction was started on Oct. 31, then prorated to its full effect on Nov. 7, then ended after the sensor was cleaned.

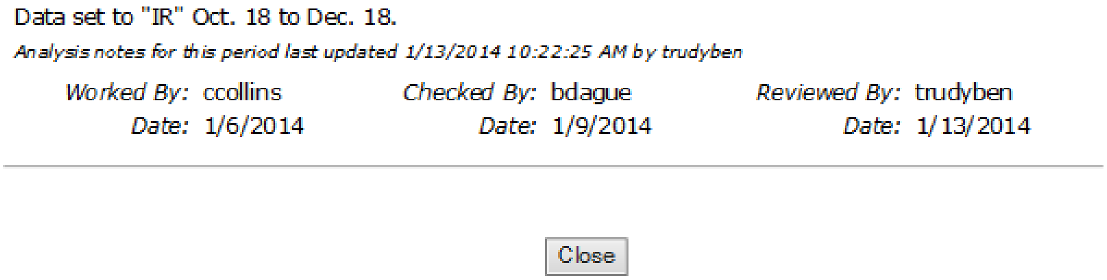
The third fouling correction was started on Nov.7, then prorated to its full effect on Nov. 26, then ended after the sensor was cleaned.

A drift correction was started on Oct. 18, then prorated to its full effect on Dec. 19, then stopped after the monitor was swapped.

--Dissolved oxygen: A drift correction was started on Oct. 18, then prorated to its full effect on Dec. 19, then stopped after the monitor was swapped.

REMARKS.--Records are rated good, except for SC and turbidity, which are rated fair to poor. Deleted data are beyond poor, therefore not rated.

Appendix 15. Example of a station analysis for NF Ninnescah River above Cheney Reservoir, Kansas



Data set to "IR" Oct. 18 to Dec. 18.

Analysis notes for this period last updated 1/13/2014 10:22:25 AM by trudyben

Worked By: ccollins
Date: 1/6/2014

Checked By: bdague
Date: 1/9/2014

Reviewed By: trudyben
Date: 1/13/2014

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4821 Quail Crest Place
Lawrence, KS 66049
(785) 842–9909

Or visit the Kansas Water Science Center Web site at:
http://ks.water.usgs.gov

Bennett and others—**U.S. Geological Survey Quality-Assurance Plan for Continuous Water-Quality Monitoring in Kansas, 2014**—OFR 2014–1151

ISSN 2331-1258 (online)

http://dx.doi.org/10.3133/ofr20141151