NEON USER GUIDE TO AIS MAINTENANCE DATA

PREPARED BY	ORGANIZATION
Kaelin M. Cawley	AQU
Bryce Nance	AQU
Nora Catolico	AQU
Kevin Styers	SCI

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1 DESCRIPTION

1.1 Purpose

This document provides an overview of the data included in the NEON Level 1 (L1) AIS maintenance data tables, the quality controlled information generated from raw Level 0 (L0) data, and associated metadata. In the NEON data products framework, the raw data collected in the field, such as the date and time of a maintenance activity, are considered the lowest level, L0. Raw data that have been quality checked via the steps detailed herein, as well as simple metrics that emerge from the raw data are considered L1 data products.

The text herein provides a discussion of measurement theory and implementation, data product provenance, quality assurance and control methods used, and approximations and/or assumptions made during L1 data creation.

1.2 Scope

This document describes the steps needed to generate the L1 data product and associated metadata from input data for AIS maintenance activities associated with sensors used to produce several data products. This document also provides details relevant to the publication of the data tables via the NEON data portal, with additional detail available in the file, NEON Data Variables for AIS Maintenance (DP1.00026.001), provided in the download package for instrument data products.

This document describes the process for ingesting and performing automated quality assurance and control procedures on the data collected in the field pertaining to AIS maintenance activities. The raw data that are processed in this document are detailed in the files, NEON Raw Data Validation for AIS Maintenance (DP0.00026.001), provided in the download packages containing maintenance information. Please note that raw data products (denoted by 'DP0') may not always have the same numbers (e.g., '20190') as the corresponding L1 data product.

2   RELATED DOCUMENTS AND ACRONYMS

2.1   Associated Documents

AD[01]	NEON.DOC.000001	NEON Observatory Design (NOD) Requirements
AD[02]	NEON.DOC.001152	Aquatic Sampling Strategy
AD[03]	NEON.DOC.002652	NEON Data Products Catalog
AD[04]	Available with data download	Validation csv
AD[05]	Available with data download	Variables csv
AD[06]	NEON.DOC.000008	NEON Acronym List
AD[07]	NEON.DOC.000243	NEON Glossary of Terms
AD[08]	NEON.DOC.004825	NEON Algorithm Theoretical Basis Document: OS Generic Transitions
AD[09]	Available on NEON data portal	NEON Ingest Conversion Language Function Library
AD[10]	Available on NEON data portal	NEON Ingest Conversion Language
AD[11]	Available with data download	Categorical Codes csv
AD[12]	NEON.DOC.002716	NEON Preventive Maintenance Procedure: AIS Nitrate Analyzer
AD[13]	NEON.DOC.001569	NEON Preventive Maintenance Procedure: AIS Surface Water Quality Multisonde
AD[14]	NEON.DOC.004361	NEON Preventive Maintenance Procedure: AIS Surface Water Level Sensor
AD[15]	NEON.DOC.004362	NEON Preventive Maintenance Procedure: AIS Groundwater Level Sensor
AD[16]	NEON.DOC.004613	NEON Preventive Maintenance Procedure: AIS Buoy
AD[17]	NEON.DOC.002757	NEON Preventive Maintenance Procedure: AIS Underwater Photosynthetically Active Radiation (uPAR)
AD[18]	NEON.DOC.004849	NEON Preventive Maintenance Procedure: TIS & AIS Secondary Precipitation Gauge
AD[19]	NEON.DOC.004757	NEON Preventive Maintenance Procedure: AIS & TIS Thermo-metrics Platinum Resistance Thermometer (PRT)
AD[20]	NEON.DOC.003880	NEON Preventive Maintenance Procedure: AIS Stream Infras-tructure
AD[21]	NEON.DOC.004821	NEON Preventive Maintenance Procedure: Aquatic Meteorolog-ical (Met) Station
AD[22]	NEON.DOC.001882	NEON Preventive Maintenance Procedure: TIS & AIS Digital Network Camera

2.2 Acronyms

Acronym	Definition
AIS	Aquatic Instrument System
TIS	Terrestrial Instrument System

3 DATA PRODUCT DESCRIPTION

Preventive Maintenance is the planned maintenance of sensors and infrastructure with the goal of ensuring that the instrument and/or infrastructure performs correctly to ensure the collection of the best available science, by preventing excess depreciation and impairment. This maintenance includes, but is not limited to, inspecting, calibrating, adjusting, cleaning, clearing, lubricating, repairing, and replacing, as appropriate. If applicable, unplanned corrective and opportunistic maintenance actions may also be reported in this data product.

3.1 Spatial Sampling Design

Maintenance information is collected at the spatial resolution of a single sensor or suite of sensors.

As much as possible, sampling occurs in the same locations over the lifetime of the Observatory. However, over time some sampling locations may become impossible to maintain, due to disturbance or other local changes. When this occurs, the location and its location ID are retired. A location may also shift to slightly different coordinates. Refer to the locations endpoint of the NEON API for details about locations that have been moved or retired: https://data.neonscience.org/data-api/endpoints/locations/

3.2 Temporal Sampling Design

AIS maintenance activities take place at frequencies ranging between weekly and annually. Cleaning of all sensors occurs ever-other-week when possible. Field calibrations of the SUNA nitrate analyzer and water quality multisonde should take place on a monthly basis. Maintenance frequencies for various sensors are detailed in the NEON Preventive Maintenance documents listed in the Associated Documents section below.

3.3 Quality Assurance and Uncertainty

NEON field procedures for maintenance and field calibration activities follow widely adopted community methods and all NEON technicians conducting this work receive proper training. See AD[12] through AD[22] for sensor specific maintenance procedures. Additionally, NEON's Calibration/Validation department has regular procedures for sensors and their reports are available to data users upon request.

3.4 Variables Reported

All variables reported from the field or laboratory technician (L0 data) are listed in the files, NEON Raw Data Validation for AIS Maintenance (DP0.00026.001). All variables reported in the published data (L1 data) are also provided separately in the files, NEON Data Variables for AIS Maintenance (DP1.00026.001).

Field names have been standardized with Darwin Core terms (http://rs.tdwg.org/dwc/; accessed 16 February 2014), the Global Biodiversity Information Facility vocabularies (http://rs.gbif.org/vocabu lary/gbif/; accessed 16 February 2014), the VegCore data dictionary (https://projects.nceas.ucsb. edu/nceas/projects/bien/wiki/VegCore; accessed 16 February 2014), where applicable. NEON AIS spatial data employs the World Geodetic System 1984 (WGS84) for its fundamental reference datum and Earth Gravitational Model 96 (EGM96) for its reference gravitational ellipsoid. Latitudes and longitudes

are denoted in decimal notation to six decimal places, with longitudes indicated as negative west of the Greenwich meridian.

Some variables described in this document may be for NEON internal use only and will not appear in downloaded data.

3.5   Spatial Resolution and Extent

The finest resolution at which AIS maintenance and calibration data are reported is a single stationID or siteID. The namedLocation is the finest spatial resolution for the table and will be either stationID or siteID. All tables also contain a domainID and siteID field in addition to the namedLocation field. Overall, this results in a spatial hierarchy of:

namedLocation (ID of the station or site location) $\rightarrow$ **siteID** (ID of NEON site) $\rightarrow$ **domainID** (ID of a NEON domain).

Shapefiles of all NEON Aquatic Observation System sampling locations can be found in the Document Library: http://data.neonscience.org/documents. If users are interested in the geospatial locations of the data relative to a global coordinate system, those can be retrieved using the NEON data API using the **namedLocation** and the following:

1. The def.extr.geo.os.R function from the geoNEON package, available here: https://github.com/NEONScience/NEON-geolocation
2. The NEON API: http://data.neonscience.org/api

3.6   Temporal Resolution and Extent

The finest resolution at which AIS maintenance temporal data are reported is the time of day. For field maintenance and calibration activities this is recorded to the nearest minute. The total number of maintenance and calibration activities per year is expected to be 26 (every-other-week) per site. Sensor specific resolution can be found in the individual protocol documents.

The NEON Data Portal currently provides data in monthly files for query and download efficiency. Queries including any part of a month will return data from the entire month. Code to stack files across months is available here: https://github.com/NEONScience/NEON-utilities

3.7   Associated Data Streams

The maintenance data is published alongside the applicable IS data. Data between tables can be linked using location and date information.

3.8   Product Instances

The NEON Observatory contains 34 aquatic sites and 47 terrestrial sites.

3.9 AIS Data Relationships

The AIS protocol dictates that a bout of preventive maintenance activities should take place approximately every-other-week for sensors at aquatic sites. Each bout of maintenance activities will result in a record in the ais_maintenance table. Field maintenance and calibration procedures for the water quality multisonde, published in the Water quality (DP1.20288.001) data product, result in a record in the ais_multisondeCleanCal table. Field maintenance and calibration procedures for the SUNA nitrate analyzer, published in the Nitrate in surface water (DP1.20033.001) data product, result in a record in the ais_sunaCleanAndCal table. Groundwater maintenance activites result in one record in ais_maintenance and one record in ais_maintenanceGroundwater and the possibility of a record in ais_wellDevelopment records. However, duplicates and/or missing data may exist where protocol and/or data entry aberrations have occurred; *users should check data carefully for anomalies before joining tables*. Below, the data relationships for a single maintenance bout are in a bulleted list.

- Air temperature above water on buoy (DP1.20046.001) has one record in ais_maintenance

- Barometric pressure above water on buoy (DP1.20004.001) has one record in ais_maintenance

- Elevation of groundwater (DP1.20100.001) has one record in ais_maintenance and one record in ais_maintenanceGroundwater and the possibility of a record in ais_wellDevelopment

- Elevation of surface water (DP1.20016.001) has one record in ais_maintenance

- Nitrate in surface water (DP1.20033.001) has one record in ais_maintenance and one record in ais_sunaCleanCal

- PAR at water surface (DP1.20042.001) has one record in ais_maintenance

- PAR below water surface (DP1.20261.001) has one record in ais_maintenance

- Relative humidity above water on buoy (DP1.20271.001) has one record in ais_maintenance

- Shortwave and longwave radiation above water on buoy (DP1.20032.001) has one record in ais_maintenance

- Specific conductivity in groundwater (DP1.20015.001) has one record in ais_maintenance and one record in ais_maintenanceGroundwater and the possibility of a record in ais_wellDevelopment

- Temperature (PRT) in surface water (DP1.20053.001) has one record in ais_maintenance

- Temperature of groundwater (DP1.20217.001) has one record in ais_maintenance and one record in ais_maintenanceGroundwater and the possibility of a record in ais_wellDevelopment

- Water quality (DP1.20288.001) has one record in ais_maintenance and one record in ais_multisondeCleanCal

- Windspeed and direction above water on buoy (DP1.20059.001) has one record in ais_maintenance

3.10 Special Considerations

Data downloaded from the NEON Data Portal are provided in separate data files for each site and month requested. Downloads will only include data deemed relevant for the individual product. The neonU-

tilities R package contains functions to merge these files across sites and months into a single file for each table described above. The neonUtilities package is available from the Comprehensive R Archive Network (CRAN; https://cran.r-project.org/web/packages/neonUtilities/index.html) and can be installed using the install.packages() function in R. For instructions on using neonUtilities to merge NEON data files, see the Download and Explore NEON Data tutorial on the NEON website: https://www.neonscience.org/download-explore-neon-data . More detailed maintenance information may be available upon request.

4 DATA QUALITY

4.1 Data Entry Constraint and Validation

Many quality control measures are implemented at the point of data entry within a mobile data entry application or web user interface (UI). For example, data formats are constrained and data values controlled through the provision of drop-down options, which reduces the number of processing steps necessary to prepare the raw data for publication. An additional set of constraints are implemented during the process of ingest into the NEON database. The product-specific data constraint and validation requirements built into data entry applications and database ingest are described in the document NEON Raw Data Validation for AIS Maintenance (DP0.00026.001), provided with every download of this data product. Contained within this file is a field named 'entryValidationRulesForm', which describes syntactically the validation rules for each field built into the data entry application. Data entry constraints are described in NICL syntax in the validation file provided with every data download, and the Nicl language is described in NEON's Ingest Conversion Language (NICL) specifications (AD[09] and AD[10]).

Data collected prior to 2017 were processed using a paper-based workflow that did not implement the full suite of quality control features associated with the interactive digital workflow.

4.2 Automated Data Processing Steps

Following data entry into a mobile application or web user interface, the steps used to process the data through to publication on the NEON Data Portal are detailed in the NEON Algorithm Theoretical Basis Document: OS Generic Transitions (AD[08]).

4.3 Data Revision

All data are provisional until a numbered version is released. Annually, NEON releases a static version of all or almost all data products, annotated with digital object identifiers (DOIs). The first data Release was made in 2021. During the provisional period, QA/QC is an active process, as opposed to a discrete activity performed once, and records are updated on a rolling basis as a result of scheduled tests or feedback from data users. The Change Log section of the data product readme, provided with every data download, contains a history of major known errors and revisions.

5 REFERENCES

Clesceri LS, Greenberg AE, Eaton AD (1996) Standard Methods for the Examination of Water and Wastewater. 20th edition, Portland, OR.