United States Environmental Protection Agency
Office of Water
Washington, DC
EPA 841-B-16-003

National Lakes Assessment 2017

Quality Assurance Project Plan

Version 1.1, May 2017

Approval Page

Sarah Lehmann, NARS Team Leader 6/5/17

For Amina Pollard — Date

National Lakes Assessment 2017 Project Leader

U.S. EPA Office of Water

Sarah Lehmann 6/5/17

Sarah Lehmann — Date

National Lakes Assessment Project Quality Assurance Coordinator

U.S. EPA Office of Water

Susan Holdsworth 6/14/17

Susan Holdsworth — Date

Chief, Monitoring Branch

U.S. EPA Office of Water

M. Heber 6/15/17

Margarete Heber — Date

Office of Wetlands, Oceans, and Watersheds Quality Assurance Officer

U.S. EPA Office of Water

VERSION HISTORY

QAPP Version	Date Approved	Changes Made
1.0	3/10/2017	Not Applicable
1.1		Minor editorial and grammatical changes throughout QAPP; List of acronyms updated; Page 5, Section 2.1: additional microcystin sample added; Page 15, Section 3.2.1 and 3.2.3: clarifications added on RLs, precision, bias;
		Changes made to NLA 2017 FOM and LOM; see Appendix B for a summary of those changes

Quality Assurance Project Plan Review & Distribution Acknowledgement & Commitment to Implement the National Lakes Assessment 2017

I/We have read the Quality Assurance Project Plan and the methods manuals for the 2017 National Lakes Assessment listed below. Our agency/organization, agrees to abide by its requirements for work performed under the National Lakes Assessment 2017. Check appropriate boxes for the appropriate documents.

Quality Assurance Project Plan □

Site Evaluation Guidelines □

Field Operations Manual □

Laboratory Operations Manual □

Field Crew leaders: I also certify that I attended an EPA-sponsored NLA 2017 training and that all members of my crew have received training in NLA protocols (check box) □

Name (printed)

Title (Cooperator's Principal Investigator)

Organization

Signature Date

Field Crews: Please send a signed, scanned copy of this page to the Logistics Contractor. The Logistics Contractor ensures all parties have signed the QA forms, compiles them and submits to the EPA Project QA Coordinator. Send your forms to: Chris Turner, cturner@glec.com.

Labs and others: Please return the signed, scanned copy to Kendra Forde who ensures all parties have signed the QA forms, compiles them, and submits them to the EPA QA Coordinator. Send your forms to: Kendra Forde, forde.kendra@epa.gov.

Retain a copy for your files.

NOTICE

The intention of the National Lakes Assessment 2017 (NLA 2017) is to provide a comprehensive "State of the Lakes" assessment for lakes, ponds, and reservoirs across the United States. The complete documentation of overall project management, design, methods, and standards is contained in this Quality Assurance Project Plan and companion documents, including:

National Lakes Assessment 2017: Site Evaluation Guidelines (EPA 841-B-16-001)

National Lakes Assessment 2017: Field Operations Manual (EPA 841-B-16-002)

National Lakes Assessment 2017: Laboratory Operations Manual (EPA 841-B-16-004)

This document, the NLA 2017 Quality Assurance Project Plan (QAPP), contains elements of the overall project management, data quality objectives, measurement and data acquisition, and information management for NLA 2017. The complete QAPP includes this document and its associated Field Operations Manual (FOM), Laboratory Operations Manual (LOM), and Site Evaluation Guidelines (SEG), which together comprise the integrated set of QAPP documents. Methods described in this document are to be used specifically in work relating to the NLA 2017. All project cooperators should follow these guidelines. Mention of trade names or commercial products in this document does not constitute endorsement or recommendation for use.

The suggested citation for this document is:

USEPA. 2017. National Lakes Assessment 2017. Quality Assurance Project Plan. V.1.1. EPA 841-B-16-003. U.S. Environmental Protection Agency, Washington, DC

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

LIST OF ACRONYMS

ANC	acid neutralizing capacity
ASTM	American Society of Testing and Materials
CH_4	methane
CO_2	carbon dioxide
CSDGM	Content Standards for Digital Geospatial Metadata
DBH	diameter at breast height
DO	dissolved oxygen
DOC	dissolved organic carbon
DQO	Data Quality Objectives
eDNA	Environmental deoxyribonucleic acid
EMAP	Environmental Monitoring and Assessment Program
FGDC	Federal Geographic Data Committee
FOIA	Freedom of Information Act
FOM	Field Operations Manual
GIS	geographic information system
GRTS	Generalized Random Tessellation Stratified (survey design)
HDPE	high density polyethylene
H_2S	hydrogen sulfide
IM	information management
LIMS	Laboratory Information Management System
LOM	Lab Operations Manual
LRL	Laboratory Reporting Limit
LT-MDL	target long-term Method Detection Limit
MDL	Method Detection Limit
MQ/cm	megaohms/centimeter
MMI	multimetric indices
MQO	Measurement Quality Objectives
NARS	National Aquatic Resource Surveys
ND	non-detect
NHD	National Hydrography Dataset
NIST	National Institute of Standards
NLA	National Lakes Assessment
N_2O	nitrous oxide
OMB	Office of Management and Budget
ORD	USEPA Office of Research and Development
OW	USEPA Office of Water
PETG	polyethylene terephthalate
QA	quality assurance
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
QC	quality control
QCS	quality control sample
RL	Reporting Limit
SEG	Site Evaluation Guidelines
SOPs	Standard Operating Procedures
SQL	Structured Query Language
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

WED USEPA Office of Research and Development's Western Ecology Division
WQX USEPA Water Quality Exchange

DISTRIBUTION LIST

This QAPP, which includes the associated manuals or guidelines, is distributed to the following: USEPA, States, Tribes, universities, labs, and contractors participating in the National Lakes Assessment 2017 (NLA). USEPA Regional Survey Coordinators are responsible for distributing the NLA QAPP to State and Tribal Water Quality Agency staff or other cooperators who will perform the field sampling and laboratory operations. The Logistics Coordinator distributes the QAPP and associated documents to participating project staff at their respective facilities and to the project contacts at participating laboratories, as they are determined. If the QAPP is updated, the project lead distributes the relevant materials via email to necessary participants.

Title	Name	Contact Information
USEPA HQ Project Lead	Amina Pollard, OW	pollard.amina@epa.gov 202-566-2360
USEPA HQ Project QA Coordinator	Sarah Lehmann, OW	lehmann.sarah@epa.gov 202-566-1379
USEPA HQ QA Officer	Margarete Heber, OW	heber.margarete@epa.gov 202 566-1189
USEPA HQ Logistics Lead	Brian Hasty, OW	hasty.brian@epa.gov 202-564-2236
USEPA HQ Laboratory Review Coordinator	Kendra Forde, OW	forde.kendra@epa.gov 202-566-0417
Contract Logistics Coordinator	Chris Turner, GLEC	cturner@glec.com 715-829-3737
NARS Information Management (IM) Coordinator	Marlys Cappaert, CSRA	cappaert.marlys@epa.gov 541-754-4467 541-754-4799 (fax)
USEPA Regional NLA Coordinators	Hilary Snook, Region 1	snook.hilary@epa.gov 617-918-8670
	Jim Kurtenbach, Region 2	kurtenbach.james@epa.gov 732-321-6695
	Frank Borsuk, Region 3 William Richardson, Region 3	borsuk.frank@epa.gov 304-234-0241 richardson.william@epa.gov 215-814-5675
	Chris McArthur, Region 4	mcarthur.christopher@epa.gov 404-562-9391
	Mari Nord, Region 5	nord.mari@epa.gov 312-886-3017
	Rob Cook, Region 6	cook.robert@epa.gov 214-665-7141
	Gary Welker, Region 7	welker.gary@epa.gov 913-551-7177
	Kris Jensen, Region 8	jensen.kris@epa.gov

	Jeff McPherson, Region 8	303-312-6237 mcpherson.jeffrey@epa.gov 303-312-7752
	Janet Hashimoto, Region 9 Matthew Bolt, Region 9	hashimoto.janet@epa.gov 415-972-3106 Bolt.matthew@epa.gov 415-972-3578
	Lil Herger, Region 10	herger.lillian@epa.gov 206-553-1074

1 EXECUTIVE SUMMARY

1.1 Background

To address the need for improved water quality monitoring and analysis at multiple scales, the USEPA Office of Water (OW), in partnership with USEPA's Office of Research and Development (ORD), USEPA regional offices, states and tribes and other partners, assesses the condition of the nation's waters via a statistically valid approach. Often referred to as probability-based surveys, these assessments, known as the National Aquatic Resource Surveys (NARS), report on core indicators of water condition using standardized field and lab methods and utilize integrated information management (IM) plans to ensure confidence in the results at national and ecoregional scales.

The NLA 2017, which builds upon the previous NLA 2012 and NLA 2007, aims to address three key questions about the quality of the nation's lakes and reservoirs:

- What percent of the nation's lakes are least, moderately, and most disturbed for key indicators of trophic state, ecological health, and human use (recreation)?
- What is the relative importance of key stressors such as nutrients and pathogens?
- What changes are occurring in the condition of the nation's lakes?

The surveys are also designed to help expand and enhance state and tribal monitoring programs. Through these surveys, states and tribes have the opportunity to collect data that can be used to supplement their existing monitoring programs or to begin development of new programs.

1.2 Project Organization

Overall project coordination is conducted by USEPA's Office of Water in Washington, DC, with technical support from the ORD's Western Ecology Division (WED) in Corvallis, Oregon. Each of the USEPA Regional Offices has identified regional coordinators to assist in implementing the survey and coordinate with the state/tribal crews who collect the water and sediment samples following NLA 2017 protocols. USEPA began planning the NLA 2017 with state, tribal, and other federal partners in 2015 and is continuing this partnership effort. USEPA expects to report the results in December 2019 in compliance with the Data Quality Act.

1.3 Quality Assurance Project Plan

The purpose of this QAPP is to document the NLA 2017 project data quality objectives and quality assurance/quality control measures needed to ensure that the data collected meets those objectives. The plan contains elements of the overall project management, data quality objectives, measurement and data acquisition, and information management for the NLA 2017 and identifies where these elements are described in detail. This QAPP and its associated documents, the Field Operations Manual, Laboratory Operations Manual and Site Evaluation Guidelines, are interdependent, integrated and together make up the full QAPP for the National Lakes Assessment 2017.

1.4 Information Management Plan

Environmental monitoring efforts that amass large quantities of information from various sources present unique and challenging data management opportunities. To meet these challenges, the NLA 2017 employs a variety of well-tested information management (IM) strategies to aid in the functional organization and ensured integrity of stored electronic data. IM is integral to all aspects of the NLA 2017 from initial selection of sampling sites through the dissemination and reporting of final, validated data.

A technical workgroup convened by the USEPA Project Leader is responsible for development of a data analysis plan that includes a verification and validation strategy. These processes are summarized in the data analysis plan section of this QAPP. Validated data are transferred to the central database managed by information management support staff located at the Western Ecology Division facilities in Corvallis. This database is known as the National Aquatic Resource Surveys Information Management System (NARS IM). All validated measurement and indicator data from the NLA 2017 are eventually transferred to USEPA's Water Quality Exchange (WQX) for archival in USEPA's STORET warehouse for public accessibility. NLA 2017 IM staff provides support and guidance to all program operations in addition to maintaining NARS IM.

1.5 NLA 2017 Design

USEPA used an unequal probability design to select approximately 1,000 lakes and reservoirs greater than 1 hectare (ha) in size (note: in NLA 2007, the lower size limit was 4 ha) in the continental United States. The design also includes revisits to approximately 10% of lakes during the 2017 sampling season for quality assurance purposes including evaluation of the ability of an indicator to distinguish *among* sites from differences *within* individual sites. Of these 1,000 lakes, 218 are lakes that were previously sampled as part of the 2012 NLA and 226 lakes were previously sampled as part of the 2007 NLA. These are collectively referred to as *resample lakes*. Related designs were also completed for sampling of lakes for 12 state intensification studies including the state of Alaska.

1.6 Field Operations

Sample collection for NLA 2017 is designed to be completed during the index period of June through the end of September 2017. Field data acquisition activities are implemented in a consistent manner across the entire country. Each site is given a unique ID which identifies it throughout the pre-field, field, lab, analysis, and data management phases of the project. Specific procedures for evaluating each sampling location and for replacing non-sampleable sites are documented in 2017 NLA Site Evaluation Guidelines (SEG, EPA-841-B-16-001).

NLA 2017 indicators include: algal toxins (microcystins and cylindrospermopsin), benthic macroinvertebrates, physical habitat, phytoplankton, atrazine pesticide screen, water chemistry and chlorophyll-*a*, and zooplankton. Additional research indicators include: bacteria (*E. coli*), sediment contaminants, sediment total organic carbon (TOC), sediment grain size, fish environmental DNA (eDNA), and dissolved gases. Field measurements and sampling methods are outlined in the NLA 2017 Field Operations Manual (FOM, EPA 841-B-16-002). Field crews are trained on these methods at a required USEPA-sponsored training session. Field sampling assistance visits are completed for each field crew for quality assurance.

1.7 Laboratory Operations

NLA 2017 laboratory analyses are conducted either by state/tribal-selected labs or "National Laboratories" set up by USEPA to conduct analyses for any state/tribe which so elects. The designated National Laboratories and state/tribal labs must comply with the QA/QC requirements described in this document and in the National Lakes Assessment 2017: Laboratory Operations Manual (LOM, EPA 841-B-16-004). Any laboratory selected to conduct analyses with NLA 2017 samples must demonstrate that it can meet the quality standards presented in this NLA 2017 QAPP and in the NLA 2017 LOM.

1.8 Peer Review

The NARS program, including the NLA utilizes a three-tiered approach for peer review of the Survey.

- internal and external review by USEPA, states, other cooperators and partners;
- external scientific peer review (when applicable); and
- public review (when applicable).

Cooperators have been actively involved in the development of the overall project management, design, indicator selection, and methods. Outside scientific experts from universities, research centers, and other federal agencies have been instrumental in indicator development and will continue to play an important role in data analysis.

2 PROJECT PLANNING AND MANAGEMENT

2.1 Introduction

In the early 2000s, several reports identified the need for improved water quality monitoring and analysis at multiple scales. In 2000, the General Accounting Office (USGAO 2000) reported that USEPA, states, and tribes collectively cannot make statistically valid inferences about water quality (via 305[b] reporting) and lack data to support key management decisions. In 2001, the National Research Council (NRC 2000) recommended USEPA, states, and tribes promote a uniform, consistent approach to ambient monitoring and data collection to support core water quality programs. In 2002, the H. John Heinz III Center for Science, Economics, and the Environment (Heinz Center 2002) found that there is inadequate data for national reporting on fresh water, coastal and ocean water quality indicators. The National Association of Public Administrators (NAPA 2002) stated that improved water quality monitoring is necessary to help states and tribes make more effective use of limited resources. USEPA's Report on the Environment 2003 (USEPA 2003) stated that there is insufficient information to provide a national answer, with confidence and scientific credibility, to the question, 'What is the condition of U.S. waters and watersheds?'

In response to this need, OW, in partnership with states and tribes, began a program to assess the condition of the nation's waters via a statistically valid approach. The current assessment, the National Lakes Assessment 2017 (referred to as NLA 2017 throughout this document), builds upon the 2012 and 2007 National Lakes Assessment as well as other NARS surveys such as the National Rivers and Streams Assessment, National Coastal Condition Assessment, and the National Wetland Condition Assessment. The NLA 2017 effort will provide important information to states and the public about the condition of the nation's lake resources and key stressors on a national and regional scale.

USEPA developed this QAPP to support project participants and to ensure that the final assessment is based on high quality data that is documented and appropriate for its intended use. The QAPP contains elements of the overall project management, data quality objectives, measurement and data acquisition, and information management for NLA 2017. USEPA recognizes that states and tribes may add elements to the survey, such as supplemental indicators, that are not covered in the scope of this integrated QAPP. USEPA expects that any supplemental elements are addressed by the states, tribes, or their designees, in a separate approved QAPP or an addendum to this QAPP. The NLA 2017 participants have agreed to follow this QAPP and the protocols and design laid out in this document, and its associated documents – the NLA 2017 FOM, LOM, and SEG.

This cooperative effort between states, tribes, and federal agencies makes it possible to produce a broad-scale assessment of the condition of the nation's lakes with both confidence and scientific credibility. Through this survey, states and tribes have the opportunity to collect data that can be used to supplement their existing monitoring programs or to begin development of new programs.

The National Lakes Assessment 2017 has three main objectives:

- Estimate the current status, trends, and changes in selected trophic, ecological, and human use indicators of the condition of the nation's lakes with known statistical confidence.
- Seek associations between selected indicators of natural and anthropogenic stresses and indicators of ecological condition.
- Assess changes in population status between 2007 and 2017.

A NLA 2017 workgroup, comprised of USEPA, state, and other partners, decided on a few improvements and changes to the NLA 2012 suite of indicators. The additions include bacteria, sediment contaminants, sediment TOC, sediment grain size, dissolved gases, fish eDNA, and an algal toxin, cylindrospermopsin. The following indicators from NLA 2012 are not being sampled or analyzed in the NLA 2017: macrophytes assemblage, sediment mercury, sediment dating, sediment diatoms, and dissolved carbon. Modifications from the NLA 2012 protocols include discontinuing collection of chlorophyll-*a*, phytoplankton (for cyanobacteria), and algal toxins at the littoral site and sampling for them only at the index site. While taxonomic information is included as part of the laboratory work for the phytoplankton index site sample, the focus for NLA (including QC and assessment) is on cyanobacteria. Mercury is included in the new sediment contaminants indicator, but changes from the previous method may result in data that is not comparable. Crews will collect the primary microcystin sample in a polyethylene terephthalate (PETG) sample container rather than the previously used high density polyethylene (HDPE) sample containers. Research has shown microcystin adsorption to HDPE bottles. To assess differences in these two approaches and to allow for comparison back to NLA 2007 and 2012, crews will collect a second microcystin sample in the previously used HDPE containers.

2.1.1 Project Organization

The responsibilities and accountability of the various principals and cooperators are described here and illustrated in **Figure 2.1**. Overall, the project is coordinated by the Office of Water (OW) in Washington, DC, with support from USEPA Western Ecology Division (WED) in Corvallis, Oregon. Each USEPA Regional Office has identified a Regional USEPA Coordinator who is part of the USEPA team providing a critical link with state and tribal partners. Cooperators work with their Regional USEPA Coordinator to address any technical issues. The NLA implements a comprehensive quality assurance (QA) program to ensure data integrity and provide support for the reliable interpretation of the findings from this project. The Project Lead convenes Technical Experts Workgroups to provide the team with support for determining the best and most appropriate approaches for key technical issues, such as: (1) the selection and establishment of reference conditions based on least-disturbed sites and expert consensus for characterizing benchmarks for assessment of ecological condition; (2) selection and calibration of ecological endpoints and attributes of the biota and relationship to stressor indicators; (3) a data analysis plan for interpreting the data and addressing the objectives in a nationwide assessment; and (4) a framework for the reporting of the condition assessment and conveying the information on the ecological status of the nation's lakes.

Contractor support is provided for all aspects of this project. Contractors provide support ranging from implementing the survey, sampling and laboratory processing, data management, data analysis, and report writing. Cooperators interact with their Regional USEPA Coordinator and the USEPA Project Leader regarding contractual services.

The primary responsibilities of the principals and cooperators are as follows:

Project Leader: Amina Pollard

- Provides overall coordination of the project and makes decisions regarding the proper functioning of all aspects of the project.
- Makes assignments and delegates authority, as needed to other parts of the project organization.
- Leads the Lakes Steering Committee and establishes needed technical workgroups.
- Interacts with USEPA Project Team on technical, logistical, and organizational issues on a regular basis.

USEPA Field Logistics Coordinator: Brian Hasty

- USEPA employee who functions to support implementation of the project based on technical guidance established by the USEPA Project Leader and serves as point-of-contact for questions from field crews and cooperators for all activities.
- Tracks progress of field sampling activities.

USEPA Project QA Coordinator: Sarah Lehmann

- Provides leadership, development, and oversight of project-level quality assurance for NLA.
- Assembles and provides leadership for a NLA 2017 Quality Team.
- Maintains official, approved QAPP.
- Maintains all training materials and documentation.
- Maintains all laboratory accreditation files.

EPA Laboratory Review Coordinator – Kendra Forde, OW

- Ensures participating laboratories have the appropriate technical competencies to process samples.
- Ensures participating laboratories complete sample analysis following Laboratory Operations Manual.
- Ensures participating laboratories follow QA activities.

Information Management Coordinator: Marlys Cappaert

- A contractor who functions to support implementation of the project based on technical guidance established by the USEPA Project Leader and Alternate USEPA Project Leader.
- Oversees all sample shipments and receives data forms from the Cooperators.
- Oversees all aspects of data entry and data management for the project.

USEPA QA Officer, Office of Wetlands, Oceans and Watersheds: Margarete Heber

- Functions as an independent officer overseeing all Quality Assurance (QA) and quality control (QC) activities.
- Responsible for ensuring that the QA program is implemented thoroughly and adequately to document the performance of all activities.

Regional USEPA Coordinators

- Assists USEPA Project Leader with regional coordination activities.
- Serves on the Technical Experts Workgroup and interacts with Project Facilitator on technical, logistical, and organizational issues on a regular basis.
- Serves as primary point-of-contact for the Cooperators.

Steering Committee (Technical Experts Workgroup): States, USEPA, and other federal agencies

- Provides expert consultation on key technical issues as identified by the USEPA Coordination crew and works with Project Facilitator to resolve approaches and strategies to enable data analysis and interpretation to be scientifically valid.

Cooperator(s): States, Tribes, USGS, others

- Under the scope of their assistance agreements, plans and executes their individual studies as part of the cross jurisdictional NLA 2017 and adheres to all QA requirements and standard operating procedures (SOPs).

- Interacts with the Grant Coordinator, Project Facilitator and USEPA Project Leader regarding technical, logistical, organizational issues.

Field Sampling Crew Leader

- Functions as the senior member of each Cooperator's field sampling crew and the point of contact for the Field Logistics Coordinator.
- Provides training and oversight to their field crew as needed.
- Accompanies and oversees other members of the sampling crew in the field.
- Responsible for overseeing all activities of the field sampling crew and ensuring that the Project field method protocols are followed during all sampling activities.

Contractor Field Logistics Coordinator: Chris Turner

- A contractor who functions to support implementation of the project based on technical guidance established by the USEPA Field Logistics Coordinator and the Project Leader
- Serves as point-of-contact for questions from field crews and cooperators for all activities.
- Tracks progress of field sampling activities.

EPA Technical Advisor: Steven Paulsen

- Advises the Project Leader on the relevant experiences and technology developed within ORD that may be used in this project.
- Facilitates consultations between NLA personnel and ORD scientists.

EPA Study Design Manager: Tony Olsen, ORD

- Provides leadership and oversight of Design Team
- Coordinates w/ Project Manager and Field Logistics Coordinator to develop and manage the Sampling Frame, select sampling locations, and track field evaluation and site reconnaissance.

2.1.2 Project Schedule

Training and field sampling is conducted in 2017. The team needs to complete sample processing and data analysis by 2018 in order to publish a report in FY 2020.

2.2 Scope of QAPP

This QAPP addresses the data acquisition efforts of the NLA 2017, which focuses on the sampling of lakes across the United States in 2017. Data from approximately 1000 site visits (selected with a probability design) located within the contiguous 48 states provide a comprehensive assessment of the nation's lakes. Quality information, requirements, and procedures are contained in the QAPP and its accompanying documents: the SEG, FOM, and LOM. Much of the detailed quality assurance information is in the companion documents to avoid redundancy. In these cases, the QAPP directs readers to the primary sources of this information.

2.2.1 Field Operations

All field operations information is available in the FOM.

Field operations are implemented for the NLA 2017 based on guidance developed by EMAP (Baker and Merritt 1990), experience from NLA 2007 and NLA 2012 advice from the NARS Team, and through consultation with a steering committee comprised of various state, tribal, federal, and regional agencies. Funding for states and tribes to conduct field data collection activities is provided by USEPA under Section 106 of the Clean Water Act. The project lead initiates field operations preparation by working

with the Design Team (led by ORD in Corvallis) to revise, as needed, the target population and sample frame and to identify state/tribal or other organization-requested intensifications/modifications. The Design Team selects sampling locations. The Project Lead distributes the list of sampling locations to the USEPA Regional NLA Coordinators, states, and tribes and to other partners. See the Site Evaluation Guidelines for the detailed design documentation.

With the sampling location list, state and tribal field crews can begin site reconnaissance on the primary sites and alternate replacement sites and begin work on obtaining permission to access each site.

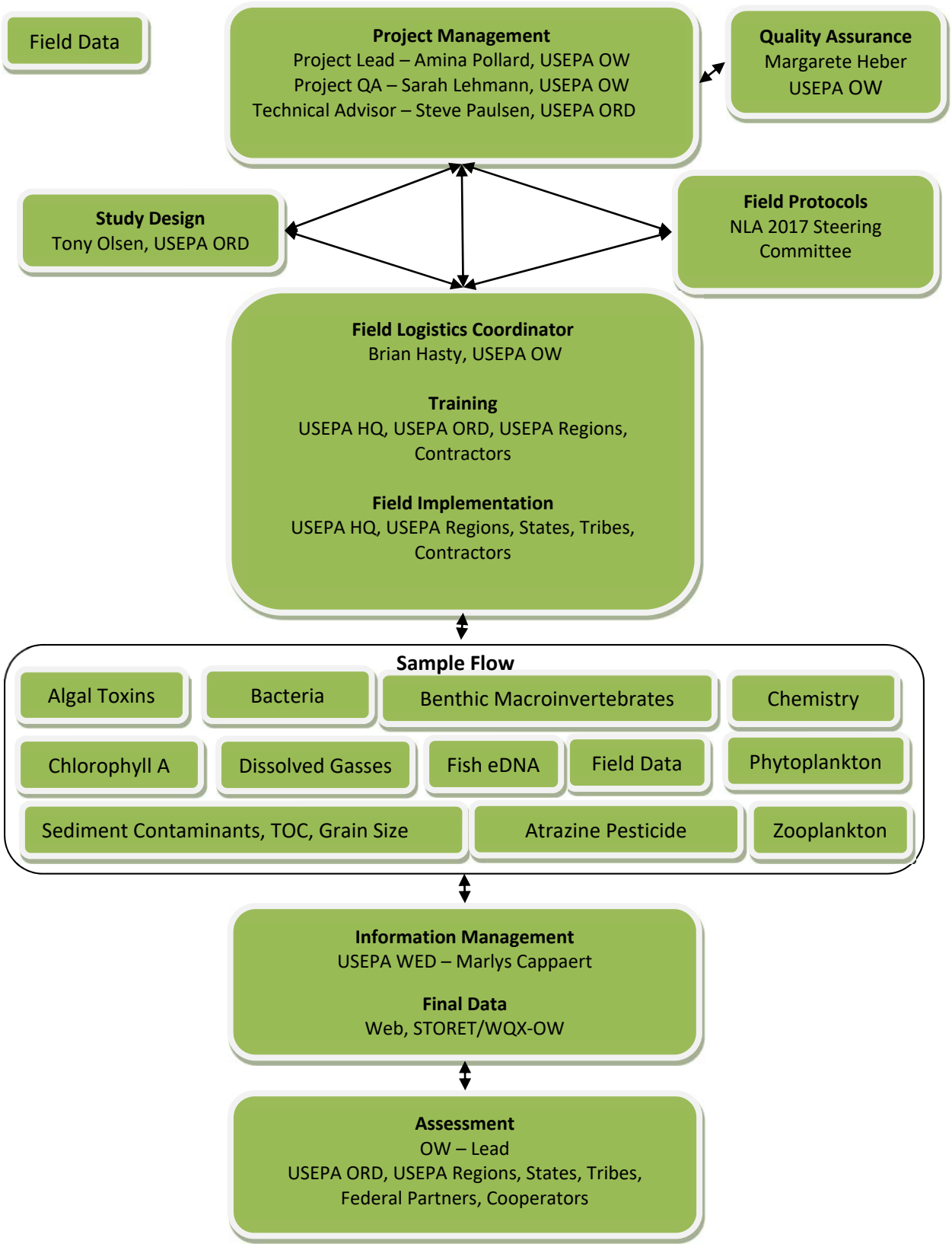


Figure 2.1 National Lakes Assessment 2017 project organization chart.

Specific procedures for evaluating each sampling location and for replacing non-sampleable sites are documented in the NLA 2017 SEG. Field crews procure scientific collecting permits from State, Tribal, and Federal agencies, as needed. The field crews use standard field equipment and supplies. Field Crew Leaders from states and tribes work with USEPA Regional Coordinators and the NARS Information Management (IM) Center to coordinate equipment and supply requirements. This helps to ensure comparability of protocols across states. Detailed lists of equipment required for each field protocol, as well as guidance on equipment inspection and maintenance, are contained in the FOM.

Trained crews collect field measurements and samples. Each Field Crew Leader must be trained at an USEPA-sponsored training session prior to the start of the field season (see **Table 2.1**), along with as many crew members as possible. USEPA provides the three-day training sessions in a number of locations around the country for cooperators and contractors. It is strongly encouraged that field crews attend all three days of training. The training program stresses hands-on practice of methods, comparability among crews, collection of high quality data and samples, and safety. All field crews providing field operational support to NLA 2017 must adhere to the provisions of this integrated QAPP, FOM, and SEG. Trainers maintain a list of all personnel trained and provide the information to the NLA Project Lead and the QA Project Lead.

The Project QA Coordinator or his/her designated member of the Quality Team maintains training documentation in NLA 2017 QA files. Field crews may not operate without a trained field crew leader present.

Table 2.1 Field training sessions for NLA 2017.

Date	Training Location	Primary Trainees*
March 6-9, 2017	Folsom Lake, CA	Train the trainer
April 4-6, 2017	Moss Landing, CA	AZ, CA, HI, NV
April 11-13, 2017	Broken Bow, OK	LA, AR, OK, NM, TX
April 18-20, 2017	Denver, CO	CO, MT, ND, SD, UT, WY
May 2-4, 2017	Flintstone, MD	PA, WV, VA, DE, MD, DC, NJ
May 9-11, 2017	St. Petersburg, FL	KY, TN, MS, AL, GA, FL, SC, NC
May 16-18, 2017	Lake Geneva, WI	IL, IN, MI, MN, OH, WI
May 25-27, 2017	Kansas City, MO	IA, MO, KS, NE
June 6-8, 2017	North Chelmsford, MA	CT, ME, MA, NH, RI, VT, NY
June 13-15, 2017	Lacey, WA	AK, ID, OR, WA

*Actual trainees will change based on training dates and who is conducting the sampling

Trained evaluators conduct evaluation and assistance visits with each Field Crew early in the sampling and data collection process. Evaluators provide corrective actions in real time. These visits provide USEPA with a basis for the uniform evaluation of the data collection techniques, and an opportunity to conduct procedural reviews to minimize data loss due to improper technique or interpretation of program guidance. The field visit evaluations are based on the uniform training, plans, and checklists. For more information on field assistance visits see Section 8 of the FOM.

Crews may use a variety of methods to access a lake. Some sampling locations require crews to hike in, transporting all equipment in backpacks. For this reason, EPA and the steering committee considered

ruggedness and weight as important considerations in the selection of equipment and instrumentation. Crews may need to camp out at the sampling location and may need to provide themselves with the necessary camping equipment.

The site verification process is outlined in the NLA 2017 SEG and FOM. EPA fully documented all methods used in the field in step-by-step procedures in the NLA 2017 FOM. The manual also contains detailed instructions for completing documentation, labeling samples, any field processing requirements, and sample storage and shipping. Field communications is through Field Crew Leaders, and involves regularly scheduled conference calls or contacts with the NLA 2017 logistics staff

Standardized field data forms are the primary means of data recording. For NLA 2017, crews are using electronic field forms (NLA eforms application). Back-up paper forms are available if needed. On completion, a field crew member other than the person who initially entered the information reviews the data forms. Prior to departure from the field site, the field crew leader reviews all forms and labels for completeness and legibility and ensures that all samples are properly labeled and packed. This review process is done for either form of data collection (electronic or paper). Field crews also back-up electronic field data to an iStick in case data are lost from the tablet.

Upon return from field sampling to the office, field crews using electronic forms send completed forms via email as soon as they have access to email. Field crews using paper forms send completed data forms to the information management staff at WED in Corvallis, Oregon for entry into a computerized database. At WED, the IM team review electronic data files independently to verify that values are consistent with those recorded on the field data form or original field data file (see **Section 5.4.4**).

Field crews store or package samples for shipment in accordance with instructions contained in the NLA 2017 Field Operations Manual, including taking precautions so holding times are not exceeded. Field crews deliver samples which must be shipped to a commercial carrier; crews maintain copies of bills of lading or other documentation. Using the tracking form, crews notify the NARS IM Center about sample shipment; thus, NARS IM and Logistics staff can initiate tracking procedures quickly in the event samples are not received. Crews complete chain-of-custody forms for all transfers of samples, with copies maintained by the field crew. The Logistics staff follows up with field crews about any missing samples and/or incomplete files.

The field operations phase is completed with collection of all samples or expiration of the sampling window.

2.2.2 Overview of Laboratory Operations

Holding times for surface water samples vary with the sample types and analytes. Some analytical measurements begin during sampling (e.g., *in situ* profiles) while others are not initiated until sampling has been completed (e.g., phytoplankton and zooplankton). Analytical methods are summarized in the NLA 2017 LOM.

Chemical, physical, or biological analyses may be performed by cooperator or contractor laboratories. Laboratories providing analytical support must have the appropriate facilities to properly store and prepare samples and appropriate instrumentation and staff to provide data of the required quality within the time period dictated by the project. Laboratories are expected to conduct operations using good laboratory practices. The following are general guidelines for analytical support laboratories:

- A program of scheduled maintenance of analytical balances, water purification systems, microscopes, laboratory equipment, and instrumentation.

- Verification of the calibration of analytical balances using class "S" weights which are certified by the National Institute of Standards and Technology (NIST).
- Verification of the calibration of top-loading balances using NIST-certified class "P" weights.
- Checking and recording the composition of fresh calibration standards against the previous lot. Acceptable comparisons are less than or equal to two percent of the theoretical value (This acceptance is tighter than the method calibration criteria.).
- Recording all analytical data in bound logbooks in ink, or on standardized recording forms.
- Verification of the calibration of uniquely identified daily use thermometers using NIST-certified thermometers.
- Monitoring and recording (in a logbook or on a recording form) temperatures and performance of cold storage areas and freezer units (where samples, reagents, and standards may be stored). During periods of sample collection operations, monitoring must be done on a daily basis.
- An overall program of laboratory health and safety including periodic inspection and verification of presence and adequacy of first aid and spill kits; verification of presence and performance of safety showers, eyewash stations, and fume hoods; sufficiently exhausted reagent storage units, where applicable; available chemical and hazardous materials inventory; and accessible safety data sheets for all required materials.
- An overall program of hazardous waste management and minimization, and evidence of proper waste handling and disposal procedures (e.g., 90-day storage, manifested waste streams, etc.).
- If needed, having a source of reagent water meeting American Society of Testing and Materials (ASTM) Type I specifications for resistivity (>18 megaohms/cm (MQ/cm; at 25 °C; ASTM D1193-6) available in sufficient quantity to support analytical operations.
- Appropriate microscopes or other magnification for biological sample sorting and organism identification.
- Approved biological identification and taxonomic keys/guides for use in biological identification (zooplankton and benthic macroinvertebrates) as appropriate.
- Labeling all containers used in the laboratory with date prepared contents, and initials of the individual who prepared the contents.
- Dating and storing all chemicals safely upon receipt. Chemicals are disposed of properly when the expiration date has expired.
- Using a laboratory information management system to track the location and status of any sample received for analysis.
- Reporting results electronically using standard formats and units compatible with NARS IM (see NLA 2017 LOM for data templates). These files are labeled properly by referencing the indicator and/or analyte and date.

All laboratories providing analytical support to NLA 2017 must adhere to the provisions of this integrated QAPP and LOM. Laboratories provide information documenting their ability to conduct the analyses with the required level of data quality prior to data analysis. EPA provides different requirements based on the type of analysis being done by the lab (i.e., chemistry vs. biological analyses).

Labs send the documentation to the Laboratory Review Coordinator at USEPA Headquarters (or other such designated parties) to maintain in the NLA 2017 QA files. Such information may include the following, depending on the evaluation by the Quality Assurance Project Coordinator and the Laboratory Review Coordinator:

- Signed Quality Assurance Project Plan by the laboratory performing the analysis.
- Signed Laboratory Form.
- Valid Accreditation or Certification.
- Laboratory's Quality Manual and/or Data Management Plan.
- Method Detection Limits (MDL).
- Demonstration of Capability.
- Results from inter-laboratory comparison studies.
- Analysis of performance evaluation samples.
- Control charts and results of internal QC sample or internal reference sample analyses to document achieved precision, bias, accuracy.

Other laboratory requirements may include:

- Participation in calls regarding laboratory procedures and processes with participating laboratories.
- Participation in a laboratory technical assessment or audit.
- Participation in performance evaluation studies.
- Participation in inter-laboratory sample exchange.

All qualified laboratories shall work with the NARS IM Center to track samples as specified in Section 1 of the LOM.

2.2.2.1 *Biological Laboratory Quality Evaluation*

The NLA 2017 Quality Team requested and, whenever possible, reviewed the past performance of biological laboratories. The biological laboratories shall adhere to the quality assurance objectives and requirements as specified for the pertinent indicators in the LOM.

2.2.3 Data Analysis and Reporting

A technical data analysis and reporting workgroup convened by the USEPA Project Leader is responsible for development of a data analysis plan that includes a verification and validation strategy. These processes are summarized in the data analysis sections of this QAPP. Validated data are transferred to the central database managed by NARS IM support staff located at WED in Corvallis. Information management activities are discussed further in Section 4. Data in the WED database are available to Cooperators for use in development of indicator metrics. All validated measurement and indicator data from NLA 2017 are eventually transferred to USEPA's Water Quality Exchange (WQX) and then the National STORET warehouse.

2.2.4 Peer Review

If deemed necessary, the NLA 2017 report will undergo a thorough peer review process. Cooperators have been actively involved in the development of the overall project management, design, methods, and standards including the drafting of four key project documents:

- Quality Assurance Project Plan.
- Site Evaluation Guidelines.

- Field Operations Manual.
- Laboratory Operations Manual.

The USEPA NARS program, including the NLA 2017, utilizes a three-tiered approach for peer review of the Survey: (1) internal and external review by USEPA, states, other cooperators and partners, (2) external scientific peer review, when applicable, and (3) public review, when applicable.

Once data analysis has been completed, cooperators examine the results. The NLA team reviews comments and feedback from the cooperators and incorporate such feedback into the draft report, when appropriate. The NLA Project Team follows Agency and OMB requirements for public and peer review. External scientific peer review and public review is initiated for new analyses or approaches as appropriate. Additionally, following applicable guidance other aspects of the NLA may undergo public and scientific peer review.

Below are the proposed measures USEPA plans for engaging in the peer review process:

- Follow the USEPA's Information Quality Guidelines and complete the checklist
- Develop and maintain a public website with links to standard operating procedures, quality assurance documents, fact sheets, scientific peer review feedback, and final report.
- Conduct technical workgroup meetings composed of scientific experts, cooperators, and USEPA to evaluate and recommend data analysis options and indicators.
- Complete data validation on all chemical, physical and biological data.
- Conduct final data analysis with workgroup to generate assessment results.
- Engage peer review contractor to identify external peer review panel (if applicable).
- Develop draft report presenting assessment results.
- Develop final draft report incorporating input from cooperators and results from data analysis group to be distributed for peer a review.
- Issue Federal Register (FR) Notice announcing document availability and hold public comment (30-45 days) (if applicable).
- Consider public comments (if applicable) and produce a final report.

The proposed peer review schedule is provided below in **Table 2.2** and is contingent upon timeliness of data validation and schedule availability for regional meetings and experts for data analysis workshop.

Table 2.2 Proposed peer review schedule for NLA 2017 report.

Proposed Schedule	Activity
May – December 2018	Data validation
May – August 2019	Internal data analysis and review meetings (e.g., web conferences)
August 2019	Draft released for external peer review (if applicable)
October 2020	Draft released for public review (if applicable)

3 DATA QUALITY OBJECTIVES

It is a policy of the USEPA that Data Quality Objectives (DQOs) be developed for all environmental data collection activities following the prescribed DQO Process. DQOs are qualitative and quantitative statements that clarify study objectives, define the appropriate types of data, and specify the tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA 2006). Data quality objectives thus provide the criteria to design a sampling program within cost and resource constraints or technology limitations imposed upon a project or study. DQOs are typically expressed in terms of acceptable uncertainty (e.g., width of an uncertainty band or interval) associated with a point estimate at a desired level of statistical confidence (USEPA 2006). The DQO Process is used to establish performance or acceptance criteria, which serve as the basis for designing a plan for collecting data of sufficient quality and quantity to support the goals of a study (USEPA 2006). As a general rule, performance criteria represent the full set of specifications that are needed to design a data or information collection effort such that, when implemented, it will generate newly-collected data that are of sufficient quality and quantity to address the project's goals (USEPA 2006). Acceptance criteria are specifications intended to evaluate the adequacy of one or more existing sources of information or data as being acceptable to support the project's intended use (USEPA 2006).

3.1 Data Quality Objectives

Target DQOs established for the NLA 2017 relate to the goal of describing the current status of selected indicators of the condition of lakes in the conterminous U.S. and ecoregions of interest. The formal statement of the DQO for national estimates is as follows:

- Estimate the proportion of lakes (± 5%) in the conterminous U.S. that fall below the designated threshold for good conditions for selected measures with 95% confidence.

For the ecoregions of interest, the DQO is:

- Estimate the proportion of lakes (± 15%) in a specific ecoregion that fall below the designated threshold for good conditions for selected measures with 95% confidence.

For estimates of change, the DQOs are:

- Estimate the proportion of lakes (± 7%) in the conterminous U.S. that have changed condition classes for selected measures with 95% confidence.

3.2 Measurement Quality Objectives

For each parameter, performance objectives (associated primarily with measurement error) are established for several different data quality indicators (following USEPA Guidance for Quality Assurance Plans, USEPA 2002). Specific Measurement Quality Objectives (MQOs) for each parameter are presented in the indicator section of the LOM or FOM as appropriate. The following sections define the data quality indicators and present approaches for evaluating them against acceptance criteria established for the program.

3.2.1 Laboratory Reporting Level (Sensitivity)

For water chemistry measurements, requirements for the method detection limit (MDL) are typically established (see indicator specific information in the LOM for specifics on what is used for each indicator). The MDL is defined as the lowest level of analyte that can be distinguished from zero with 99

percent confidence based on seven measurements (40CFR136 App. B). USGS NWQL has developed a variant of the MDL called the long-term MDL (LT-MDL) to capture greater method variability (Oblinger Childress et al. 1999). Unlike MDL, it is designed to incorporate more of the measurement variability that is typical for routine analyses in a production laboratory, such as multiple instruments, operators, calibrations, and sample preparation events (Oblinger Childress et al. 1999). Because the LT-MDL addresses more potential sources of variability than the MDL, the NLA uses the LT-MDL.

For the NLA, target long-term MDL (LT-MDL, following Oblinger-Childress et al., 1999) values were established for each chemical analyte based on the anticipated range of concentrations expected, values required as thresholds for assigning lake condition based on chemical stressors (e.g., nutrients, acidification, salinity, etc.) or trophic state (oligotrophic vs. mesotrophic vs. eutrophic), and the capability of analytical laboratories to measure an analyte at low concentrations over time given available methods.

The LT-MDL determination ideally employs at least 24 blanks and spiked samples prepared and analyzed by multiple analysts on multiple instruments over a 6- to 12-month period at a frequency of about two samples per month (USEPA 2004). The LT-MDL uses "F-pseudosigma" (F_σ) in place of s, the sample standard deviation, used in the EPA MDL calculation. F-pseudosigma is a non-parametric measure of variability that is based on the interquartile range of the data (USEPA 2004). The LT-MDL is calculated using either the mean or median of a set of long-term blanks, and from long-term spiked sample results (depending on the analyte and specific analytical method). The LT-MDL for an individual analyte is calculated as:

Equation 3-1. LT-MDL calculation for an individual analyte.

$$LT-MDL = M + \left(t_{0.99,n-1} \times F_\sigma\right)$$

a.

where:

M = the mean or median of blank results

n = the number of spiked sample results

F_σ = F-pseudosigma, a nonparametric estimate of variability calculated as:

b.

$$F_\sigma = \frac{Q_3 - Q_1}{1.349}$$

where:

Q_3 = the 75th percentile of spiked sample results

Q_1 = the 25th percentile of spiked sample results

LT-MDL is designed to be used in conjunction with a laboratory reporting level (LRL; Oblinger Childress et al. 1999).

The lab monitors performance using the determined/calculated LT-MDL values, but uses the MDLs as determined based on 40CFR136 App. B to establish MDLs and Reporting Levels for reporting purpose,

estimates and flagging (RLs are also known as minimal reporting levels). The RL values are designed to achieve a risk of ≤1% for both false negatives and false positives (Oblinger- Childress et al., 1999). The Laboratory Reporting Limit (LRL) is set as two times higher than the target LT-MDL value. Therefore, multiple measurements of a sample having a true concentration at the RL should result in the concentration being detected and reported 99 percent of the time (Oblinger- Childress et al., 1999).

Target MDL and RL values are based on the presumption that a laboratory receives samples from across the United States. Laboratories analyzing NLA samples from a more restricted region may have modified target RL values based on the range of expected concentrations and required thresholds values. A modified RL for a "regional" laboratory cannot be greater than a required threshold value used in the NLA assessment. The objective for NLA is to minimize the number of values reported as "estimated" by an individual laboratory (i.e., between an estimated MDL and the laboratory RL).

For chemical analyses, all participating laboratories will monitor their target RL values by one (or both) of the following approaches:

1) For every calibration curve, include a calibration standard with an analyte concentration equal to the RL.
2) Monitor the RL by including a Quality Control Sample (QCS) with a concentration equal to the RL with each analytical batch. Results of each QCS analysis must meet the acceptance criteria established for precision and bias (**Section 3.2.3**).

Laboratories are encouraged to conduct evaluations of analytical performance using samples at the target RLs established based on a "national" laboratory (receiving samples from across the US). These studies provide an indication of the confidence that can be placed on "estimated" results reported by the laboratory.

Laboratories must submit estimates of RLs (and how they are determined) with analytical results. Laboratories must flag analytical results associated with RLs that exceed the objectives as being associated with unacceptable RLs. Laboratories must report analytical data that are below the estimated RLs, but above the laboratory's MDL, but laboratories also flag these as "estimated" values (detected but not quantified). Laboratories should report (if possible), values below the MDL, but the laboratory must flag the value as being below the MDL. If a laboratory has to report values below the MDL as being equal to the MDL, this must be clearly stated in the metadata submitted with any analytical results to avoid the misuse of these results in assessment analyses.

3.2.2 Field Measurements

Since analytical (or field) precision, bias, and accuracy of field measurements is not monitored separately during the NLA 2017, a revisit site approach is implemented to help evaluate the quality of data (revisiting sites within the NLA 2017 index period). The survey design also incorporates a plan for resampling a subset of sites from previous NLAs (including a subset of 226 lakes that were originally sampled in NLA 2007 and 218 lakes that were originally sampled in NLA 2012). Data from these repeat visits provide estimates of important components of variance to evaluate the performance of ecological indicators, evaluate the capability of the survey design to estimate status vs. detect trend, and to potentially reduce bias in the population estimates by "de-convoluting" the variance. These variance components are presented in **Table 3.1**. If estimates of these components are available from other studies, they are used in conjunction with the project requirements to evaluate alternative design scenarios (Larsen et al., 1995, 2001, 2004). Status estimates are influenced most by the interaction (if multiple years are required to complete sampling) and residual variance components. Residual variance is composed of temporal variance within a sampling period confounded with measurement error of

various types. If the magnitude of residual variance is sufficiently large to impact status estimates (see above), then relative magnitudes of the interaction variance and various components of residual variance are examined to determine if any reduction can be achieved in the future. Interaction variance can only be reduced by increasing the sample size. Index variance can be reduced by either increasing the number of sites, increasing the number of times a site is visited within a year, reducing the length of the index period, or by reducing measurement error. Trend detection is evaluated using the equation to determine the variance in the slope of the trend (**Table 3.1**). In the equation, residual variance also includes the interaction component. For multi-site networks such as the national aquatic resource assessments, trend detection is most sensitive to coherent year variance, which can only be reduced by extending the time period for monitoring (Larsen et al., 1995, 2001, 2004). If residual variance is large relative to the coherent year variance, then trend detection within a fixed time period can be improved by increasing the number of sites sampled each year, increasing the number of times each site is sampled within a year, or by reducing measurement error.

Table 3.1 Important variance components for aquatic resource assessments.

Model for status estimation	Model for trend detection
$\sigma^2_{total} = \sigma^2_{sites} + \left(\sigma^2_{year} + \sigma^2_{site\times year} + \sigma^2_{residual}\right)$	$\mathrm{var}(slope) = \dfrac{\frac{\sigma^2_{sites}}{N_{sites}} + \left(\sigma^2_{year} + \frac{s^2_{residual}}{N_{sites}}\right)}{\sum_{i=1}^{years}\left(y_i - \bar{Y}\right)^2}$
and	
$\sigma^2_{residual} = \sigma^2_{within\text{-}year} + \sigma^2_{error}$	
	And
	$s^2_{residual} = \sigma^2_{site\times year} + \dfrac{\sigma^2_{residual}}{N_{visit}}$
Components in parentheses represent "extraneous" variance	

Variance Component	Description
σ^2_{sites}	Observed variance among all sites or streams sampled over multiple-year sampling cycle. If sites are revisited across years, this effect can be eliminated.
σ^2_{year}	Coherent variance across years that affects all sites equally, due to regional-scale factors such as climate or hydrology. Principal effect on trend detection, reduced only by increasing number of years
$\sigma^2_{site\times year}$	"Interaction" variance occurring at each site across years that affects each site independently. Principal effect on status, reduce by increasing number of sites.
$\sigma^2_{residual}$	"Residual" variance: Includes temporal variance at each site within a single index period ($\sigma^2_{within\text{-}year}$) confounded with measurement error (σ^2_{error}) due to acquiring the data from the site (e.g., sample collection and analysis) Principal effect on status, If $\sigma^2_{index} >> \sigma^2_{error}$ reduce by increasing number of sites or altering index period. If σ^2_{error} is large relative to σ^2_{index}, then modify sampling and analysis procedures.

For NLA 2017, 10 percent of all sample sites receive repeat visits to determine temporal variability plus analytical variability within the index period. Revisit sites must be sampled at least 2 and as long as possible within the index period to ensure that temporal variability is assessed. The NLA team

implements control measures to minimize measurement error among crews and sites. These control measures include the use of standardized field protocols provided in the FOM, consistent training of all crews, field assistance visits to all field crews, and availability of experienced technical personnel during the field season to respond to site-specific questions from field crews as they arise.

3.2.3 Chemical Precision, Bias, and Accuracy

The information in this section is particularly relevant to analysis of water chemistry precision, bias and accuracy; sediment chemistry precision and accuracy and bacteria precision. See more specifics for how these are applied in the relevant sections of the LOM. See additional information on QC procedures for other indicators in the relevant sections of the LOM.

Precision and bias are estimates of random and systematic error in a measurement process (Kirchmer, 1983; Hunt and Wilson, 1986; USEPA, 2002). Collectively, precision and bias provide an estimate of the total error or uncertainty associated with an individual measurement or set of measurements. Systematic errors are minimized by using validated methods and standardized procedures across all laboratories. Precision is estimated from repeated measurements of samples. Net bias is determined from repeated measurements of solutions of known composition, or from the analysis of samples that have been fortified by the addition of a known quantity of analyte. For analytes with large ranges of expected concentrations, MQOs for precision and bias are established in both absolute and relative terms, following the approach outlined in Hunt and Wilson (1986). At lower concentrations, MQOs are specified in absolute terms. At higher concentrations, MQOs are stated in relative terms. The point of transition between an absolute and relative MQO is calculated as the quotient of the absolute objective divided by the relative objective (expressed as a proportion, e.g., 0.10 rather than as a percentage, e.g., 10%).

Precision in absolute terms is estimated as the sample standard deviation(*s*) when the number of measurements is greater than two:

Equation 3-2. Precision in absolute terms.

$$s = \sqrt{\frac{i = \sum_{1}^{n} (x_i - \bar{x})^2}{n-1}}$$

where x_i is the value of the replicate, $\bar{x}$ is the mean of repeated sample measurements, and n is the number of replicates. Relative precision for such measurements is estimated as the relative standard deviation (*RSD*, or coefficient of variation, [CV]):

Equation 3-3. Relative precision.

$$RSD = \frac{s}{\bar{X}}$$

where *s* is the sample standard deviation of the set of measurements, and $\bar{x}$ equals the mean value for the set of measurements. Both RSD and CV can be expressed as percentages by multiplying by 100.

Precision based on duplicate measurements is estimated based on the range of measured values (which equals the difference for two measurements).
The relative percent difference (*RPD*) is calculated as:

Equation 3-4. Relative percent difference.

$$RPD = \left(\frac{|A - B|}{(A + B)/2} \right) \times 100$$

where *A* is the first measured value, and *B* is the second measured value.

For repeated measurements of samples of known composition, net bias (*B*) is estimated in absolute terms as:

Equation 3-5. Net bias.

$$B = \bar{x} - T$$

where $\bar{x}$ equals the mean value for the set of measurements, and *T* equals the theoretical or target value of a performance evaluation sample.

Bias in relative terms (*B[%]*) is calculated as:

Equation 3-6. Bias in relative terms.

$$B(\%) = \frac{\bar{x} - T}{T} \times 100$$

where $\bar{x}$ equals the mean value for the set of measurements, and *T* equals the theoretical or target value of a performance evaluation sample.

Accuracy is estimated for some analytes from fortified or spiked samples as the percent recovery. Percent recovery (*%recovery*) is calculated as:

Equation 3-7. Percent recovery.

$$\%recovery = \frac{C_{is} - C_{ii}}{C_s} \times 100$$

where C_{is} is the measured concentration of the spiked sample, C_{ii} is the concentration of the unspiked sample, and C_s is the concentration of the spike.

For NLA 2017 each laboratory must monitor precision and bias for every sample batch by the analysis of internal QC samples. Laboratories also report on percent recovery to determine accuracy. Laboratories must review and re-analyze samples associated with unacceptable QC sample results within one week or analyte holding time, whichever is longer. Laboratories should consult with the Project QA manager about any unacceptable results within one week and to verify that the appropriate corrective actions are taken.

3.2.4 Taxonomic Precision and Accuracy of Benthic Macroinvertebrates and Zooplankton

NLA 2017 includes two layers of quality assurance for biological data: internal and external.

3.2.4.1 *Internal quality assurance and quality control for biological data*

Each laboratory conducts internal, or within laboratory, quality assurance and quality control activities. Each laboratory must evaluate the sorting efficiency of the NLA 2017 laboratory analysts. All laboratory

analysts responsible for taxonomic identification must participate in an internal taxonomic verification check. The details of the sorting and taxonomic verifications can be found in the indicator-specific sections of the NLA 2017 LOM.

3.2.4.2 *External quality assurance for biological data*

Each laboratory participates in external, or among laboratory, quality assurance. In general, external quality assurance takes two forms: (1) an independent taxonomist re-analyzes 10% of samples or (2) all of the laboratories participate in a round robin, where they swap 10% of samples among laboratories and re-analyze them. The details of the external quality assurance requirements (e.g., taxonomic resolution, calculations) are found in the indicator-specific sections of the NLA 2017 LOM.

For benthic macroinvertebrates and zooplankton, accuracy of taxonomy is qualitatively evaluated through specification of target hierarchical levels (e.g., family, genus, or species); and the specification of appropriate technical taxonomic literature or other references (e.g., identification keys). To calculate taxonomic precision, USEPA randomly selects 10% of the samples for re-identification by an independent, outside taxonomist or laboratory. Comparison of the results of whole sample re-identifications provides a Percent Taxonomic Disagreement (*PTD*) calculated as:

Equation 3-8. Percent taxonomic disagreement.

$$PTD = \left[1 - \left(\frac{comp_{pos}}{N}\right)\right] \times 100$$

where $comp_{pos}$ is the number of agreements, and *N* is the total number of individuals in the larger of the two counts. The lower the *PTD*, the more similar the taxonomic results and the greater the overall taxonomic precision. An MQO of 15% is recommended for taxonomic difference (overall mean <15% is acceptable). Individual samples exceeding 15% are examined for taxonomic areas of substantial disagreement, and the reasons for disagreement investigated.

In addition, percent similarity (*PSC*) is calculated between the taxonomic laboratories. Percent similarity is a measure of similarity between two communities or two samples (Washington, 1984). Values range from 0% for samples with no species in common, to 100% for samples which are identical. It is calculated as follows:

Equation 3-9. Percent similarity.

$$PSC = 1 - 0.5\sum_{i=1}^{K}\left|a - b\right|$$

where: *a* and *b* are, for a given species, the relative proportions of the total samples A and B, respectively, which that species represents. An MQO of ≥85% is recommended for percent similarity of taxonomic identification. If the MQO is not met, the reasons for the discrepancies between analysts is discussed. If a major discrepancy is found in how the two analysts have been identifying organisms, the last batch of samples that have been counted by the analyst under review may have to be re-counted.

Sample enumeration is another component of taxonomic precision. Final specimen counts for samples are dependent on the taxonomist, not the rough counts obtained during the sorting activity.

Comparison of counts is quantified by calculation of Percent Difference in Enumeration (*PDE*), calculated as:

Equation 3-10. Percent difference in enumeration.

$$PDE = \left(\frac{|Lab1 - Lab2|}{Lab1 + Lab2} \right) \times 100$$

An MQO of 5% is recommended (overall mean of ≤5% is acceptable). Individual samples exceeding 5% are examined to determine reasons for the exceedance.

Corrective actions for samples exceeding these MQOs can include defining the taxa for which re-identification may be necessary (potentially even by third party), for which samples (even outside of the 10% lot of QC samples) it is necessary, and where there may be issues of nomenclatural or enumeration problems. Specific corrective actions are identified in the indicator sections of the LOM.

Taxonomic accuracy is evaluated by having individual specimens (representative of selected taxa) identified by recognized experts. Samples are identified using the most appropriate technical literature that is accepted by the taxonomic discipline and that reflects the accepted nomenclature including the NLA taxonomic lists from past surveys. Specific references are identified in the indicator sections in the LOM. Any laboratory or taxonomist who believes these are not sufficient must contact the USEPA NLA Project Leader and Project QA Coordinator to discuss options. The internal NLA taxonomic lists are used to verify nomenclatural validity and spelling. A reference collection is compiled as the samples are identified. If necessary, specialists in several taxonomic groups verify selected individuals of different taxa, as determined by the NLA workgroup.

3.2.5 Precision of Physical Habitat Indicators

In a regional or national assessment of status, differences among lakes are the signal of interest, but real differences can be obscured by noise variance (Paulsen et al. 1991, Kaufmann et al. 1999). The habitat variables (metrics) of interest are lake summary variables based on measurements at 10 randomized, equidistant nearshore stations employing measurements and observations at littoral, riparian, and drawdown zone plots at each of those stations.

Measures of variance between repeat visits within the sampling season of the same year provide accurate estimates of the variances in individual lake habitat metrics that would be encountered in a spatially extensive survey carried out over a typical summer field season. Repeat visit variance includes the combined effects of within-season habitat variation, measurement variation, changes in the locations of sampling plots between visits to individual lakes, and variation in estimates obtained by different field crews. Analysts employed variance components analysis to estimate repeat visit variance and the signal:noise (S/N) ratio which is one expression of the relative precision of habitat metrics (Kaufmann et al. 1999).

Equation 3-11. Repeat visit variance.

σ^2_{rep}

Equation 3-12. Signal:noise ratio.

$S/N = \sigma^2_{lake}/\sigma^2_{rep}$

Analysts used the general random-effects model of Kincaid, et al. (2004) to model the sources of variation in any habitat variable, *Y*, as

Equation 3-13. Source of variation in habitat variable.

$$Y_{ijk} = \mu + L_i + T_j + LT_{ij} + E_{ijk},$$

Here Y_{ijk} is the measured metric value for the k^{th} visit to lake i within the j^{th} year. The grand mean value is μ, and L and T are random lake and year effects, respectively. For the NLA, data came from a single year, so the year (T) and lake:year interaction (LT) terms in Equation 3-13 are zero, and the model simplifies to the form $Y_{ik} = \mu + L_i + E_{ik}$. The residual error ($E_{ik}$) of the simplified model represents within-year variation at any single lake, which we estimated from a subset of the lakes that were resampled the same summer. Analysts assume that L_i and E_{ik} are normally-distributed random effects, with variances of σ^2_{lake} and σ^2_{rep}, respectively. The combined data set containing samples from different lakes as well as revisits to same lakes, enabled estimation of both among-lake variance (σ^2_{lake}) and repeat visit variance (σ^2_{rep}) using restricted maximum likelihood (Littell et al. 2006).

In the synoptic survey context, variance among lakes (σ^2_{lake}) is the signal of interest, and the variance in revisits within the index period from all sources (σ^2_{rep}) is noise variance; we define their ratio as *S/N*. The methods used to quantify precision, the precision of NLA lake physical habitat metrics and key habitat condition indices, the implications of varying precision levels for monitoring and assessment, application of habitat condition indicators in a national assessment, and the biological relevance of the NLA indicators are comprehensively evaluated by Kaufmann et al. (2014a,b,c). Below is a summary of precision for key physical habitat indicators based on the NLA 2012 survey data, which employed the same field methods as NLA 2017.

The key NLA physical habitat indices had moderate to high *S/N* (2.2 – 11.0) over the entire NLA-2012 survey (Table 7 and Appendix B, USEPA 2016). Compared with the other composite indices, the human disturbance index *RDis_IX* and horizontal drawdown index had the highest *S/N* (9.1-11), whereas the littoral cover O/E index had the lowest S/N (2.2). The advantage of *S/N* as a precision measure is its relevance to many types of statistical analysis and detecting differences in subpopulation means (Zar 1999). High noise in habitat descriptions relative to the signal (i.e., low signal: noise ratio, *S/N*) diminishes statistical power to detect differences among lakes or groups of lakes. Imprecise data limit the ability to detect temporal trends (Larsen et al. 2001, 2004). Noise variance also limits the maximum amount of variance that can be explained by models such as multiple linear regression (Van Sickle et al. 2005, Kaufmann and Hughes 2006). By reducing the ability to quantify associations between variables (Allen et al. 1999, Kaufmann et al. 1999), imprecision compromises the usefulness of habitat data for discerning likely controls on biota and diagnosing probable causes of impairment. The adverse effects of noise variance on these types of analysis are negligible when *S/N* >10; becoming minor as *S/N* decreases to 6, increasing to moderate as *S/N* decreases to 2, and finally becoming severely limiting as *S/N* approaches 0 (Paulsen et al. 1991, Kaufmann et al. 1999). At *S/N*=0, all the metric variance observed among lakes in the survey can be attributed to measurement "noise". Based on these guidelines, the effects of imprecision are minor for all the indicators except for the Littoral Cover index, for which the effects are minor-to-moderate.

Kaufmann et al. (2014a) explain that the *S/N* ratio may not always be a good measure of the potential of a given metric to discern ecologically important differences among sites. For example, a metric may easily discriminate between sparse and abundant littoral cover for fish, but S/N for the metric would be low in a region where littoral cover does not vary greatly among lakes. In cases where the signal variance (σ^2_{lake}) observed in a regional survey reflects a large range of habitat alteration or a large range in natural habitat conditions, *S/N* would be a good measure of the precision of a metric relative to what we want it to measure. However, in random surveys or in relatively homogeneous regions, σ^2_{lake} and consequently *S/N*, may be less than would be calculated for a set of sites specifically chosen to span the full range of habitat conditions occurring in a region. To evaluate the potential usefulness of metrics, Kaufmann et al. (2014a) suggested that an alternate measure of relative precision, σ_{rep} divided by its potential or observed range (Rg_{pot} or Rg_{obs}) offers additional insight. The minimum detectable

difference in means between 2 lakes (or between two times in one lake) is given by $D_{min} = 1.96\sigma_{rep}(2n)^{1/2} = 2.77\sigma_{rep}$, using a 2-sided Z-test with $\alpha = 0.05$ (Zar 1999). Thus, to detect any specified difference between 2 lakes in a metric relative to its potential or observed range (Rg_{pot} or Rg_{obs}, the standardized within-lake standard deviation, σ_{rep}/Rg, cannot exceed $(D_{min}/Rg)/2.77$. By the criteria in Kaufmann et al. (2014a, Table 2), the key NLA physical habitat indices were precise or moderately precise, with σ_{rep}/Rg_{obs} between 0.052 – 0.107 (Table 7, USEPA 2016). Depending on the index, they have the potential to discern differences between single lakes (or one lake at two different times) that are between 1/3rd and 1/8th the magnitude of the observed ranges of these indices.

3.2.6 Completeness

Completeness requirements are established and evaluated from two perspectives. First, valid data for individual parameters must be acquired from a minimum number of sampling locations in order to make subpopulation estimates with a specified level of confidence or sampling precision. The objective of this study is to complete sampling at 95% or more of the 1000 initial sampling sites. Percent completeness (*%C*) is calculated as:

Equation 3-14. Percent completeness.

$$\%C = {}^{V}\!/_{T} \times 100$$

where *V* is the number of measurements/samples judged valid, and *T* is the total number of planned measurements/samples. Within each indicator, completeness objectives are also established for individual samples or individual measurement variables or analytes. These objectives are estimated as the percentage of valid data obtained versus the amount of data expected based on the number of samples collected or number of measurements conducted. Where necessary, supplementary objectives for completeness are presented in the indicator-specific sections of the LOM.

In addition to evaluating completeness for each laboratory, the completeness objectives are established for each measurement *per site type* (e.g., probability sites, revisit sites, etc.). Failure to achieve the minimum requirements for a particular site type results in regional population estimates having wider confidence intervals. Failure to achieve requirements for repeat sampling (10% of samples collected) and revisit samples (10% of sites visited) reduces the precision of estimates of index period and annual variance components, and may impact the representativeness of these estimates because of possible bias in the set of measurements obtained.

3.2.7 Comparability

Comparability is defined as the confidence with which one data set can be compared to another (USEPA,2002). A performance-based methods approach is being utilized for water chemistry and chlorophyll *a* analyses that defines a set of laboratory method performance requirements for data quality. Following this approach, participating laboratories may choose which analytical methods they use for each target analyte as long as they are able to achieve the performance requirements as listed in Table 10.4 of the LOM. Requirements for reporting limits may be modified for regional laboratories based on the expected range of concentrations for samples they may receive and required threshold values for assessing condition. For all parameters, comparability is addressed by the use of standardized sampling procedures and analytical methods by all sampling crews and laboratories. Comparability of data within and among parameters is also facilitated by the implementation of standardized quality assurance and quality control techniques and standardized performance and acceptance criteria. For all measurements, reporting units and format are specified, incorporated into standardized data recording forms, and documented in the information management system. Comparability is also addressed by

providing results of QA sample data, such as estimates of precision and bias, conducting methods comparison studies when requested by the grantees and conducting inter-laboratory performance evaluation studies among state, university, and NLA 2017 contract laboratories. See indicator specific sections of the LOM for more information when appropriate.

3.2.8 Representativeness

Representativeness is defined as "the degree to which the data accurately and precisely represent a characteristic of a population parameter, variation of a property, a process characteristic, or an operational condition" (USEPA, 2002). At one level, representativeness is affected by problems in any or all of the other data quality indicators.

At another level, representativeness is affected by the selection of the target surface water bodies, the location of sampling sites within that body, the time period when samples are collected, and the time period when samples are analyzed. The probability-based sampling design should provide estimates of condition of surface water resource populations that are representative of the region. The individual sampling programs defined for each indicator attempt to address representativeness within the constraints of the *response design*, (which includes when, where, and how to collect a sample at each site). Holding time requirements for analyses ensure analytical results are representative of conditions at the time of sampling. See indicator specific sections of the LOM for more information and Appendix B of the FOM for more information.

4 SAMPLING DESIGN AND SITE SELECTION

The overall sampling program for the NLA 2017 project requires a randomized, probability-based approach for selecting lakes where sampling activities are to be conducted. Details regarding the specific application of the probability design to surface waters resources are described in Paulsen et al., (1991), Peck et al., (2013), and Stevens (1994).

4.1 Probability Based Sampling Design and Site Selection

The target population for this project includes all lakes, reservoirs, and ponds within the 48 contiguous United States greater than 1 hectare (2.5 acres) in surface area that are permanent water bodies. Lakes that are saline due to tidal influence are excluded as are those used for aquaculture, disposal-tailings, sewage treatment, evaporation, or other unspecified disposal use. The National Hydrography Dataset (NHD, 1:100,000 scale) was employed by USEPA to derive a list of lakes for potential inclusion in the survey. The overall sample size was set to include 1000 lake sampling events. In NLA 2017, 904 lakes will be sampled; and 96 of the lakes will be sampled twice for a total of 1000 lake visits. The 904 lakes consist of three sets of lakes. The first set is 226 lakes that were originally sampled in NLA 2007, resampled in NLA 2012 and will be resampled again in NLA 2017. Of these, 43 lakes will be sampled twice in NLA 2017. The second set is 218 lakes originally sampled in NLA 2012 and will be resampled again in NLA 2017. Of these, 53 lakes will be sampled twice in NLA 2017. The third set is 460 new lakes that will be sampled for the first time in NLA 2017. This design provides a robust number of sites that we will use to evaluate change between the 2007 and the 2017 lakes assessments. **Figure 4.1** displays the distribution of the 904 base sites from the original NLA 2017 design.

A Generalized Random Tessellation Stratified (GRTS) survey design for a finite resource was used for site selection. Lake selection for the survey provided for six size class categories (1-4 hectares (ha), 4-10 ha, 10-20 ha, 20-50 ha, 50-100 ha, >100 ha), as well as spatial distribution across the lower 48 states and nine aggregated Omernik Level 3 ecoregions (for more information on Omernik ecoregions see https://www.epa.gov/eco-research/ecoregions). USEPA developed another subset of lakes for states that may want to do state level assessments (to increase the overall sample size to 50 per state). Additional lakes were selected as potential replacement lakes (oversample sites). The oversample is used to replace a candidate lake that is determined to be non-target or to replace a target lake that is not accessible due to landowner denials, physical barriers, or safety concerns. Crews must take replacement sites from the Oversample List in the order that they appear in the site list (numerically by SITE_ID). Skipping over sites on the list compromises the integrity of the survey design and complicates the assessment analyses. It is important that crews assign a final status to all sites on the list regardless of whether they end up being sampled.

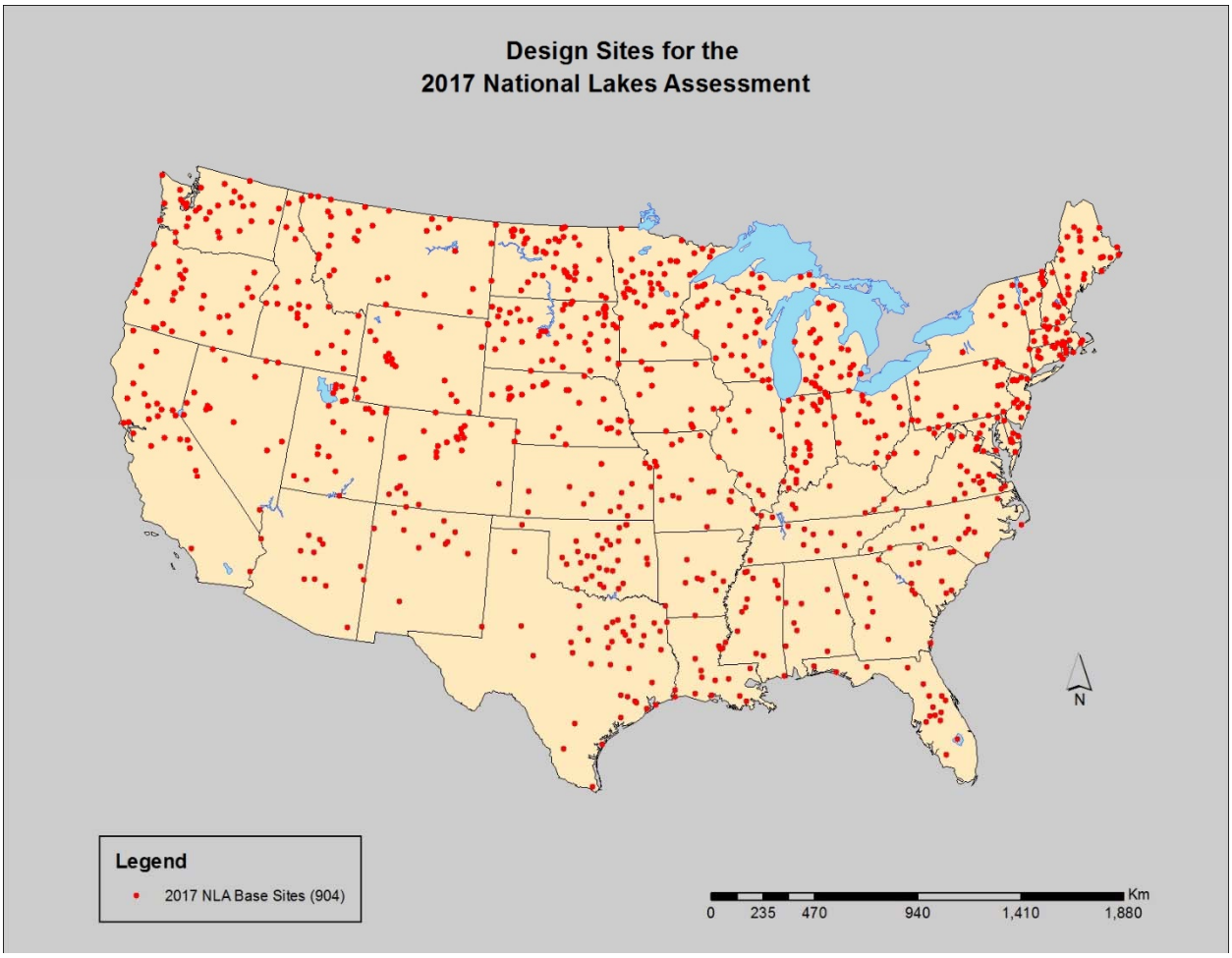


Figure 4.1 Design sites for the 2017 National Lakes Assessment.

Complete documentation is included in Appendix C in the Site Evaluation Guidelines document.

4.2 Reference (or Least-Disturbed) Site Selection

A set of reference lakes (least disturbed lakes), i.e., those that USEPA will use to inform benchmarks in the assessment, will be determined after the complete set of data is returned. At that point, USEPA will run a set of screening criteria similar to that used in NLA 2012 (USEPA, 2009). Analysts will consider whether information from these sites, combined with information from past surveys, indicates a need to revise thresholds used in the NLA 2012.

5 INFORMATION MANAGEMENT

Environmental monitoring efforts that amass large quantities of information from various sources present unique and challenging data management opportunities. To meet these challenges, the NLA 2017 employs a variety of well-tested information management (IM) strategies to aid in the functional organization and ensured integrity of stored electronic data. IM is integral to all aspects of the NLA 2017 from initial selection of sampling sites through the dissemination and reporting of final, validated data. And, by extension, all participants in the NLA 2017 have certain responsibilities and obligations which also make them a part of the IM system. This "inclusive" approach to managing information helps to:

- Strengthen relationships among NLA 2017 cooperators.
- Increase the quality and relevance of accumulated data.
- Ensure the flexibility and sustainability of the NLA 2017 IM structure.

This IM strategy provides a congruent and scientifically meaningful approach for maintaining environmental monitoring data that satisfies both the scientific and technological requirements of the NLA 2017.

5.1 Roles and Responsibilities

At each point where data and information are generated, compiled, or stored, the NLA 2017 team must manage the information. Thus, the IM system includes all of the data-generating activities, all of the means of recording and storing information, and all of the processes that use data. The IM system also includes both hardcopy and electronic means of generating, storing, organizing and archiving data, and the effort to achieve a functional IM process is all encompassing. *To that end, all participants in the NLA 2017 play an integral part within the IM system.* **Table 5.1** provides a summary of the IM responsibilities identified by the NLA 2017 IM group. Specific information on the field crew responsibilities for tracking and sending information is found in the FOM.

Table 5.1 Summary of IM responsibilities.

NLA 2017 Group	Contact	Primary Role	Responsibility
Field Crews	State/tribal partners and contractor or other field crews (regional USEPA, etc.)	Acquire *in-situ* measurements and prescribed list of biotic/abiotic samples at each site targeted for the survey	Complete and review field data forms and sample tracking forms for accuracy, completeness, and legibility. Ship/email field and sample tracking forms to NARS IM Center so information can be integrated into the central database. Work with the NARS IM Center staff to develop acceptable file structures and electronic data transfer protocols should there be a need to transfer and integrate data into the central database. Provide all data as specified in FOM, SEG or as negotiated with the NLA Project Leader. Maintain open communications with NARS IM Center regarding any data issues.
Analytical Laboratories	State/tribal partners and contractors	Analyze samples received from field crews in the	Review all electronic data transmittal files for completeness and accuracy (as identified in the QAPP).

		manner appropriate to acquire biotic/abiotic indicators/measurements requested.	Work with the NARS IM Center staff to develop file structures and electronic data transfer protocols for electronically-based data. Submit completed sample tracking forms to NARS IM Center so information can be updated in the central database. Provide all data and metadata as specified in the laboratory transmittal guidance section of the QAPP or as negotiated with the NLA Project Leader. Maintain open communications with NARS IM Center regarding any data issues.
IM Center staff	USEPA ORD NHEERL Western Ecology Division-Corvallis, Contractors	Provides support and guidance for all IM operations related to maintaining a central data management system for NLA 2017	Develop/update field data forms. Plan and implement electronic data flow and management processes. Manage the centralized database and implement related administration duties. Receive, scan, and conduct error checking of field data forms. Monitor and track samples from field collection, through shipment to appropriate laboratory. Receive data submission packages (analytical results and metadata) as compiled by the NLA 2017 Quality Team from each laboratory or directly (e.g., national water chemistry laboratory). Run automated error checking, e.g., formatting differences, field edits, range checks, logic checks, etc. Receive verified, validated, and final indicator data files (including record changes and reason for change) from QA reviewers. Maintain history of all changes to data records from inception through delivery to WQX. Organize data in preparation for data verification and validation analysis and public dissemination. Implement backup and recovery support for central database. Implement data version control as appropriate.
Project Quality Assurance Coordinator	USEPA Office of Water	Review and evaluate the relevancy and quality of information/data collected and generated through the NLA 2017 survey.	Oversee NLA 2017 Quality Team including initial review of laboratory electronic data deliverables, quality checks and submission of compiled datasets to the NARS IM Center Monitor quality control information. Evaluate results stemming from field and laboratory audits. Investigate and take corrective action, as necessary, to mitigate any data quality issues.

			Issue guidance to NLA 2017 Project Leader and IM Center staff for qualifying data when quality standards are not met or when protocols deviate from plan.
Steering Committee	NLA Project Lead and other team members, USEPA Regional and ORD staff, States, tribes, other federal agencies	Provide technical recommendations related to data analysis, reporting and overall implementation	Provide feedback and recommendations related to QA, data management, analysis, reporting and data distribution issues. Review and comment on QA and information management documentation (QAPP, data templates, etc).
Data Analysis and Reporting Team	USEPA Office of Water, ORD WED, Partners	Provide the data analysis and technical support for NLA 2017 reporting requirements	Provide data integration, aggregation and transformation support as needed for data analysis. Provide supporting information necessary to create metadata. Investigate and follow-up on data anomalies using identified data analysis activities. Produce estimates of extent and ecological condition of the target population of the resource. Provide written background information and data analysis interpretation for report(s). Document in-depth data analysis procedures used. Provide mapping/graphical support. Document formatting and version control. Develops QA report for management.
Data Finalization Team	TBD	Provides data librarian support	Prepare NLA 2017 data for transfer to USEPA public web-server(s). Generate data inventory catalog record (Science Inventory Record). Ensure all metadata is consistent, complete, and compliant with USEPA standards.

5.1.1 State/Tribe-Based Data Management

Some state or tribal partners manage activities for both field sampling and laboratory analyses. While the NARS program encourages states to use these in-house capabilities, it is imperative that NLA 2017 partners understand their particular role and responsibilities for executing these functions within the context of the national program. If a state or Tribe chooses to do IM in-house, the state or tribe performs all of the functions associated with the following roles:

- Field Crew—including shipping/emailing of field data forms to the IM Coordinator (NLA 2017 paper or electronic field forms must be used and the original field forms must be sent to the NARS IM Center as outlined in the NLA 2017 FOM).

- Laboratory quality assurance including responding to the NLA 2017 Quality Team questions after submitting data
- Submission of data from the state or tribe to the Laboratory Review Coordinator or other designated member of the Quality Team (who submit to the NARS IM Center). Typically, the state or tribe must provide a single point of contact for all activities related to NLA 2017 data. However, it may be advantageous for the Laboratory Review Coordinator to have direct communication with the state or tribe-participating laboratories to facilitate the transfer of data. This is a point that may be negotiated between the primary state or tribal contact, the regional coordinator and the Laboratory Review Coordinator.
- Data transfers to the NARS IM Center must be timely. States must submit all initial laboratory results (i.e., those that have been verified by the laboratory and have passed all internal laboratory QA/QC criteria) in the appropriate format to the Laboratory Review Coordinator by May 2018, in order to meet NLA 2017 product deadlines (unless otherwise indicated for a contract/grant requirement).
- Data transfers must be complete. For example, laboratory analysis results submitted by the state or tribe must be accompanied by related quality control and quality assurance data, qualifiers code definitions, contaminant/parameter code cross-references/descriptions, test methods, instrumentation information and any other relevant laboratory-based assessments or documentation related to specific analytical batch runs.
- The state or tribe must ensure that data meet minimum quality standards and that data transfer files meet negotiated content and file structure standards.

The Laboratory Review Coordinator communicates the necessary guidance for data management and submission requirements (i.e., data templates). Each group that performs in-house IM functions incorporates these guidelines as is practicable or as previously negotiated.

5.2 Overview of System Structure

In its entirety, the NARS IM system includes site selection and logistics information, sample labels and field data forms, tracking records, map and analytical data, data validation and analysis processes, reports, and archives. NARS IM staff provides support and guidance to all program operations in addition to maintaining a central database management system for the NLA data.

The central repository for data and associated information collected for use by NLA 2017 is a secure, access-controlled server located at WED-Corvallis.

This database is known as the NARS IM. Data are stored and managed on this system using the Structured Query Language (SQL). Data review (e.g., verification and validation) and data analysis (e.g., estimates of status and extent) are accomplished primarily using programs developed in either SAS or R language software packages.

5.2.1 Data Flow

The NLA 2017 will accumulate large quantities of observational and laboratory analysis data. To appropriately manage this information, it is essential to have a well-defined data flow model and documented approach for acquiring, storing, and summarizing the data. This conceptual model (**Figure 5.1**) helps focus efforts on maintaining organizational and custodial integrity, ensuring that data available for analyses are of the highest possible quality.

5.2.2 Simplified Description of Data Flow

There are several components associated with the flow of information. These are described below and also shown in **Figure 5.1**:

- Communication—between the NARS IM Center and the various data contributors (e.g., field crews, the NLA Quality Team, laboratories and the data analysis and reporting team)—is vital for maintaining an organized, timely, and successful flow of information and data.
- Data are *captured* or acquired from four basic sources — field data transcription, laboratory analysis reporting, automated data capture, and submission of external data files (e.g., GIS data)—encompassing an array of data types: site characterization; biotic assessment; sediment and tissue contaminants; and water quality analysis. Data capture generally relies on the transference of electronic data, e.g., optical character readers and email, to a central data repository. However, some data must be transcribed by hand in order to complete a record.
- Data repository or *storage*—provides the computing platform where raw data are archived, partially processed data are staged, and the "final" data, assimilated into a final, user-ready data file structure, are stored. The raw data archive is maintained in a manner consistent with providing an audit trail of all incoming records. The staging area provides the IM Center staff with a platform for running the data through all of its QA/QC paces as well as providing data analysts a first look at the incoming data. This area of the data system evolves as new data are gathered and user-requirements are updated. The final data format becomes the primary source for all statistical analysis and data distribution.
- Metadata—a descriptive document that contains information compliant with the Content Standards for Digital Geospatial Metadata (CSDGM) developed by the Federal Geographic Data Committee (FGDC).

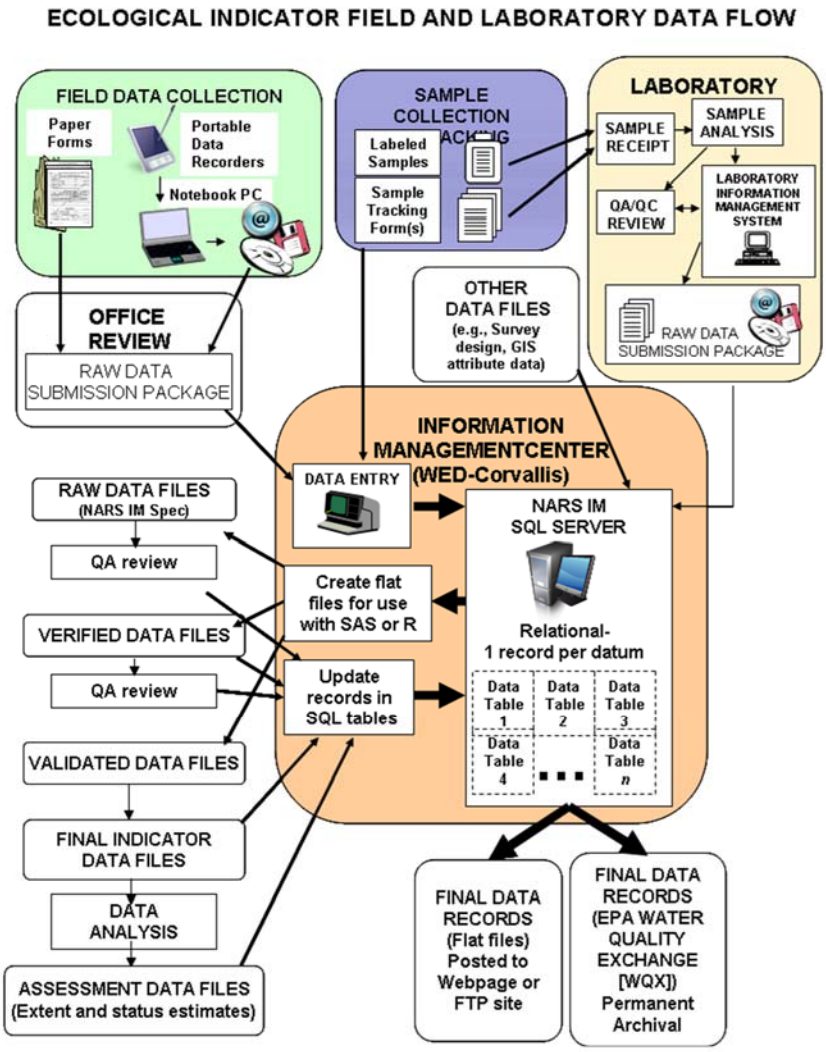


Figure 5.1 Conceptual model of data flow into and out of the master SQL database for the NLA 2017.

The following sections describe core information management standards, data transfer protocols, and data quality and results validation. Additionally, **Section 5.4** describes the major data inputs to the central database and the associated QA/QC processes used to record, enter, and validate measurement and analytical data collected.

5.2.3 Core Information Management Standards

The development and organization of the NARS IM system is compliant with current USEPA guidelines and standards. Areas addressed by these policies and guidelines include, but are not limited to, the following:

- Taxonomic nomenclature and coding.
- Locational data.
- Sampling unit identification and reference.
- Hardware and software.
- Data catalog documentation.

NLA 2017 is committed to compliance with all applicable regulations and guidance concerning hardware and software procurement, maintenance, configuration control, and QA/QC. To that end, the NLA 2017 team has adopted several IM standards that help maximize the ability to exchange data within the study and with other aquatic resource surveys or similar large-scale monitoring and assessment studies (e.g., NARS, past EMAP and R-EMAP studies). Specific information follows.

5.2.4 Data Formats

5.2.4.1 *Attribute Data*

- SQL Tables
- SAS Data Sets
- R[a] Workspaces
- American Standard Code for Information Interchange (Ascii) Files: Comma-Separated values, or space-delimited, or fixed column

5.2.4.2 *GIS Data*

- ARC/INFO native and export files; compressed .tar file of ARC/INFO workspace

5.2.4.3 *Standard Coding Systems*

- Sampling Site: (USEPA National Locational Data Policy; USEPA, 2004)
- Coordinates: Latitude and Longitude in decimal degrees (±0.002)
- Datum: NAD83
- Chemical Compounds: Chemical Abstracts Service (CAS, 1999)
- Species Codes: Integrated Taxonomic Information System when possible
- Land cover/land use codes: Multi-Resolution Land Characteristics; National Hydrography Dataset Plus Version 1.0 (NHDPlus, 2005)

5.2.5 Public Accessibility

While any data created using public funds are subject to the Freedom of Information Act (FOIA), some basic rules apply for general public accessibility and use.

- Program must comply with Data Quality Act requirements before making any data available to the public and the person generating data must fill out and have a signed the Information Quality Guidelines package available before any posting to the Web or distribution of any kind.
- Data and metadata files are made available to the contributor or participating group for review or other project-related use from NARS IM or in flat files before moving to an USEPA-approved public website.
- Data to be placed on a public website undergo QA/QC review according to the approved QAPP.

[a] **R** is a freely available software programming language and a software environment for statistical computing and graphics. The R language is widely used among statisticians and data miners for developing statistical software and data analysis.

- Only "final" data (those used to prepare the final project report) are readily available through an USEPA-approved public website[b].

As new guidance and requirements are issued, the NARS IM staff assess the impact upon the IM system and develop plans for ensuring timely compliance.

5.3 Data Transfer Protocols

Field crews are expected to use the provided electronic field forms containing *in situ* measurement and event information to the NARS IM Center defined in the FOM for submission. If crews need to use paper forms, they must send in hard copies of field forms within two weeks of sampling. Laboratories must submit electronic data files. Field crews and laboratories must submit all sample tracking and analytical results data to the NARS IM Center in electronic form using a standard software package to export and format data. Data submission templates for laboratories are included in the LOM. Examples of software and the associated formats are presented in **Table 5.2**:

Table 5.2 NLA 2017 Data submission software and associated file formats.

Software	Export Options (file extensions)
Microsoft Excel®	xls, xlsx, csv, formatted txt delimited
SAS®	csv, formatted txt delimited
R	csv, formatted txt delimited, R workspaces (.Rdata)

All electronic files must be accompanied by appropriate documentation (e.g., metadata, laboratory reports, QA/QC data and review results). This documentation must contain sufficient information to identify field contents, field formats, qualifier codes, etc. It is very important to keep USEPA informed of the completeness of the analyses. Laboratories may send files periodically, before all samples are analyzed, but USEPA must be informed that more data are pending if a partial file is submitted[c]. All data files sent by the laboratories must be accompanied by text documentation describing the status of the analyses, any QA/QC problems encountered during processing, and any other information pertaining to the quality of the data. Following is a list of general transmittal requirements each laboratory or state-based IM group should consider when packaging data for electronic transfer to the NLA team and that is captured in the applicable data submission templates using row/column data file/table structure (see Appendix C in the LOM for templates):

- Include NLA site and sample ID provided on the sample container label in a field for each record (row) to ensure that each data file/table record can be related to a site visit.
- Use a consistent set of column labels.
- Use file structures consistently.
- Use a consistent set of data qualifiers.
- Use a consistent set of units.

[b] If data collected as part of the NLA that are distributed with less rigorous QC applied because the data were not used in the NLA assessment, this shall be clearly indicated in metadata.

[c] Laboratories must adhere to contract or grant requirements for submission of data.

- Include method detection limit (MDL) as part of each result record[d].
- Include reporting limit (RL) as part of each result record.
- Provide a description of each result/QC/QA qualifier.
- Provide results/measurements/MDL/RL in numeric form.
- Maintain result qualifiers (e.g., <, ND) in a separate column.
- Use a separate column to identify record-type. For example, if QA or QC data are included in a data file, there should be a column that allows the IM staff to readily identify the different result types.
- Include laboratory sample identifier.
- Include batch numbers/information so results can be paired with appropriate QA/QC information.
- Include "true value" concentrations, if appropriate, in QA/QC records.
- Include a short description of preparation and analytical methods used (where appropriate) either as part of the record or as a separate description for the test(s) performed on the sample. For example, EPAxxxx.x, ASTMxxx.x, etc. Provide a broader description (e.g., citation) if a non-standard method is used.
- Include a short description of instrumentation used to acquire the test result (where appropriate). This may be reported either as part of the record or as a separate description for each test performed on the sample. For example, GC/MS-ECD, ICP-MS, etc.
- Ensure that data ready for transfer to NARS IM are verified and validated, and results are qualified to the extent possible (final verification and validation are conducted by USEPA).
- Data results must complement expectations (analysis results) as specified by contract or agreement.
- Identify and qualify missing data (why are the data missing?).
- Submit any other associated quality assurance assessments and relevant data related to laboratory results (i.e., chemistry, nutrients). Examples include summaries of QC sample analyses (blanks, duplicates, check standards, matrix spikes, standard or certified reference materials, etc.), results for external performance evaluation or proficiency testing samples, and any internal consistency checks conducted by the laboratory. For requirements, please see specific indicator sections of this QAPP and lab SOP.

The Laboratory Review Coordinator works with the NARS IM Coordinator to establish a data load process into NARS IM.

5.4 Data Quality and Results Validation

Data quality is integrated throughout the life cycle of the data. This includes development of appropriate forms, labels etc. for capturing data as well as verifying data entry, results, and other assessments. Indicator workgroup experts and the data analysis and reporting teams submit any recommended changes to the Project QA Coordinator who recommends and submits any changes (deletions, additions, corrections) to the NARS IM data center for inclusion in the validated data repository. The NARS IM Center includes all explanation for data changes in the record history.

[d] National lab to provide MDL with each result, and may provide an "estimate" comment for each result below the RL but above the MDL, and a flag when a result is below the MDL.

5.4.1 Design and Site Status Data Files

The site selection process described in **Section 4** produces a list of candidate sampling locations, inclusion probabilities, and associated site classification data (e.g., target status, ecoregion, etc.). The Design Team provides this file to the NLA 2017 Project Leader, who in turn distributes to the IM staff, and field coordinators. Field coordinators determine ownership and contacts for acquiring permission to access each site, and conduct site evaluation and reconnaissance activities. Field Crews document information from site evaluation and reconnaissance activities following the SEG and the FOM. The site evaluation spreadsheets and verification forms are submitted to the Project Lead by the field crews via SharePoint. The Contractor Field Logistics Coordinator and the NARS IM Center compiles all information such as ownership, site evaluation, and reconnaissance information for each site into a "site status" data file. Any missing information from the site status data file is identified and a request is made by Contractor Field Logistics Coordinator to the field crew (or site evaluator) to complete the record. Revised information is then submitted to the NARS IM Center.

5.4.2 Sample Collection and Field Data

Field crews record sampling event observational data in a standard and consistent manner using field data collection forms). Prior to initiation of field activities, the NARS IM staff works with the indicator leads and analytical support laboratories to develop standardized field data forms and sample labels. Adhesive labels, completed by the field crews, have a standard recording format and are affixed to each sample container. Field protocols include precautions to ensure that label information remains legible and the label remains attached to the sample.

NLA 2017 provides two options for completing field forms: electronic data entry using pre-developed forms on a tablet or smart phone or "traditional" paper. Paper forms are printed for field crews on water resistant paper. Copies of the field data forms and instructions for completing each form are documented in the NLA 2017 FOM. Recorded data – whether through e-forms or paper – are reviewed upon completion of data collection and recording activities by the Field Crew Leader. Field crews check completed data forms and sample labels before leaving a sampling site to ensure information and data were recorded legibly and completely. Errors are corrected by field crews if possible, and data considered as suspect are qualified using a flag variable. The field sampling crew enters explanations for all flagged data in a comments section. Field crews transmit e-forms to the NARS IM Staff by selecting the "submit" button as described in the FOM. Field crews ship completed paper field data forms to the NARS IM staff for entry into the central database management system.

All samples are tracked from the point of collection. Field crews ensure that copies of the shipping and custody record accompany all sample transfers; other copies are transmitted to the NARS IM Center. The NARS IM Center tracks samples to ensure that they are delivered to the appropriate laboratory, that lost shipments can be quickly identified and traced, and that any problems with samples observed when received at the laboratory are reported promptly so that corrective action can be taken if necessary. Detailed procedures on shipping and sample tracking can be found in the Field Operations Manual.

Procedures for completion of sample labels and electronic field data forms are covered extensively in training sessions. General QC checks and procedures associated with sample collection and transfer, field measurements, and field data form completion for most indicators are listed in **Table 5.3**. Additional QA/QC checks or procedures specific to individual indicators are described in the NLA 2017 Lab Operations Manual.

Table 5.3 Summary sample and field data quality control activities.

Quality Control Activity	Description and/or Requirements
Contamination Prevention	All containers for individual site sealed in plastic bags until use; specific contamination avoidance measures covered in training
Sample Identification	Pre-printed labels with unique ID number on each sample
Data Recording	Data recorded on pre-printed forms of water-resistant paper; field sampling crew reviews data forms for accuracy, completeness, and legibility
Data Qualifiers	Defined qualifier codes used on data form; qualifiers explained in comments section on data form
Sample Custody	Unique sample ID and tracking form information entered in LIMS; sample shipment and receipt confirmed
Sample Tracking	Sample condition inspected upon receipt and noted on tracking form with copies sent to ORD Technical Lead and/or IM
Data Entry	Data entered using customized entry screens that resemble the data forms; entries reviewed manually or by automated comparison of double entry
Data Submission	Standard format defined for each measurement including units, significant figures, and decimal places, accepted code values, and required field width
Data Archival	All data records, including raw data, archived in an organized manner. For example, following verification/validation of the last submission into the NARS database, it is copied to a terabit external hard drive and sent to the Project Leader for inclusion in his project file, scheduled as 501, permanent records. Processed samples and reference collections of taxonomic specimens submitted for cataloging and curing at an appropriate museum facility

5.4.3 Laboratory Analyses and Data Recording

Upon receipt of a sample shipment, analytical laboratory receiving personnel check the condition and identification of each sample against the sample tracking record. Each sample is identified by information written on the sample label. Any discrepancies, damaged samples, or missing samples are reported to the NARS IM staff and NLA 2017 Project Lead electronically.

Most of the laboratory analyses for the NLA 2017 indicators, particularly chemical and physical analyses, follow or are based on standard methods. Standard methods generally include requirements for QC checks and procedures. General laboratory QA/QC procedures applicable to most NLA 2017 indicators are described in **Table 5.4**. Additional QA/QC procedures specific to individual indicator and parameter analyses are described in the LOM. Biological sample analyses are generally based on current acceptable practices within the particular biological discipline. QC checks and procedures applicable to most NLA 2017 biological samples are described in the LOM.

Table 5.4 Summary laboratory data quality control activities.

Quality Control Activity	Description and/or Requirements
Instrument Maintenance	Follow manufacturer's recommendations and specific guidelines in methods; maintain logbook of maintenance/repair activities
Calibration	Calibrate according to manufacturer's recommendations; recalibrate or replace before analyzing any samples if producing erratic results
QC Data	Maintain control charts, determine LT-MDLs and achieved data attributes; include QC data summary (narrative and compatible electronic format) in submission package
Data Recording	Use software compatible with NARS IM system, check all data entered against the original bench sheet to identify and correct entry errors. Review other QA data (e.g., condition upon receipt, etc.) for possible problems with sample or specimen.
Data Qualifiers	Use defined qualifier codes; explain all qualifiers
Data Entry	Automated comparison of double entry or 100% manual check against original data form
Submission Package	Includes: • Letter by laboratory manager • Data • Data qualifiers and explanations • Electronic format compatible with NARS IM • Documentation of file and database structures • Metadata: variable descriptions and formats • Summary report of any problems and corrective actions implemented

A laboratory's IM system may consist of only hardcopy records such as bench sheets and logbooks, an electronic laboratory information management system (LIMS), or some combination of hardcopy and electronic records. Laboratory data records are reviewed at the end of each analysis day by the designated laboratory onsite QA coordinator or by supervisory personnel. Errors are corrected by laboratory personnel if possible, and data considered as suspect by laboratory analysts are qualified by the laboratory personnel with a flag variable. The laboratory explains all flagged data in a comments section. Private contract laboratories generally have a laboratory Quality Assurance Plan and established procedures for recording, reviewing, and validating analysis data.

Once analytical data have passed all of the laboratory's internal review procedures, the laboratory prepares and transfers a submission package using the prescribed templates in the LOM. The contents of the submission package are largely dictated by the type of analysis (physical, chemical, or biological).

Remaining sample material may be transferred to USEPA's designated laboratory or facilities as directed by the NLA 2017 Project Lead. All samples and raw data files (including logbooks, bench sheets, and instrument tracings) are to be retained by the laboratory for 3 years or until authorized for disposal, in writing, by the USEPA Project Leader. Deliverables from contractors and cooperators, including raw data, are permanent as per USEPA Record Schedule 258. USEPA's project records are scheduled 501 and are also permanent.

5.4.4 Data Review, Verification, and Validation Activities

Raw data files are created from entry of field and analytical data, including data for QA/QC samples and any data qualifiers noted on the field forms or analytical data package.

5.4.4.1 *Paper Forms*

The NARS IM Center either optically scans or transcribes information from field collection forms into an electronic format (sometimes using a combination of both processes). During the scanning process, incoming data are subjected to a number of automated error checking routines. The NARS IM Center corrects obvious errors immediately at the time of scanning. Suspected errors that cannot be confirmed at the time of scanning are qualified for later review by someone with the appropriate background and experience (e.g., a chemist or aquatic ecologist). The process continues until the transcribed data are 100% verified or no corrections are required.

5.4.4.2 *Electronic Forms*

The NARS IM Center directly uploads information from the electronic field collection forms into their database. During the upload process, incoming data are subjected to a number of automated error checking routines. Omissions and errors are automatically noted in an email message to the field crew lead.

5.4.4.3 *Additional Review*

Additional validation is accomplished by the NARS IM Center staff using a specific set of guidelines and executing a series of programs (computer code) to check for: correct file structure and variable naming and formats, outliers, missing data, typographical errors and illogical or inconsistent data based on expected relationships to other variables. Data that fail any check routine are identified in an "exception report" that is reviewed by an appropriate scientist for resolution.

The NARS IM Center brings any remaining questionable data to the attention of the QA manager and individuals responsible for collecting the data for resolution.

The NLA Quality Team evaluates all data to determine completeness and validity. Additionally, the data are run through a rigorous inspection using SQL queries or other computer programs such as SAS or R to check for anomalous data values that are especially large or small, or are noteworthy in other ways. Focus is on rare, extreme values since outliers may affect statistical quantities such as averages and standard deviations.

The NLA Quality Team examines all laboratory quality assurance (QA) information to determine if the laboratory met the predefined data quality objectives - available through the QAPP.

Some of the typical checks made in the processes of verification and validation are described in **Table 5.5**. QA staff use automated review procedures. The primary purpose of the initial checks is to confirm that each data value present in an electronic data file is accurate with respect to the value that was initially recorded on a data form or obtained from an analytical instrument. In general, these activities focus on individual variables in the raw data file and may include range checks for numeric variables, frequency tabulations of coded or alphanumeric variables to identify erroneous codes or misspelled entries, and summations of variables reported in terms of percent or percentiles. In addition, associated QA information (e.g., sample holding time) and QC sample data are reviewed to determine if they meet acceptance criteria. Suspect values are assigned a data qualifier. They are either corrected, replaced with a new acceptable value from sample reanalysis, or confirmed suspect after sample reanalysis. For biological samples, species identifications are corrected for entry errors associated with incorrect or

misspelled codes. Files corrected for entry errors are considered to be raw data files. Copies of all raw data files are maintained in the centralized NARS IM System.

Any suspect data are flagged for data qualification.

The NARS IM staff, with the support of the NLA 2017 Quality Team, correct and qualify all questionable data. Copies of the raw data files are maintained in NARS IM, generally in active files until completion of reporting and then in archive files. Redundant copies of all data files are maintained and all files are periodically backed up to the EPA headquarters shared G: drive system.

Table 5.5 Data review, verification, and validation quality control activities.

Quality Control Activity	Description and/or Requirements
Review any qualifiers associated with variable	Determine if value is suspect or invalid; assign validation qualifiers as appropriate
Determine if MQOs and project DQOs have been achieved	Determine potential impact on achieving research and/or program objectives
Exploratory data analyses (univariate, bivariate, multivariate) utilizing all data	Identify outlier values and determine if analytical error or site-specific phenomenon is responsible
Confirm assumptions regarding specific types of statistical techniques being utilized in development of metrics and indicators	Determine potential impact on achieving research and/or program objectives

In the final stage of data verification and validation, exploratory data analysis techniques may be used to identify extreme data points or statistical outliers in the data set. Examples of univariate analysis techniques include the generation and examination of box-and-whisker plots and subsequent statistical tests of any outlying data points. Bivariate techniques include calculation of Spearman correlation coefficients for all pairs of variables in the data set with subsequent examination of bivariate plots of variables having high correlation coefficients. Multivariate techniques have also been used in detecting extreme or outlying values in environmental data sets (Meglen, 1985; Garner et al., 1991; Stapanian et al., 1993).

The Quality Team reviews suspect data to determine the source of error, if possible. If the error is correctable, the data set is edited to incorporate the correct data. If the source of the error cannot be determined, the Quality Team qualifies the data as questionable or invalid. Data qualified as questionable may be acceptable for certain types of data analyses and interpretation activities. The decision to use questionable data must be made by the individual data users. Data qualified as invalid are considered to be unacceptable for use in any analysis or interpretation activities and are generally removed from the data file and replaced with a missing value code and explanatory comment or flag code. After completion of verification and validation activities, a final data file is created, with copies transmitted for archival and for uploading to the NARS IM system.

Once verified and validated, data files are made available for use in various types of interpretation activities; each activity may require additional restructuring of the data files. These restructuring activities are collectively referred to as "data enhancement." In order to develop indicator metrics from one or more variables, data files may be restructured so as to provide a single record per lake.

5.5 Data Transfer

Field crews may transmit data electronically; hardcopies of completed data and sample tracking forms may be sent via express courier service. Copies of raw, verified, and validated data files are transferred from the Project QA Coordinator (or designee) to the NARS IM staff for inclusion in the NARS IM system. All transfers of data are conducted using a means of transfer, file structure, and file format that has been approved by the NARS IM staff. Data files that do not meet the required specifications are not incorporated into the centralized data access and management system.

5.5.1 Database Changes

The NARS IM Center staff complete data corrections at the lowest level to ensure that any subsequent updates contain only the most correct data. The NARS IM Center alerts the Laboratory Review Coordinator if a laboratory result is found to be in error. The Laboratory Review Coordinator, or other identified member of the NLA team, sends the laboratory results found to be in error to the originator (lab) for correction. After the originator makes any corrections, the Laboratory Review Coordinator resubmits the entire batch or file to the NARS IM Center (unless otherwise discussed with the NARS IM staff). The NARS IM Center uses these resubmissions to replace any previous versions of the same data.

The NARS IM Center uses a version control methodology when receiving files. Incoming data are not always immediately transportable into a format compatible with the desired file structures. When this situation occurs, the IM staff creates a copy of the original data file, which then becomes the working file in which any formatting changes take place. The NARS IM staff works with the Quality team to address significant problems with formatting. The original raw data remains unchanged. This practice further ensures the integrity of the data and provides an additional data recovery avenue, should the need arise.

All significant changes are documented by the NARS IM Center staff. The NARS IM Center includes this information in the final summary documentation for the database (metadata).

After corrections have been applied to the data, the NARS IM Center reruns the validation programs to re-inspect the data.

The NARS IM Center may implement database auditing features to track changes.

5.6 Metadata

All metadata will be documented following the procedures outlined by the Federal Geographic Data Committee, Content standard for digital geospatial metadata, version 2.0. FGDC-STD-001-1998 (FGDC, 1998).

5.7 Information Management Operations

5.7.1 Computing Infrastructure

The NARS IM Center collects and maintains electronic data within a central server housed at WED using a Windows Server (current configuration) or higher computing platform in SQL native tables for the primary data repository and SAS® native data sets or R datasets for data analysis. The NARS IM Center conducts official IM functions in a centralized environment.

5.7.2 Data Security and Accessibility

The NARS IM Center ensures that all data files in NARS IM are protected from corruption by computer viruses, unauthorized access, and hardware and software failures. The NARS IM Center follows guidance

and policy documents of USEPA and management policies established by the IM Technical Coordination Group for data access and data confidentiality. Raw and verified data files are accessible only to the NLA 2017 collaborators. Validated data files are accessible only to users specifically authorized by the NLA 2017 Project Leader. Data files in the central repository used for access and dissemination are marked as read-only to prevent corruption by inadvertent editing, additions, or deletions.

The NARS IM Center routinely stores and archives on redundant systems the data generated, processed, and incorporated into the IM system. This ensures that if one system is destroyed or incapacitated, IM staff can reconstruct the databases. Procedures developed to archive the data, monitor the process, and recover the data are described in IM documentation.

Data security and accessibility standards implemented for NLA 2017 IM meet USEPA's standard security authentication (i.e., username, password) process in accordance with USEPA's *Information Security Policy* (USEPA Order 2150). Any data sharing requiring file transfer protocol (FTP) or internet protocol is provided through an authenticated site.

5.7.3 Life Cycle

Data may be retrieved electronically by the NLA 2017 team, partners and others throughout the records retention and disposition lifecycle or as practicable (See **Section 5.7.5**). Data in the NARS IM database are subject to EPA Record Schedule 0089 as described in the NARSPROC-003 standard operating procedure.

5.7.4 Data Recovery and Emergency Backup Procedures

The NARS IM Center maintains several backup copies of all data files and of the programs used for processing the data. The NARS IM Center maintains backups of the entire system off-site. The IM process used by the NARS IM Center for NLA 2017 also uses system backup procedures. The NARS IM Center backs up and archives the central database according to procedures already established for WED and NARS IM. All laboratories generating data and developing data files are expected to establish procedures for backing up and archiving computerized data.

5.7.5 Long-Term Data Accessibility and Archive

All data are transferred by OW's Water Quality Exchange (WQX) team working with the NARS IM Team to USEPA's agency-wide WQX data management system for archival purposes. WQX is a repository for water quality, biological, and physical data and is used by state environmental agencies, USEPA and other federal agencies, universities, and private citizens. Data from the NLA 2017 project are run through an Interface Module in an Excel format and uploaded to WQX by the WQX team. Once uploaded, states and tribes and the public can download data. Data are also provided in flat files on the NARS website.

5.8 Records Management

The NARS IM Center maintains removable storage media (i.e., CDs, thumb drives) and paper records in a centrally located area at the NARS IM Center. Paper records are returned to OW once the assessment is complete or destroyed per records retention schedules. The NARS IM staff identifies and maintains files using standard divisional procedures. Records retention and disposition comply with USEPA directive 2160 Records Management Manual (July, 1984) in accordance with the Federal Records Act of 1950.

6 INDICATORS

6.1 Summary

The NLA Project Team provides detailed, indicator-specific design, collection method, sample handling, and quality control procedures for field operations in the National Lakes Assessment 2017 Field Operations Manual. Similarly, the team provides detailed, indicator-specific sample handling, laboratory procedure, and quality control procedures for laboratory operations in the National Lakes Assessment 2017 Laboratory Operations Manual. Quality assurance objectives for physical habitat, which does not collect samples or have laboratory analysis associated with its measurements, are in the data analysis plan of this document. A summary of the QA procedures and the Indicator QA Coordinators is shown in **Table 6.1**.

6.1.1 Sampling Design

Field crews collect samples from an index site and/or littoral sites on each lake as described in the National Lakes Assessment 2017 Field Operations Manual.

6.1.2 Sampling and Analytical Methods

6.1.2.1 *Sample Collection*

Detailed sample collection and handling procedures are described in the National Lakes Assessment 2017 Field Operations Manual.

6.1.2.2 *Analysis*

Detailed analysis procedures are described in the National Lakes Assessment 2017 Laboratory Operations Manual.

6.1.3 Quality Assurance Objectives

Quality assurance objectives are described in detail in the National Lakes Assessment 2017 Laboratory Operations Manual.

6.1.4 Quality Control Procedures: Field Operations

Detailed design, collection, sample handling and quality control procedures for field operations are described in the National Lakes Assessment 2017 Field Operations Manual.

6.1.5 Quality Control Procedures: Laboratory Operations

Specific information about sample receipt, processing, and analysis are in the National Lakes Assessment 2017 Laboratory Operations Manual.

6.1.6 Data Management, Review, and Validation

Detailed information about data management, review, and validation are in the National Lakes Assessment 2017 Laboratory Operations Manual.

Table 6.1 Summary of indicator QA procedures and coordinators.

Indicator	Lab Verification	Method Verification	Lab Analyses QA	Taxa Requirements	Indicator QA Coordinator(s)	QA Analyst
Algal Toxins (microcystins and cylindrospermopsin)	Documentation review (e.g., SOPs, lab certifications, prior experience) Audit documentation (if applicable)	Methods Call	Interlab comparison Lab blanks, duplicates and spiked samples	N/A	Kendra Forde	Kendra Forde
Bacteria (***E. coli***)	Documentation review (e.g., SOPs, lab certifications, prior experience) Audit documentation (if applicable)	Methods Call	Interlab comparison Lab reagent blanks and duplicates	N/A	Kendra Forde	Kenda Forde
Benthic Macro-invertebrates	Taxa QC samples Documentation review (e.g., SOPs, lab certifications, prior experience) Audit documentation (if applicable)	Methods Call	Outside Lab QA Taxonomist to review 10% of samples - photos Reconciliation calls	Genus or Family (see LOM)	Brian Hasty	Brian Hasty
Dissolved Gases	Documentation review (e.g., SOPs, lab certifications, prior experience) Audit documentation (if applicable)		3rd party analytical standards Continuing calibration checks	N/A	Jake Beaulieu	Jake Beaulieu
Fish eDNA	--	--	--	N/A	Erik Pilgrim	Erik Pilgrim
Physical Habitat	--	--	--	N/A	Phil Kaufmann	Phil Kaufmann

Phytoplankton	Taxa QC samples Documentation review (e.g., SOPs, lab certifications, prior experience) Audit documentation (if applicable)	Methods Call	Outside Lab QA Taxonomist round robin Reconciliation calls	Species	Brian Hasty	Brian Hasty
Sediment Contaminants, TOC and grain size	Documentation review (e.g., SOPs, lab certifications, prior experience) Audit documentation (if applicable)	Methods Call	Lab blanks, duplicates and spiked samples (as appropriate)	N/A	Mari Nord Kendra Forde	Kendra Forde
Atrazine Pesticide Screen	Documentation review (e.g., SOPs, lab certifications, prior experience) Audit documentation (if applicable)	Methods Call	Duplicates Standard Solution	N/A	Kendra Forde	Kendra Forde
Water Chemistry and Chlorophyll-***a***	Documentation review (e.g., SOPs, lab certifications, prior experience) Audit documentation (if applicable)	Methods Call	Lab blanks, duplicates and spiked samples (as appropriate)	N/A	Dave Peck Alan Herlihy	Dave Peck
Zooplankton	Taxa QC samples Lab blanks, duplicates and spiked samples (as appropriate)	Methods Call	Outside Lab QA Taxonomist to review 10% of samples - photos Reconciliation calls	Species	Brian Hasty	Brian Hasty

7 ASSISTANCE VISITS

Assistance visits are a component of the QA program for the NLA 2017. Both these sections have been explained clearly in the National Lakes Assessment 2017 FOM and LOM and therefore are not included here.

7.1 Field Evaluation and Assistance Visit Plan

Please see the NLA 2017 Field Operations Manual for details.

7.2 Laboratory Evaluation and Assistance Visit Plan

Please see the NLA 2017 Lab Operations Manual for details.

8 DATA ANALYSIS PLAN

The Data Analysis Plan describes the general process used to evaluate the data for the survey. It outlines the steps taken to assess the condition of the nation's lakes and identify the relative impact of stressors on this condition. Results from the analysis are included in the final report and used in future analysis. The data analysis plan may be refined and clarified as the data are analyzed by USEPA and states.

8.1 Data Interpretation Background

The basic intent of data interpretation is to evaluate the occurrence and distribution of parameters throughout the population of lakes in the United States within the context of regionally relevant expectations for least disturbed reference conditions. This is presented using a cumulative distribution function or similar graphic. For most indicators the analysis categorizes the condition of water as least, moderately, or most disturbed. Because of the large-scale and multijurisdictional nature of this effort, the key issues for data interpretation are unique and include: the scale of assessment, selecting the best indicators, defining the least impacted reference conditions, and determining thresholds for judging condition.

8.1.1 Scale of assessment

This is the third national report on the ecological condition of the nation's lakes using comparable methods. USEPA selected the sampling locations for the assessment using a probability based design, and developed rules for selection to meet certain distribution criteria, while ensuring that the design yielded a set of lakes that would provide for statistically valid conclusions about the condition of the population of lakes across the nation. A challenge that this mosaic of waterbodies poses is developing a data analysis plan that allows USEPA and other partners to interpret data and present results at a large, aggregate scale.

8.1.2 Selecting the best indicators

Indicators should be applicable across all reporting units, and must be able to differentiate a range of conditions. USEPA formed a steering committee for these discussions. The Committee, comprised of state representatives from each of the USEPA regions, provides advice and recommendations to USEPA on matters related to the NLA 2017. This committee was able to develop and refine indicators and sampling methodologies.

USEPA developed screening and evaluation criteria which included indicator applicability on a national scale, the ability of an indicator to reflect various aspects of ecological condition, and cost-effectiveness.

8.1.3 Defining least impacted (reference) condition

Reference condition data are necessary to describe expectations for biological conditions under least disturbed settings. Analysts expect to use an approach similar to that used in NLA 2012, which is described in detail in the NLA 2012 Technical Report (EPA 841-R-16-114) (USEPA 2016). Analysts will consider whether data from additional 2017 reference sites indicate that NLA 2012 thresholds need to be updated or not.

8.1.4 Determining thresholds for judging condition

This reference site approach is then used to set expectations and benchmarks for interpreting the data on lake condition. The range of conditions found in the reference sites for an ecoregion describes a distribution of those biological or stressor values expected for least disturbed condition. The

benchmarks used to define distinct condition classes (e.g., least disturbed, moderately, most disturbed) are drawn from this reference distribution. USEPA's approach is to examine the range of values for a biological or stressor indicator in all of the reference sites in a region, and to use the 5th percentile of the reference distribution for that indicator to separate the most disturbed of all sites from moderately disturbed sites. Using the 5th percentile means that lakes in the most disturbed category are worse than 95% of the best sites used to define reference condition. Similarly, the 25th percentile of the reference distribution can be used to distinguish between moderately disturbed sites and those in least disturbed condition. This means that lakes reported as least disturbed are as good as 75% of the sites used to define reference condition. Thresholds may also be adjusted following the process in Herlihy et al., (2008). For some indicators, analysts use literature or other established values.

8.2 Geospatial Data

Geospatial data is an integral part of data analysis for the NLA 2017, as it has been for all other surveys. The following activities are anticipated: review of coordinate data and corrections, pourpoint (the outlet of the lake) identification, watershed delineations, and computing landscape metrics. Through the site evaluation process, lakes that have changed or are inaccurately represented in the National Hydrography Dataset will be noted and provided to those that update the NHD.

8.3 Datasets Used for the Report

The datasets available for use in the report were developed based on analytical methods selected during the NLA data analysis workshop. Many of the analytical methods used in the survey stem from discussions, input, and feedback provided by the National Lakes Assessment Steering Committee. Many of the methods are an outgrowth of the testing and refinement of the existing and developed methods and the logistical foundation constructed during the implementation of the Environmental Monitoring and Assessment Program (EMAP) studies from 1991 through 1994 (Whittier et al., 2002), from a New England pilot study conducted in 2005, from focused pilot studies for methods development, and from various state water quality agency methods currently in use.

The survey uses indicators to assess trophic status and water quality, ecological integrity, and the human use of lakes.

8.3.1 Trophic status and water quality

Lakes are typically classified according to their trophic state. Three variables, chlorophyll *a*, Secchi disk depth, and total phosphorus, are used by USEPA to estimate biomass and define the trophic state of a particular lake. Other variables are measured in conjunction with the trophic state variables to supplement and enhance understanding of lake processes that affect primary productivity.

8.3.2 Ecological integrity

Ecological integrity describes the ecological condition of a lake based on different assemblages of the aquatic community and their physical habitat. The indicators include zooplankton, benthic macroinvertebrates, and the physical habitat of the shoreline and littoral zone. Analysts will also examine a research indicator – fish eDNA.

8.3.3 Human use

Human use indicators address the ability of the population to support recreational uses such as swimming, fishing and boating. The protection of these uses is one of the requirements in the Clean

Water Act under 305(b). The extent of algal toxins (microcystins and cylindrospermopsin), bacteria (*E. coli*), sediment contaminants, and atrazine pesticide will serve as the primary indicators of human use.

8.4 Indicator Data Analysis

8.4.1 Algal Toxins

Cyanobacterial (blue-green algal) blooms are common midsummer to late fall events that occur in many lakes and reservoirs throughout the United States. Algal toxin production has been identified as a significant potential human health problem that has been associated with many of these bloom events. However, little is known about the general occurrence of algal toxins in the pelagic zones of these water bodies, where extensive blooms are less likely to occur than in near-shore areas.

Laboratories analyze the total (whole water) concentrations of microcystins and cylindrospermopsin in lakes and reservoirs throughout the United States using a standardized immunoassay test. The data analysis team compares these concentrations to national or other literature values. In addition, the data analysis team analyzes and interpret the data for microcystin occurrence and concentration in the context of other environmental data that is collected as part of the lake assessment (e.g. nutrients, phytoplankton, chlorophyll *a*, turbidity, specific conductance, pH).

8.4.2 Bacteria (*E. coli*)

The presence of bacteria (*E. coli*) in water samples will be analyzed to indicate possible contamination by human and other animal wastes. Laboratories analyze the concentration of *E.coli* in water samples from lakes and reservoirs throughout the United States using a standard method. The data analysis team plans to compare *E. coli* concentrations to USEPA's national guideline for recreation.

8.4.3 Benthic Macroinvertebrate and Zooplankton Assemblages

The data analysis team calculates benthic macroinvertebrate and zooplankton assemblage will be analyzed using multimetric indices (MMI). The MMI approach summarizes various assemblage attributes, such as composition, tolerance to disturbance, trophic and habitat preferences, as individual metrics or measures of the biological community. Candidate metrics are evaluated for aspects of performance and a subset of the best performing metrics are combined into an index known as a Macroinvertebrate Index of Biotic Condition. This index is then used to rank the condition of the resource.

8.4.4 Dissolved Gases

Researchers analyze samples for dissolved carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) concentration, and the carbon isotopic composition of CO_2 and CH_4. The results will be used to estimate the magnitude of CO_2, CH_4, and N_2O emissions from lakes and reservoirs across the nation. This is a supplemental research indicator and may not result in an assessment endpoint.

8.4.5 Fish eDNA

Water samples will be analyzed for fish environmental DNA. This is a supplemental research indicator and may not result in an assessment endpoint. NLA will use this sample to evaluate whether general fish occurrence information can be determined from this sample.

8.4.6 Physical Habitat

8.4.6.1 *Quality assurance objectives and procedures*

MQOs are presented in **Table 8.1**. General requirements for comparability and representativeness are addressed in **Section 3.2**. The MQOs given in **Table 8.1** represent the maximum allowable criteria for statistical control purposes. Precision is determined from results of revisits (field measurements) taken on a different day and by duplicate measurements taken on the same day.

Table 8.1 Physical habitat measurement data quality objectives.

Variable or Measurement	Precision	Accuracy	Completeness
Field Measurements and Observations	±10%	NA	90%

Specific quality control measures are listed in **Table 8.2** for field measurements and observations.

Table 8.2 Physical habitat field quality control.

Check Description	Frequency	Acceptance Criteria	Corrective Actions
QUALITY CONTROL			
Check totals for cover class categories (vegetation type, substrate, cover)	Each station	Sum must be reasonable	Repeat observations
Check completeness of station depth measurements	Each station	Depth measurements for all stations	Obtain best estimate of depth where actual measurement not possible
DATA VALIDATION			
Estimate precision of measurements based on repeat visits	2 visits	Measurements should be within 10 percent	Review data for reasonableness; Determine if acceptance criteria need to be modified

8.4.6.2 *Shoreline human disturbances*

Crews record the presence or absence of 12 predefined types of human land use or disturbance for each of the 10 stations. As part of the NLA 2017, crews separately identify additional human disturbances outside of, but adjacent to, the plots. For each of the 12 disturbance categories, the data analysis team calculates the proportion of lakeshore stations where the disturbance is observed on each lake. Proportions are weighted according to the proximity of the disturbance before computing the whole-lake metrics. Weightings are 1.0 for disturbance observations within the riparian sample plots and 0.33 for those behind or adjacent to the plots. Two types of summary metrics are calculated by synthesizing all the human disturbance observations. The first, a measure of the extent of shoreline disturbance, is calculated as the proportion of stations at which one or more human disturbances were observed. The second, a measure of disturbance intensity, is calculated as the mean number of human disturbance types observed at each of the 10 shoreline stations.

8.4.6.3 *Riparian vegetation*

Crews visually estimate riparian vegetation type and areal cover in three layers: the canopy (>5 m high), mid-layer (0.5–5 m high) and ground cover (<0.5 m high). Coniferous and deciduous vegetation is distinguished in the canopy and mid-layer; woody and herbaceous vegetation is distinguished in the mid-layer and ground cover. As was done in NLA 2007 and NLA 2012, crews estimate cover in four classes: absent (0), sparse (0-10%), moderate (10-40%), heavy (40-75%) and very heavy (>75%). The data analysis team calculates simple whole-lake metrics by assigning the cover class mid-point value to each station's observations and then averaging those cover values across all 10 stations. The data analysis team calculates summary metrics for each lake by summing the areal cover or tallying the presence of defined combinations of riparian vegetation layers or vegetation types.

8.4.6.4 *Aquatic macrophytes*

Using the same cover classes as for riparian vegetation, crews estimate areal covers of nearshore emergent, floating, and submerged aquatic macrophytes visually. The data analysis team calculates simple and summary aquatic macrophyte metrics for each lake in the same fashion as for riparian vegetation.

8.4.6.5 *Fish concealment features*

Crews record the presence or absence of eight specified types of fish concealment features within each 10-m × 15-m littoral plot. Crews assign the areal cover of each type to one of the same cover classes listed above. Simple metrics for each type of fish concealment feature are calculated as the proportion of littoral stations with the particular concealment feature present. The data analysis team calculates summary metrics as the mean number of concealment types per station. The team then uses the areal cover class designation to unweight very sparse cover in the calculation of both simple and summary fish cover metrics.

8.4.6.6 *Shoreline and littoral bottom substrate*

Crews make visual estimates of areal cover of 9 defined substrate types (bedrock, boulders, cobble, gravel, sand, silt/clay/muck, woody debris, organic matter, and vegetation) separately for the 1-m shoreline band and the bottom within the 10-m × 15-m littoral plot. Cover classes are the same as for riparian vegetation, with the same modification to include an additional higher cover class. In cases where the bottom substrate cannot be observed directly, crew observers use a clear plastic viewing bucket, a 3-m plastic (PVC) sounding tube, or an anchor to examine or obtain samples of bottom sediments.

The data analysis team obtains simple metrics describing the lake-wide mean cover of littoral and shoreline substrate in each cover class size category by averaging the cover estimates at each station, using the cover class midpoint approach described for riparian vegetation. The team then calculates three substrate summary metrics for both shoreline and littoral bottom substrates. First is the mean cover of the dominant substrate type. Second and third are measures of the central tendency and variety of substrate size. Because the size categories are approximately logarithmic, the data analysis team calculates a cover-weighted mean substrate size class and its standard deviation; ranks the substrate classes by size from 1 to 6, weighting them by their lakewide mean cover, and then averages weighted cover or computes its variance across size classes.

8.4.6.7 *Littoral depth, bank characteristics and other observations*

Crews measure lake depth 10 m offshore using SONAR, sounding line, or sounding rod. Field crews estimate the bank angle based on high and low water marks and the vertical and lateral range in lake water level fluctuation. They also note the presence of water surface scums, algal mats, oil slicks, and sediment color and odor. The data analysis team calculates whole-lake metrics for littoral depth and water level fluctuations as arithmetic averages and standard deviations. For bank angle classes and qualitative observations of water surface condition, sediment color, and odor, the team calculates the proportion of stations where the described features are present.

8.4.6.8 *Human Disturbances in Riparian/Littoral*

12 Simple metrics describe presence (proportion of shore) with: buildings, commercial land use, lawns, developed parkland, roads/railroads, docks/boats, trash/landfill, seawalls/revetments, row crop agriculture, pasture, orchards, and other human activities.

2 Summary metrics describe mean number of disturbance types observed per station and proportion of shoreline with human disturbance of any type.

8.4.6.9 *Riparian Vegetation Structure*

8 Simple metrics describe areal cover of trees >0.3 m diameter at breast height (DBH) and <0.3 m DBH in canopy layer; woody and herbaceous vegetation in mid-layer; barren ground and woody, herbaceous, and inundated vegetation in ground cover layer.

6 Summary metrics describe aggregate covers in canopy + mid-layer, woody vegetation in canopy + mid-layer, and canopy + mid-layer + ground cover layers; presence of vegetation in canopy layer; presence in both canopy and mid-layer.

8.4.6.10 *Littoral Aquatic Macrophytes*

Simple metrics describe cover of emergent, floating, and submergent macrophytes; and presence of macrophytes lakeward from the shoreline observation plot.

2 Summary metrics describe mean combined cover and proportion of shoreline with macrophytes present.

8.4.6.11 *Shoreline and Littoral Substrate Type and Size*

14 Simple metrics separately describing shoreline and littoral substrate: areal cover estimates of bedrock (>4000 mm), boulder (250–4000 mm), cobble (64–250 mm), gravel (2–64 mm), sand (0.06–2.0 mm), soil or silt/clay/muck (<0.06 mm), and vegetation or woody debris (if concealing substrate).

6 Summary metrics (3 for shore and 3 for littoral bottom) estimating cover-weighted mean size class, size class variance, and the areal cover of the dominant substrate type.

8.4.6.12 *Littoral Fish Cover*

8 Simple metrics estimating proportion of shore zone with various fish cover types: boulder, rock ledge, brush, inundated live trees, overhanging vegetation, snags >0.3 m diameter, aquatic macrophytes, and human structures (e.g., docks, enhancement structures).

Summary metrics describing the mean number of fish cover types.

8.4.6.13 *Littoral Depth, Banks, and Level Fluctuations*

7 Simple metrics describing mean depth and depth variation among sampling station, bank angle, and apparent height and extent of vertical and horizontal lake water level fluctuations.

1 Summary metric describing spatial variation of station depths on lake.

8.4.6.14 *Miscellaneous Habitat Variables*

7 Simple metrics describing proportion of sampling sites with sediment odor (petrol, H_2S,) sediment colors (black, brown, other), and water surface films (oil, algal mat, other).

1 Summary metric describing proportion of sampling sites with surface film of any type.

8.4.7 Phytoplankton Assemblages

Phytoplankton will be collected as an integrated sample from the euphotic zone in open water. Both abundance and biovolume on a species-specific basis will be determined. The data will be used in to calculate cyanobacteria cell density, which will be compared to algal toxin benchmarks established by the World Health Organization.

8.4.8 Sediment Contaminants

Concentrations of chemical constituents and percent TOC are measured in the sediments in order to determine sediment condition in lakes and reservoirs. Sediment contaminant measures will be compared to existing published quotients. Data analysts can use the total organic carbon and grain size information to help interpret other sediment contaminant information as part of the analysis process.

8.4.9 Atrazine Pesticide Screen

Analysts plan to determine atrazine occurrence and concentration from lake water samples. Comparisons will be made among lakes, relative to land use in the watershed and other water quality characteristics (e.g., nutrient concentrations). Atrazine concentrations will be compared to USEPA's level of concern for plant communities.

8.4.10 Trophic Status

The trophic state of lakes is analyzed using chlorophyll *a* concentrations, which is considered the most accurate estimator of tropic state. Trophic state is assessed using chlorophyll *a* concentration thresholds, as follows: oligotrophic, <2 µg/L; mesotrophic, 2 to 7 µg/L; eutrophic, 7 to <30 µg/L; and hypereutrophic, ≥30 µg/L. These categories will be used to rank the condition of lakes relative to their trophic state.

8.4.11 Water Chemistry, Chlorophyll a and Secchi Depth

Laboratories measure a wide array of water chemistry parameters, including DO, pH, total nitrogen (TN), total phosphorus (TP), clarity, DOC, color, ANC, primary productivity, and other analytes. The data analysis team plans to assess some of these parameters using the reference based approach and some using nationally-consistent values. Additionally, the team reports on values for these parameters and their distribution. Water chemistry analysis is critical for interpreting the biological indicators. Temperature profiles is used to determine degree of lake stratification.

9 LITERATURE CITED

Allen AP, Whittier TR, Kaufmann PR, Larsen DP, O'Connor RJ, Hughes RM, Stemberger RS, Dixit SS, Brinkhurst RO, Herlihy AT, Paulsen SG. 1999. Concordance of taxonomic composition patterns across multiple lake assemblages: effects of scale, body size, and land use. *Canadian Journal of Fisheries and Aquatic Sciences* 56: 2029-2040.

Baker, J.R. and G.D. Merritt, 1990. Environmental Monitoring and Assessment Program: Guidelines for Preparing Logistics Plans. EPA 600/4-91-001. U.S. Environmental Protection Agency. Las Vegas, Nevada.

Carlson, R.E. 1977. A trophic state index for lakes. *Limnology and Oceanography* 22(2):361-369.

CAS - Chemical Abstracts Service (CAS 1999).

Code of Federal Regulations, Title 40 - Protection of Environment. 40CFR Part 136, App. B Definition and Procedure for the Determination of the Method Detection Limit.

FGDC. 1998. Federal Grographic Data Committee. Content standard for digital geospatial metadata, version 2.0. FGDC-STD-001-1998. https://www.fgdc.gov/metadata/csdgm.

Garner, F.C., M.A. Stapanian, and K.E. Fitzgerald. 1991. Finding causes of outliers in multivariate environmental data. Journal of Chemometrics. 5: 241-248.

Heinz Center. 2002. *The State of the Nation's Ecosystems.* The Cambridge University Press.

Herlihy, A. T., S. G. Paulsen, J. V. Sickle, J. L. Stoddard, C. P. Hawkins, and L. L. Yuan. 2008. Striving for consistency in a national assessment: the challenges of applying a reference-condition approach at a continental scale. *Journal of the North American Benthological Society* 27:860-877.

Hunt, D.T.E and A.L. Wilson. 1986. *The chemical analysis of water: general principles and techniques.* 2nd edition. Royal Society of Chemistry, London, England.

Kaufmann PR, Hughes RM. 2006. Geomorphic and anthropogenic influences on fish and amphibians in Pacific Northwest coastal streams. Pages 429-455 in Hughes RM, Wang L, Seelbach PW (editors). Landscape influences on stream habitat and biological assemblages. American Fisheries Society Symposium 48, Bethesda, Maryland.

Kaufmann PR, Hughes RM, Van Sickle J, Whittier TR, Seeliger CW, Paulsen SG. 2014a. Lake shore and littoral habitat structure: A field survey method and its precision. *Lake and Reservoir Management*. 30:157–176.

Kaufmann PR, Hughes RM, Whittier TR, Bryce SA, Paulsen SG. 2014b. Relevance of lake physical habitat assessment indices to fish and riparian birds. *Lake and Reservoir Management*. 30:177–191.

Kaufmann PR, Levine P, Robison EG, Seeliger C, Peck DV. 1999. Quantifying physical habitat in wadeable streams. EPA/620/R-99/003. U.S. Environmental Protection Agency, Office of Research and Development,Washington, DC. Available at http://www.epa.gov/emap/html/pubs/docs/groupdocs/surfwatr/field/phyhab.html. Accessed April 2011.

Kaufmann PR, Peck DV, Paulsen SG, Seeliger CW, Hughes RM, Whittier TR, Kamman NC. 2014c. Lakeshore and littoral physical habitat structure in a national lakes assessment. *Lake and Reservoir Management.* 30:192–215.

Kincaid TM, Larsen DP, Urquhart NS. 2004. The structure of variation and its influence on the estimation of status: indicators of condition of lakes in the Northeast USA. Environmental Monitoring and Assessment 98:1-21.

Kirchmer, C.J. 1983. Quality control in water analysis. Environmental Science & Technology. 17: 174A-181A.

Klemm, D.J., P.A. Lewis, F. Fulk, and J.M. Lazorchak. 1990. *Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters*. EPA 600/4-90/030. U.S. Environmental Protection Agency, Cincinnati, Ohio.

Larsen DP, Kinkaid TM, Jacobs SE, Urquhart NS. 2001. Designs for evaluating local and regional scale trends. *BioScience* 51(12):1069-1078.

Larsen DP, Kaufmann PR, Kincaid TM, Urquhart NS. 2004. Detecting persistent change in the habitat of salmon-bearing streams in the Pacific Northwest. *Canadian Journal of Fisheries and Aquatic Sciences* 61:283–291.

Larsen, D. P., N. S. Urquhart, and D. L. Kugler. 1995. Regional-scale trend monitoring of indicators of trophic condition of lakes. *Water Resources Bulletin* 31:117-139.

Lemmon, P.E. 1957. A new instrument for measuring forest overstory density. *J. For.* 55(9): 667-669.

Littel RC, Milliken GA, Stroup WW, Wolfinger RD, Schabenberger O. 2006. SAS for mixed models, Second Edition. Cary, N.C. SAS Institute, Inc. 814p.

Meglen, R.R. 1985. A quality control protocol for the analytical laboratory. Pg. 250-270. IN: J.J. Breen and P.E. Robinson (eds). Environmental Applications of Cehmometrics. ACS Symposium Series 292. American Chemical Society, Washington, D.C.

NHDPlus 2005. NHD - National Hydrography Dataset Plus Version 1.0 http://www.horizonsystems.com/nhdplus/index.php.

NAPA. 2002. *Environment.gov.* National Academy of Public Administration. ISBN: 1-57744-083-8. 219 pages.

NRC. 2000. Ecological Indicators for the Nation. National Research Council.

Oblinger Childress, C.J., Foreman, W.T., Connor, B.F. and T.J. Maloney. 1999. New reporting procedures based on long-term method detection levels and some considerations for interpretations of water-quality data provided by the U.S. Geological Survey National Water Quality Laboratory. U.S.G.S Open-File Report 99–193, Reston, Virginia.

Paulsen, S.G., D.P. Larsen, P.R. Kaufmann, T.R. Whittier, J.R. Baker, D. Peck, J., McGue, R.M. Hughes, D. McMullen, D. Stevens, J.L. Stoddard, J. Lazorchak, W.Kinney, A.R. Selle, and R. Hjort. 1991. EMAP - surface waters monitoring and research strategy, fiscal year 1991. EPA-600-3-91-002. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. and Environmental Research Laboratory, Corvallis, Oregon.

Peck, D. V., A. R. Olsen, M. H. Weber, S. G. Paulsen, C. Peterson, and S. M. Holdsworth. 2013. Survey design and extent estimates for the National Lakes Assessment. *Freshwater Science* 32:1231-1245.

Peck, D.V., J.M. Lazorchak, and D.J. Klemm (editors). 2003. Unpublished draft. Environmental Monitoring and Assessment Program – Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams. U.S. Environmental Protection Agency, Washington, D.C.

Peck, D. V., and R. C. Metcalf. 1991. Dilute, neutral pH standard of known conductivity and acid neutralizing capacity. Analyst 116:221-231

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish.* EPA 440/4-89/001. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. *Methods for Evaluating Stream, Riparian, and Biotic Conditions*. USDA Forest Service, Gen. Tech. Rep. INT-183. 71pp.

Stapanian, M.A., F.C. Garner, K.E. Fitzgerald, G.T. Flatman, and J.M. Nocerino. 1993. Finding suspected causes of measurement error in multivariate environmental data. Journal of Chemometrics. 7: 165-176.

Stevens, D. L., Jr., 1994. Implementation of a National Monitoring Program. Journal of Environ. Management 42:1-29.

USEPA. 1984. EPA Order 2160 (July 1984), Records Management Manual, U.S. Environmental Protection Agency, Washington, DC.U.S. EPA, 1999. EPA's Information Management Security Manual. EPA Directive 2195 A1.

USEPA. 2002. Guidance for Quality Assurance Project Plans (EPA QA/G-5). EPA/240/R-02/009. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, D.C. http://www.epa.gov/quality/qs-docs/g5-final.pdf

USEPA. 2003. *Draft Report on the Environment*. ORD and OEI. EPA-260-R-02-006.

USEPA. 2004. National Geospatial Data Policy. https://www.epa.gov/sites/production/files/2014-08/documents/national_geospatial_data_policy_0.pdf

USEPA. 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4). EPA/240/B-06/001. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, D.C. http://www.epa.gov/quality/qs-docs/g4-final.pdf

USEPA. 2009. National Lakes Assessment: Technical Appendix. EPA 841-B-09-001a. U.S. Environmental Protection Agency, Washington, DC.

USEPA. 2013. EPA's Information Security Policy. EPA Order 2150. https://www.epa.gov/sites/production/files/2013-11/documents/ansp_interim_policy.pdf

USEPA. 2016. National Lakes Assessment 2012: Technical Report. EPA 841-R-16-114. U.S. Environmental Protection Agency, Washington, D.C.

USGAO. 2000. *Water Quality*. GAO/RCED-00-54.

Van Sickle J, Hawkins CP, Larsen DP, Herlihy AT. 2005. A null model for the expected macroinvertebrate assemblage in streams. *Journal of the North American Benthological Society*. 24(1):178-191.

Washington, H.G. 1984. Diversity, biotic, and similarity indices. *Water Research* 18(6): 653-694.

Whittier, T. R., S. G. Paulsen, D. P. Larsen, S. A. Peterson, A. T. Herlihy, and P. R. Kaufmann. 2002. Indicators of ecological stress and their extent in the population of northeastern lakes: a regional-scale assessment. *BioScience* 52:235-247.

Zar JH. 1999. Biostatistical Analysis, 4th ed. Prentice-Hall, Inc. New Jersey, USA.

APPENDIX A: LABORATORY LIST

National Lakes Assessment 2017 Contract Laboratory List

Analysis	Contact	Contractor	Contractor No. & Task No.	Project Officer
Algal Toxins (microcystins and cylindrospermopsin)	Kendra Forde	EnviroScience	EP-C-12-002; TO 30	Sarah Lehmann
Algal Toxins (microcystins – HDPE sample container)	Kendra Forde	GLEC	EP-C-16-008	Sarah Lehmann
Benthic Macroinvertebrates	Brian Hasty	PG Environmental	EP-C-12-004; TO 28	Sarah Lehmann
Bacteria (E. coli)	Kendra Forde	EnviroScience	EP-C-12-002; TO 33	Sarah Lehmann
Sediment Contaminants	Kendra Forde	EnviroScience	EP-C-12-002; TO 29	Sarah Lehmann
Atrazine Pesticide Screen	Kendra Forde	EnviroScience	EP-C-12-002; TO 31	Sarah Lehmann
Water Chemistry	Dave Peck	CSS	EP-D-16-021, TO 02	Dave Peck
Zooplankton and Phytoplankton	Brian Hasty	BSA Envirnmental Services	GS-10F-0302S	Sarah Lehmann

APPENDIX B: REVISION HISTORY

NLA 2017 Changes made to the Field Operations Manual Version 1.0 (incorporated into Version 1.1).

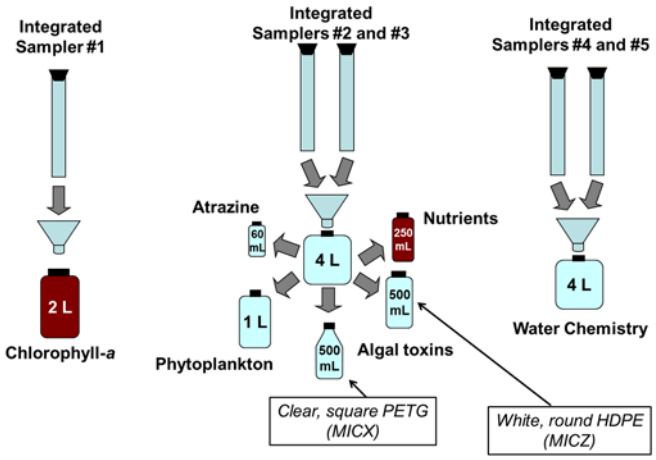
Background on change: There has been a recent change to the index water sampling protocol. There will now be two Algal Toxins samples collected at the index site; the primary sample (MICX) collected in a 500 mL square clear PETG bottle and a second sample (for a bottle comparison) in a 500 mL white HDPE bottle called MICZ. MICX samples will be processed for both microcystins and cylindrospermopsin, while the MICZ will be processed for only microcystins as was done in 2007 and 2012.

There is new guidance that suggests HDPE (which was used in both 2007 and 2012) may adsorb cyanobacteria cells to it which could result in a lower reported level in the sample. To help determine whether the 2007 and 2012 results were under-reported, it is essential that EPA conducts a side-by-side test with both the old and new bottle style.

In order to do a true comparison, we need to provide the same bottle and volume as was collected in 2007 and 2012, which means crews will need to collect some additional water at the index site. Crews will now collect 5 integrated samples (5 full, 10 halves, etc.). The first will go straight to the CHLA sample bottle, #2 and #3 will be composited in the cubitainer and divided, and then #4 and #5 will become the CHEM sample. The new steps have been incorporated into both Version 1.1 of the FOM and Index Presentation.

A summary of the FOM changes are below. Forms and labels will also include the new sample.

- Figure 3.1 has been updated to include the change in numbers of integrated sampler pulls and the bottles into which water will be dispensed.
- Figure 5.3 (below) has been updated to include the changes in sample collection.



- In Appendix A, the site kit equipment list has been updated to include both bottle types:

PETG bottle (500 mL, clear, narrow-mouth, square)	1	Algal Toxins (MICX)
HDPE bottle (500 mL, white, wide-mouth, round)		Algal Toxins (MICZ)

- In Appendix B, the shipping table and flowchart have been updated to reflect the new sample, which will be shipped with the other T2 chilled immediate samples to GLEC.

NLA 2017 Changes made to the Laboratory Operations Manual

LOM Version	Date Approved	Changes Made
1.1		Minor editorial and grammatical changes throughout LOM; some section header language revised. "Chain of Custody" changed to "sample tracking form" throughout to reflect NARS procedures. Section and table numbering revised to reflect additions and deletions.
		Section 1.3 and 1.4 revised to clarify that data templates are available from EPA not as an Appendix to the LOM
		Section 2.0 revised to clarify that labs all participate in a laboratory review process not receive an evaluation
		Section 2.1 assistance visit section deleted.
		Section 3.0 information on shipping of samples moved from old Section 3.5 for consistency with other chapters.
		Section 3.1 header removed for consistency with other chapters
		Section 3.2 and Section 3.4 removed because issues covered in Section 1.
		New Section 3.2 added – Precautions.
		Section 3.5.3 Step 5 added text related to adding conjugate solution .
		Deleted Table 3.2 and references to the table because the required data submission elements are included in the data templates.
		Section 3.6.2 (previous 3.7.2) added information on precision and accuracy.
		Table 3.2 (previous 3.3) added >$\bar{A}_6$ in calibration and changed .605 to .60 in kit control.
		Section 3.8 Sample and Record Retention deleted because information is included in Section 1.4.
		Section 4.0 added reference to EPA standard method; information on shipping of samples moved from old Section 4.5 for consistency with other chapters.
		Health and safety information moved to Section 4.2 Precautions for consistency with other chapters.
		Section 4.4 removed because issues covered in Section 1.

		Deleted Table 4.2 and references to the table because the required data submission elements are included in the data templates.
		Section 4.5.2 (previous 4.7.2) information on precision and accuracy added.
		Section 4.8 Sample and Record Retention deleted because information is included in Section 1.4.
		Section 5.4 Sample Receipt added.
		Section 5.5.4 (previous 5.5.3) Deleted previous Table 5.2 and related text. Inserted information on EPA data templates.
		Table 5.3 inserted information on assuming samples collected at 12:00 noon.
		Section 6.4 Sample Receipt added.
		Section 7.4 Sample Receipt added.
		Section 7.7.2 (previous Section 7.6.2) inserted information to clarify that EPA may choose to conduct external QC.
		Section 8.0 revised to indicate that TOC is frozen not refrigerated by the laboratory.
		Section 8.2 removed because issues covered in Section 1.
		Section 8.1 Personnel deleted reference to immunoassays.
		Added new Section 8.2 Precautions.
		Section 8.4 Step 2 (new) deleted reference to shipping as this is covered in Section 8.0; Step 5 (new) clarified that TOC is frozen; and added Step 7 regarding maintaining sample tracking forms.
		Table 8.2 updated including footnotes.
		Table 8.3 added “%” as an additional unit for TOC
		Deleted Table 8.4 because required data elements are identified in EPA data templates.
		Deleted Section 8.7.1.
		Section 8.6.2 (previous 8.7.3) added matrix spike duplicate.
		Section 8.8 Sample and Record Retention deleted because information is included in Section 1.4.
		Section 9.4 Sample Receipt added.
		Section 9.9.5 Data Entry added.
		Table 9.3 added.

		Section 10.2 sample receipt added.
		Table 10.3 updated to change NH to NH_3-N.
		Section 10.5.4 Data Entry added.
		Section 11.4 sample receipt added.
		Section 11.6 information on EPA's data template added.
		Section 11.7.2 information added on proportional QC analyses and to clarify that EPA may choose to conduct external QC.