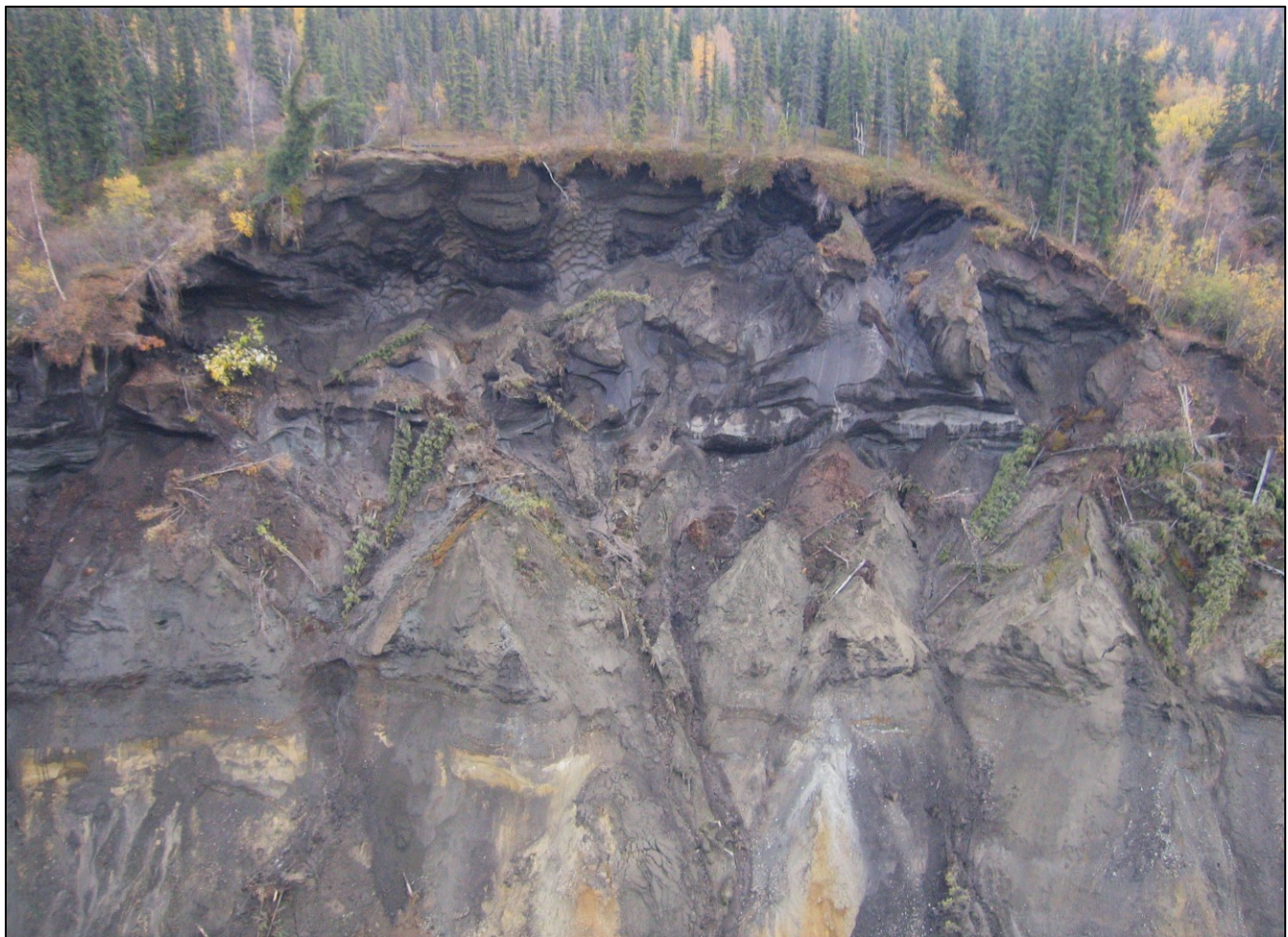




Permafrost Monitoring in the Central Alaska Network

Data Quality Standards, Version 1.0

Natural Resource Report NPS/CAKN/NRR—2018/1764



ON THE COVER

Aerial view of ice wedges exposed in bluffs alongside Toklat River, Denali National Park and Preserve, Alaska.
NPS photo.

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U.S. Department of the Interior
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Natural Resource Stewardship and Science
Fort Collins, Colorado

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This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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Revision History Log

All edits and amendments made to this document since its inception should be recorded in the table below. Users of this protocol should promptly notify the project managers of recommended edits or changes. The project managers will review and incorporate suggested changes as necessary, record these changes in the revision history log, and modify the date and version number on the title page of this document to reflect these changes.

Revision History Log

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
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Executive Summary

The purpose of this report is to document the standards used by the National Park Service (NPS) Central Alaska Network (CAKN) Inventory and Monitoring Program for activities related to the collection, processing, analysis, and publication of permafrost monitoring data as described in *Permafrost Monitoring in the Central Alaska Network: Protocol Narrative* (Loso 2018). This plan also serves as a guide for CAKN personnel who are involved in protocol/program activities and as a resource for identifying memoranda, publications, and other literature that describe associated techniques and requirements in more detail.

Acknowledgments

The format and content of this document borrows from Wilson and Shepherd (2017) and Rattenbury and Schmidt (2017). Thanks to them, and to Maggie MacCluskie and Scott Miller, for their guidance in developing these standards. Funding for this project was provided through the National Park Service, Inventory and Monitoring Program. The creation of the accompanying protocol narrative involved the contributions of numerous individuals acknowledged more completely in that document. I gratefully acknowledge the contributions of peer-reviewers Elchin Jafarov, Dmitri Nicolsky, Sergey Marchenko, and Joel Reynolds.

1. Introduction

The three national park units which comprise the National Park Service Inventory and Monitoring Program's Central Alaska Network (CAKN: Wrangell-St. Elias, Denali, and Yukon-Charley Rivers) are underlain by permafrost—ground that remains at or below 0°C for at least two, but typically many, years. Much of that permafrost, however, is geographically discontinuous, thin, and close to the melting point of water. Under the warming conditions that characterize these parks, permafrost thaw is likely to have significant impacts on the landscapes of these parks. These impacts may include development of thermokarst, landslides and slumping, changes in hydrology and vegetation, growth and/or drainage of lakes, enhanced release of greenhouse gases, and decay of characteristic permafrost features like pingos and rock glaciers. The CAKN permafrost monitoring program is designed to monitor a subset of these changes over multiple decades.

The permafrost monitoring program is formulated as a protocol, as documented by a Protocol Narrative (Loso 2018), by Data Quality Standards (this document), and by Standard Operating Procedures (SOPs) that provide detailed instructions for protocol implementation. Collectively, these documents describe how monitoring data will be collected, managed, and reported as part of the NPS Inventory and Monitoring program and as described in the CAKN Vital Signs Monitoring Plan (MacCluskie et al. 2005).

As part of the permafrost monitoring protocol, this report documents the standards used by the CAKN Inventory and Monitoring Program for activities related to the collection, processing, analysis, and publication of permafrost monitoring data as described in *Permafrost Monitoring in the Central Alaska Network: Protocol Narrative* (Loso 2018). The policies and procedures documented in this quality-assurance plan follow the quality-assurance plan for other monitoring activities conducted by CAKN and supplement the National Inventory & Monitoring Division Quality Management Plan. This plan also serves as a guide for CAKN personnel who are involved in protocol/program activities and as a resource for identifying memoranda, publications, and other literature that describe associated techniques and requirements in more detail.

2. Protocol Overview

2.1 Objectives

The CAKN permafrost protocol has two network-wide focus areas: 1) the thermal state of permafrost, and 2) the physical state of permafrost (**Table 1**). These measurements will contribute directly to the Global Terrestrial Network for Permafrost (GTN-P), the primary international program concerned with monitoring permafrost parameters (Christiansen 2012). We will also monitor changes in the dynamics of one rock glacier in WRST—a unique type of permafrost feature not included in other long-term permafrost monitoring programs. Proposed locations for these measurements are shown in **Figure 1**.

Table 1. Overview of proposed activities for the CAKN permafrost monitoring program.

Focus area	Objective	Unit	# sites WRST	# sites DENA	# sites YUCH	Frequency
Thermal state	Soil temperature	deg C	10	8	3	hourly
	Borehole temperature	deg C	1	1	1	annual
Physical state	Active layer thickness	m	5	4	4	every 3 yr
	Soil surface elevation	m asl	5	4	4	every 3 yr
Rock glacier	Areal extent	polygon	1	0	0	every 6 yr
	Surface elevations	m asl	1	0	0	every 6 yr
	Surface velocities	m/d	1	0	0	every 6 yr

The objective of focus area one—the thermal state of permafrost—is to track changes over time in ground temperatures at a variety of monitoring sites. Ground temperatures determine the presence or absence of permafrost, and over time the trends in these temperatures dictate the progress of permafrost thaw. To take advantage of existing weather/climate stations and cover the broadest possible area with minimal additional disturbance, most sites will be measured within only the shallowest 0.5 – 2.0 meters and the measurements will be made regardless of the presence or absence of permafrost. Where possible, such measurements will be paired with soil moisture measurements on an opportunistic basis. At one site within or adjacent to each park, however, thermal state will also be measured in a much deeper (29-70 m) cased borehole to provide a more complete view of long-term thermal changes with less influence from seasonal and intra-annual fluctuations. Most of the measurements associated with this objective will be done in close collaboration with other research groups, most notably including the CAKN Climate Monitoring Vital Sign and the University of Alaska Geophysical Institute’s Permafrost Laboratory.

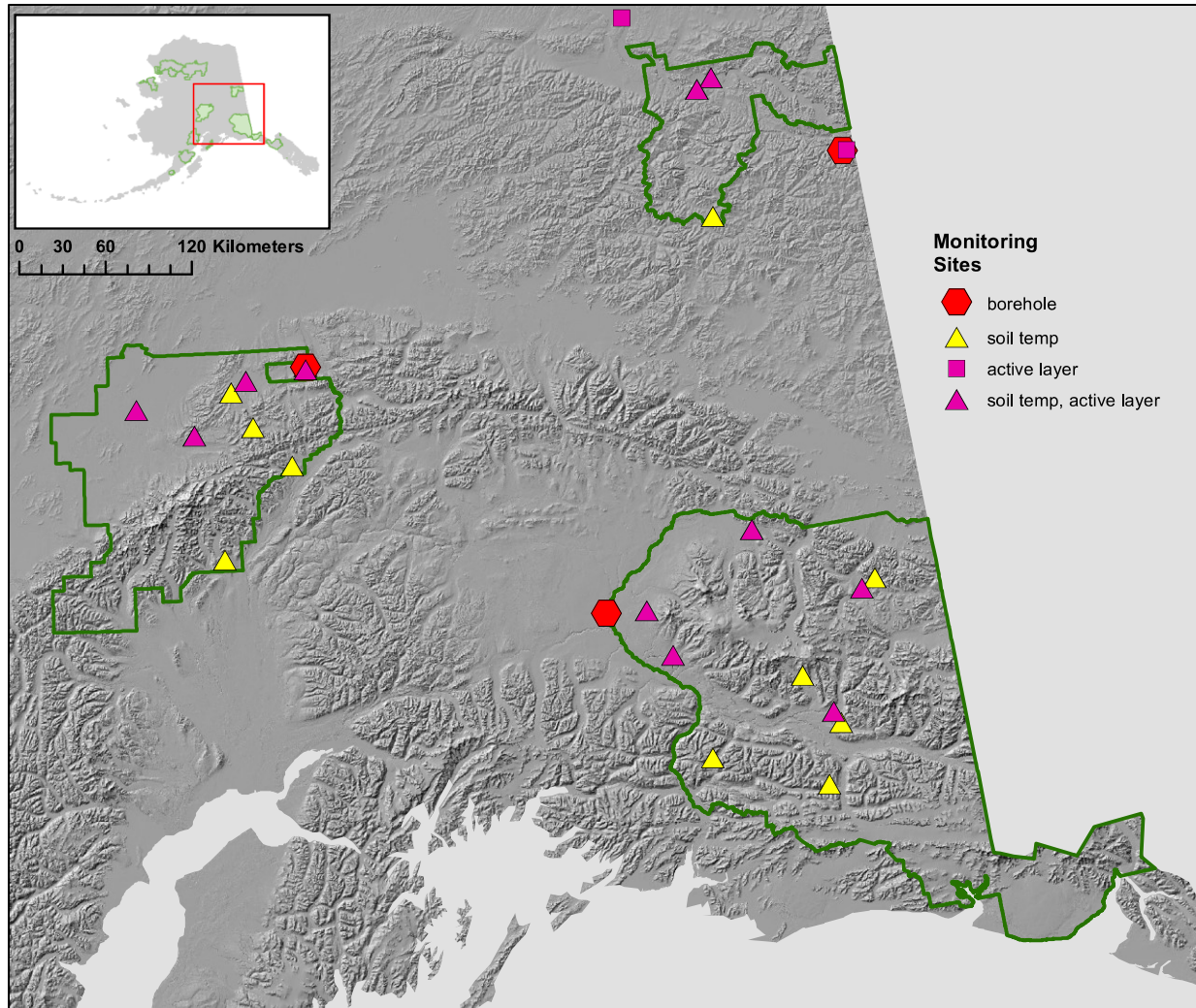


Figure 1. Proposed monitoring sites. Some include multiple measurements. Site list is expected to evolve over the first few years of the protocol.

The objectives of focus area two—the physical state of permafrost—are to determine the depth of the perennially frozen layer and the extent (if any) of associated soil surface subsidence. In practice, the depth of the perennially frozen layer is measured as the active layer thickness: the thickness of seasonally thawed (and hence, at least in fine-grained soils, penetrable) soil at the end of the melt season. This is measured by probing a series of points on a transect or grid. Soil surface elevation will be concurrently determined at each probing point using survey-grade dGPS or another survey method with comparable accuracy. Some of the sites proposed for active layer monitoring have been previously studied, and this program will update active layer measurements begun in 2003 at Toklat Basin in DENA (Schoor et al. 2015a), in 2012 at Andrew Flat in YUCH (Wells 2017), and in 2009 along the Tanada Lake Trail in WRST (Arp and Simmons 2012). Other measurements from those previous studies (vegetation, soil stratigraphy, etc.) are outside the objectives of this protocol and are not formally included in it, but may be included in future fieldwork if supported by collaboration and/or outside resources.

A third focus area—rock glacier monitoring—is more narrowly focused on a single example (Sourdough Rock Glacier; Petersen et al. 2016) of a globally unique concentration of rock glaciers in the central Wrangell Mountains. Our objective here is to determine, through periodic measurements of surface elevation, areal extent, and flow velocity if, and how, there is a discernible long-term change in the geometry or dynamics of a unique permafrost feature not presently being monitored anywhere in Alaska: rock glaciers.

2.2 Sampling Design

Measurement sites shown in **Figure 1** were chosen to maximize spatial coverage while minimizing the costs and logistical demands of access. Measurement sites for thermal state (hexagons and triangles) rely primarily upon existing boreholes and/or climate measurement stations, and it is acknowledged that some sites are not in ideal locations for capturing permafrost temperatures. Within the broad permafrost distribution classification of Jorgenson (2008), 17 of the 21 sites selected for shallow soil temperature measurements are in the discontinuous permafrost zone, with three in the continuous zone and one in the isolated zone. Of the deep borehole sites, the Gulkana site is in the continuous permafrost zone and the other two are in discontinuous permafrost.

Some sites may not even be located on permafrost soils, but monitoring the evolution of soil temperatures at those sites is nonetheless considered valuable for the broader purpose of providing a spatially comprehensive record of the thermal evolution of the discontinuous permafrost zone within the parks. Physical models that link observations of atmospheric temperatures with predicted evolution of soil temperatures (e.g. Panda et al. 2014a, 2014b) are becoming more common, and our soil temperature measurements (whether in permafrost or not) will serve as a valuable calibration for such models, thus improving our ability to infer spatially distributed evolution of permafrost soil temperatures throughout the study area.

Because active layer measurements require fine-grained permafrost soils that do not always coincide with locations of existing stations, these sites (purple squares and triangles) are in many cases less accessible and we consequently selected a smaller number of locations for regular measurements. Where active layer measurement locations do not coincide with existing boreholes and/or climate measurement stations, we will co-locate new permafrost temperature measurement sensors at those sites. All of the active layer measurement sites are located in the discontinuous permafrost zone of Jorgenson (2008).

The sampling schedule for permafrost measurements is summarized in Table 1, and like the choice of sampling sites reflects the costs and logistical demands of access. Automated soil temperature measurements are amenable to frequent (hourly) measurements, but other measurements that require site visits are scheduled to be conducted every 3 years (active layer thickness) or 6 years (rock glacier metrics). Active layer measurement must further be timed fairly precisely during the summer, to coincide with the late-summer period of maximum thaw depth. This further demands the staggering of site visits among parks, since all parks cannot be visited simultaneously. Precise timing of all measurements is expected to evolve with budgetary constraints, logistical and weather contingencies, and other factors.

3. Data Quality Objectives

This section is intended to demonstrate how this project generates data of known and documented quality, resulting in complete, accurate and transferable information.

3.1 Representativeness and Data Comparability

Because of the sample design described above, and also because some of the sampling locations are in non-permafrost soils, these measurements are not randomly distributed through space. Like many comparable studies, the site selection was not probabilistic and the measurements of soil temperature, active layer thickness, and other metrics will be interpreted using a time series approach where the focus is on trends—at each sampling site—over time. This is especially true of the rock glacier study, which will examine trends in only a single rock glacier.

That said, the soil temperature, borehole temperature, and active layer thickness measurements are being collected using techniques and equipment that are directly comparable to (and in many cases identical to) those used for measurements elsewhere in Alaska. At this writing, these types of measurements are more common in permafrost areas outside the parks than inside, and this protocol will therefore significantly expand the existing network of Alaskan permafrost measurement sites with new datasets that can be analyzed more broadly in direct comparison with such sites.

3.2 Data Completeness and Quality

If measurements or data downloads are unable to be completed in a scheduled year due to funding or logistical issues, they will be attempted in the next year if possible. In the event of automated soil temperature measurements, this delay will not result in any lost data but may delay the posting of certified datasets. For the other variables, a skipped data collection season could not be recovered, but data collection at a later date would still allow calculation of long-term trends, albeit with reduced temporal resolution for that epoch.

Target data quality objectives for each measurement type are summarized in **Table 2**. The soil temperature error target ($\pm 0.25^{\circ}\text{C}$) is larger than those of any of the various individual sensors used in this protocol, and were deliberately chosen to reflect not only those instrument errors but also unknown error associated with the use of differing sensors and installation techniques. The borehole temperature error ($\pm 0.10^{\circ}\text{C}$) and spatial resolution (2 m) targets were selected to match those already employed by the UAF Permafrost Laboratory. Active layer thickness error targets are ($\pm 0.02\text{ m}$). The soil surface elevation target ($\pm 0.02\text{ m}$) is based upon the expected maximum error of post-processed positions using survey-grade dGPS, and will evolve if derived errors are significantly greater or less than this target. The rock glacier areal extent error target (10.0 m) generously allows for errors in orthorectification of aerial/satellite imagery and also digitizing errors. The surface elevation error target of $\pm 0.5\text{ m}$ is expected to be accomplishable with SfM or lidar-based DEM acquisition at a pixel resolution of $<1\text{ m}$. Evolving technology will likely allow us to exceed this standard by an increasing margin over time. Finally, the surface velocity error target of $\pm 0.02\text{ m/d}$ should be easily accomplishable, since that is a realistic error margin for individual stake measurements using post-processed dGPS and the velocity error over seasonal timescales, calculated in quadrature, will be much lower.

Table 2. Target data quality standards for the permafrost protocol.

Focus area	Objective	Unit	Quality target
Thermal state	Soil temperature	deg C	+/- 0.25° C using buried soil temp sensors
	Borehole temperature	deg C	+/- 0.10° C error from calibrated cabled sensor dropped down hole in 2 m increments
Physical state	Active layer thickness	m	+/- 0.02 m error due to timing of measurements
	Soil surface elevation	m asl	+/- 0.02 m z (+/- 0.02 m xy) from survey-grade dGPS
Rock glacier	Areal extent	polygon	line digitized within 10.0 m of actual boundary at 1:5000
	Surface elevations	m asl	+/- 0.5 m z, <1.0 m pixel resolution using remote sensing
	Surface velocities	m/d	+/- 0.02 m/d from repeat survey measurements

Equipment and techniques required to meet these objectives are described in the Standard Operating Procedures. These SOPs are expected to evolve over the course of the measurement cycle due to improved equipment and techniques, so these target quality objectives should be viewed as minimum expectations that will shrink to even tighter tolerances over coming years. In all cases, data reporting will include a discussion of uncertainties associated with each measurement.

3.3 Data Archival, Closeout, and Certification Procedures

Data archival, closeout, and certification procedures will generally follow the guidelines established in Miller (2017). All protocol associated data will be uploaded to the IRMA Data Store within Dataset References that correspond to the rows of Table 3. Links to the authoritative IRMA records (both data and metadata) will also be provided to GTN-P and other regional permafrost monitoring databases.

Table 3. CAKN permafrost monitoring data deliverables references.

Identifier	Deliverable	Description	SOPs	Format	Schedule*	Viewable
PRM01	Study site locations	Generalized xyz locations of all current field measurement sites associated with the permafrost protocol.	1	Google Earth .kmz	Annual	Public
PRM02	Field notes	Scanned copies of all field notes collected during protocol activities in the previous year.	2,4,6	Scans .pdf	Annual	Internal
PRMst01	Soil temperature logger files	Raw logger files plus spreadsheet of soil temperature logger data. Spreadsheet will be annotated and QC'd.	2	Various + spreadsheet .xlsx	Annual + 1 yr	Internal

* '+1 yr' indicates permissible 12 month lag between data collection and delivery

Table 4 (continued). CAKN permafrost monitoring data deliverables references.

Identifier	Deliverable	Description	SOPs	Format	Schedule*	Viewable
PRMst02	Certified soil temperature	Machine-readable table of hourly temperature measurements for each site/depth, with metadata.	3	Text file .csv	Annual + 1 yr	Public
PRMbh01	Borehole temperature logger files	Raw logger files plus spreadsheet of borehole temperature logger data. Spreadsheet will be annotated and QC'd.	4	.hobo + spreadsheet .xlsx	Annual + 1 yr	Internal
PRMbh02	Certified borehole temperature	Machine-readable table of annual temperature measurements for each site/depth, with metadata.	5	Text file .csv	Annual + 1 yr	Public
PRMal01	Active layer survey files	Packaged electronic files from collection and processing of survey data. If using dGPS, files would include raw data files, data dictionary, processing logs, and processed differentially corrected locations.	6	Various	3 rd year + 1 yr	Internal
PRMal02	Certified active layer depths and positions	Machine-readable table of active layer (probing) depths, plus latitudes, longitudes, and elevations for all probed points, with metadata.	7	Text file .csv	3 rd year + 1 yr	Public
PRMrg01	Rock glacier survey files	Packaged electronic files from collection and processing of survey data. If using SfM, includes raw photographs, processing logs, and output. Also includes dGPS/COSI-Corr processing data.	8	Various	6 th year + 1 yr	Internal
PRMrg02	Certified rock glacier rasters	Orthophotographs, digital elevation models, and velocity maps, with metadata.	9	ArcMap .gdb	6 th year + 1 yr	Public

* '+1 yr' indicates permissible 12 month lag between data collection and delivery

This is a “file based data management system,” per Miller (2017), and it consists fundamentally of two different types of data: internal and public references. Internal references include raw data files, field notes, and other items that will be archived in the IRMA Data Store but are not viewable to the general public. These files are not considered “certified.” Public references are based upon the internal references, but will have been quality-controlled by the PI prior to publication. Quality control safeguards applied, as appropriate, to all deliverables described in Table 3 include:

- Immediate (within 48 hour) checking of collected/downloaded data for completeness,

- Regular collection, scanning, and archiving of field notes to maintain a record of data collection abnormalities,
- Double data entry in the rare case of manually entered data,
- Regular checking of data for extreme or impossible values,
- Regular calibration of sensors on manufacturer recommended schedules,
- Graphical and visual exploratory data analysis, and
- Statistical error or outlier identification.

This quality control, followed by posting as public references, constitutes “implied certification.” All files posted in this way will include “certified” in their titles, and are considered to be developed to analytical quality. All certified data products will be presented in human and machine readable formats, and presented with metadata in FGDC (spatial; FGDC 1998)) or Ecological Metadata Language (tabular; Knowledge Network for Biocomplexity 2015) language.

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