Alberta Biodiversity Monitoring Institute

Quality Management Plan

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Approvals

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Revision History Log

Revision #	Revision Date	Author	Changes
1.0	04/2016	Katherine Maxcy	Drafted
1.1	10/2016	Katherine Maxcy	Incorporated revisions after internal review

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CHAPTER 1: DOCUMENT DESCRIPTION AND ORGANIZATION

1.1 Background

The Alberta Biodiversity Monitoring Institute (ABMI) collects data on a range of attributes (e.g., species, habitats, ecosystems, land use) that are used as indicators of environmental health in Alberta. This is a valuable source of data for the province, and as such, it is important to ensure the data is of known quality (Houston and Hiederer 2009, Ferretti, 2009, 2011, Sólymos et al. 2015). When setting quality objectives for data it is important to understand its intended use (EPA 2001, Chapman 2005, GLNPO 2008, Martin and Ballard 2010, Ferretti 2009, 2011, Gasparini et al. 2011, Sólymos et al. 2015). A structured quality management plan (QMP) improves confidence that data is being effectively handled and, therefore, increases its use by stakeholders (Chapman 2005, Houston and Hiederer 2009, Sólymos et al. 2015).

A QMP is an organization's description of the processes that govern quality assurance activities (Lawrence 1999, GLNPO 2008). It contains the necessary elements to plan, implement, document, assess, and improve a quality management system (EPA 2001, Ferretti 2009). The QMP may be viewed as an "umbrella" document under which all quality assurance (QA) and quality control (QC) products and activities are contained (EPA 2001). The basic goal of the QMP is to provide a means to document and verify the quality of information being produced, and provide guidance to program personnel to meet quality objectives (Shampine 1993). A QMP is a critical feature of a biodiversity monitoring program to ensure the program can meet stated quality objectives (Shampine 1993, EPA 2001, Sólymos et al. 2015). This QMP outlines the ABMI quality management system.

1.2 Objective

The objective of this QMP is to describe the ABMI quality management system as it relates to all data collection and processing activities, data analysis, and the production of associated data products. It describes how each ABMI business unit (Centre) will plan, implement, document, assess, and improve its quality system to produce and curate high-quality well documented biodiversity information.

1.3 QMP Report Organization

This QMP outlines the ABMI's quality management system. There are six Centres within the ABMI (see Chapter 2 for a complete description of each Centre). Because each Centre is responsible for different aspects of the data management cycle, each Centre has created their own QMP which is included as a chapter in this overarching document. Each Centre QMP follows the same format (following EPA 2001, GLNPO 2008), and includes the following elements:

- **Element 1.0 Quality Management Policy, Goals, and Objectives:** defines Centre quality management policies, goals, and objectives;
- **Element 2.0 Quality System Components:** describes the main components of the quality management system and the activities and tools used to implement this system;
- **Element 3.0 Quality Training System:** describes the quality training system implemented by each Centre to ensure quality management objectives are being met;
- **Element 4.0 Contractor Requirements:** discusses the process for procuring services and Contractor requirements for meeting quality objectives;
- **Element 5.0 Documents and Records:** provides information on the document control system including: document preparation; document reviews, approvals, and revisions; document control; document storage and archival system;
- **Element 6.0 Information Management:** discusses the processes for managing information, including a description of computer hardware and software administration;
- **Element 7.0 Systematic Quality Assurance Planning:** discusses the process for systematically planning and implementing the quality management system;
- **Element 8.0 Quality Implementation of Work Processes:** discusses how each Centre implements its quality work processes;
- **Element 9.0 Quality Assessment and Response System:** describes the application of assessment tools that are used to evaluate the effectiveness of each Centre's quality management system and to improve its performance;
- **Element 10.0 Commitment to Quality Improvement:** summarizes each Centre's ongoing activities towards continued improvement of data collection, analysis, and management activities as well as biodiversity information products.

Not all 10 elements are applicable within each Centre's data quality management activities. If an element does not apply for a Centre, then it is left out of their respective QMP.

1.4 Maintenance of This Document

This is the ABMI's first full iteration of a QMP. As such, this QMP is a working document that will undergo changes as the ABMI quality management system evolves and grows with the addition of new information, and revision of existing procedures as part of the ABMI's continuous improvement efforts.

The Information Coordinator (Information Centre) will be responsible for updating and/or coordinating reviews of the QMP. The QMP document control system is as follows:

- The Information Coordinator will be responsible for coordinating reviews of the ABMI QMP, and collating the Centre QMPs into the final QMP document.
- One person from each Centre who is a current member of the ABMI's Data Management Committee will be accountable for review and update of their respective Centre's QMP.

- During the first three years of the QMP implementation, the QMP will be reviewed annually to test, revise and update the quality management system within each Centre, and to ensure all components of the quality management process have been included.
- After this development period, the document will be reviewed every two years to ensure QA procedures are up-to-date.
- Edits made to the document will be classified as minor or major by the Information Coordinator. Minor edits encompass small changes to this plan, while major edits encompass significant changes to specific document sections, the addition/omission of a specific section, change in responsibilities, or reorganization of existing functions.
- Document changes will be noted in the tracking sheet at the beginning of this document. Minor edits will require the number after the decimal to be changed. All major edits require the number preceding the decimal place to be changed. The individual making the edit is required to put their name, the date of the edit, and make a comment as to where changes were made.
- The most current version of this document will be kept in Sharepoint under ABMI Home/Shared Documents/Quality Management Resources. All older versions will be archived on Sharepoint within the same directory in the archive folder. A hard copy of the document will also be available from the Information Coordinator.
- The ABMI QMP will be made publically available on the ABMI website in the fall of 2016.

1.5 Report Overview

This report is divided into eight chapters (and appendices) including:

- Chapter 1: Document Description and Organization
- Chapter 2: The ABMI Program
- Chapter 3: Monitoring Centre QMP
- Chapter 4: Processing Centre QMP
- Chapter 5: Information Centre QMP
- Chapter 6: Science Centre QMP
- Chapter 7: Geospatial Centre QMP
- Chapter 8: Application Centre QMP
- Appendices

1.6 Chapter 1: References

Chapman, A.D. 2005. Principles of data quality. Report available at: www2.gbif.org/DataQuality.pdf.

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Gasparini, P., R. Bertani, F. De Natale, L. Di Cosmo and E. Pompei. 2011. Quality control procedures in the Italian national forest inventory. Journal of Environmental Monitoring 11:761-768.

GLNPO (Great Lakes National Program Office). 2008. Great Lakes National Program Office: Quality Managment Plan. Report available at: www.epa.gov/glnpo/qmp/glnpo_qmp_2008.pdf

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Lawrence, J. 1999. Ecological quality assurance principle. USDA RMRS-P-12.

Martín, E. and G. Ballard. 2010. Data Management Best Practices and Standards for Biodiversity Data Applicable to Bird Monitoring Data. U.S. North American Bird Conservation Initiative Monitoring Subcommittee. Available at: http://www.nabci-us.org/.

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CHAPTER 2: THE ABMI PROGRAM

2.1 ABMI Description

The ABMI is a not-for-profit, science organization that conducts biodiversity monitoring in the province of Alberta. The ABMI's mission is to track changes in Alberta's wildlife and their habitats from border to border, and provide ongoing, relevant information on Alberta's living resources to support natural resource and land-use decision making in the province (Burton 2014, Sólymos et al. 2015).

The ABMI manages and implements a science-based program that monitors and reports on biodiversity status and trends throughout Alberta. As one component of our status and trend monitoring, the ABMI employs a systematic grid of 1,656 site locations, spaced 20 km apart, to collect biodiversity data on terrestrial and wetland sites. In addition, the ABMI Geospatial Centre (GC) monitors the state of Alberta's human footprint using fine-resolution aerial photography and satellite imagery.

Data collection and analysis are significant components of the ABMI program. The Science Centre (SC) leads the development and improvement of data collection protocols. The ABMI's Monitoring Centre (MC) leads the implementation of these protocols in the field while the Processing Centre (PC) leads the implementation of laboratory based protocols. The ABMI's Information Centre (IC) ensures data is stored and accessible to stakeholders. Together the SC and IC are responsible for aspects of data evaluation and reporting. In addition, the Application Centre (AC) uses the ABMI data to support a wide range of environmental planning and management needs. Projects such as the implementation of regional monitoring priorities, climate change adaptation and reclamation consultations, and the assessment of ecosystem services underscore the importance of the ABMI program.

2.2 Operational Management

To execute its mission, the ABMI relies on leadership provided by its Board of Directors and a Science Advisory Committee. The Board of Directors has authority and responsibility over the business of the Institute. As the governing body, the Board helps to direct the strategic management and corporate performance at the ABMI. In addition, the Science Advisory Committee provides external, third-party review and recommendations on strategic science decisions as they relate to the operating principles endorsed by the Institute's members.

The ABMI has an Executive Office and six Centres (Figure 2.1): the Monitoring Centre, the Processing Centre, the Information Centre, the Science Centre, the Geospatial Centre, and the Application Centre.

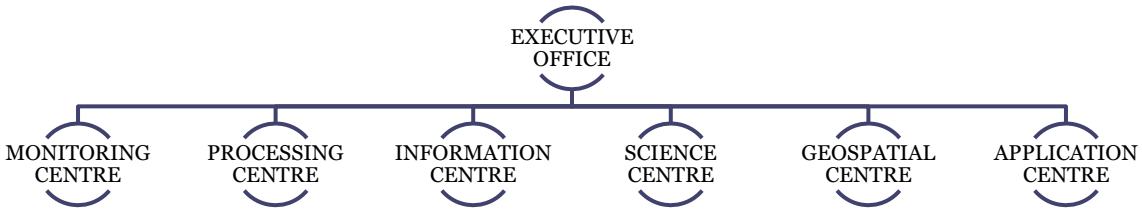

Figure 2.1. Organizational structure of the ABMI.

Each Centre in the ABMI is accountable for implementing QAQC activities consistent with their mandate:

- **Executive Office (EO)** → holds ultimate operational accountability.
- **Monitoring Centre (MC)** → is responsible for collecting biodiversity-related field data for the ABMI program. This involves ensuring data is collected consistently and reflects the conditions in the field, communicating all aspects of the data collection activities to other units, delivering data components to the correct destinations, and providing "first pass" quality control.
- **Processing Centre (PC)** → manages the curatorial and taxonomic expertise for the specimens and samples collected in the field. The PC plays an important role in the information flow within the Institute, being responsible for the processing and identification of all specimens collected in the field, and generating the ABMI's species-level data.
- **Information Centre (IC)** → is responsible for providing data management and infrastructure support for the data and information generated by the ABMI. This includes the execution of quality control procedures on all aspects of the data cycle to ensure standards described in this document are met for all ABMI data products and services. Also part of the IC business portfolio is the management of the website and the development of new communication strategies to deliver information to users.
- **Science Centre (SC)** → analyzes and produces information from the data collected in the field that allows users to interpret patterns and trends in the changing environment in Alberta. The SC is vital to maintaining scientific excellence in the data and information generated by the ABMI, and plays an important role in managing quality control of the field activities.
- **Geospatial Centre (GC)** → generates all the remote sensing and geospatial data and information to support the ABMI's user needs. This is a multifaceted responsibility that includes developing and testing new remotely sensed methodologies, developing new data products, and performing quality assurance on the information and products being delivered to the public.
- **Application Centre (AC)** → leverages the data generated by the ABMI and undertakes projects that help demonstrate the value of the program and the benefit to Albertans. In applying the data and information of the ABMI, the AC brings value to the ABMI's mission.

2.3 The Data

As a source of biodiversity knowledge for the province of Alberta, the data produced by the ABMI must meet high quality standards to maximize usage and support environmental decisions (Houston and Hiederer 2009, Ferretti 2009, 2011, Sólymos et al. 2015). Without good data, the ability of government, industry, academics and the people of Alberta to understand the implications of environmental change to the province would be severely impaired.

The credibility of the ABMI in fulfilling its key role in monitoring Alberta's biodiversity rests on its core operating principles of being:

- **Independent**, as it operates at arm's length from government and industry;
- **Scientifically Credible**, with the program being validated through peer review and by the Science Advisory Committee;
- **Relevant and Accessible**, developing products that will meet stakeholder's needs; and
- **Transparent**, with open governance and operations to promote engagement and accountability.

2.4 Data Products Explained

The ABMI delivers data on the status of the biodiversity of Alberta. To do so, the Institute collects a variety of types of data, and generates unique products, all of which are part of the Institute's portfolio.

The ABMI's data products fall into three categories: collected data, processed data, and derived products, with a variety of products classified under each category (Figure 2.2). Quality management of each product is defined and delivered based on guidelines created by the responsible Centre.

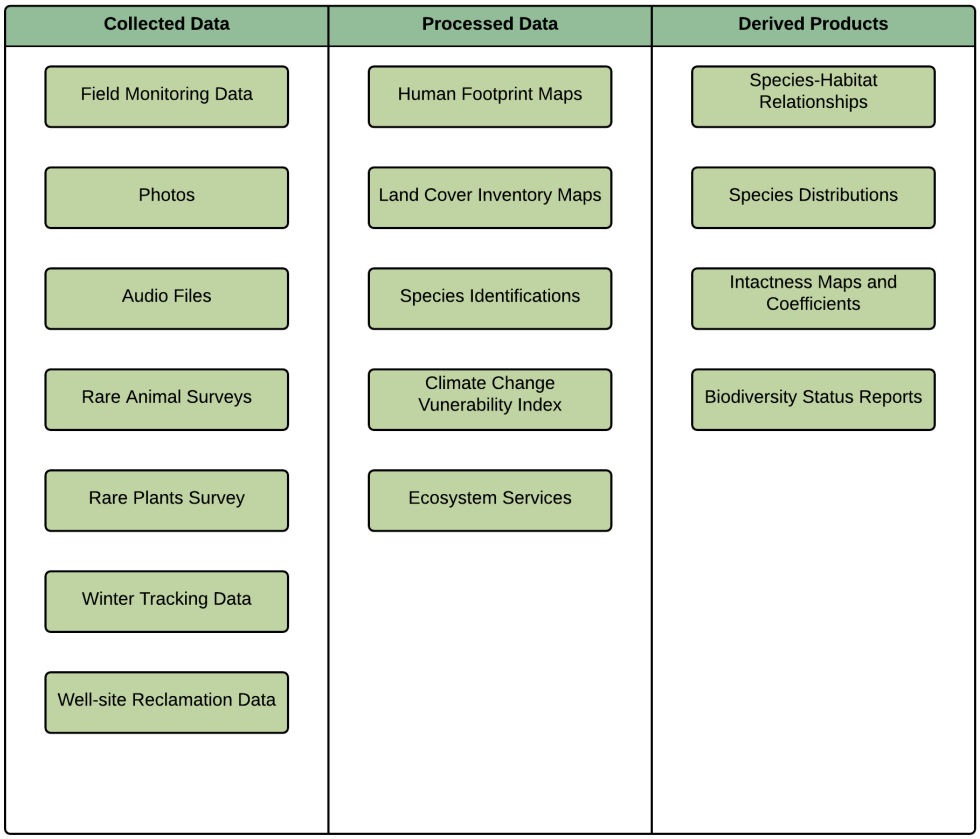

Figure 2.2. All ABMI products divided into the 3 categories, collected data, processed data, and derived products.

Collected data refers to all data that are collected by the ABMI from the field and that receive no further manipulation (See Sólymos et al. 2015 for a description of the data collection process). Processed data refers to all the data generated by the organization based on the collected or external data sources. Derived products refer to all the products produced by the ABMI through the interpretation and analysis of the collected or processed data.

For a summary and description of the ABMI data management cycle see Sólymos et al. (2015).

2.5 Dimensions, Definitions, and Deliveries

The ABMI QMP uses quality assurance dimensions and definitions derived by the Statistics Canada's Quality Assurance Framework (Table 2.1; Statistics Canada 2002). The dimensions have been modified to fit within the ABMI's data quality management system.

Table 2.1. Definitions and ABMI deliverables organized according to the six data quality dimensions defined in the Statistics Canada's Quality Assurance Framework (Statistics Canada 2002).

Dimensions	Definitions	ABMI Deliverables
Accuracy	The degree to which data correctly describes the observed or predicted phenomena they were designed to measure.	● Continuous training of new and existing staff on quality assurance practices ● Automated quality assurance systems ● Standard Operating Procedures ● Internal and external audits

Interpretability	Availability of supplementary information and metadata necessary to interpret and utilize data appropriately.	● Metadata templates and automated real-time updates ● Metadata policy ● Online documentation and instructions
Coherence	The degree to which the data can be brought together with other data, products, or information within the broader analytical framework and over time.	● Quality control practices including user-based updates and yearly activity evaluations ● Standard Operating Procedures ● Data entry templates and online portals ● Data Management Committee and data longevity and archival process
Timeliness	The delay between the reference point of collection data and information and the date data become available for public use.	● Data release schedules ● Data delivery agreement
Accessibility	The ease with which data can be accessed as it pertains to the ease of getting the data as well as the suitability of the form with which the data is accessed.	● Database infrastructure and online delivery vehicle ● Multi-format delivery
Relevance	The degree to which data meets the needs of the users. It is concerned with whether the available information sheds light on the issues of most importance to users.	● Selection of biodiversity and land cover variables measured ● Sampling design and implementation data collection protocols ● Project design framework ● Product updates and relevance evaluation ● Long-term monitoring data value

2.6 Chapter 2: References

Burton, A.C., D. Huggard, E. Bayne, J. Schieck, P. Sólymos, T. Muhly, D. Farr, and S. Boutin. 2014. A framework for adaptive monitoring of the cumulative effects of human footprint on biodiversity. Environmental Monitoring and Assessment 186:3605-3617.

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CHAPTER 3: MONITORING CENTRE QMP

The ABMI Monitoring Centre (MC) is the business unit that collects biodiversity-related field data for the ABMI program. This complex process involves a breadth of activities including ensuring data is collected with integrity and reflects the true conditions in the field, communicating all aspects of the data collection activities to other units in full disclosure, delivering data components to the correct destinations, and providing "first pass" quality control by maintaining a feedback loop with other units on the efficacy or inadequacy of the field protocols.

As the primary handlers of field data, the MC is responsible for collecting data with accuracy, error checking the data, and delivering this data in a timely manner to other Centres for further management processing. This quality management plan (QMP) outlines the MC's quality management system as it related to data collection activities.

3.1 Element 1: Quality Management Policy, Goals, and Objectives

3.1.1 Quality Assurance Policy

The ABMI MC is responsible for the collection of a broad range of environmental data used as indicators of environmental health in the province of Alberta. As the foundation of the program, the MC policy ensures that all data generated is of known quality and adequate for its intended use, its quality assurance (QA) procedures are well documented, and that the data is verifiable. The MC quality management system establishes acceptable performance criteria concerning the collection and documentation of data. This includes ensuring adequate quality management steps and procedures are used throughout the entire data collection process, from protocol development and refinement through data transfer to the Information Centre (IC). The MC Director, Team Lead and Field Coordinators are responsible for the annual review of the MC quality assurance/quality control (QAQC) processes and documentation to ensure they accurately reflect MC actions prior to, during and post field data collection.

3.1.2 Monitoring Centre Organizational Structure

Figure 3.1 represents the organizational structure of the MC and identifies responsibilities associated with each job title.

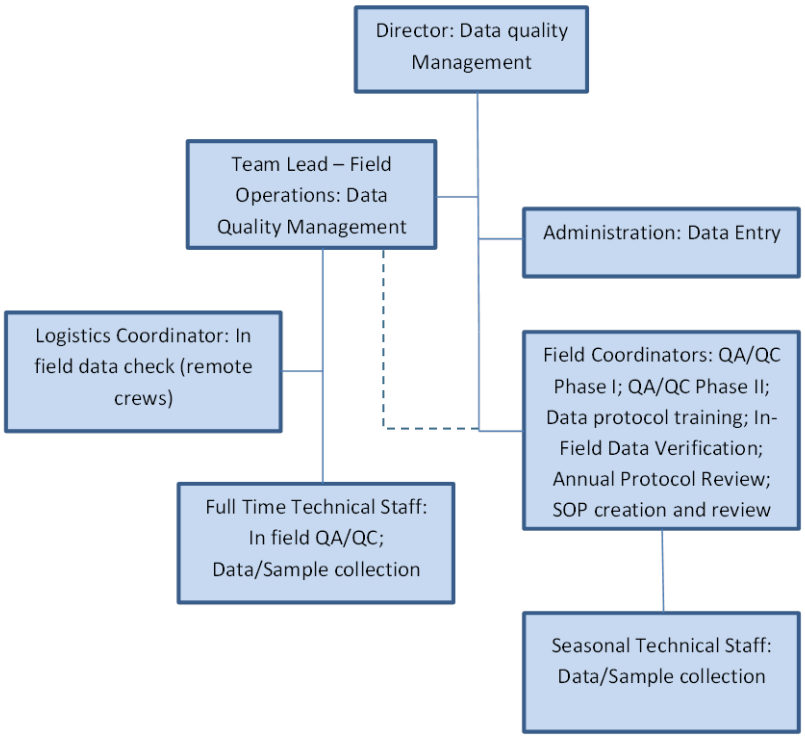

Figure 3.1. Organization chart representing roles within the Monitoring Centre. Dotted line indicates a spot check, by the Team Lead, of data reviewed by the field coordinators.

3.1.3 Staff Roles, Responsibilities, and Authorities

MC staff roles, responsibilities, and authorities as they pertain to QAQC procedures are summarized in Table 3.1.

Table 3.1. Staff roles, responsibilities, and authorities for the MC.

Responsibility	Data Task	Technical Activities	Authority
Director	Data Quality Management	Facilitate the development of data QAQC processes. Ensure these processes are implemented and monitor how the system is performing. Promote the concept of continuous improvement.	MC sign off on all processes and procedures.
Lead - Field Operations	Data Quality Management	Assist in facilitating development and improvement of data QAQC processes.	Delegated by the Director
	Data Quality	Ensure QAQC process implementation and monitoring.	As delegated by the Director

	Monitoring	Monitor QAQC processes and direct changes through data and field checks on field staff.	As required by the Team Lead
Field Coordinators	Field Site Selection	Off-grid sites and alternative field sites must be selected using satellite imagery/GIS, and based on predefined criteria.	Off-grid site selection confirmed by Science Centre (SC) to ensure sites meet site selection criteria
	QAQC Phase I	Verification and assurance of compiled raw field data	Carry out data QAQC activities and confirm completion with Information Coordinator
	QAQC Phase II	Field data and associated metadata are checked for errors, duplicates and inconsistencies prior to public release.	Carry out data QAQC activities and confirm completion with Information Coordinator
	Data Protocol Training	Summer technologists and winter contract staff are trained to collect data according to standardized protocols	Provide instruction and feedback to technologists
	In-Field Data Verification	Field Coordinators accompany crews to field sites in order to review collection methods and correct mistakes.	Provide instruction and feedback to technologists
	Annual Protocol Review	Review field data collection protocols to make any necessary additions or revisions	Complete draft revisions and submit to SC for final approval
	Standard Operating Procedure (SOP) Creation and Review	Create, review and revise data SOPs on an as needed basis i.e., protocol changes or additions	Submit to MC Director for final approval
Logistics Coordinator	Hardware Care and Maintenance	Coordinate and manage the maintenance and calibration of field equipment for data collection	
	In-field Data Verification	(see above)	
Full-time Technical Staff	In-field Data Verification	(see above)	
	Data protocol training	(see above)	

Field Technologists	In-field Data Verification	(see above)	
	Data and Sample Collection	Data and samples are collected from the field and submitted to Field Coordinators	Confirm completion with Field Coordinators

3.1.4 Technical Activities

The MC's primary role is to collect, validate and deliver ABMI biodiversity field data. Cyclical operation, data collection, validation and delivery is planned and implemented on an annual basis following set timelines for each phase. The various activities in this process, described in Table 3.1, are governed by standardized protocols and procedures aimed at managing quality control and ensuring a high level of consistency and accuracy in ABMI field data from year to year. Figure 3.2 provides a basic overview of the MC annual data cycle and activities involved in planning, collection, and release of biodiversity field data by the MC.

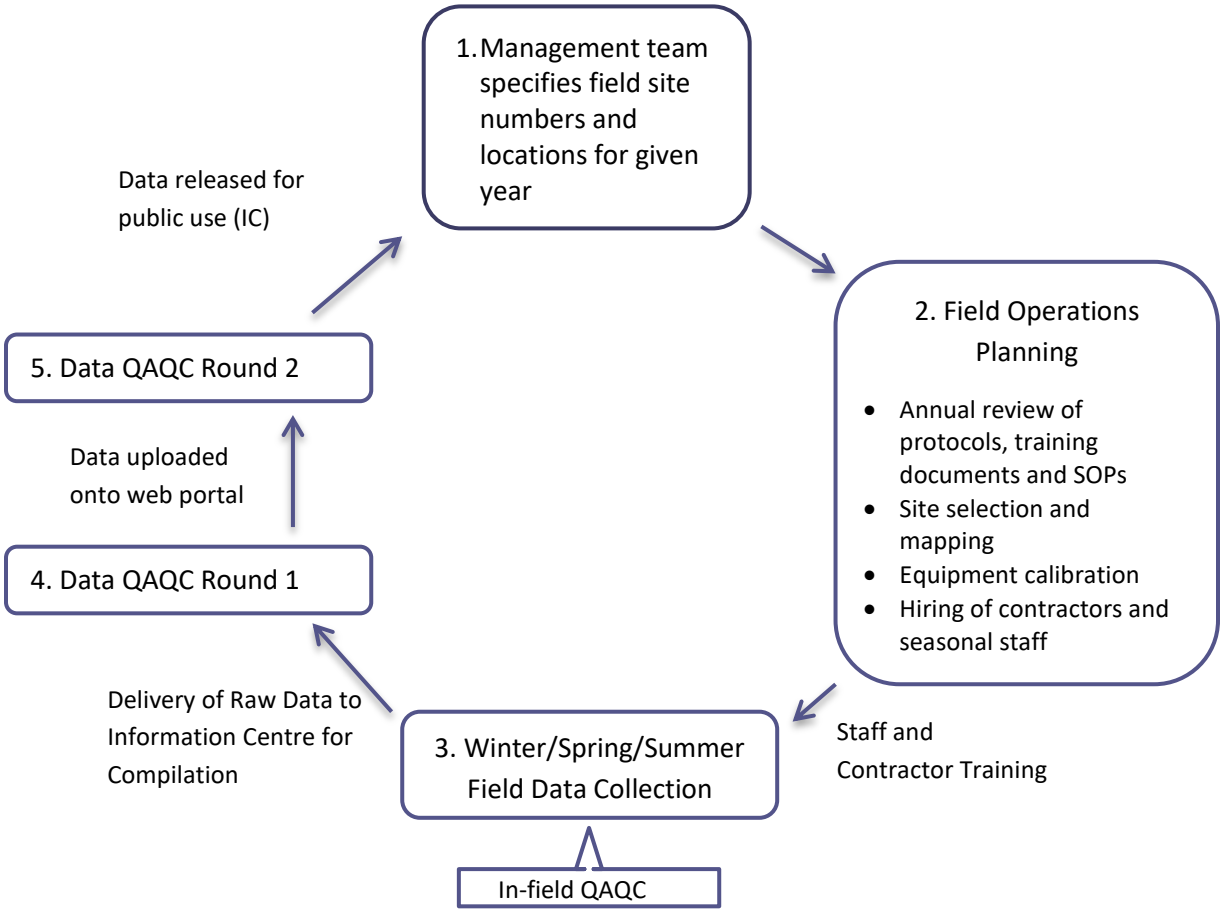

Figure 3.2. Overview of data cycle for planning, collection and release of ABMI biodiversity field data.

3.1.5 Quality System Implementation

MC Management will ensure that all applicable elements of the quality system are understood and implemented by:

- Conducting annual quality management system reviews and updates by all applicable staff;
- Conducting periodic in season quality checks to ensure compliance of applicable elements. For example, the Team Lead will conduct spot checks on data collected to ensure that the data being reviewed by Field Coordinators follows the MC QMP throughout the field season. The Team Lead will check for accuracy, consistency, and ensure that the data meets the quality guidelines set;
- Compiling a summary for the IC highlighting areas of concern where data quality and management processes may be improved;
- Providing an overview of the quality management system as part of the onboarding process for new employees.

3.2 Element 2: Quality System Components

The ABMI MC's management of data quality is governed by a variety of documents and resources that comprise the MC's quality management system. These act to provide clear and consistent guidance over the various activities and processes involved in collection and delivery of high quality data. A broad overview of the system components is provided in Table 3.2.

Table 3.2. Quality system components completed by the MC.

Component	Status
Centre QMP	Quality Management Plan for the ABMI MC
Quality Planning	Ongoing. Planning occurs at various levels, from across ABMI Centres by the Management Team or Data Management Committee, to regular internal meetings and operational planning by MC staff.
Field Data Collection Protocols	Reviewed on an annual basis each fall, with changes made as needed to improve data collection or when new protocols are introduced.
Data Verification SOP	Updated whenever necessary to maintain concurrence with data collection protocols.
Data Management Tools and Software	Updated whenever necessary to maintain concurrence with data collection protocols, and to meet data collection and management needs.
Field Staff Training Program	Ongoing with respect to full-time staff. Internal training program materials for seasonal staff and contractors are reviewed and updated annually to maintain concurrence and improve delivery.

3.2.1 Monitoring Centre Quality Management Plan (QMP)

The QMP is a key document within the ABMI's overall quality management system and describes the means by which the MC's quality policy is applied. This provides an overview of the documents and activities involved in managing and ensuring the delivery of high quality field data. This includes systematic planning and review processes, as well as the personnel responsible for carrying out data related activities.

3.2.2 Annual Reviews and Planning

Various documents are subject to annual review with the aim of continually improving the quality of ABMI biodiversity field data collection. These include but are not limited to:

- Data collection protocols;
- Data verification SOPs;
- Equipment and data collection tools;
- Protocol training modules, materials and resources;
- Data management software and tools (i.e., ABMI tablet program).

MC management is responsible for monitoring program performance and evaluating the adequacy and completeness of the data quality activities, typically with significant input from MC staff as well as other ABMI centres, specifically the IC and SC. Staff suggesting changes or that have expertise in an area typically draft suggested revisions. Final draft revisions are submitted to management for approval before implementation.

3.2.3 Centre Specific Documentation

All collection of ABMI biodiversity field data conducted by the MC is standardized through the use of field protocols which describe the materials and methods used to collect each type of data, from ecosites, and breeding bird recordings to soil cores. Separate sets of field protocols have been developed for both Terrestrial and Wetland data collection, and also for deployment and retrieval of Automated Recording Units (ARUs) and camera traps. Additional protocols are also in place for samples collected in the field that must be analyzed in the laboratory to get data, such as soil core and tree core processing. See Table 3.3 for a complete list of field and laboratory protocol documents utilized by the ABMI MC.

Table 3.3. Field and lab data collection protocols.

Protocol Document	Version	Centre Responsible	Last update	Notes
Terrestrial Field Protocols	5-18-2015	MC	2016	Individual protocols include: Ecosites; Breeding Birds; Soil Cores; Surface Substrate; Trees, Snags and Stumps; Tree Cores; Vascular Plants; Moss and Lichen Collection; Downed Woody Material; Shrub 2D, Rangeland Status Assessments (RSAs); Incidental Species; Site Photos; Canopy Cover
Wetland Field Protocols	5-26-2016	MC	2016	Individual protocols include: Water Chemistry; Aquatic Invertebrate Survey; Incidental Species; Vertebrate Survey; Shoreline Characteristics; Bathymetry; Vascular Plant Survey; Zone Delineation; Shrub 2D
Camera and ARU	2-09-2015	MC	2015	Details standardized methods for

Deployment and Retrieval Protocol				collection of camera-trap and automated recording unit data
Soil Core Processing	10-30-2014	MC	2014	Protocol describing laboratory testing of soil pH and carbon
Tree Core Processing	10-30-2014	MC	2014	Protocol describing processing of tree cores for dendrochronology data

3.2.4 Data Verification and Validation

Data verification and quality assurance is a central component of both training and review of field data collection protocols. The MC implements a number of quality assurance procedures that support collection of high quality field data. These procedures are described in the "Field" and "In-Season" Data Verification SOPs listed in Table 3.4.

Following both classroom and practical instruction, field technicians must demonstrate their ability to follow protocols and collect high quality field data during a "Mock field day" which follows each training period. The mock field day provides an opportunity for technicians to collect a complete site's worth of data at a practice field site while under supervision of qualified instructors. This allows instructors to observe and correct any errors that technicians may be making and ensures protocols are being followed accurately before technicians begin collecting real data in the field.

A second quality check occurs when technicians begin collecting data in the field (refer to SOP: Field Verification for Terrestrial and Wetland Protocols). During this check, Field Coordinators accompany technicians to sampling sites to observe and verify that protocols are being followed correctly. To ensure consistency in how the audit is carried out by different Field Coordinators, a standard checklist has been developed which describes observations and questions when assessing technicians as they implement the field protocols (both terrestrial and wetland).

Once site level data and samples have been collected, technicians submit these to Field Coordinators for a final review before data is submitted to the IC for compilation (refer to SOP: In-Season Data Verification for Terrestrial and Aquatic Protocols). This review occurs either during or at the end of each field shift. The check allows Field Coordinators to identify and correct errors or inconsistencies in technicians' data and provide constructive feedback to technicians to avoid similar mistakes in the future.

3.2.5 Standard Operating Procedures

The MC uses a series of SOPs that govern work on data verification and validation. These SOPs are instructions Field Coordinators and full time technical staff follow to systematically verify that ABMI biodiversity data is being collected in the same way, and that these data are verified in a consistent, and complete manner. This ensures the data is accurate and errors in the datasets are minimized.

Table 3.4. List of SOPs governing field data management.

Data SOP	SOP Number	Centre Responsible	Date
Post-Season Data Verification for Terrestrial and Wetland Protocols	ABMI-MC-SOP-001	MC	2013
In-Season Data Verification for Terrestrial and Wetland Protocols	ABMI-MC-SOP-002	MC	2013
Field Verification for Terrestrial and Wetland Protocols	ABMI-MC-SOP-003	MC	2014
Naming Process for Core Sites and Off Grid Sites	ABMI-MC-SOP-004	MC	2015

3.2.6 Training Program

Given the many different types of field data collected as part of the ABMI's biodiversity monitoring program, a substantial level of training is required for field and technical staff, which also includes training of external contractors. In order to standardize training and instruction, individual training modules have been developed for each type of data collected (e.g., tree coring, vascular plant surveys). These modules generally include a combination of classroom and field exercises. The training modules are reviewed annually and updated (if necessary) depending on changes to established field protocols.

Training is supplemented through the provision of additional resources that assist in accurate collection of data, including maps, guidebooks, cheat-sheets, and other materials.

Additional training specific to job requirements is provided to field technologists on an as-needed basis (See Appendix 1.0 for a complete list of safety-related training). While not necessarily related to data management, this training provides technical staff with the appropriate skills and knowledge to carry out data collection activities in a safe and effective manner. Full-time staff such as Field Coordinators and full time Technical Staff are provided with training on an ongoing, as-needed basis.

3.2.7 Data Management Tools and Software

In addition to collection protocols, data quality management is supported through the use of a number of software tools and applications. Refer to Section 3.6 for further details.

3.3 Element 3: Quality Training System

A combination of full-time and short-term contract staff are used to collect ABMI data. When hiring new or returning staff the requirements listed in Table 3.5 are the primary technical qualifications considered.

Table 3.5. General qualifications and training requirements.

Type of Qualification	Minimum requirement	Before or After Hiring
Post-Secondary Education	2 Years in a Scientific Discipline	Before
Field Experience	Preferably a paid position for 2 summers, but equivalent experience accepted.	Before
Safety Training	All SOP and training courses relevant to the type of protocols being conducted and the region staff will be working in. See Appendix 1.0 for safety training requirements.	After
Protocol Training	All protocol training relevant to the type of work being conducted and region staff will be working in.	After
Plant Identification	Minimum 20% on test administered at interview for Plant Technicians only.	Before and After
Driver's License	A Class 5 License	Before

After staff are hired, the MC has established a process for instructing staff on ABMI protocols, and the minimum testing requirements technicians must pass before collecting data; protocol training requirements are listed and described in Table 3.6.

Table 3.6. Protocol training requirements.

Protocol	Elements	Responsibility	Updated	QAQC Checks
Wetland Reconnaissance	In classroom presentation and mock field exercise.	Wetland Field Coordinators	Annually	• Standardized presentation. • Data from one full site's worth of mock data collection submitted to supervisor for review and feedback.
Terrestrial Establishment	In classroom presentations, field practice, and mock field exercise.	All Field Coordinators	Annually	• Standardized presentations. • Cheat Sheets. • Establishment of a minimum of ¼ of a site evaluated by full-time staff and assessed for accuracy.
Terrestrial Spring Protocols	In classroom presentations, field practice, and mock field exercise.	All Field Coordinators	Annually	• Standardized presentations. • Group field exercises to calibrate technicians' visual estimates and ecosite classifications. All estimates should be within one category of the group average or +/- 20%. • Data from a minimum of ¼ of a mock site on all protocols must be submitted to a supervisor for review and feedback. • A minimum of 2 days of Moss/Lichen training consisting of both field and class-room training. • Moss/Lichen data from a minimum of ¼ of a mock site must be submitted to a Moss/Lichen expert for review and feedback.
Terrestrial	In classroom	Terrestrial Field	Annually	• Standardized presentations.

Summer Protocols- Plant	presentations, field practice, and mock field exercise.	Coordinators		• A minimum of 2 days of Vascular Plant training consisting of both field and class-room training. • Data from a minimum of ¼ of a mock site on all protocols must be submitted to a supervisor for review and feedback.
Terrestrial Summer Protocols- Non-Plant	In classroom presentations, field practice, and mock field exercise.	Terrestrial Field Coordinators	Annually	• Standardized presentations. • Data from a minimum of ¼ of a mock site on all protocols must be submitted to a supervisor for review and feedback.
Wetland Summer Protocols Plant	In classroom presentations, worksheets, scenarios, field practice, and mock field exercise.	Wetland Field Coordinators	Annually	• Standardized presentations. • A minimum of 2 days of Vascular Plant training consisting of both field and class-room training. • Group field exercises to calibrate technicians' visual estimates, zone classifications and ecosite classifications. All estimates should be within one category of the group average or +/- 20%. • A minimum of one common transect must be completed by all plant technicians. All technicians should miss/collect additional species within 25% of each other and a vegetation expert. • A minimum of ¼ of a wetland site's worth of mock site data, preferably with at least one transect in each zone present at the wetland. • Mock site data for Riparian Status Assessment (RSA) must be within the range of one category above or below all other staff's assessment.
Wetland Summer Protocols- Non-Plant	In classroom presentations, worksheets, scenarios, field practice, and mock field exercise.	Wetland Field Coordinators	Annually	• Standardized presentations. • Group practice visual estimates to calibrate all staff's data collection. All estimates should be within one category of the group average or +/- 20%. • A minimum of 5 practice depth transects. • A minimum of 1/3 of a wetland site's worth of mock site data, preferably with at least some data for each protocol.

See Appendix 1.0 for the non-protocol related training that staff receive.

3.4 Element 4: Contractor Requirements

Procurement for the MC can range from general supplies to highly technical data collection equipment, to contracts for winter equipment deployment, sample processing and analysis. All procurement of items and/or services by the MC is done under Contract number DOC11249-2007-Amdt1 between the ABMI and Alberta Innovates. All procurement of items/services follows the Directives and Policies outlined by Alberta Innovates (Table 3.7).

Table 3.7. Directives and policies related to procurement of items/services for Alberta Innovates, and followed by the MC.

Document	Version	Responsible Authority	Effective Date
Procurement	FAM-200.4	Alberta Innovates	September 01, 2015
Capital and Attractive Asset	FAM-200.3	Alberta Innovates	September 01, 2015
Procurement Procedure	FAM-200.400	Alberta Innovates	October 01, 2015
Shipping and Receiving Procedure	FAM – 200.401	Alberta Innovates	October 01, 2015
Delegation of Authority	COA – 101.1	Alberta Innovates	October 01, 2015
Contracts Procedure	Alberta Innovates is still reworking this document	Alberta Innovates	

While the MC does procure items/services through Alberta Innovates, the MC also has separate and detailed documents pertaining to specific services that are contracted (Table 3.8).

Table 3.8. Items and services contracted by the MC.

Document	Version	Responsible Authority	Effective Date
Processing Tree Core Samples	2014-10-30	Monitoring Centre	October 2014
Processing Mineral Soil Samples	2014-10-30	Monitoring Centre	October 2014
Processing Water Samples	2010-11-17	Monitoring Centre	November 2010

3.5 Element 5: Documents and Records

The MC maintains three types of documents that need to be reviewed, updated, and approved on a regular basis. These documents include: standard operating procedures (SOPs, lab protocols, and field protocols. The management of these documents will be discussed in turn.

3.5.1 Standard Operating Procedures

- *Review:* data-related SOPs are reviewed on an annual basis. After QAQC of each year's data, the SOPs listed in Table 3 are updated by MC staff, resolving issues identified in the data management cycle that impact data quality.
- *Approval:* Field Coordinators (MC) and the Information Coordinator (IC) finalize resolutions for data inconsistencies. The MC edits the SOPs and makes the final approval.
- *Maintenance:*

- All drafts are documented on the ShareDrive on the Alberta Innovates network.
- The Field Coordinators are responsible for SOP update and revisions.
- All versions are documented within the SOP.

3.5.2 Lab Protocols

Lab protocols are the responsibility of the MC, IC, and the Royal Alberta Museum (RAM). Each lab protocol remains in a draft format until it is complete. Staff members will know when a protocol is finished being revised when it is changed to a final version. Versions and the person responsible for protocol edits are tracked on *Sharepoint.abmi.ca*. The review process is as follows:

- *Review:* as needed when relevant changes occur to the field protocols which would alter how lab samples are collected.
- *Approval:* Field Coordinators (MC), the RAM, the Canadian Forest Service Analyzing Laboratory, and the ABMI IC are responsible for updates and approvals to the lab protocols.
- *Maintenance:*
  - All drafts are saved at *Sharepoint.abmi.ca* and on the public ABMI website.
  - MC Field Coordinators are responsible for updates to the lab protocols as required.
  - All versions are managed on SharePoint to track edits and who was responsible for the edits.

3.5.3 Field Protocols

Field protocols are the responsibility of the SC and the MC. Field protocols remain in a draft format until they are complete. Staff members will know when a protocol is finished being revised when it is changed to a final version. Versions and the person responsible for protocol edits are tracked on *Sharepoint.abmi.ca*. The review process is as follows:

- *Review:* after each field season, the protocols are reviewed for inconsistencies, redundant data collection, opportunities for improved efficiency and effectiveness of data collection.
- *Revision:* the MC suggests changes to the protocols based on success and failures during the implementation of data collection in the field. These suggestions are tracked in Microsoft Word and are shared with the SC through *sharepoint.abmi.ca*. The protocol stays in a draft format until the SC has approved the final updates. The MC updates the protocols and will change the document to a final version. All versions are tracked. Protocols are updated annually.
- *Approval:* the SC provides feedback on protocol updates. The SC is responsible for accepting all of the changes made by the MC and will complete the final approval of these documents.
- *Maintenance:*
  - Complete protocol drafts and final versions are kept on sharepoint.abmi.ca and are made available to the MC and the SC.
  - An abridged copy of the protocols are maintained by the SC and are made publicly available at abmi.ca in the Publications section.
  - A hard copy and an electronic copy are made available to the technical staff hired to complete data collection. These copies are dated and expire at the end of each season. The old copies are then recycled and removed from hardware (Tablets).
- *Preparation:* new protocols are written as new processes are introduced.
- *Confidentiality:*

- All staff members who handle confidential data (e.g., site location coordinates, access information) are required to sign a *Confidentiality Agreement*.
- Site locations and data sensitive information are saved on a confidential network and server with strict access requirements.
- All data are uploaded onto an FTP server and are handled by the Database Programmer within the IC.
- Equipment used for data collection is handled by the MC and is cleared once the data is saved on the secure network.

3.6 Element 6: Information Management

3.6.1 MC Hardware Description and Maintenance

The MC uses several types of hardware to collect data (Table 3.9). A description of hardware testing, verification, and management is summarized below.

Table 3.9. Hardware used by the MC to complete field data collection.

Hardware	Requires software management	SOP	Centre Responsible
Quanta Hydrolab	N	Manufacturer User Manual and Checklist; Maintenance Log	MC
Camera Trap: Reconynx PC900	Y	Deployment and Retrieval Protocol; Manufacturer Instructions	MC
ARUs (SM2 and SM3 Units)	Y	Song Meter User Manual, Model SM2+. Wildlife Acoustics, Inc. Wildlife Acoustics, Song Meter SM3 Bioacoustics Recorder User Guide. Wildlife Acoustics, Inc. ABMI Automated Recording Unit (ARU) and Remote Camera Trap Spring Visit Protocol, Version: 2015-02-09	MC
Riverforks E3A-CM Bioacoustic Monitor	N	User Manual Field Manual Riverforks Calibration SOP (awaiting approval)	MC
Panasonic Toughbook Tablets	Y	N/A	MC | IC
Digital Camera	N	Manufacturer User Manual	MC

3.6.1.1 Hydrolabs

To monitor water quality at ABMI wetland sites, the ABMI uses the Quanta Hydrolab. The MC uses the following quality assurance procedures to ensure each Hydrolab unit is functioning properly:

- Testing and verification of each Hydrolab Unit is performed by MC Field Coordinators following the procedure designed by ABMI staff and Campbell Scientific; procedures are outlined in Hydrolab operating manual (available online);

- Hydrolab maintenance procedures are performed by Field Coordinators in accordance with the operating manual; all maintenance procedures are recorded in designated hydrolab maintenance logs;
- Pre-season, and in-season calibration of the Hydrolab units are performed by Field Coordinators following the procedure designed by MC and maintenance guidelines;
- All Hydrolab units are tested in field by technical staff for usability, durability, and functionality.

These additional procedures are followed to ensure water quality readings are as accurate as possible:

- Standard Hydrolab operating procedures are outlined in ABMI's Wetland Field Data Collection Protocols (Alberta Biodiversity Monitoring Institute, 2016), and training is provided by ABMI Field Coordinators;
- Expected Hydrolab readings and ranges are provided by the ABMI SC Wetland Ecologist in accordance with historical data. Readings falling outside of these ranges are confirmed with alternative measures (reference standards, pH strips);
- Prior to field use, hydrolabs are tested and compared to each other to ensure accuracy and consistency;
- In-field quality checks are performed by MC Field Coordinators;
- Post-season data quality management is performed by MC Field Coordinators.

3.6.1.2 Camera Traps

To monitor wildlife (mainly mammals) at ABMI sites, the ABMI uses camera traps to detect species that are present at each site. Camera trap setting parameters are developed by the SC. The MC programs the cameras pre-deployment or in the field using the *Remote Camera Trap Settings* outlined in Appendix 1 of the Automated Recording Unit (ARU) and Remote Camera Trap Protocols (2015). Any changes are verified by the SC prior to deployment in the field. During camera retrieval, MC documents any physical or mechanical camera errors. These units are examined in detail after the field season by the MC, field tested, and, if necessary, sent to Reconyx for repair or exchange. The MC is responsible for keeping an updated inventory of cameras, which includes ordering and maintaining records of any repairs.

3.6.1.3 Automated Recording Units:

To monitor vocalizing species at ABMI sites, such as songbirds, owls, and amphibians, the ABMI uses ARUs at each site. Prior to deployment, ARUs are programmed using a PGM file and the SM3 configuration utility. The program file contains all the information for audio settings, file type, gain and schedule with the exception of date, time and field prefix which are checked and set by the MC Field Coordinators manually. Specific settings are outlined in the ARU and Remote Camera Trap Protocols (2015). Any scheduling changes are verified by the SC prior to deployment in the field. During ARU retrieval, the MC physically inspects and documents externally damaged units, microphones missing etc. During the recording proofing stage, ARU audio files are checked for discrepancies between microphones or microphones not working during recording. Units with physical or mechanical damages are either sent to be fixed or microphones are re-calibrated using ABMI Extech calibrators. This is the responsibility of the MC.

3.6.1.4 River Forks E3A-CM:

To monitor the breeding bird vocalizations at ABMI sites in the spring, the ABMI utilized River Forks Units (2003-2015). As of 2016, these units have been replaced by ARUs. The following procedures were used to calibrate and maintain the River Forks units:

- The River Forks unit was programmed using settings found in the Field Manual and manufacturer-provided User Manual.
- The MC was responsible for calibrating each River Forks unit according to the River Forks Calibration SOP in order to ensure that recording volume is consistent among all units.
- The MC was responsible for in-field maintenance and cleaning of electronic connections to prevent static interference. If static was detected in the recordings, the unit is decommissioned until the source of the static was discovered and repaired.
- Field techs were provided with a cleaning kit and spare microphone cord in case the primary cord gets wet or damaged while in the field.
- The MC was responsible for keeping track of which units needing repair, and repairs or adjust units accordingly.

3.6.1.5 Panasonic Tablet:

Panasonic tablets are used in the field so data can be entered directly into the computer during data collection. Each field protocol has associated data sheets preprogrammed into the tablet to maximize data entry efficiency. The MC uses the following quality assurance procedures to ensure tablets are functioning properly:

- The Field Coordinators are responsible for ensuring each tablet is loaded with the most recent updates from the IC;
- The MC works with the IC to test data entry sheets, and make modifications as needed, prior to the start of the field season;
- Technical staff is responsible for maintaining tablets in the field;
- General software updates are performed on the hardware on an as needed basis;
- New models of tablets are tested in field by the MC on a small scale before implementing newer models on a large scale. This ensures hardware performance still meets the demands of field data collection.

3.6.2 MC Software Description and Maintenance

The MC uses several pieces of software during data collection (Table 3.10). A description of software testing, verification, and management is summarized below.

Table 3.10. Software used by the MC to complete field data collection and ensure its accuracy.

Software name	Version	SOP	Function/Use	Centre Responsible for updating and management
Bulk Rename Utility	2.7.1.3	NONE	Mass file naming program.	MC
Automated Recording Unit Firmware	SM2: SYS3-3-9.SM2 SM3: SYS1-2-8.SM3	http://wildlifeacoustics.com/support/download-software	Ensures the units are working properly.	MC
ARU Program	SM2: SMConfigInstaller-3.2.4.exe SM3: SM3ConfiguratorInstaller-1.2.6.exe	http://wildlifeacoustics.com/support/download-software	SC uses the program to delineate when protocols are being collected.	SC | IC | MC
ABMI Tablet	N/A	N/A	Field data collection	IC | MC
Site Summary Workbench	N/A	NA	Tracks field data collections.	IC
GPS Pathfinder Office	N/A	N/A	Trimble data storage and management. Data upload download interface – refer to owner's manual.	MC
Terrasync	N/A	N/A	Trimble software loaded on handheld units used to create sub meter data points – refer to Trimble Getting Started Guide Terrasync Software and MC training materials.	MC
Garmin Express	N/A	N/A	Used to help manage Garmin GPS devices.	MC
ArcGIS	N/A	In development	Site selection and mapping; field planning; management of site coordinate data.	AITF | MC
Trello	N/A	NA	Organizational tool during QAQC rounds.	IC
OziExplorer	N/A	NA	GPS coordinate data collection and management.	MC

3.6.2.1 Bulk Rename Utility

The Bulk Rename Utility is used to rename multiple files and/or folders based upon flexible criteria. This software is used by the MC to simultaneously rename multiple files or folders according to the standard practices described in field, lab or other protocols (i.e., naming of images captured by camera traps).

This ensures consistency among file and document naming and is an important tool for good data organization and management of digital information. Bulk Rename Utility is available for download from http://www.bulkrenameutility.co.uk with version updates on the website as well. The version used by the MC is updated whenever use or compatibility with other programs necessitates.

3.6.2.2 Automated Recording Unit Firmware and Program

ARUs are used to record breeding bird vocalizations in order to collect data on species presence and abundance. ARU Firmware refers to permanent software that supplies the units' function. The ARU Program is software that sets the schedule during which the unit is turned on to record. Pre-field season the SC creates the ARU recording schedule. It is then written to file using the SM Configurator software listed in Table 3.10 creating the scheduling program and sent to the MC. It is the responsibility of the MC to ensure all ARUs are updated with the latest Firmware and the updated scheduling program is loaded onto each unit prior to field deployment.

3.6.2.3 ABMI Tablet Program

The ABMI IC has built and maintains a custom-built software program loaded onto tablet computers which are designed for collecting the ABMI field data. This data collection software replaces paper data sheets, and it incorporates various tools and features which support the collection of consistent, complete and accurate field data. It also expedites the process for compiling and submitting raw field data for verification and quality assurance.

In cooperation with the IC, the data collection software is reviewed and updated on an annual basis to incorporate changes to improve function and maintain concurrency with protocols and project needs. Any software changes are tested prior to field deployments to ensure program function and data integrity are maintained. The program runs on Windows 7 operating system. Hardware used is a Panasonic Toughbook™ tablet computer.

3.6.2.4 Terrasync

Terrasync is licensed software provided by Trimble and is designed to collect high quality positional GIS data efficiently in the field. A Trimble unit with Terrasync software is used when permanent markers cannot be used to mark the location of an ABMI site, in order to ensure high quality positional GIS data is collected for subsequent years of data collection.

- Software updates are provided as required – Trimble;
- Testing and maintenance of software – MC Field Coordinator;
- Instructions for use are provided with units – Trimble;
- Additional training for field staff written and maintained by ABMI staff – MC Field Coordinator
- Post field data collection, all coordinate data is verified and stored on a secure drive – MC Field Coordinator.

3.6.2.5 Garmin Express

- Licensed software is used by the Monitoring Centre to help manage Garmin GPS devices.

- Garmin Express, and accompanying updates, are available for download at http://software.garmin.com/en-US/express.html

3.6.2.6 ArcGIS

- GIS software used in various respects for field planning and data management, including site selection, access, habitat and wetland zone classification, as well as mapping and management of wetland bathymetric transects.
- The MC is responsible for the testing and maintenance of the software.

3.6.2.7 Trello

- Web-based project and work-flow management tool used by the ABMI Monitoring and Information Centres to communicate, track and record data verification activities involved in Data QAQC Phase 1 and Phase 2.

3.6.2.8 Oziexplorer

- Licensed software used by the MC for management of GPS points given to technical staff and received from staff from the field. GPS points are edited, uploaded (from GPS units to laptops), downloaded (to GPS units), and viewed using this program.

3.7 Element 7: Systematic Quality Assurance Planning

3.7.1 Planning and Prioritization

Data operations are planned and prioritized in accordance with seasonal timelines for field data collection, verification and delivery, as well as in balance with other operational activities carried out by the MC. Examples of this include site visits and protocol verification while technical staff are in the field, as well as data QAQC activities that occur once collection has been completed. An overview of the data collection cycle is provided in Figure 3.2.

Collection of biodiversity field data is carried out on an annual seasonal cycle (e.g., camera trapping in winter, moss and lichen surveys in the spring, vascular plant surveys in summer) with verification and quality management processes occurring at multiple stages throughout. Systems used to ensure effective planning and prioritization of data collection activities include:

- Periodic team meetings throughout the year between the MC Director and MC staff that allow for strategic planning of data operations, field preparations, and follow-up processes;
- Regular meetings among terrestrial and wetland Field and Logistics Coordinators along with the Team Lead to prioritize and plan specific activities. The Team Lead facilitates delegation of priorities which involve full-time Technical Staff;

Both types of meetings are used to generate “action items”, wherein staff are assigned to carry out specific tasks prior to planned deadlines, as well as identify needs and objectives for developing or revising quality-related documentation.

Specific planning items related to the data collection and quality are:

- Annual revision of protocols, SOPs, and training modules;
- Annual updating and improvements to ABMI tablet program;
- Regular updating to the ABMI site summary workbench before, during and after data collection;
- Site selection, mapping and access (See GIS and Access SOPs, Table 3.4);
- Hiring and training of qualified personnel for contract and seasonal data collection work;
- Data verification and QAQC processes that occur before, during, and after various stages in the data collection and release cycle (Figure 3.2).

3.7.2 Resource Allocation

Scheduling of data activities, including field data collection, are determined based on a variety of factors which include budget, stakeholder involvement, and pre-existing capacity and resources. These factors determine the number of field sites and associated data that the MC is able to deliver on an annual basis.

- The MC's annual budget is allocated by ABMI's Executive Management Team and managed internally by the MC Director. On a project basis, budget planning is supported by the Team Lead - Field Operations, as well as the Logistics Coordinator who manages the MC's field equipment inventory.
- Allocation of resources is meted out based on funding priorities, as well as efficiencies and projected costs associated with deliverables. Delivery of data from sites only accessible by helicopter for example, requires proportionally more resources than data delivered for sites accessible by foot and road.
- Personnel requirements and individual involvement are determined on the basis of tasks and associated deliverables (i.e., hiring of seasonal technicians). Wherever advantageous, involvement of staff may be decided based on relevant experience or expertise with the specific task or deliverable at hand.

Specifications for measuring and verifying data quality are described in data verification SOPs (Table 3.2, 3.4). Timelines associated with these activities are based around the annual planning cycle described in Figure 3.2.

Updates to QAQC activities are made as needed, such as when protocols are updated, or when problem areas are identified. Updates are generally made by Field Coordinators in consultation with the Information Coordinator and SC specialists. Changes are subject to final approval by the MC Director.

3.8 Element 8: Quality Implementation of Work Processes

At every step in the data cycle (Figure 3.2) there are several work processes (e.g., field protocols, SOPs) that provide the instructions for completing each step. In addition, the MC uses several mechanisms to ensure work processes are being implemented correctly and have been completed as required.

3.8.1 Site Summary Workbench

- Ensure all selected sites for the applicable field season are uploaded prior to data collection
- Ensure sites and associated protocols are updated frequently throughout data collection to inform the IC and Processing Centre (PC) of data collection completion, issues and discrepancies.

3.8.2 Pre-season Checklist

- Ensure all equipment is functioning, tested for accuracy, and is fully calibrated
- Confirm with the Information Coordinator site names for applicable sites (i.e., off-grid)
- Confirm field sites with the IC Access Team, create a tentative data collection schedule
- Ensure all protocols are up-to-date for data collection, confirm with the SC.

3.8.3 Field Data Collection Verification

Quality assurance processes are in place during field data collection to ensure technicians collect the full complement of ABMI data, and that the data have been verified, checked for completeness, errors, and inconsistencies so that mistakes can be rectified. These processes are documented in the SOP *ABMI_MC_SOP002_In Season Verification*, and include the following:

- Field checklists are filled out at each site by the Field Coordinators; this ensures all data was collected at each site, or if there were unforeseen difficulties, records the reason for the missing data.
- Field Coordinators complete data checks with their technical staff correcting for data errors when detected (e.g., recorded percent cover of trees is inconsistent with selected ecosite classification).
- The Team Lead checks for accuracy and completeness of data collected submitted by the Field Coordinators during QAQC data checks.
- All data that is collected is assigned initials so there is a record of who completed the work and it is known who to direct questions to.
- At the end of each data collection shift, Field Coordinators submit data to the Database Programmer to compile.
- Site Summary work bench is completed by the Field Coordinators every three days during shift, as well as at the end of each shift. Site Summary documents whether a site was completed and contains important information pertaining to site specific data collections. It is checked by the RAM, the Team Lead from the MC, SC and IC.

3.8.4 Field Data QAQC Procedure Implementation

Following completion of field data collection at the end of each season, the raw field data from all sites are compiled by the IC Database Programmer. These files are reviewed in detail by Field Coordinators as part of the ABMI's data quality and assurance process to ensure the data is complete, consistent, and free of substantive errors. QAQC of field data occurs in two phases.

In Phase 1, QC procedures are implemented by MC Field Coordinators in the following way:

- All raw data files are uploaded onto Trello by the Database Programmer;
- Two Coordinators are designated to each protocol (example: Vascular plant protocol) to QAQC the data. QC procedures are implemented using a checklist to identify and correct errors/omissions in the data for each protocol. Once the checklist is completed a list of corrections are made on Trello to track changes to the data;
- Errors are evaluated on a case by case basis. Whenever possible data are corrected using a variety of resources including other existing data for the site, observer field comments, and site photos. In cases where irreparable errors are found, value records are assigned with as DNC (Did Not Collect);

Following the first phase of post-season data verification, data are uploaded by the IC Database Programmer into DevWeb—a pre-cursory platform of the ABMI's online data portal.

In Phase 2, QC procedures entail data verification implemented by Field Coordinators and the IC in order to ensure no errors were generated through the upload process, as well as to verify that data is consistent with metadata and protocol descriptions supplied in the download package. QC procedures are implemented the following way:

- A checklist is used to identify and correct errors/omissions in the data and metadata for each protocol.
- The original two Field Coordinators designated to each protocol download and review the data packages from the development website. Field Coordinators ensure the downloaded data package contains the necessary files and documents.
- Any corrections, errors or inconsistencies in the downloaded data or metadata are documented on Trello.
- If an error is detected (e.g., shifted headings, null values, sites missing) it is brought to the attention of the Database Programmer and Information Coordinator. Errors are evaluated on a case by case basis.
- If a scripting error is observed (e.g., shifted headers), the Database Programmer will edit the script and reload the file.
- If a data error is detected, the same evaluation process outlined in Phase 1 is followed.
- Metadata corrections are made by the Information Coordinator or Database Programmer. Updating metadata requires consultation of field protocols and guidance from protocol experts when required.

Following the completion of Phase 2 QAQC, ABMI raw data are made publically available.

3.8.5 Contractor Training-Deployment of Cameras and ARUs:

The MC uses the following work processes as part of QAQC procedures associated with cameras and ARUs:

- All contractors hired to deploy remote cameras and ARUs are required to complete ABMI designed field training modules before going into the field.
- Field Coordinators develop training modules which are edited for accuracy and completeness by other Field Coordinators. Work completed on the training modules is documented and tracked.
- Field exercises are conducted to ensure accuracy of data collection with the contractors.
- After the first field visit, Field coordinators go through the data looking for errors, inconsistencies, completeness and overall quality. Issues are discussed and clarifications are made to prevent future error.
- The MC is responsible for contractor data during QAQC Phase 1 and QAQC Phase 2.

3.8.6 Off-grid Site Selection

The SC often supplements data collection at ABMI sites with data collected at off-grid site. These sites are chosen to complement the ABMI's systematic grid, to improve sampling coverage along the gradient of human footprint levels. This improves estimation of relationships between biodiversity and human land use, in addition to allowing the ABMI to address specific short-term questions. Therefore, these sites are selected based on predefined criteria established by the SC. The following is a description of the work processes implemented by the MC to ensure off grid site selection meets the established criteria:

- The SC is responsible for outlining the off grid site criteria;
- The MC selects sites that fit the outlined criteria and save these on ArcGIS.
- The Information Coordinator from the IC is responsible for providing permanent off-grid site names to the MC (see *ABMI_MC_SOP-004*).

3.8.7 GIS Data Management

GIS data is critical to ensure all ABMI sites (including terrestrial and wetland sites) can be revisited during Rotation 2 of the data collection cycle. Therefore, all information required in order to revisit each site are compiled, organized, checked for completeness, and archived by the MC for future use.

3.8.8 Sample Management

During data collection, the MC must collect a number of samples that need processing in the laboratory before data can be recorded. Implementation of work processes associated with managing samples collected are described in lab processing manuals (Table 3.11).

Table 3.11. List of field samples collected by the MC, and the title of sample management protocols for each sample type. All protocols are available at: http://www.abmi.ca/home/publications.

Sample Type	Sample Management Protocols	Updates Managed By:
Soil cores	*30102014_Soil Lab Processing*	MC | PC | SC
Tree cores	*30102014_Tree Core Processing*	MC | Canadian Forest Service Analyzing Laboratory
Water sampling	*Processing Water Samples*	MC | IC | RAM

3.9 Element 9: Quality Assessment and Response System

Technical assessments are evaluation processes focused on specific technical practices and procedures, such as data checking. The purpose is to measure the performance or effectiveness of technical systems and their elements (with respect to documented specifications and objectives). The MC uses a number of assessment tools to evaluate the performance of data management processes, identify potential quality issues, and outline corrective actions, including:

- All MC Protocols and SOPs are reviewed and updated annually to ensure the quality management system is adequate and functioning as expected and required based on the previous season's data collection. Reviews and updates are completed by MC Field Coordinators with input and recommendations from the SC and the Information Coordinator.
- Modifications to Field Data Collection Protocols are made by Field Coordinators with final approval of all changes by the MC Director and the SC.
- Software and Firmware of all technical equipment are updated as released by the manufacturer.
- Tablet updates are as required, and significant updates are made annually based on the previous field season activities.
- All process and document changes are maintained and managed through "versions" that are kept on a permanent record.
- Field Coordinators document all quality issues that arise during the field season and initiate immediate action to issue, if possible. If it cannot be immediately remediated, Field Coordinators will document the issue and provide a solution in the off season, and incorporate the solution into the appropriate QAQC document.
- The Team Lead will ensure that all protocols and procedures are consistent throughout the field season by conducting on site field visits and spot checks.
- The MC Director facilitates and finalizes all changes and updates to documents, procedures, and SOPs before submitting to the IC and SC if required.

3.10 Element 10: Commitment to Quality Improvement

With oversight and facilitation by the MC Director and Team Lead, Field Coordinators and full time Technical Staff are committed to improving the quality of ABMI data that is collected in the field. Quality improvement activities to identify and ameliorate adverse conditions to quality include:

- Ensuring that all Protocols, Procedures, Equipment, and SOPs are updated (if required) at minimum annually and if possible, in field (Element 5 – Documents and Records);
- Documenting changes to Quality Documents through "versions" in a permanent record (SharePoint);
- With oversight by the MC Director and Team Lead, preventing quality breakdown by having consistent simultaneous training at all training locations (Table 3.6);
- Identifying areas for improvement through data quality control and assurance activities (field sites visits, post-collection data review);

- Identifying necessary updates to the ABMI tablet program in order to maintain concurrence with protocols and improve quality functions (e.g. program restrictions and data entry menus, taxonomic changes to species lists). Coordinate implementation and testing of changes with the ABMI Database Programmer (IC);
- Involving ABMI staff from other Centre's to provide specific expertise where of benefit to quality (i.e., moss and lichen collection, plant taxonomy);
- The Team Lead and two Field Coordinators, one terrestrial and one wetland, represent the MC at ABMI Data Management Committee meetings. Here they discuss data management, quality issues, and improvement options, with representatives from other Centre's, as well as receive and relay updates from other Centre's.

Conditions that may negatively impact data quality are managed through:

- Prevention by using standardized procedures that govern data collection, and verification and review;
- Systematic checks at multiple stages of the data management process to identify present concerns (e.g., data collection procedures during site visits, annual reviews). Corrective and preventative actions are implemented on a case-by-case basis depending on the type of condition (i.e., individual vs systemic error).

Staff at all levels are encouraged to participate in the quality improvement process in accordance with the Monitoring Centre's Quality Assurance Policy outlined in Section 3.1.

3.11 MC QMP: References

ABMI-MC-SOP-001. 2013. Post-Season Data Verification for Terrestrial and Wetland Protocols. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI-MC-SOP-002. 2013. In-Season Data Verification for Terrestrial and Wetland Protocols. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

ABMI-MC-SOP-003. 2014. Field Verification for Terrestrial and Wetland Protocols. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

Alberta Biodiversity Monitoring Institute. 2016a. Terrestrial field data collection protocols (Abridged Version) 2016-05-18. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Report available at: abmi.ca.

Alberta Biodiversity Monitoring Institute. 2016b. Wetland Field Data Collection Protocols (Abridged Version) 2016-05-26. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Report available at: abmi.ca.

Alberta Biodiversity Monitoring Institute. 2013. Processing Tree Core Samples (10011), Version 2014-10-30. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Report available at: abmi.ca.

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Alberta Biodiversity Monitoring Institute – Monitoring Centre. 2015. Camera and ARU Deployment and Retrieval Process. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Internal Report.

CHAPTER 4: PROCESSING CENTRE: QMP

The Processing Centre (PC) is responsible for processing and identifying samples of vascular plants, bryophytes, lichen, armoured mites, and aquatic invertebrates collected by the Monitoring Centre (MC) each year from ABMI terrestrial and wetland field sites. Creating the highest quality data possible involves quality control strategies for: field collection training, collection methods, transport procedures, metadata management, sample preparation, sorting, and lastly, advanced classification and curation of specimens for long-term storage. This QMP outlines the PC's quality management system to curate high quality specimen data.

4.1 Element 1: Quality Management Policy, Goals, and Objectives

4.1.1 Quality Assurance Policy

The PC is committed to the identification of ABMI specimens to the highest degree of accuracy possible, using the most up-to-date scientific naming standards (ABMI 2016, ABMI 10017 2015). A high level of taxonomic expertise is maintained throughout the PC to ensure this policy is met.

4.1.2 Organizational Structure:

The organization of the PC is outlined in Figure 4.1.

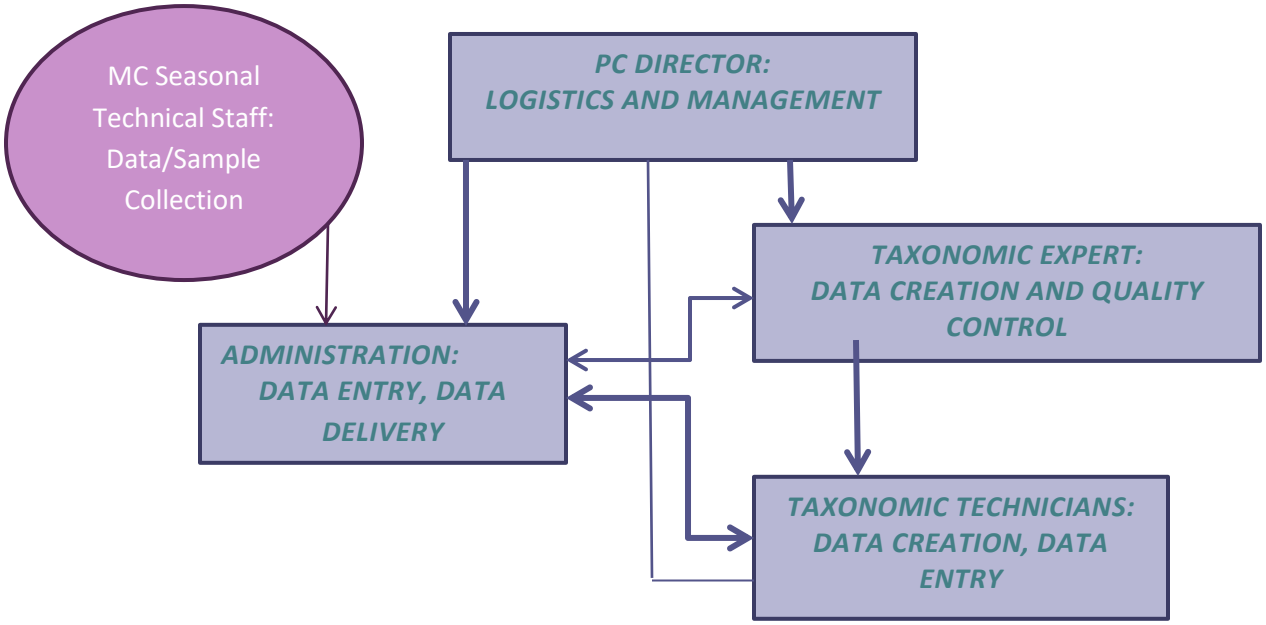

Figure 4.1. PC organizational chart.

There are three levels of designation within the PC:

1. Administrative → The administrative roles provide logistical support and event coordination, managing data only as it arrives from the field and just prior to being delivered to the Information Centre (IC) as outlined in Table 4.1
2. Taxonomic Expert → In Development
3. Taxonomic Technician → In Development

These procedures are QAQC'ed by the various taxonomic teams. Mineral and water analysis are done out of house by companies that are ISO/IEC 17025 certified. Data products are sent directly to the IC when completed.

Table 4.1. Summary of data task, technical activities and the quality system tools used to support quality management in the PC.

Data Task	Responsible Party	Technical Activities	Quality System Tools Used
Field Tech Training and Field QAQC	Taxonomic Teams | MC Field Coordinators	Visits by Lichen, Bryophyte and Vascular Plant teams to Field training centres to ensure correct collection methods and uniform search protocols. • Train field crews to identify species in the field • Train field crews to collect and store voucher quality specimens	Field Training manual (ABMI 10001)
Field QAQC for Vascular Plant ID	Vascular Plant Expert	Teaches Family+ level ID skills and introduces ID resources to be used in field to go beyond Family. • Oversees training collection, pressing and labeling training • Trains for difficult groups and rare plant sampling protocols. • Vascular Plant Taxonomist develops field voucher list	• Field Training manual (ABMI 10001) • Protocols for Processing Vascular Plants (ABMI 10020) • Specimen Verification Summary (ABMI 2016)
Sample Receipt	Lab Coordinator, Taxonomic Teams	Initial upload of all data from field. QAQC of samples to ensure data and sample information match	Protocols for Processing (ABMI 10017, 10010, 10008, 10009, 10020, ABMI 2016)
Data Portal Upload	System Analyst	Field data uploaded into the Data Portal for all Plant, Lichen, Bryophyte, and Aquatic samples received	
Rough Sort	Lead Taxonomists, Laboratory Technicians, and Some Field	• Field crews identify common species of Moss and Lichen, each data entry is seconded	Protocols for processing (ABMI 10017, 10010, 10009)

	Technicians	by a qualified Taxonomist. • Aquatic Invertebrates are separated from sample and sorted to Order. ID's and residuals are double-checked by a trained Taxonomist. • Oribatid Mites are sorted, identified and slide mounted for further verification by the Lead Taxonomist	
Advanced Identification	Taxonomic Teams	Data is created as specimens are identified to the lowest taxonomic rank possible via: • Microscope analysis • Advanced imaging (SEM) • Chemical and/or molecular analysis if required • Reference collection • Internal verification	Protocols for processing (ABMI 10017, 10010, 10008, 10009, 10020, ABMI 2016)
Data Submission	Lead Taxonomists, IC System Analyst	IC verifies new ABMI species records and ensures it is incorporated into Taxonomic Workbench.	
Specimen Storage & Accessioning	Taxonomic Teams and Royal Alberta Museum Curatorial staff	Generation of unique T.M.S. numbers to be assigned to those specimens to be accessioned into the permanent collect.	Procedure under development
Data Amendments	Lead Taxonomists	• Corrections are uploaded annually or on as-needed basis. • Newly described species incorporated as published	Data Portal, Taxonomic Workbench
Taxonomic Updates	Lead Taxonomists	• Nomenclature changes and revisions to be done as and when they occur	Taxonomic Workbench updated a minimum of 1 per annum (ABMI-IC-SOP-008 | ABMI-IC-UG-001)

4.1.3 Technical activities:

The PC's primary role is to process and identify collected specimens, and to update and maintain the ABMI taxonomic database according to accepted Standard Operator Procedures (SOPs; ABMI-IC-SOP-008: Taxonomic Workbench). An annual cycle of data activities is followed starting with taxonomic database updates, field crew training, processing specimens, specimen identification and data entry, data validation and delivery. The various activities in this process (described in Table 4.1) are governed by standardized protocols and procedures aimed at managing quality control, ensuring a high level of consistency in terms of managing samples and identifying specimens from year to year. Figure 4.2

provides a basic overview of the PC annual data cycle and activities involved in planning, training, identification, and release of species data by the PC.

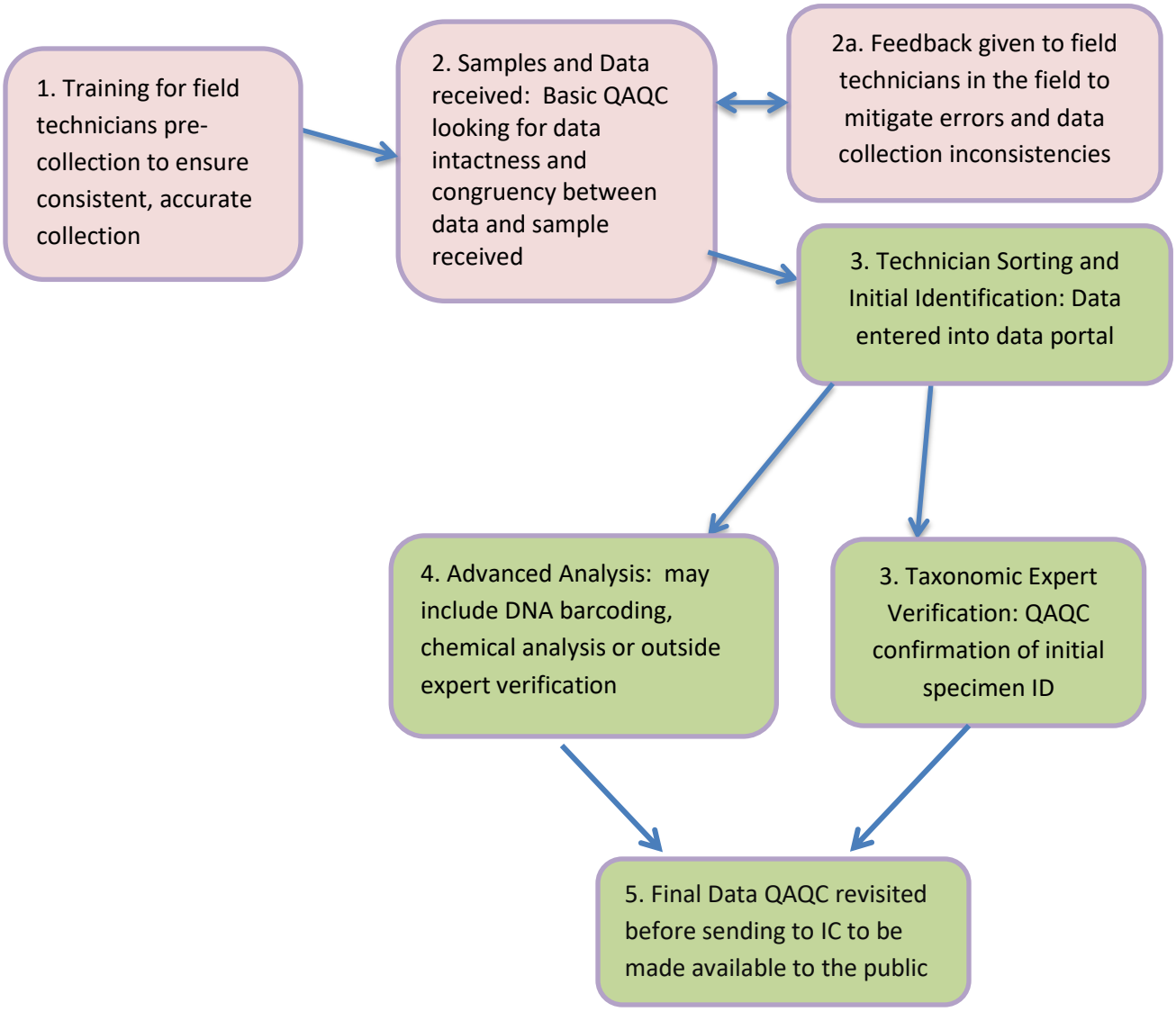

Figure 4.2. Specimen and sample data flow from pre-collection through generation to public delivery. Pink boxes denote pre-identification quality control measures. Green boxes denote species data generation processes.

4.1.4 Quality System Implementation

PC management will ensure that all applicable elements of the quality system are understood and implemented by:

- conducting annual quality management system reviews and updates by all applicable staff;

- conducting predetermined number and frequency of quality checks during specimen processing to ensure accuracy and consistency during the identification process;
- taxonomic experts checking for accuracy, consistency, and ensuring that specimen identification meets the quality guidelines set;
- using audits to assess curation and database accuracy and ease of specimen retrieval;
- compiling a summary of quality management activities during specimen processing highlighting areas of concern where data quality and management processes may be improved;
- ensuring the quality management system is part of staff training for new employees;
- making all necessary resources available for the Taxonomists to adequately perform their duties in a timely manner. This includes, but is not limited to: standard operational procedure training, access to Provincial museum reference collection, laboratory space, high quality diagnostic tools, as well as computer and advanced procedural training.

4.2 Element 2: Quality System Components

The management of data quality in the PC is governed by a variety of documents and resources that comprise the PC's quality management system. These act to provide clear and consistent guidance over the various activities and processes involved in collection, processing, identification, and delivery of high quality data. PC quality system components include:

- SOPs and Lab Protocols;
- ongoing training and specialization via both internal and external education;
- high quality equipment access including SEM imaging and full laboratory access for advanced chemical testing to ensure the most advanced identification possible;
- annual reviews and planning with an aim to improve specimen processing and identification, and data entry and data management;
- operating at the Provincial government museum standards of curation.

4.2.1 Standard Operating Procedures and Lab Protocols

The PC uses a series of SOPs and Lab Protocols to achieve overall data quality goals and objectives, promoting consistency in the quality and integrity of specimen processing and identification procedures, along with the data generated (Table 4.2). The development and implementation of SOPs and Lab Protocols at all stages of the sample collection, processing, identification, and data entry is one of the key mechanisms to ensure the implementation of the QMP.

Taxonomic experts are responsible for overseeing the maintenance and implementation of Lab Protocols and SOPs associated with their particular taxa. SOPs are written and maintained by ABMI Lead Taxonomists. SOPs may be developed collaboratively, particularly for procedures with complex workflows. All SOPs are reviewed and approved by the PC Lab Coordinator and Taxonomic Advisor, with final approval by the PC Director. External reviews are conducted where necessary at the discretion of

the Taxonomic Advisors and/or the PC Director. See Table 4.2 for a list of SOPs and Lab Protocols currently maintained by the PC.

Table 4.2. List of SOPs developed for data management cycle.

Lab Protocol/SOP Title	SOP Number	Date Created/Modified
SOP Template	ABMI-PC-SOP-001	2012
Processing Aquatic Invertebrates	ABMI-PC-SOP-017	2015
Processing Bryophytes	ABMI-PC-SOP-009	2011
Processing Lichens	ABMI-PC-SOP-008	2010
Processing Mineral Soil	ABMI-PC-SOP-010	2013
Processing Organic Soil	ABMI-PC-SOP-010	2013
Processing Vascular Plants	ABMI-PC-SOP-006	2011
Processing Water Samples	ABMI-PC-SOP-017	2015

4.2.2 Ongoing Training and Specialization

The success of the quality management system depends on commitment by the employees to implement the system on a daily basis. Given that a substantial level of training is required by PC staff in order to process and identify collected specimens, the PC includes the following components as part of its training program, including:

- annual training seminars run by taxonomic experts to ensure technicians are adequately trained to process and identify specimens. Training is supplemented through the provision of additional resources that assist in accurate specimen identification and data entry, such as: taxonomic keys, guidebooks, and reference collections;
- regular testing of the year-round technical staff to determine the knowledge and competence for identification, individual training needs, and next steps in their taxonomic skill development;
- resources for additional training as necessary (e.g., courses, seminars, and conferences);
- certification, training records, and performance review records kept current and maintained by PC Director.

4.2.3 Annual Reviews and Planning

There is an annual performance evaluation, in which all employees meet with the PC Director to review and assess the previous year's performance. This process serves not only to highlight competencies, but also areas of improvement where corrective measures may be required. Informal reviews are conducted within each Taxonomic team at the conclusion of each field season to identify any areas of concern that may have arisen.

4.3 Element 3: Quality Training System

The PC ensures all staff are adequately trained to perform their assigned duties. This includes ensuring that candidates meet educational requirements (graduate degrees, certifications, diplomas, etc.).

Taxonomic experts must have demonstrated productivity and experience in their field (years of experience working with taxon, peer-reviewed publications, technical reports, etc.). Staff are provided with the resources and other relevant material required to perform their duties. The PC Director ensures resources are available for staff members to participate in local and international conferences and workshops to stay current with taxonomic changes.

A combination of full-time and short-term contract staff are used to process and identify specimens at the PC. For both returning staff or when hiring new staff, the criteria outlined in Table 4.5 are the primary technical qualifications that are considered during the hiring process.

Table 4.5. General qualifications and training requirements for taxonomic technicians.

Type of Qualification	Minimum Requirement	Before or After Hiring
Post-Secondary Education	2 Years in a scientific discipline	Before
Field Experience	Preferably a paid position for 2 summers, but equivalent experience accepted.	Before
Computer Competency	General computer literacy required; further training provided for specialty programs (such as Photoshop).	Before
Lab Training	All lab training relevant to the taxonomic identification.	After
Collection Skills	All field training will be provided by Core Taxonomic crew to ensure correct collection techniques are applied.	After

The following section outlines the process used to train staff on PC protocols and the minimum testing requirements technicians must pass before processing and identifying specimens.

4.3.1 Taxonomic Identification Training Requirements

4.3.1.1 Oribatid Mites

Training to identify Oribatid mites is as follows:

- New staff are given classroom instruction and begin to work with practice samples for the first month, or until such a time as they can correctly identify 95% or more of the mite specimens accurately to morphospecies. Once this has occurred, the trainee identifies mites specimens collected at ABMI sites; 100% of specimens identified are verified by their supervisor until ≥95% accuracy of identification has been achieved at two ABMI sites.
- A qualified sorting supervisor verifies 25% of all morphospecies identifications by each lab staff for every two out of five randomly selected ABMI sites during the second week to ensure that ≥ 95% of specimens are sorted to correct morphospecies.
- In subsequent weeks, a qualified sorting supervisor verifies 25% of all morphospecies identifications by each lab staff for one out of five randomly selected ABMI sites to ensure that ≥ 95% of specimens are sorted to correct morphospecies.
- All advanced slide mounted IDs are completed by the Lead Taxonomist, and a minimum of 10% of morphospecies verified belonging to an experienced second year Technician.

4.3.1.2 Lichens, Bryophytes and Aquatic Invertebrates

Taxonomic technicians supervise all summer technicians in their coarse sort verifying all IDs and checking all completed sites until such a time as those technicians can ensure ≥95% accuracy to the desired taxonomic level consistently. To be classified as a Taxonomic technician to identify lichen, bryophyte, and aquatic invertebrates, the person must have:

- more than 1 years' experience identifying taxa found in Alberta;
- successfully completed an exam by identifying representative specimens with at least 95% accuracy from the samples that are sorted for the ABMI.

4.3.1.3 Vascular Plants

One Vascular Plant Taxonomic Specialist is employed by RAM to identify plant specimens. Verification of identifications is completed by external experts as described in the Specimen Verification Summary document (ABMI 2016).

4.4 Element 4: Contractor Requirements

Procurement of services for the PC is generally related to identifying specimens. In keeping with the Government of Alberta's policy, contracts may be awarded through an open bidding process, or may be directly awarded when advanced identification services are required. In all instances, the PC ensures contractors have the required expertise, particularly when advanced identification services are required (ABMI 2016).

In order to ensure that the ABMI expert's identifications are congruent with other specialists in the field, all identified specimens undergo a verification process to determine what specimens are subject to differences of interpretation, nomenclatorial variation, or unintended errors of identification. This process may involve a second expert's identification of previously identified material, or the use of a different means to estimate the precision of the first expert's identifications (e.g., DNA analysis). If a discrepancy cannot be resolved, the specimen in question will be recorded in the database at the lowest taxonomic level that is agreed upon by the two experts.

4.5 Element 5: Documents and Records

The PC maintains SOPs and Lab Protocols as the primary QAQC documents; management of these documents is described below.

4.5.1 Standard Operating Procedures

There is an SOP (other lab protocol) for each taxonomic group that details the lab protocols and procedures regarding QAQC for that particular group (ABMI 10017, 10010, 10008, 10009, 10020). Each SOP is reviewed and updated as required by the Lead Taxonomist to accommodate any program or procedural alterations. Protocols are approved by the Laboratory Coordinator and PC Director.

4.5.2 Laboratory Procedures

There are laboratory procedures for each taxonomic group that outlines in detail how lab data is processed (e.g. soil, water, tree cores, etc.). Current drafts of the most up-to-date Laboratory Procedures are available on the ABMI website (abmi.ca).

4.6 Element 6: Information Management

4.6.1 PC Software and Maintenance

The PC uses software applications to assist with data management, processing, and review. Software is described in the following.

4.6.1.1 Online Data Portal

The PC is moving towards an online data portal for its data storage and specimen processing requirements. This data portal, tailored for each taxonomic group, is used to enter data directly into a database during the identification process. The online data portal replaces paper data sheets, and it incorporates various tools and features which support data entry and minimize errors that could potentially be made during the data entry process (e.g., eliminating spelling errors, flagging rare and uncommon species for verification). In cooperation with the IC, the online data portal is reviewed and updated on a semi-annual basis to incorporate changes to improve functionality with protocols and project needs.

4.6.1.2 Taxonomic Workbench

Taxonomic naming alterations are reviewed and edited annually via the Taxonomic Workbench (ABMI-IC-SOP-008; ABMI-IC-UG-001). The Taxonomic Workbench (TWB) is a database created in Oracle which is used to track and update taxonomic information associated with species data collected using ABMI protocols. Each year, the TWB is updated with new taxa added, and all the taxonomic information is reviewed by taxonomic experts.

4.6.1.3 Site Summary Workbench

The Site Summary Workbench is a web-based application used for tracking completion of data and specimen collection at the field site level. It functions as an important tool in communicating site-level information about data and specimen collection between ABMI Centres.

4.6.1.4 ABMI Tablet Program

The ABMI IC maintains a custom-built software program loaded onto tablet computers which are designed for collecting the ABMI field data. As part of the yearly software updates, PC taxonomic experts provide feedback to the IC regarding tablet updates to populate data fields such as the vascular plant voucher list (ABMI-IC-SOP-017), species list and synonym list. This ensures the tablet software includes the most current taxonomic information available and minimizes naming errors in the field.

4.7 Element 7: Systematic Quality Assurance Planning

The primary mechanisms used by the PC to support systematic quality assurance planning include the following.

4.7.1 Bi-weekly Planning Meetings:

It is impossible to know with certainty how many specimens will be received in any given sampling season. This inherent variability requires open lines of communication amongst taxonomic teams so that continuous adjustments can be made to increase efficiencies, and determine the needs of the PC on any given year. The effectiveness of the systems in place is assessed and maintained primarily by each Taxonomic Head, who is responsible for giving an approximated data delivery date for dissemination and analysis to the public. This may mean designing a new data portal, or hiring more personnel as the sample sizes dictate.

Bi-weekly meetings provide updates and progress reports which allow the PC to address any logistical problems as issues arise. With all members of staff and the PC Director present, issues and/or concerns and potential solutions are discussed, with action items and timelines assigned to the appropriate member of staff. The resolution progress is then followed up on or coordinated by the Laboratory Coordinator. The frequency of these sessions allows for quick response to any current or foreseeable obstacles so that they may be addressed in a timely manner.

4.7.2 Quality Assurance Documents

The required annual review and updates of quality assurance documents such as this QMP and approved SOPs (managed by the Taxonomic Coordinator) ensure there is continuous planning and quality improvement associated with all aspects of the data management cycle managed by the PC.

4.8 Element 8: Quality Implementation of Work Processes

At every step in the data cycle managed by the PC, there are several work processes (e.g., lab protocols, SOPs) that provide the instructions for completing each step. In addition, the PC uses several mechanisms (e.g., regular meetings, training) to ensure work processes are being implemented correctly and have been completed as required.

4.8.1 Standard Operating Procedures

The main system of implementation for PC QA management activities is through the development and execution of SOPs, and the development and maintenance of taxonomic keys. SOPs detail the operational tasks associated with identifying specimens in each taxonomic group. Table 4.2 provides a current list of SOPs that have been developed as part of the PC's sample processing, specimen

identification, and data management activities. Please note some SOPs are at early stages of development. The Laboratory Coordinator ensures that all staff have access to SOPs.

4.8.2 Training

As discussed in Section 4.5, the Taxonomic Leads make certain that all PC personnel are trained in QA procedures, understand their specific roles and responsibilities, and that the QC activities as described in the SOPs are adhered to. The active engagement of staff in the QA planning process raises the awareness and understanding of the quality management system at the earliest stages of planning.

4.9 Element 9: Quality Assessment and Response System

To evaluate the performance of the PC's quality management system, the PC uses the following assessment tools: taxonomic identification audits, data quality audits, and performance evaluations.

4.9.1 Taxonomic Identification Audits

The ABMI Botany Team at the RAM strives to assign the most accurate scientific name to each collected specimen. Ascribing a taxonomic name to a specimen with confidence is not always a rapid and straight forward exercise—proper identification often requires multiple lines of evidence. All taxonomic groups undergo periodic audits to ensure specimens are being correctly identified. There are two levels of audits:

- Internal audits: Internal audits are performed on a regular basis at all steps of the sorting and identification process to ensure a minimum level of accuracy.
    - Rough sort → a 95% identification rate is the goal during the rough sort—a process meant to separate individual species from each other in a sample, and identify common species
    - Identification → approximately 1/5 of randomly selected samples identified by full Taxonomists are audited by the Taxonomic Lead for each group; accuracy of ≥ 95% is expected for identification;
    - Specimens are regularly cross-checked by at least one other individual. These checks can be random, or targeted when experts lack confidence in certain identifications.

    Internal audits for Botany identification (including vascular plants, lichens, and bryophytes):
    - Microscopes and related equipment → Each specimen is first examined and dissected under a dissecting microscope. With the use of the taxonomic resources described below, many common species of lichens and bryophytes, and almost all vascular plants, can be identified at this stage without any further work. Some lichens and bryophytes require sectioning and further examination with a compound microscope, and/or the use of chemistry such as staining for cell structures, spot tests for diagnostic substances, or thin layer chromatography for secondary metabolite identification (lichens).
    - Taxonomic resources → Structures examined using microscopy are compared with treatments in relevant floras from North America and around the world, and with

additional information from scientific papers, reports, keys, online resources (e.g., photo galleries), and other sources (e.g., herbaria, academic or governmental institutions). The taxonomy of many species has recently changed or is currently in flux, so the PC continually updates reference literature and information. Each Lead Taxonomist maintains a list or compendium of resources used in their SOPs.

- Reference collections → Species that are regionally rare, provincially tracked, at-risk, or even just phenotypically plastic, are compared against accessioned herbaria material such as Provincial Museum of Alberta, Edmonton (PMAE) at the RAM, or University of Alberta Vascular Plant Herbarium (ALTA) at the University of Alberta. Some herbarium specimens are misidentified however, so reference material is chosen with care; where possible, specimens are selected for reference that have been identified by a botanist with known expertise in the species or species group in question. Ideally, the accessioned specimen(s) used in verification is recorded. If no collections of a taxon are available at local herbaria then a loan from outside herbaria may be required.
- Data on existing collections/Compiled data collections → Consortium websites (e.g., Consortium of North American Bryophyte Herbaria) are accessed to locate specimens housed at different herbaria, to examine specimen label information, and to map geographic locations of specimens. Data from Alberta Conservation Information Management System (ACIMS) and other regional conservation data centres are referenced to assess a species' conservation status, and to understand where and how many times a species has been documented. Particular caution is used in the determination of species that are new to the province or to Canada, or are well outside of their documented range.
- Residual uncertainty→ Specimens vary in quality, and are sometimes underdeveloped or incomplete. This is unavoidable in biodiversity monitoring. In addition, plants and lichens display a high degree of plasticity with respect to reproduction, ploidy and phenology, which complicates the task of accurately delineating taxa. When a specimen cannot be identified with certainty using the tools and resources described above, the remaining uncertainty is handled by using standard botanical annotations such as *cf.* ("compare to") or *sensu lato* ("in the broad sense").

- External audits: for specific taxonomic groups, audits include sending samples as loans to other institution for verification.
  - Outside expert opinion → For specimens that are difficult to identify, team members discuss the specimen and attempt to reach consensus. If a consensus cannot be reached, then outside experts may need to be consulted. Complicated specimens may need to be sent to outside experts for verification, as digital images of the specimen are usually insufficient for conveying detailed, fine features. In the case of vascular plants, which are identified by a single Taxonomist with no team, specimens requiring confirmation are sent directly to outside experts.

4.9.2 Performance Reviews

Staff performance reviews are conducted on an annual basis, in which all employees meet with the PC Director to review and assess the previous year's performance. This process serves to highlight competencies and challenges so that actions may be taken to improve weaknesses and augment processes to overcome challenges faced.

4.9.3 Quality Improvement

One of the underlying philosophies of the ABMI PC's quality management system (like all other Centre's in the ABMI) is that of continuous improvement. Many of the activities described in this QMP are included, in part, to facilitate continued improvement of sample processing and specimen identification in the PC. For example, annual workplans, annual staff training, and taxonomic identification audits all serve as mechanisms to identify areas that need improvement and provide opportunities to make those improvements.

4.10 Element 10: Commitment to Quality Improvement

The PC is fully committed to a process of continual improvement to sample processing and specimen identification as part of our sample management system, to produce and curate high-quality, well-documented taxonomic data that is trusted by all users. With oversight and facilitation by the PC Director and Lead Taxonomists, Taxonomic Teams will identify and improve adverse conditions to quality, and future quality by:

- ensuring that all protocols, procedures, equipment, and SOPs are updated annually, or as required;
- with oversight by the PC Director, Laboratory Coordinator and Team Leads, prevent quality breakdown by having quality and consistent training at all levels of specimen handling, processing, and identification;
- identifying areas for improvement through data QAQC activities like data verification, post-collection data review, and taxonomic audits;
- identifying necessary updates to the ABMI tablet program, Site Summary Workbench and the Data Portal program in order to maintain concurrence with protocols and improve quality functions (e.g., program restrictions and data entry menus, taxonomic changes to species lists);
- Identifying necessary updates to the TWB to ensure the species taxonomic list is up-to-date;
- coordinating implementation and testing of changes to the Data Portal program with the ABMI Database Programmer (IC). Custom built software tools with built-in mechanisms for consistent QAQC such as preloaded species names to negate spelling errors, of flagging cryptic or rare species identification for further verification;
- involving ABMI staff from other Centres where there is benefit of their expertise to quality of data collected and/or provided. Active data management, communications, and participation in ABMI-wide committees to address and collectively solve any cross-Centre problems or concerns.

4.11 PC References

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CHAPTER 5: INFORMATION CENTRE QMP

The ABMI is committed to the collection, generation and distribution of high quality biodiversity information for the province of Alberta. The ABMI Information Centre (IC) is the curator of all ABMI data, and as such, is responsible for providing data management and infrastructure support for all the data and data information products generated by the ABMI. The IC Quality Management Plan (QMP) describes the quality management system employed by the IC to ensure the execution of quality control procedures at all steps in the data management cycle. The following is a description of the IC quality management system.

5.1 Element 1: Quality Management Policy, Goals, and Objectives

The goal of the IC QMP is to provide an overview of the IC's guiding principles and practices which ensure the creation of high quality data and data products. The quality management policy of the IC is four-fold (following EPA 2002):

- Accuracy: all ABMI data is collected and verified to be as accurate as possible;
- Objectivity: all ABMI biodiversity information is presented in an accurate, understandable, clear, and unbiased manner;
- Utility: the IC provides quality data for intended use;[*]
- Integrity: all ABMI biodiversity information is protected from unauthorized access to ensure the information is not corrupted or falsified.

To meet these policy objectives, the IC has established the following quality management objectives (FREP 2005; GLNPO 2008):

- Resources:[†] IC management will ensure there are adequate resources allocated to data quality management. Resources which are essential to maintain and improve the quality of biodiversity information include: appropriate staffing and training, the development and maintenance of quality management systems, appropriate use of technology, and dedicated financial resources;
- Ongoing activity: data quality management is embedded in daily IC activities (e.g., training, Standard Operating Procedures [SOPs]) creating an expectation of quality and excellence;
- Systematic planning: through goal setting, action, and corrective activities, quality management activities will be systematically incorporated into all IC activities;

[*] Data quality is a critical aspect to an environmental monitoring program. However, data quality can only be determined by the context in which the data is used (Ferretti 2009, 2011). Therefore, data quality is often generally defined by its "fitness of use" as determined by the user (Chapman 2005, Martin and Ballard 2010).

[†] It is also important to consider constraints in financial and human resource limitations when discussing quality management, in the sense that management of quality is not the maximization of quality at all costs, but the balance between the quantity and quality of information, which can only be achieved through a comprehensive approach.

- Quality system documentation: all quality management activities will have documentation to ensure users are able to evaluate the data relative to their own needs (Shampine 1993). This includes a QMP, approved by the IC Information Director, which describes how the IC will meet its quality objectives;
- Data Management Group: a dedicated data management group within the IC meets monthly to discuss data management issues and identify ways to improve the data management process to ensure proper data organization, management, and delivery;
- Cost effectiveness: quality management activities will be implemented as cost effectively as possible without compromising data quality objectives (DWR 1998).

5.1.1 Organizational Structure

Figure 5.1 represents the organizational structure of the IC.

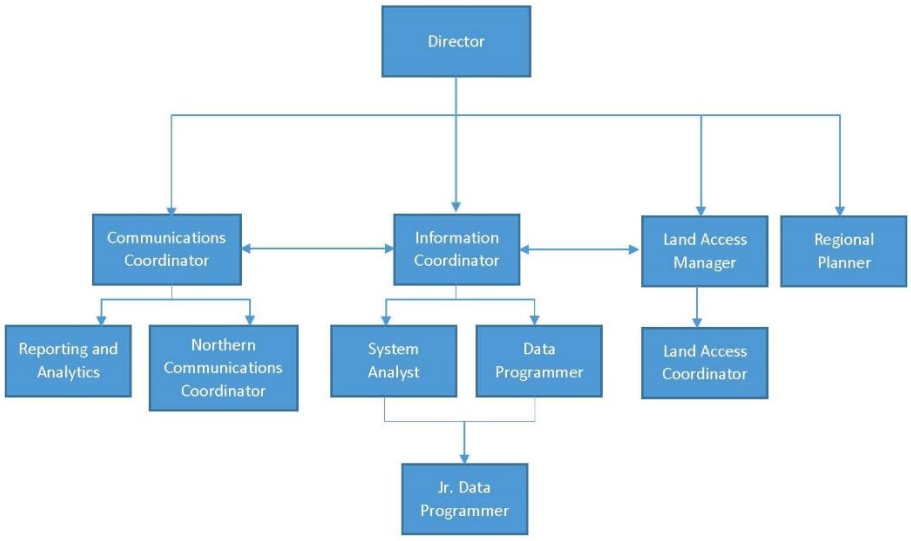

Figure 5.1. Organization chart representing roles within the Information Centre.

5.1.2 Staff Roles, Responsibilities, and Authorities

The Information Coordinator, Systems Analyst, and Database Programmer are the three staff members primarily responsible for the quality management system in the IC. A complete description of IC staff roles, responsibilities, and authorities as they pertain to data management are listed in Table 5.1.

Table 5.1. *S*taff roles, responsibilities, and authorities for the IC.

Responsibility	Data task	Technical Activities	Authority
Information Coordinator	Manage QAQC Phase I	Check data tables for duplicates, empty cells, missing sites, etc.	Confirms completion of QAQC Phase 1
	Manage QAQC Phase II	Double-check data tables for duplicates, empty cells, and verify tables contain data from all sites expected; metadata is checked and verified.	Confirms completion of QAQC Phase II
	Data Receiving, Cleaning & Loading	Load all data to temporary holding system. Manage error resolution, and data verification.	Confirms all data modifications and QAQC activities are recorded. Ensures the SOP is followed
	Updating Metadata	Manage updates to ABMI written methods for each written protocol. Manage updates to the metadata workbench.	Confirms metadata is up-to-date. Confirms metadata corresponds to datasets. Ensures the SOP is followed.
	Data Contamination & Error Resolution	Perform preliminary error review on data. Update raw data tables using data modification tool. Develop and maintain an error tracking table. Perform or manage problem analyses and resolution.	Confirms the completion of error review. Confirms the documentation of error resolution. Ensures the SOP is followed.
	Data Storage & Backup	Backup and archive all active files. Manage the archiving of all static files. Oversee development of a recovery system testing plan.	Confirms static files are archived. Ensures the SOP is followed.
	Data Security	Oversee risk assessment to electronic information.	Ensures workstation is protected. Ensures the SOP is followed.
	Website Synchronization	Update and upload metadata files.	Confirms uploaded metadata is accurate. Ensures the SOP is followed.
	Taxonomic Workbench	Manage the implementation of guild structure. Coordinate the review of species by Taxonomist for verification.	Confirms the workbench is updated by Taxonomist annually. Confirms the review of assigned groups and species by experts.
	Species of Concern Data Screening	Initiate the screening process. Update list of potential elements of management concern. Manage the screening of species/data.	Confirms the completion of the screening process. Verifies these species are removed from the public file. Ensure the SOP is followed.
	Personal Access Management	Grant/decline access to non ABMI staff.	

	Bird Recording and Site Receiving	Obtain data from data authorities. Manage data verification process. Manage error resolution process.	Confirms all data is successfully loaded to servers. Ensures a permanent record of all QAQC activities is archived. Ensures the SOP is followed.
	Coordinate Camera Trap Image Processing	Coordinate and manage image tagging process.	Ensures the SOP is followed.
	Public Release of Photos	Manage the review and release process for site and camera trap images internally and externally.	Ensures the SOP is followed.
Database Programmer	Data Receiving, Cleaning & Loading	Load data to Oracle database. Assess data for errors.	Informs Information Coordinator about errors.
	Updating Metadata	Maintain metadata workbench.	
	Data Contamination & Error Resolution	Run algorithms on data tables. Develop and update a data modification tool.	Provides outputs to Information Coordinator.
	Combine Tablet Data Tables	Combine data from all tablets and field techs into one table per protocol.	
	Upload Data	Upload combined data tables to Trello.	
	Load Data onto Development Website	Query, combine, and transpose tablet data into output format.	
	Data Storage & Backup	Manage servers. Backup and archive all active files. Manage database, web and GIS servers. Manage and test data recovery of local servers.	Confirms active files are backed up. Confirms servers are working properly. Ensures the SOP is followed.
	Data Security	Administer access control over local, database, web and GIS servers.	Ensures the SOP is followed.
	Camera Trap Image Processing	Load images to the server.	Confirms all images have be uploaded to the server and website.
System Analyst	Website Synchronization	Update taxonomic information and biodiversity browser on ABMI website. Create and copy commonly requested data files to the Web Server.	Verifies biodiversity browser is up-to-date. Ensures the SOP is followed.
	Data Security	Administer access control over local, database, web and GIS servers.	Ensures the SOP is followed.
	Taxonomic Workbench	Update taxonomic information.	
	Personal Access Management	Manage user accounts, grant/revoke access to ABMI resources.	
Land Access Manager	Species of Concern Data Screening	Update list of potential elements of management	Verifies the list is updated annually. Confirms the

		concern. Manage the screening of species/data.	completion of the screening process. Ensures the SOP is followed.
Land Access Coordinator	Public Release of ABMI Photos	Manage the review and release process for site and camera trap images externally.	Ensures the SOP is followed.
Director	Personal Access Management	Submit requests to add/remove staff access.	
	QMP and SOP Review and Approval	Review and approve all IC QMP and all IC SOPs.	Approves final QMP and SOPs.
Digital Data Coordinator	Manage Camera Trap Image Processing	Manage image uploading and tagging.	Ensures the SOP is followed.
	Coordinate and Manage ARU Processing	Coordinate the proofing, processing and data management.	Ensures the SOP is followed.
All Staff	Data Storage & Backup	Backup workstations to server.	Confirms that backups are made weekly to their personal file on the server.
	Public Release of ABMI Photos	Review all archived photos.	Ensures photos satisfy criteria specified in the SOP. Consults Information Coordinator or Land Access Manager.
	Data Security	Manage security at personal workstation.	Verifies the installation of data security software. Ensures workstation is protected.

5.1.3 Technical Activities and Tasks

The IC performs several tasks that relate to the handling of ABMI data. These tasks include, but are not limited to:

- Data receiving, cleaning, verification and loading: ensures data integrity, correctness, and completeness by conducting routine and consistent checks. This activity is crucial to maintaining data quality in environmental monitoring programs;
- Updating metadata: ensures that the supplementary data which defines and describes characteristics of all ABMI data sets are maintained and updated on a regular basis. This activity promotes the usability and longevity of data sets;
- Data contamination and error resolution: assessing data sets for range errors, outliers, and logic errors. Ensures data quality is maintained;
- Data screening: ensures that potentially sensitive information is not publicly released;
- Data storage, back-up and archiving: regular backups and archiving is essential to maintaining data integrity, and ensures the long-term protection and accessibility of ABMI data;
- Data security: ensures that systems, processes and procedures are protected from unintended activity or threats.

These umbrella activities are broken down into more specific tasks which are overseen by one to multiple IC staff (see Table 5.1 for specific task associated with each role).

5.1.4 Quality System Implementation

Implementation of the quality system will ensure staff are aware and familiar with their role and responsibility as it pertains to specific activities and tasks. Staff will then be able to regularly evaluate the implemented quality system to ensure efficient methods are utilized.

5.2 Element 2: Quality System Components

The ABMI IC must implement a quality management system which ensures ABMI biodiversity information meet quality management policies and objectives (See Section 5.1). The IC uses the following quality management practices and tools to implement its quality system, including (EPA 2001; GLNPO 2008):

- Quality Management Plan (QMP)
- Quality objectives and systematic planning
- Quality system documentation
- SOPs
- Training
- Quality Management Monthly Reporting
- Data Management Group (IC only)
- Data Management Committee (ABMI wide)
- Quality System Audits and Technical System Audits
- Annual review and monthly work planning
- Hardware and software with built-in checks and verification rules
- Internal and external audits of QA systems

Each will be discussed in turn.

5.2.1 Quality Management Plan

The IC QMP is a description of the processes that govern the QA program within the ABMI IC, including QA-related policies and objectives, and the management and technical activities required to meet these policies and objectives. The QMP further serves to communicate the overall quality system to IC staff and collaborators; staff are encouraged to refer to the QMP on an ongoing basis to reinforce the QA program. The IC QMP is approved by the IC Director and Information Coordinator.

5.2.2 Systematic Planning and Quality Objectives

A systematic planning process is used to assess IC QA needs at each step of the data management process from the data receiving phase to the public delivery phase. This logical structure facilitates the

planning of all data management activities in an iterative process of guidance, design, and feedback, ensuring quality objectives are met as efficiently as possible (EPA 2002).

As part of the planning process, the Information Coordinator chairs the ABMI Data Management Committee. The goal of the committee is to ensure proper data organization, management, and delivery. In order to accomplish this, the committee is tasked with identifying and understanding the ABMI's data management needs, developing strategies to improve data management shortcomings within the ABMI, and implementing new policies and processes relating to any data services provided by the Institute.

Execution and implementation of work plans, strategies, or processes developed by the Data Management Committee will remain the responsibility of individual business units. Ultimately, it falls on the ABMI Executive Team to decide whether or not to follow the committee's recommendations. The complete terms of reference for the Data Management Committee are included in Appendix 2.0.

5.2.3 Quality System Documentation

The IC is required to have written and approved quality system documentation (e.g., QMP, SOPs) which provides details of the QA program. At a minimum, all QA documentation must be reviewed and approved by the Information Coordinator, with final approval by the IC Director. Approvals by domain experts and/or external reviewers are encouraged, and in many instances, also necessary. All QA documentation is filed with the Information Coordinator, who is also responsible for version control and archiving documents. Relevant documents related to quality system documentation include:

- 001_ABMI-IC-SOP-001_Guidance for Preparing Standard Operating Procedures
- ABMI Public Document Archive Policy and Procedure.pdf. (Internal report)
- MetadataTemplate_ForAuthors.xls
- 005_ABMI-IC-SOP_Data storage back-up and archiving
- SOP for the Web Content Manager (in prep)

5.2.4 Standard Operating Procedures

The IC uses a series of SOPs to achieve overall data quality goals and objectives, promoting consistency in the quality and integrity of ABMI data and associated products. The development and implementation of SOPs at all stages of the data cycle is one of the key mechanisms to ensure the implementation of the QMP. These SOPs are not only critical to ensure that data processing activities are performed correctly and consistently, but also provide the basis for staff training programs (GLNPO 2008). The series of SOPs produced and maintained by the IC provide a systematic approach to verify and document that ABMI biodiversity data is consistent, complete, of known acceptable quality, and provides the IC with the following benefits (EPA 2008):

- Consistency in performance, particularly with respect to data verification and validation tasks;
- Improved data credibility and defensibility;

- Reduced errors;
- Improved efficiency throughout the data management system;
- QA documentation.

The Information Coordinator is responsible for overseeing the development and implementation of IC SOPs. SOPs are written by the Information Coordinator and/or domain experts. SOPs may be developed collaboratively, particularly for procedures with complex workflows. All SOPs are reviewed and approved by the Information Coordinator, with final approval by the IC Director. External reviews are conducted where necessary at the discretion of the Information Coordinator and/or IC Director. See Table 5.2 for a list of SOPs currently maintained by the IC.

Table 5.2. List of SOPs developed for data management cycle.

SOP Title	SOP Number	Date
Guidance for preparing SOPs	ABMI-IC-SOP-001	2013
Data receiving, data validation and cleaning, and data loading	ABMI-IC-SOP-002	2013
Updating Metadata	ABMI-IC-SOP-003	2012
Data contamination and error resolution	ABMI-IC-SOP-004	2011
Data storage back-up and archiving	ABMI-IC-SOP-005	2011
Data security	ABMI-IC-SOP-006	2011
Website synchronization	ABMI-IC-SOP-007	2011
Updating the taxonomic workbench	ABMI-IC-SOP-008	2011
Data modification and auditing	ABMI-IC-SOP-010	2012
Personnel access management	ABMI-IC-SOP-011	2013
Bird recording and site photo receiving	ABMI-IC-SOP-012	2013
Tablet data receiving and cleaning	ABMI-IC-SOP-013	2013
Camera trap image processing	ABMI-IC-SOP-014	2016
Public release of ABMI photos	ABMI-IC-SOP-015	2016
ABMI mandatory vascular plant specimen collection list	ABMI-IC-SOP-017	In development in cooperation with the Processing Centre

See Appendix 3.0 for a copy of the foundational document—*Guidance for Preparing Standard Operating Procedures* (ABMI-IC-SOP-001)—used by the ABMI to implement quality control procedures as part of the data management cycle.

5.2.5 Training (in development)

Through its policies, guidelines and internal communications, ABMI has made it clear that everyone has a role to play in assuring quality of the data. The success of the quality management system depends on commitment by the employees who are required to implement the program on a daily basis. To facilitate staff awareness of the quality management system, a quality awareness training program is implemented by the IC. Components of this training program include (but are not limited to):

- Mentorship and shadowing for new employees within the organization;

- General training seminar providing an overview of the IC QA program including: QA policies and objectives, description of roles and responsibilities, and a description of the QA documentation (e.g., QMP, SOPs) and where these documents can be accessed;
- Detailed training seminars pertaining to specific data management activities for domain experts;
- Record of QA training by IC staff;
- Testing to determine the knowledge and competence of domain experts on their use of appropriate QAQC procedures and to determine individual training needs;
- Resources made available for additional quality training (e.g., course, seminars, conferences).

See Section 5.3 for further details on quality system training.

5.2.6 Quality Management Monthly Reporting (in development)

A brief status report is completed each month by the Information Coordinator which provides an update on the status of quality management activities. The report will be presented to the IC Data Management Group. This is an important management tool in the planning and implementation phases of the QA program to:

- prioritize QA activities; provide an update on the status and progress of action items;
- identify new tasks and priorities;
- identify problems/issues with specific QC tasks/processes;
- adjust work plans and workloads.

At later stages, as the quality system cycle matures, this monthly reporting system will provide a means to assess QA activities and apply corrective action, as necessary, to ensure continued improvement in QA activities (GLNPO 2008).

5.2.7 Quality System Audits and Technical System

QA management system reviews (or quality system audits) are performed internally to evaluate the effectiveness of a quality management program (EPA 2001, GLNPO 2008). Internal audits are a priority for IC staff during the planning and implementation phases of the quality management program. Internal audits of data management workflows (e.g., data receiving, data verification, data modification) are conducted by the Information Coordinator to ensure:

- adherence to the QMP;
- the existence of procedures to develop quality objectives and acceptance criteria;
- the existence of procedures to develop and approve quality assurance documentation;
- the existence of procedures to develop and approve SOPs;
- procedures, criteria, and schedules for designing and performing audits;
- the existence of a tracking system for ensuring corrective changes to the data are adequately reported;

- sufficient management support;
- adequacy of allocated resources to achieve QA goals and objectives including appropriate level of financial and capacity devoted to the implementation of the quality system.

For example, the IC conducts regular audits on ABMI historical data to ensure data quality standards are maintained, and any changes to the field protocols over time are corrected and standardized. In addition, the Information Coordinator contracts taxonomy experts to audit the taxonomic library of ABMI at the end of the field season when new species are added.

5.2.8 Annual Review and Work Planning **(currently being implemented)**

An annual review of the quality management system is conducted by the Information Coordinator. The Information Coordinator prepares a briefing document for the Information Director (and other IC staff) providing (at a minimum) (GLNPO 2008):

- status and update of all QA activities;
- status and update on quality system documentation (e.g., QMP and SOPs i.e., have they been reviewed and updated for the year);
- results of all technical system audits and/or reviews;
- outstanding issues;
- QA workplan for upcoming year.

Following a review of the briefing report by IC staff, the Information Coordinator will coordinate and host an annual QA meeting. This will be an opportunity to review the workplan and ensure expectations around QA for the upcoming year are clearly outlined and understood. In the systematic planning framework of "plan, implement, assess, and correct", this annual review will ensure the continued application of the quality system cycle. In addition, part of the mandate of the ABMI Data Management Committee which meets at a minimum of three times throughout the year, is to ensure data management systems are being implemented, quality control issues are addressed on an ongoing basis, and coordination of QAQC among Centres is maintained.

5.3 Element 3: Quality Training System

With an underlying philosophy of quality improvement, the success of the IC quality management system depends on commitment by the personnel who are required to implement the program on a daily basis. It is the IC policy to provide appropriate quality training to ensure all staff involved in the data management process use the quality management system and understand their roles and responsibilities with respect to quality management. The following describes the ABMI IC's quality management training system.

5.3.1 Personnel Qualifications

IC staff are hired based on their ability and qualifications to perform data quality-related tasks as identified in their job description. Education and experience constitute the primary means of qualification. Additional on-the-job training is also provided as needed at the discretion of the IC Director. Full records are maintained for all training undertaken by employees.

Towards assurance that all staff members are qualified and meet the required job specifications, the ABMI IC must follow and adhere to the University of Alberta staff hiring Rules and Regulation. Personnel qualifications are established by the Position Classification Plan, which describes the job specifications and the education and/or experience necessary to fill that position. The qualifications of all job applicants are reviewed by the IC Director and at least two other IC staff members to ensure applicants meet the minimum job requirements. The IC Director and at least two IC staff interview prescreened applicants and assess their qualifications as it relates to the posted job description. It is the responsibility of the IC Director to ensure staff members who need specialized training receive it.

5.3.2 Information Coordinator Training

The Information Coordinator will participate in training courses and presentations (including online training courses and webinars) on quality management topics that pertain to (data) quality management and assessment. Relevant conferences and meetings on the development and implementation of quality systems may be used for further training. In addition, the Information Coordinator will commit to an ongoing program of self-directed study to remain up-to-date on quality assurance topics.

5.3.3 IC Personnel Quality Training System **(being implemented)**

The IC Director and the Information Coordinator are responsible for ensuring personnel are qualified to perform their jobs, including those aspects related to the quality management system. Further, it is the Information Coordinator who ensures all IC personnel are trained in QA procedures, and that the QC activities as described in IC SOPs are adhered to. Therefore, the Information Coordinator will develop and coordinate a quality assurance training program for IC staff. The basic intent of training is to describe, explain the importance of, and outline roles and responsibilities of the IC quality management system. In order for responsibilities to be effectively understood, adequate training is essential.

The quality management training program includes (but is not limited to) (GLNPO 2008):

- training with respect to the QMP;
- training with respect to specific SOPs that pertain to staff job descriptions;
- performance evaluations pertaining to QA activities;
- assessment of training needs to maintain QA competencies;
- completion of QA self-certification forms on an annual basis.

The Information Coordinator will develop and maintain a library of quality management documentation which is available to all IC staff for reference. And to maintain a pro-active approach to quality

assurance, the Information Coordinator will actively engage employees on an ongoing basis in the development of quality management activities.

The Information Coordinator will keep a record of quality assurance training for each employee, and a summary of quality system training activities (e.g., list of training seminars/courses/conferences attended) will be included in the annual report.

Whenever the IC QMP undergoes major revision, training will take place within 6 months of its approval to ensure all IC staff are fully updated on changes to the quality system. Similarly, after SOP revision and approval, IC staff responsible for tasks within the SOP will receive necessary training to implement the SOP.

5.4 Element 4: Contractor Requirements

Contractors hired under the IC will be required to read the QMP and participate in a brief QAQC seminar outlining the standard operating procedures associated with their specific work. Seminar length will depend on the services the contractor is providing which will determine the QA procedures they must adhere to.

5.5 Element 5: Documents and Records

The Information Coordinator is responsible for establishing and maintaining procedures for the timely preparation, review, approval, use, control, and revision of IC documents associated with the quality management system (GLNPO 2008). In addition, QA documentation must be appropriately archived so that information is readily retrievable for review and inspection (DWR 1998, GLNPO 2008). This section will outline the IC procedures for managing QA documents and records.

5.5.1 Document Preparation

The ABMI IC Director, Information Coordinator, or domain experts (e.g. data programmers) will identify the need for a particular QA document. The Information Coordinator will identify who will prepare a particular QA document. A team approach may be used for multi-tasked processes where the experiences of a number of individuals are required.

5.5.2 QA Documentation Reviews, Approvals, and Revisions

Quality assurance document reviews, approvals, and revisions are managed by the Information Coordinator. All QA documents must be reviewed and accepted (at a minimum) by the Information Coordinator, with final approval by the IC Director. The need for additional reviews (either internal or external) will be assessed on a case-by-case basis. For example, in addition to review and approval by the Information Coordinator and IC Director, all SOPs must be reviewed and accepted by the domain experts who perform the work and use the process. Signature approval indicates that a QA document has been both reviewed and approved by management.

SOP's will be systematically reviewed every year to ensure that procedures remain current and appropriate. The review date will be added to each SOP that has been reviewed. If an SOP describes a process that is no longer followed, the SOP will be withdrawn from the active file and archived.

5.5.3 Document Control

The Information Coordinator implements a documentation control system for QA documents, which includes two main responsibilities: keeping an inventory of all IC QA documents and assignment of a QA documentation number to all QA documents and records. Documents and records maintained by the Information Coordinator include (DWR 1998, EPA 2001, GLNPO 2008):

- Quality Management Plan;
- IC Standard Operating Procedures (See ABMI-IC-SOP-001 for information on document control of Standard Operating Procedures);
- Records of employee training;
- Annual reports and workplans;
- Results of performance and system audits/reviews;
- Documentation of QAQC issues and corrective actions taken.

5.5.4 Document Storage and Archival System **(In development)**

The system of storing QA documents, including current versions, old versions, and documents no longer in use, is managed by the Information Coordinator. The system ensures only the most recent version of each document is used. It also must outline where, and how, old versions are archived to prevent their continued use, while still ensuring the documents are available for auditing purposes or for historical review. An electronic storage and retrieval system is recommended over a hard-copy document format. Electronic access must be limited to a read-only format, thereby protecting against unauthorized changes made to the document. See GLNPO 2008, Daley 2005, NPS 2008 for systems related to data and documents.

The ABMI has also developed policy guidelines related to access and use of ABMI's public document archive. ABMI produces valuable grey literature, including: core reports on the status of biodiversity, reports from research projects, and technical documents such as standards and protocols as well as science development reports. ABMI also publishes in the peer-reviewed literature. These publications are at the centre of ABMI's business, demonstrating the value of our monitoring system and applied research projects to our diverse stakeholders. They also represent a significant investment. To ensure the continued access and preservation of these valuable documents, the ABMI maintains a document archive system. The following documents provide instructions about how to manage and archive biodiversity-related information products:

- ABMI Public Document Archive Policy and Procedure.pdf. (Internal report);
- MetadataTemplate_ForAuthors.xls;

- 005_ABMI-IC-SOP_Data storage back-up and archiving;
- SOP for the Web Content Manager (in prep).

5.6 Element 6: Information Management

5.6.1 Information Management System

Information management includes all activities associated with planning, budgeting, organizing, directing, and controlling information (GLNPO 2008). As indicated by its title, the main function of the IC is to manage information. The primary goal of the IC is to develop and implement an efficient means of collating, storing, managing, searching, and disseminating quality biodiversity information in a variety of different forms (e.g., raw data, compiled data, processed data, graphs, maps, reports). The IC responsibilities include (Daley 2005, NPS 2008):

- defining IC information management policy;
- developing and maintaining information management systems (e.g., networks, hardware, software);
- providing database administration, management, and technical support;
- supporting specialized processing requirements (geographical information systems [GIS], remote sensing, etc.);
- serving as the main contact point for data/information dissemination.

The foundation for providing these services is a reliable and secure network of current computer technology including hardware (e.g., computers, servers, hardware necessary for networking), software (e.g., applications, database systems, computer programs), and web applications (NPS 2008) as described below.

5.6.2 Infrastructure Description

Because the ABMI collects and curates large amounts of data, specialized software and hardware architecture are required to support data management and user interaction (Sólymos et al. 2015). The system needs practical, logical, and cost effective methods to organize, link, and store a diverse range of data sets—from raw field data, to audio files, to GIS layers, to results of predictive modeling—in a systematic framework. Below is a basic summary of the ABMI infrastructure used to support the data management cycle.

5.6.2.1 Servers

The ABMI currently possesses four physical and more than ten virtual servers that support the organization's activities. These servers can be broken into four primary functional types:

- Work File Server: organizational and employee server, where any staff can store working files. These servers are regularly maintained and back-up in accordance to the ABMI back-up procedure (See ABMI-IC-SOP-005);
- Data File Server: read-only repository of data files. Files stored here do not typically change often and need a consistent location, such as in the case of GIS base layers, imagery, or final reports. These servers are designed for large storage capacities;
- Database Server: uses Oracle database software. Write access is under strict control to the database manager and systems analyst. Databases on this server are for long-term data storage and require quality database design, documentation, and administration.
- Website Server: provides the ”front-end” to accessing the data and products generated by the organization. This server is closely tied to the data file and database server. Because files on this server change quickly, a well-designed back-up system is required.

5.6.2.2 Data Tablets

The ABMI uses specialized handheld computers (Panasonic Toughbook U1 Ultra) with customized databases to collect data in the field, allowing automated data quality control procedures to be implemented during data input. These computers bypass the step of manually recording field data on data sheets, allowing field crews to enter data directly into computer databases. Data tablets run standard Windows 7 OS, the field collection software uses .NET WinForms technology to create data entry interfaces, and SQLite databases to store data collected in the field. Data verification rules are built into the database to ensure that data are consistent and only include allowable codes. Each protocol is checked for accuracy and completeness by field supervisors from the MC and data backups are created.

Tablet software is updated annually. Updating the software removes any bugs present in the system from the previous field season. It is the responsibility of the Field Coordinators to notify the data programmer when any glitches in the software are identified by the field technicians. This also includes updates to any procedures or protocols that may have been altered since the last field season, such as the addition/removal of a collection field. Prior to the use of the tablets in the field by field technicians, the new updated software is tested by the data programmer and MC Field Coordinators.

The plant collection/voucher list is an example of a file that needs to be updated in the tablet. This list is developed and updated by the Information Coordinator and Plant Taxonomist at the PC on an annual basis (see ABMI-IC-SOP-017).

5.6.2.3 Automated Recording Units

The ABMI uses Automated Recording Units (ARUs) to collect large quantities of breeding bird data (in the order of 10s of gigabytes). These data need to be kept secure as they are transferred from the ARU in the field to their final data storage locations. In the field this involves keeping the memory cards organized and backing them up on hard drives in the office (see Bioacoustic Unit Data Handling Protocols).

ARU data management and processing is completed by the Bioacoustic Unit ([BU] joint partnership with the ABMI and University of Alberta). The BU is a full-service organization that focuses on wildlife acoustic studies for clients. The BU has developed standardized protocols for data handling and processing to ensure data quality and assurance. In addition, the IC has developed automated scripts, to randomly select listening assignments predetermined by the SC. Species identifications by the BU are input into an existing Access Database where general QAQC occurs. This database is updated annually to address bugs and inefficiencies present in the previous field season.

Note: The ABMI and BU are working towards the development of a Bioacoustic Information System. This system will assist and enhance data quality, management, and organization.

5.7 Element 7: Systematic Quality Assurance Planning

The primary mechanisms used by the IC to support systematic quality assurance planning include:

- IC Work Planning: the IC Director, in consultation with IC staff and other ABMI directors, develops a work plan and budget for the IC. This work plan includes identifying priorities for the quality management system and the allocation of appropriate resources (staff and budget) to complete work plan deliverables.
- Annual Individual Work Planning: All IC staff are required to submit annual work plans and budgets associated with those work plans to the IC Director. QAQC activities are highlighted as part of work planning. The IC Director discusses the work plans with all staff members, identifies priorities, and approves the final individual work plan.
- Data Management Group: the Data Management Group meets every month to discuss IC activities around data management. These regular meetings allow for the coordination, prioritization, and planning of data-related activities managed by the IC. In addition, quality management issues can be discussed and solutions proposed as part of the quality improvement process.
- Quality Assurance Documents: the required annual review and updates of quality assurance documents such as QMPs and approved SOPs (managed by the Information Coordinator) ensure there is continuous planning and quality improvement associated with all aspects of the data management cycle.
- Project Management Systems: the IC uses the program Trello to plan the QAQC data workflow and track the process identifying who is responsible for what tasks, ensure tasks are completed, and to track changes and discrepancies in ABMI data.

5.8 Element 8: Quality Implementation of Work Processes

The implementation of a quality management system is as important as planning the QA system (GLNPO 2008). Details of the processes for implementing the IC's quality management system are discussed in the following sections (following GLNPO 2008).

5.8.1 Standard Operating Procedures

The main system of implementation for QA management activities is through the development and execution of SOPs. SOPs detail the operational tasks associated with each step in the data management process. Table 5.2 provides a current list of SOPs that have been developed as part of the ABMI'S IC data management process, and more are in development.

The Information Coordinator ensures that all staff have access to relevant planning documents, such as SOPs. As discussed in Section 5.3, the Information Coordinator makes certain all IC personnel are trained in QA procedures, understand their specific roles and responsibilities, and that the QC activities as described in the SOPs are adhered to. The active engagement of staff in the QA planning process raises the awareness and understanding of the quality management system at the earliest stages of planning.

5.8.2 Data Management Group

The IC Data Management Group meets monthly to provide status updates on the data management cycle, and to respond to any issues that materialize during management activities. Action items are identified, and agenda items are added to the next meeting to ensure any issues have been dealt with.

5.8.3 Staff Training

As discussed in Section 5.3, all staff within the IC are provided with appropriate training to ensure all staff involved in the data management process understand their roles and responsibilities with respect to the quality management system and implement the system as outlined in quality management documents (e.g., SOPs).

5.8.4 Dispute Resolution

Disagreements may occur during the implementation of quality management activities. Involved IC staff will attempt to resolve conflict through discussion and negotiation first. If a resolution cannot be reached among involved parties, the IC Director will decide the final outcome.

5.9 Element 9: Quality Assessment and Response System

An assessment is defined as a "formal evaluation of performance relative to pre-determined standards" (GLNPO 2008). Quality assessments must be conducted periodically to evaluate the effectiveness of a quality system in meeting its goals, and to implement corrective actions where necessary to improve performance (DWR 1998, GLNPO 2008). There are a number of assessment tools that may be used to evaluate the effectiveness of the IC's quality system and to improve performance such as (DWR 1998, GLNPO 2008): quality system audits and technical system audits; data quality audits; peer reviews;

performance evaluations. The following is a description of the ABMI IC's quality assessment and response system.

5.9.1.1 Quality System Audits and Technical System Audits (in development)

Quality system audits (QSAs), or management system reviews, are on-site evaluations to determine if the IC is implementing an effective quality management program (GLNPO 2008). QSAs may be performed internally and managed by the Information Coordinator, or they may be performed by parties external to the IC. QSAs will be developed to evaluate adherence to the quality management system, effectiveness of the system, and the availability of resources (personnel, time, budget) to meet quality objectives (GLNPO 2008). The IC QSA may include reviews of the following (after GLNPO 2008):

- adherence to the ABMI IC quality management plan;
- procedures for developing quality objectives and other acceptance criteria;
- procedures for developing and approving quality system documentation;
- the existence and quality of QA documentation and its conformance with requirements of the QMP;
- procedures for developing and approving SOPs;
- procedures, criteria, and schedules for designing and conducting audits;
- tracking systems for ensuring that the quality management program is functional and operating and that corrective actions disclosed by audits have been taken;
- responsibilities and authorities of the IC Director, Information Coordinator, and IC staff for carrying out the quality system;
- the level of financial resources and personnel devoted to the implementation of the quality system.

5.9.1.2 Performance Reviews

Staff performance reviews are conducted on an annual basis.

5.9.1.3 Quality Improvement

One of the underlying philosophies of the ABMI IC's quality management system is that of continuous improvement. Many of the activities described in this QMP are included, in part, to facilitate continued improvement of data management in the IC. For example, monthly reporting, annual workplans, quality system training, and quality system audits all serve as mechanisms to identify areas that need improvement and provide opportunities to implement corrective measures. In particular, the transition of manually recording data to inputting data directly into tablets is one key mechanism implemented by the ABMI to reduce steps in the data management cycle and to reduce error.

5.10 Element 10: Commitment to Quality Improvement

The ABMI IC is fully committed to a process of continual improvement of our data management activities to produce and curate high-quality, well documented biodiversity information that is trusted by all users.

5.11 IC QMP References

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CHAPTER 6: SCIENCE CENTRE QMP

The ABMI Science Centre (SC) summarizes and synthesizes data collected by ABMI using science-based tools to support effective management of natural resources in Alberta. The primary responsibilities of the SC include the following:

- Maintain and continuously improve scientific excellence;
- Advance the science of biodiversity monitoring in Alberta;
- Oversee training and the application of quality control;
- Scientific auditing;
- Improve data collection protocols;
- Advance methods for data analysis and interpretation;
- Ensure scientific credibility.

This QMP outlines the SC's quality management system as it related to analysis and interpretation of ABMI data.

6.1 Element 1: Quality Management Policy, Goals, and Objectives

The goal of the SC Quality Management Plan (QMP) is to provide an overview of the Centre's guiding principles and practices in ensuring the development and dissemination of science-based information and decision support tools. The objective is to ensure that all information generated by the SC is science-based and the products are relevant to intended users.

To fulfill this mandate, the quality assurance policy of the SC follows the ABMI's overarching criteria for all information and products which include:

- Objectivity: all information and tools generated by the SC are science-based, repeatable and transparent;
- Utility: the SC generates quality information relevant for effective decision making.[‡]
- Integrity: the SC maintains and assures the accuracy of its products over its production cycle (raw data acquisition, processing and analysis) and provides supporting information (manuals, metadata, and presentations) to prevent unintentional changes and use of the information.

To meet these policy objectives, the SC has established the following quality management objectives (FREP 2005; GLNPO 2008):

[‡] Data quality is a critical aspect to an environmental monitoring program. However, data quality can only be determined by the context in which the data is used (Ferretti 2011). Therefore, data quality is often generally defined by its "fitness of use" as determined by the user (Chapman 2005, Martin and Ballard 2010).

- Resources[§] – SC management will ensure there are adequate resources allocated to quality management. Resources which are essential to maintain and improve the quality of biodiversity information include: appropriate staffing and training, the development and maintenance of quality management systems, appropriate use of technology, and dedicated financial resources;
- Ongoing activity - Quality management will be embedded in daily SC activities (e.g., Standard Operating Procedures [SOPs], internal review) creating an expectation of quality and excellence;
- Systematic planning – Through goal setting, action, and corrective activities, quality management activities will be systematically incorporated into all SC activities;
- Quality system documentation – All quality management activities will have documentation to ensure users are able to evaluate the data relative to their own needs (Shampine 1993). This includes a QMP, approved by the Science Director, which describes how the SC will meet its quality objectives.

6.1.1 Organizational structure

All members of the SC are involved with data quality assurance and control (Figure 6.1). The specific tasks assigned to each member vary by project, taxon, and through time. In addition, all the researchers are engaged in the QAQC processes that pertain to centre-wide data activities and information products. The SC also engages with a variety of research collaborators and stakeholders who use SC information for their specific area of interest.

[§] It is also important to consider constraints in financial and human resource limitations when discussing quality management, in the sense that management of quality is not the maximization of quality at all costs, but the balance between the quantity and quality of information, which can only be achieved through a comprehensive approach.

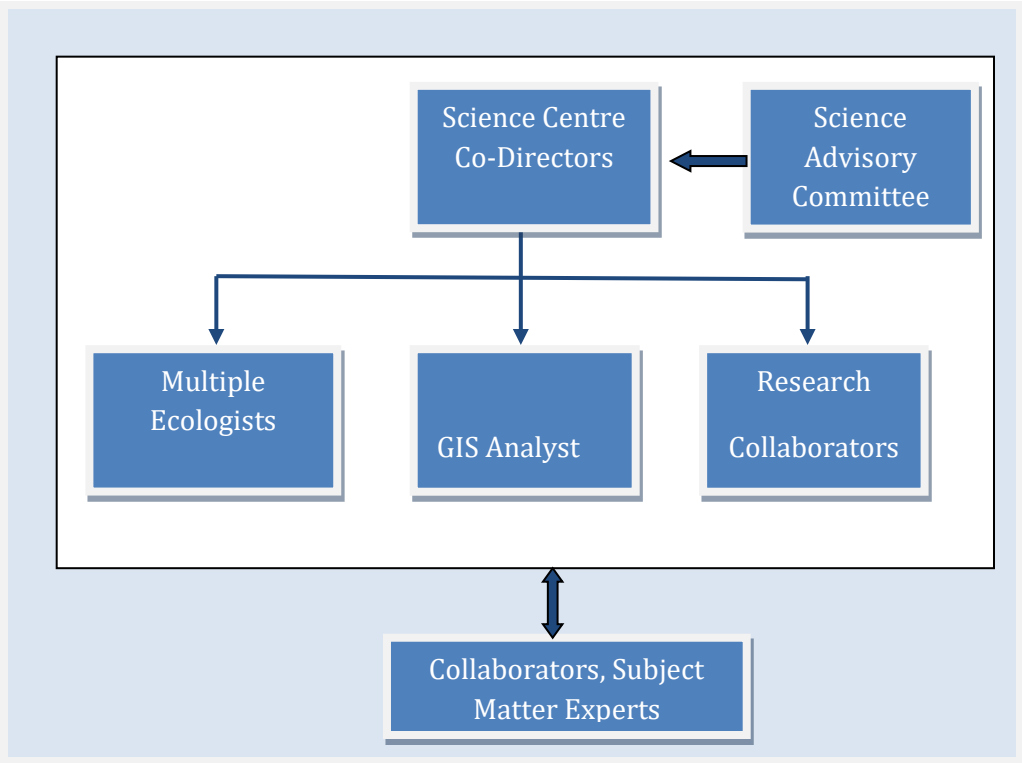

Figure 6.3. Organizational structure of the ABMI SC. All positions identified within the figure are involved with data quality.

6.1.2 Staff Roles, Responsibilities, Authorities, and Technical Activities

All technical activities undertaken by the SC are described in Table 6.1.

Table 6.1. Data tasks, staff responsibilities, technical activities, and quality tools used by the ABMI SC.

Data Task	Responsibility	Technical Activities	Quality System Tools Used	Notes
Create GIS layers describing current vegetation and backfilled (reference) vegetation	GIS Expert	Vegetation layers from a variety of sources are combined to create the best layers possible for all of Alberta	ArcGIS	After each input layer is incorporated, the product is checked visually to ensure information was incorporated as planned. The input and final GIS layers are stored on the ABMI GIS server
Evaluate change in human footprint (HF) over time	Multiple Ecologists	HF information for the 3 × 7s is compared among years	R-statistical package	

Summarize vegetation and HF into broad categories to support modelling and analyses	GIS Expert and Statistical Ecologist	Human footprint and vegetation are summarized at a variety of spatial scales around field sites, and for 1 km pixels throughout Alberta	ArcGIS and R-statistical package Unit tests[1] are used to test R package mefa4 regularly through continuous integration[2] procedures	Data sets are archived on the ABMI ftp server
Check ABMI species and habitat data for inconsistencies and summarize the data for modelling.	Multiple Ecologists; one for each taxonomic group	Data tables downloaded from the Oracle database are queried for inconsistency of species records	R-statistical package/Excel/Oracle	Identified issues are noted to respective Taxonomist at PC and corrections are implemented in the database accordingly
Model species distribution and habitat associations based on species, vegetation, and HF data. Predict species relative abundance throughout Alberta under reference and current conditions, differences between reference and current, and derive uncertainty in the predictions and generate excel and raster maps for dissemination. Combine information among species, habitats and landscapes to create products that managers can use.	Multiple Ecologists; one for each taxonomic group	R-scripts are created to do the modelling and outputs for each species checked for any errors	R-statistical package	Scripts and compiled data are archived on the ftp server

[1]Unit tests are meant to test the basic functionalities of software—if the software does not pass the test cases, source code is modified and tested again to ensure results are as error-free as possible. For more information see:

Solymos, P. 2009. Processing Ecological Data in R with the mefa Package. Journal of Statistical Software 29(8), 1-28. URL http://www.jstatsoft.org/v29/i08/.

[2]Continuous integration is the practice of frequently integrating new code or changed code into the source code repository allowing programmers to immediately detect and correct small errors when the errors are easier to resolve.

6.2 Element 2: Quality System Components

The SC management of data quality is governed by a variety of documents and resources that provide clear and consistent guidance over the various activities and processes involved in the data analysis process; these components are described below.

6.2.1 Quality Management Plan

The SC QMP describes the general processes that govern data management in the SC, including the policies and objectives and the technical and management activities required to meet them. SC staff use the QMP on an ongoing basis to confirm that process are being followed.

6.2.2 Data and Model Documentation

Researchers in the SC publish technical reports or peer-reviewed publications that document data collection methods and modelling procedures. The SC Researchers maintain interim documentation of active data or models in progress, including but not limited to model code and data processing and analysis code (e.g., R).

6.2.3 Contracts and Grants with Research Collaborators

The SC enters into contracts and grants with research collaborators from other institutions. Expectations for deliverables for these collaborations are defined in the contracts. Deliverables are assessed against the contract specifications.

Relevant documents include the following:

- ABMI Agreement Template
- Contract for Services with Individuals or Small Businesses Template
- ABMI Grant Template

6.3 Element 3: Quality Training System

The SC ensures all staff are adequately trained to perform their assigned duties. This includes ensuring that candidates meet educational requirements (graduate degrees, certifications, diplomas, etc.), have demonstrated productivity and experience in the subject matter (peer-reviewed publications, technical reports, etc.), and by checking professional recommendations. Staff are provided with the resources and other relevant material required to perform their duties. The SC Director ensures resources are available for staff members to participate in local and international conferences and workshops.

6.4 Element 4: Contractor Requirements

The SC procures data and services from a range of providers and collaborators. In all instances, the SC ensures the data and services are of a known and acceptable quality, and metadata are included. The SC follows the standard ABMI contracting procedures and contract templates; the ”Description of Services” in each contract specifies the list of deliverables and the expected data quality.

6.5 Element 5: Documents and Records

The SC creates and maintains SOPs for data products created by SC staff (Table 6.). Each SOP is updated as necessary when new data versions are released. Each SOP is reviewed and approved by the SC Director prior to release.

Table 6.2. List of SOPs, technical documents, and metadata produced by the ABMI SC.

Name	Brief Description	Last Updated
Alberta Backfilled Wall-to-Wall Vegetation Layer (Version 5) Metadata	This document provides metadata related to the Backfilled Wall-to-Wall Vegetation Layer created by ABMI. This GIS polygon layer includes information on six main landscape characteristics: 1. Vegetation Types, 2. Percentage of Pine, 3. Wetland Types and Moisture Regime, 4. Year of Origin (age), and 5. Soil Types.	June 22, 2015
Manual for Species Modeling and Intactness (20029), Version 2015-11-27	This document details the statistical methods used to produce models of the relationship of species and habitat elements to natural vegetation types, human footprint and climate and geographical gradients, and to derive current and reference conditions. In addition, the document outlines the index that the ABMI has developed to assess the intactness (or deviation from reference condition) for species, groups of species and habitat features. The methods presented here are continuously in revision, and updated versions of this document are released periodically.	November 27, 2015
Wetland – Spatial Data – GIS Processing for Wetland Habitat and Human Footprint	This SOP describes the GIS processing for summarizing wetland habitat and HF data associated with the wetland spatial data. At each step, the location of the data, the responsible personnel, the task to be performed, and the process for error resolution are described.	May 12, 2016
Winter Snow Tracking – Spatial Data – GIS Processing	This SOP describes the GIS processing for summarizing HF data associated with the spatial mammal tracking data. At each step, the location of the data, the responsible personnel, the task to be performed, and the process for error resolution are described.	May 5, 2014
Effective Mesh Size Layers Version 1.0 – Metadata	This document provides metadata for the Effective Mesh Size layers (Version 1.0) that were derived from the 2012 Wall-to-Wall Human Footprint Layer.	January 20, 2016
Wall-to-Wall Natural Cover Layers and Human Footprint Edge Buffer Layers Version 1.0 - Metadata	This document provides metadata related to the 2015 Edge Buffer Layer (Version 1.0) that ABMI created using the 2012 Wall-to-Wall Human Footprint Layer.	December 16, 2015

6.6 Element 6: Information Management

6.6.1 Computer Hardware and Software

The SC relies on a range of software and computer languages for a variety of tasks:

- **Databases:** MS Access, Oracle, SQL
- **Statistical Analysis:** R Software for Statistical Computing, STATA, MS Excel, python
- **Geographic Information Systems:** ArcMap, Google Earth, QGIS
- **Cloud Computing:** Westgrid resources
- **Version Control:** Git and GitHub

All SC researchers maintain up-to-date software installations. Because the analysis carried by multiple ecologists are similar and have to be coordinated among the researchers, all members are required to ensure the installation and updating of all the necessary packages as well as ensuring the scripts are in good order. Moreover, the SC ensures that high-performance computing hardware and data storage systems are available to the researchers to carry the data-intensive and high-level statistical computing tasks.

6.7 Element 7: Systematic Quality Assurance Planning

The SC activities are planned to meet ABMI's overall objectives of tracking changes in Alberta's wildlife and their habitats, and providing independent, ongoing, relevant, scientifically credible, and transparent information on Alberta's living resources. To fulfill the ABMI's mission the SC uses the following tools and/or activities to support quality management planning:

- Science Advisory Committee: provides high-level feedback to the ABMI Board about biodiversity monitoring and analyses;
- Operations and Management Teams: provide direction and feedback to the SC directors about monitoring and analyses methods, and how to position these to meet stakeholder needs;
- MC, PC, Geospatial Centre (GC) and IC: provide feedback to the SC about data collection protocols, information integration protocols, SOPs, and help to resolve issues as they arise;
- SC Team: holds bi-weekly teleconference calls and multiple face-to-face meetings each year to discuss and implement improvements to data collection, analyses and reporting;
- Annual Work Plan for the SC: at the beginning of the fiscal year, a work plan is developed by the SC Co-directors (in consultation with the ABMI Management Team) describing activities for the year;
- Annual Work Plans for each SC staff member, in consultation with the SC Directors, creates an annual work plan to complete their portion of the identified SC tasks.

6.8 Element 8: Quality Implementation of Work Processes

The SC Co-Directors ensure that all applicable elements of the quality system are understood and implemented by:

- Creating and maintaining SOPs, or process documents, for regularly executed tasks;
- Developing metadata for data products created by the SC;
- Scheduling regular meetings to discuss data quality issues;

- Participating in formal and informal peer-review of data products.

The SC staff are all responsible for ensuring that work is performed according to project work plans, that appropriate protocols are in use or being prepared as required for each project, and that staff are fulfilling their obligations under the executed contract or terms of employment. Annual work plans for each staff state their role in data quality management project, including how much time they will allocate to work plans to ensure all project objectives, including data quality management tasks, have sufficient resources to be completed.

6.9 Element 9: Quality Assessment and Response System

The SC Director conducts regular reviews of the information products and tools generated by the Centre to ensure their quality and relevance for the intended users. All SC staff are involved in the technical review of interim and final products to ensure quality and adequacy of these. Moreover, the SC solicits reviews from other ABMI Centres and subject matter experts as required. The SC holds quarterly meetings where it shares its products and ongoing activities with staff from other Centres and collaborators for feedback. Expert reviews and recommendations are documented and, when required, corrective measures are implemented.

The main mechanisms of review of biodiversity information created by the SC, include:

- Internal review (i.e., within-SC);
- ABMI review (IC when report writing);
- External review;
- Peer review of scientific articles;
- Review by Scientific Advisory Committee.

6.10 Element 10: Commitment to Quality Improvement

All SC staff are required to participate in the quality assessment processes identified above through:

- Continual (internal) review of methods and SOPs;
- Updating previous analyses when new data and methods are available;
- Updating data sets to correct identified problems and to use new data or methods;
- Incorporating feedback from peer-review and Advisory Committee.

SC staff members are all responsible for ensuring quality management and improvement of the data, methods used, and the analyses produced. One-on-one discussions and group meetings with SC staff and other Centres are frequently held to discuss problems as they occur. The appropriate corrective actions, and actions to prevent reoccurrence, are discussed and implemented. The SC staff that identified the issue is responsible to track corrective actions to closure.

6.11 SC QMP References

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CHAPTER 7: GEOSPATIAL CENTRE QMP

The ABMI Geospatial Centre (GC) develops and implements methods to monitor changes in habitat and human footprint. The Centre staff use aerial photography and satellite imagery to update or create GIS data and information products. The Centre currently maintains three product lines:

- Coarse scale: wall-to-wall (W2W) and regional scale GIS layers describing Vegetation (VEG) and Human Footprint (HF) throughout Alberta. Existing VEG layers include W2W 2000 and 2010 VEG layers based on Landsat TM data. Existing W2W HF layers include W2W 2007, 2010, 2012 HF layers; this product is updated approximately every two years. Existing regional scale products includes updated linear Base Features for the Oil Sands region;
- Sample-based scale: GIS inventory describing VEG and HF features for a grid of 3x7 km sample plots that cover approximately 5% of the province. These products are used by the SC and IC to report on the annual trend in habitat and human footprint change;
- Site-specific scale: GIS inventory describing human footprint in buffers around ABMI field sites. This information is used by the SC to determine how species sampled by ABMI vary among human footprint types. The resulting models are used to describe and map status and change in biodiversity.

The GC QMP outlines the GC quality management system as it pertains to these three product lines.

7.1 Element 1: Quality Management Policy, Goals, and Objectives

7.1.1 Quality Assurance Policy

ABMI's GC is committed to the collection, generation, and distribution of high quality geospatial information to the ABMI and the public. The Centre meets and follows the ABMI's threefold quality assurance policy (Objectivity; Utility; Integrity) in its daily activities. To fulfill this mandate, the following must be implemented when creating geospatial information:

- Quality management: developing and testing methods to ensure delivery of high quality geospatial products; this includes goal setting, training and corrective activities;
- Quality system and data documentation: creating Standard Operating Procedures (SOPs), data processing logs and metadata documentation for ABMI geospatial information and products;
- Geospatial product management: storing and managing delivery of all products to other ABMI Centres and the public;
- QAQC: Performing quality control and quality assurance on the information and products being delivered to ABMI and the public.

7.1.2 Organizational Structure

Table 7.1 represents the organizational structure of the GC and identifies QAQC responsibilities associated with each job title.

Table 7.1. GC organizational structure.

Job Title	QAQC Responsibility
GC Director	Data Quality Management
Air Photo Interpretation Lead	QAQC Air photo plots
GIS Coordinator - Human Footprint Mapping Group (HFMG)	QAQC HF products
Northern GIS Coordinator - Base Features (BF) Group	QAQC BF blocks
Geospatial Analyst	QAQC own work
Air Photo Interpreters (3)	QAQC own work
Human Footprint (HF)Technicians (4)	QAQC own work
BF Technicians (2)	QAQC own work

7.1.3 Staff Roles, Responsibilities, and Authorities

Table 7.2 outlines staff roles, data tasks, and technical activities as they pertain to the quality management system. More detail is provided below.

Table 7.2. Staff roles, responsibilities, and authorities for the GC.

Responsibility	Data task	Technical Activities	Authority
Air Photo Interpretation Lead	3x7 km Air Photo Interpretation	Data creation; Data storage; Data Quality; Data upload; Air photo acquisition	Air Photo Lead
		Air photo quality	GoA/ Air Photo Lead
		Air photo storage	Server Administrator
	Primary Land Vegetation	Contract management | Data creation	Air photo Lead
GIS Coordinator - Human Footprint	HF 3x7 annual update	Coordination of HF Mapping Group (HFMG) effort to update existing HF dataset to current conditions.	GIS Coordinator of HFMG
	W2W HF mapping	Coordination of HFMG effort to update existing HF dataset to current conditions.	GIS Coordinator of HFMG
	HF on ABMI's wetland mapping	Coordination of HFMG effort to update existing HF dataset to current conditions.	GIS Coordinator of HFMG
	HF on ABMI's 1x1 terrestrial sample sites mapping	Coordination of HFMG effort to update existing HF dataset to current conditions.	GIS Coordinator of HFMG
Northern GIS Coordinator	BF updates	Coordination with GOA for receiving data and delivering final edits. Coordinate with BF techs who make the edits following GOA	Northern GIS Coordinator

specs.

7.1.4 Technical Activities:

The GC is responsible for three main geospatial products; 3x7 Air Photo Interpretation layers, HF, and BF Updates. For each product, the technical activities associated with QAQC procedures are outlined below.

7.1.4.1 3x7 Air Photo Interpretation

Air photo plot data is compiled by air photo interpreters who stratify and categorize vegetation, anthropogenic disturbance, land use, and other characteristics that influence the land cover within the province of Alberta. The vector data compiled by interpreters is in polygon, line and point format. The data compiled by interpreters follows a stringent set of guidelines and protocols found in air photo interpretation manuals and air photo interpretation quality control manuals (ABMI-GC, 2014a,b,c).

For the interpretation of the photo plots, the ABMI has acquired stereo imagery for the majority of ABMI sites. The quality control protocols emphasize proper sun angle, complete photo plot coverage with sufficient overlap, ensure the imagery is free from cloud, smoke or emulsions that may hinder the clarity of the imagery, and that support files and aerial triangulation is complete and operational.

7.1.4.2 Human Footprint

The ABMI W2W HF Inventory (scale 1:15,000) is a complete representation of provincial scale anthropogenic footprint information for the province of Alberta. This comprehensive layer includes all the HF information related to the energy, forestry, and agriculture industries, as well as urban development; this product is updated every two years.

The QAQC responsibilities of the GIS Coordinator to produce the WTW HF Inventory include the following:

a. to correspond with AITF GIS staff to receive the SPOT imagery and to review quality of the province-wide mosaic and the metadata;
b. to prepare training materials and to develop interpreting rules, methods, and strategies to ensure correctness and consistency of interpretation within HFMG members;
c. to create user accounts at ArcSDE server for GIS Technicians so they are able to access and edit human footprint sublayers;
d. to lead interpretation and update effort of the HFMG in providing technical and/or interpretation support ;
e. to QC updated layers:
    i. control of the correctness of interpretation;
    ii. control of correctness of polygon delineation;
f. to backup updated layers;
g. to finalize sublayers for the final integration;

h. sublayer dataset integration into final wall to wall geodatabase;
i. QC of final dataset;
j. HF dataset delivery for upload to ABMI web page.

The QAQC responsibilities of GIS Technician include:

a. to follow established interpretation procedure (HFMG_Interpretation_Key_ABMI_DRAFT.pdf);
b. to perform self-audits daily including the following QC procedures:
    i. use document metadata to check for errors or inconsistencies of interpretation;
    ii. check for accuracy of digitization;
    iii. check for attribute value;
    iv. check for completeness of edited sites;
c. to QC data collected by another GIS Technician when required;
d. to provide feedback to GIS Coordinator, when further discussion is required.

7.1.4.3 Base Feature Updates

BF Updates is a project in association with the Government of Alberta (GOA) to bring their Access datasets (roads, pipelines, cutlines, etc.) up to current imagery status. All updates follow rules and guidelines provided by GOA. Datasets are provided to the GC by the GOA and once updated, datasets are returned to the GOA where they are integrated into the provincial database. Currently only the Oil Sands Region is being updated by the GC. The following QAQC procedures are used for BFs:

- When editing the feature data layers, manuals supplied by GOA (GOA, 2007, 2013) are used in order to identify access features from SPOT imagery using the same methodology to ensure consistency;
- Topology checks (a feature in ArcGIS) has a number of assigned rules that are used to ensure the data is in the correct geometrical format;
- Once all new features have been captured and existing data has been edited to the current status based on the imagery, a series of attribute checks and visual checks are performed by the technician to ensure rules set by the GOA manual are followed;
- BF Coordinator checks the data again before integrating back into the replica database. Attribute and visual checks are performed again;
- Data is returned to the GOA where further QC procedures are performed before being integrated into the provincial database.

7.2 Element 2: Quality System Components

The ABMI GC must implement a quality management system which ensures ABMI GIS data and data products meet quality management policies and objectives. The GC staff use the following quality management practices and tools to implement its quality system, including (EPA 2001; GLNPO 2008):

- Quality system documentation;
- SOPs;
- Training;
- Annual review and work planning;
- Hardware and software with built-in checks and verification rules.

For the three main activities of the GC—3×7 photo interpretation, GIS inventory of HF, and BF updates—the GC uses several tools to implement its quality management system. The following provides a summary of the components of the quality management system that apply to these three activities.

7.2.1 Quality System Documentation

The GC is required to have written and approved quality system documentation (e.g., QMP, SOPs, manuals) which provides details of the GIS QA program. At a minimum, all QA documentation must be reviewed and approved by the Group Leads, with final approval by the GC Director. Approvals by domain experts and/or external reviewers are encouraged, and in many instances, also necessary. All QA documentation is filed by individual Group Leads who are also responsible for version control and archiving documents.

7.2.1.1 3x7 Air Photo Interpretation

To ensure the QAQC procedures are implemented consistently on the 3x7 photo interpretation layers, the GC uses the following three manuals:

- Air Photo Interpretation Manual under Geospatial Centre 2014
- Air Photo Interpretation Data Model Manual under Geospatial Centre 2014
- Air Photo Interpretation Quality Control Manual under Geospatial Centre 2014

These manuals are updated each year to ensure QAQC procedures are up-to-date.

7.2.1.2 Human Footprint

The GC uses the following documents to ensure a high quality HF product is being created:

- Standard Operating Procedures Human Footprint 3x7;
- Standard Operating Procedures Human Footprint – wall to wall;
- Standard Operating Procedures Wetlands – Spatial Data – GIS Processing for Human Footprint;
- Human Footprint Interpretation Key.

7.2.1.3 Training Documentation

The Human Footprint Interpretation Key is the standard document for HF interpretation. The Human Footprint Interpretation Key is a peer reviewed document containing:

- terrestrial photos of HF types;
- aerial photos of HF types;

- satellite scene snapshots of HF types;
- visual elements of interpreted HF features on satellite imagery, including: color, structure, texture, shape, size, pattern, shadows;
- interpretation rules.

7.2.1.4 Base Feature Updates

The GC uses the following tools and processes to implement the quality management system with respect to BF updates:

- instruction manuals provided by GOA to guide the editing and photo interpretation of BFs (GOA 2007,2013);
- topology rules (ArcGIS) are followed and performed that check for geometrical consistency and errors. Topology rules were created by GOA (e.g., road points must be covered by road arcs; pipeline arcs must not self-intersect);
- technicians are trained by the Northern GIS Coordinator based on specifications provided by GOA; any unclear questions that come up during editing (not answered in the manuals) are posed to the GOA contact;
- an SOP was created to explain the process, with reference to all the GOA documents that are a part of the SOP;
- Upon completion of each NTS block, data is returned to GOA where it is reviewed again and feedback provided to ABMI BF Coordinator.

7.2.2 Standard Operating Procedures

The ABMI GC uses a series of SOPs to achieve overall data quality goals and objectives. These SOPs are not only critical to ensure that data processing activities are performed correctly and consistently, but also provide the basis for staff training programs. The series of SOPs produced and maintained by the ABMI's GC provides a systematic approach to verify and document that ABMI GIS data and data products are consistent, complete, and of known acceptable quality.

SOPs may be developed collaboratively, particularly for procedures with complex workflows. SOPs are written by each Team Lead, who also oversees their development and implementation. All SOPs are reviewed and approved by the GC Director. External reviews are conducted where necessary at the discretion of the GC Director. See Table 7.3 for a list of SOPs currently maintained by the GC.

Table 7.3 List of SOPs developed for GIS data products produced by the GC.

SOP Title	SOP Number	Centre Responsible	Date
Human Footprint wall to wall	ABMI_GC_HG_w2w_SOP	Geospatial Centre	2015
Human Footprint 3x7	ABMI_GC_HF3x7_SOP	Geospatial Centre	2015
Alberta Base Feature Updates for GOA	ABMI_GC_SOP_BaseFeatureUpdates	Geospatial Centre	2015
Wetlands-Spatial Data-GIS Processing	ABMI-SC-SOP-003	Science Centre	2014

for Human Footprint			
Air photo Interpretation Manuals	ABMI_Photoplot_DataModel, ABMI_ Photoplot_Interp Manual, ABMI_QC_Manual version 2.4.1	Geospatial Centre	2014
Winter Snow Tracking – Spatial Data – GIS Processing	ABMI-SOP-SC-002	Science Centre	2014

7.3 Element 3: Quality Training System

Personnel qualifications and training requirements for each of the three main GIS activities associated with the GC are presented in the following sections.

7.3.1 3x7 Air Photo Interpretation

All staff hired for 3x7 air photo interpretation must have appropriate levels of education and experience. Once hired, on-the-job training includes:

- one-on-one mentorship and guidance supplemented with use of manuals;
- field work to calibrate on screen interpretation;
- mentorship to ensure interpretation is consistent among all interpreters.

7.3.2 Human Footprint

7.3.2.1 Training Policy

It is required that all personnel involved in human footprint mapping are fully capable of:

- efficient use of GIS software;
- correct and consistent interpretation of HF types.

7.3.2.2 Training Processes

The GIS Coordinator is responsible for providing comprehensive training of interpretation rules for GIS Technicians. The HF training process includes an office and field component. Office training consists of:

1. reviewing existing data layers as an example of previous interpretations;
2. learning about HF categories and types based on: terrestrial photos, aerial photos, satellite scene snapshots;
3. reviewing all visual elements of interpreted HF features: color, structure, texture, shape, size, pattern, shadows;
4. learning all interpretation rules associated with HF types;
5. hands-on interpretation of HF types using the training dataset;
6. assessment of hands-on interpretation on the training dataset.

Results are verified by the GIS Coordinator and GIS Technicians as necessary using:

- terrestrial photographs of interpreted human footprint types;

- notes;
- unmanned Aerial Vehicle (UAV) photographs of interpreted human footprint types when possible.

After completion of Human Footprint Mapping Training GIS Technicians are able to:

- understand existing data layers including: data sources, data structures, list of attributes;
- understand available imagery sources, including: source, spatial resolution, and horizontal accuracy of the imagery;
- recognize and distinguish different HF categories;
- create new HF polygons with correct attributes;
- create logs and records required to maintain consistent HF database.

7.3.3 Base Feature Updates

Technicians are hired for their ability to interpret satellite imagery (e.g., being able to distinguish between pipelines and road features). Basic understanding of GIS and using ArcGIS is an asset but not necessary as the skill can be obtained through training. Editing involves digitizing and delineating points and lines on the screen and updating tables.

7.4 Element 4: Contractor Requirements

Contractors are used to audit 3x7 air photo interpretation layers for accuracy and consistency. Contractors must:

- have appropriate levels of certification, experience and skill sets;
- be referred by the GOA and other vendors;
- respond to Requests for Proposals (RFP) which requires corporate resumes, certifications, and identification of desired skill sets.

7.5 Element 5: Documents and Records

Metadata and SOP documents are updated annually, and when a new version of a dataset (e.g., Human Footprint 2012) is released publically.

The Human Footprint progress report is a sub table incorporated into ArcSDE data structure. The progress report is continuously updated by GIS Technicians as they finish a task and by the GIS Coordinator when QC is performed.

BF Update records are kept of the progress of each edited NTS block but as GOA makes final changes and incorporates the data into the provincial data set, no other records are kept.

7.6 Element 6: Information Management

The GC uses ESRI ArcGIS (version 10.1) to process and create GIS products. ArcSDE (version 10.2.2) is used for data storage. The 3x7 Air Photo Interpretation group also uses Datem (version 7.0). Both of these software types are the industry standards and enable collaboration with GOA.

7.7 Element 7: Systematic Quality Assurance Planning

Within the GC, quarterly planning is performed for each group as to which geographical areas are going to be worked on for the coming term.

Within each group, the QAQC performed each time is the same for each geographical area dependent on the specific projects.

7.7.1 Human Footprint

Progress status meetings are held on a biweekly basis to incorporate feedback into the data capture process. All new findings are documented and correct interpretation is discussed. Accuracy measures are implemented into the interpretation if uncertainty in the existing interpretation occurs.

7.8 Element 8: Quality Implementation of Work Processes

A description of the implementation of the quality management system for each of the three main activities associated with the GC follows.

7.8.1 3x7 Air Photo Interpretation

- Overseeing of implementation: Air Photo Interpretation Lead
- Tracking sheet ensures completion: Air Photo Interpretation
- QC processes ensures all necessary interpretation steps completed properly: Air Photo Interpretation Lead

7.8.2 Human Footprint

HF work processes are detailed in Table 7.4.

Table 7.4. Human Footprint work processes.

Step 1. Satellite Imagery
→ ArcSDE mosaic database containing SPOT imagery is created on *geospatial* server by GIS Coordinator. → GIS Coordinator creates accounts for GIS Technicians within ArcSDE database to allow access. → GIS Coordinator instructs GIS Technicians how to connect into ArcSDE containing SPOT imagery.
Step 2. Data preparation

→ Base layer for current year update is created on ArcSDE server by importing of the last year 3x7 dataset into new database by GIS Coordinator.
→ ArcSDE database containing all previous year datasets (1999 to the latest minus one).
→ GIS Coordinator creates accounts for GIS Technicians within ArcSDE database to allow access and editing.
→ GIS Coordinator instructs GIS Technicians how to connect into ArcSDE databases containing both current and previous years 3x7 datasets.

Step 3. ArcGIS workstation setup

→ Imagery:
- Historical orthophoto mosaic SDE (1949-1963)
- Valtus orthorectified aerial photomosaic (1999-2003)
- IRS satellite imagery GDBs (2001-2004)
- SPOT5 satellite imagery GDBs (2005-2012)
- SPOT6 satellite imagery SDEs (2013-2014)
- Valtus Views ArcServer online mosaic of orthorectified aerial photomosaic

→ Datasets:
- current 3x7 dataset - ArcSDE
- previous years 3x7 dataset - ArcSDE
- ABMI site boundaries - ArcSDE
- temporary centre lines layer - ArcSDE

Step 4. Editing feature updates

→ Set the working scale to 1:5,000
→ Delete the HF from the reference map if it disappears from the satellite imagery following these rules:

- former HF no longer recognizable on Imagery sources:
  - no visual difference detected between area of former HF and its surrounding areas (no difference in visual elements of: color, structure, texture, shape, size, pattern, shadows)
    - this must be confirmed on at least three imagery sources dating back from the current mosaic (e.g. SPOT6 – 2014, SPOT6 -2013 and Valtus VIEWs -2012 for year 2014 update)

→ Add new HF(s) to the layer if new HF(s) is/are found following these rules:

- if new HF feature is adjacent to existing HF polygon, TRACE tool must be used to create new feature on places were boundaries are shared by both polygons.
- if new HF feature is overlaid on existing polygon, CLIP tool must be used to avoid creation of overlapped polygons (e.g., new road on top of agriculture).

→ Edit the HF feature if situation on the landscape has been changed.
→ Correct the HF feature if interpretation errors are found for the current 3x7 dataset.
→ Correct the human footprint feature if interpretation errors are found for the previous year 3x7 datasets.
→ Digitize centreline of linear features and measure average width of HF.
→ Create polygon feature by buffering (use half of the width value) of centrelines.
→ Copy and paste buffered polygon from temporary centreline layer into current 3x7 layer.

7.8.3 Base Feature Updates

- Geographical areas to edit are chosen based on their location within the Oil Sands Management Area (OSM) boundaries.
- Tracking document keeps track of which blocks have been completed and by whom.
- Project is not intended to be long-term; once OSM area has been updated, that portion of the project is complete.

7.9 Element 9: Quality Assessment and Response System

Technical Assessments are evaluation processes focused on specific technical practices and procedures, such as data checking. The purpose is to measure the performance or effectiveness of technical systems and their elements (with respect to documented specifications and objectives). The following is a summary of the assessment system used by the GC.

7.9.1 3x7 Air Photo Interpretation

Air photo interpreters use three assessment tools to ensure 3x7 data is as accurate and error-free as possible:

- Technical assessments: manuals and automated QC tools are used to ensure completeness of attributes and proper structure. Topology rules are also used to ensure a spatially acceptable product, such as: no overlap, no self-overlap, no gaps, and plots cover polygon.
- External audits: completed by an external certified AVI level 3 photo interpreters, the auditor identifies and documents errors and trends to improve future interpretation while ensuring a high quality product.
- Peer reviews: senior interpreters review junior interpreters' work to ensure consistency and aid in identifying trends and building experience.

7.9.2 Human Footprint

During the creation of the HF dataset, there are several assessment tools in place to identify and correct errors as detailed in Table 7.6.

Table 7.6. Quality control process applied during creation of HF dataset

Self assessment tools	QC process
Self audit (Daily)	→ use document metadata to check for errors or inconsistencies of interpretation → check for accuracy of digitization → check for attribute value → check for completeness of edited sites

Peer audit (Weekly)	→ randomly select 10% of the sites edited on the previous week → Check all items as in QA self-audit
GIS Coordinator Check - Topology	→ Topology Rules: Must Not Overlap → Error Inspector: To find errors for all rules → Fixes: Clip/Merge if there is an overlap → Fixes: Delete if smaller than cluster tolerance
GIS Coordinator Check – (Weekly)	→ overall QC on randomly selected 10% of the sites edited on the previous week → report back to GIS Technicians when corrections are needed → report back to entire HFMG if interpretation trends need to be corrected
GIS Coordinator Check – (Final)	→ overall QC on the rest of sites that have not been QC-ed yet → create final QC document
GIS Professional outside of HFMG – (Audit)	→ randomly selected 10% of ABMI sites to be QC-ed by professional outside of HFMG → **Geometry check** – quality of digitization is QC-ed: Quality Categories: • acceptable • acceptable with modification • not acceptable → **Attribution check** – quality of digitization is QC-ed: Quality Categories: • acceptable • not acceptable **Both checks – geometry and attribution, must have 80% features in acceptable categories for final geodatabase to pass the audit.**

7.9.3 Base Feature Updates

Complete edits are ultimately returned to GOA after each NTS block is finished. If they have any problems with the work provided by the GC, they provide feedback for future blocks.

7.10 Element 10: Commitment to Quality Improvement

The GC is responsible for producing datasets that are both continuous and require a lot of time to produce. Further, the GC is committed to the continual improvement of the GIS products being produced. Though the core product remains the same, procedures are constantly updated based on improvements with software, better imagery and error catching methods.

7.10.1 3x7 Air Photo Interpretation

Since the genesis of the photo plot program, alterations have continually transpired to improve the quality of the product, including:

- use of higher resolution imagery;
- application of field measurements to ensure accuracy of interpretation;
- external audits;
- manuals created to provide transparency and quality assurance to users; and
- improved methods to provide efficiency while maintaining high standards.

Consistent efforts to improve the value of the data have generated confidence in its high standard among users. In the future, application of data such as LiDAR will be employed to strengthen the product and ensure user approval.

7.10.2 Human Footprint

The HFMG is committed to the continual improvement of GIS HF products through the implementation of processes such as status meetings, training, and audits.

7.10.3 Base Feature Updates

Feedback between technicians, from coordinator to technicians as well as any feedback received from the GOA are all incorporated to make future data better.

7.11 GC QMP References

ABMI-GC. 2015a. Alberta Base Feature Updates – Standard Operating Procedures.
ABMI-GC. 2015b. Human footprint 3x7– Standard Operating Procedures.
ABMI-GC. 2015c. Human footprint wall to wall– Standard Operating Procedures.
ABMI-GC. 2014a. Air Photo Interpretation Manual.
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CHAPTER 8: APPLICATION CENTRE QMP

Application Centre Overview

Over the course of monitoring terrestrial and wetland ecosystems across the province for more than a decade, the ABMI has assembled a massive biodiversity database, developed reliable measurement protocols, and found innovative ways to summarize complex ecological information. These data have enormous value to environmental managers and land-use decision makers. But the ABMI has extended its relevance beyond its core business of measuring and reporting on the state of biodiversity in Alberta through the Application Centre (AC) which applies ABMI data to specific management issues. The AC's current projects use the ABMI's biodiversity and human footprint data, along with its scientific capacity to address challenges like managing rare species in a changing climate and mapping ecosystem services like pollination, carbon storage, and water purification. These projects are collaborative efforts between the ABMI and partner organizations and researchers.

The Application Centre (AC) leverages the data generated by the ABMI to demonstrate the value of the Institute and its benefits to Albertans. In addition, the AC is involved in all phases of the data management cycle— separate from the ABMI data cycle—through its delivery of applied research projects, including project design, data collection and management, data analysis and modelling, and reporting for applied research projects. Descriptions of current and completed AC projects are available in Appendix 4.0.

The AC QMP provides an overview of the AC practices that ensure the data and data products produced through AC activities can be appropriately interpreted and used by others to support further research and decision-making with an understood level of certainty. Wherever data activities align with the core ABMI program, standard ABMI data quality management practices are implemented; all other AC data activities are governed by the present QMP document.

The 2015-2016 AC Quality Management Plan (QMP) outlines the roles, responsibilities, resources, and procedures that govern data quality management in the AC. The QMP will be reviewed annually under the leadership of the AC Director. Current initiatives for improving data quality management in the AC are focused on ensuring adequate resources for data storage and developing a procedure for archiving completed projects.

8.1 Element 1: Quality Management Policy, Goals, and Objectives

8.1.1 Quality Assurance Policy

Following other ABMI Centres, the AC adheres to a threefold quality assurance policy:

1. Objectivity: all AC data and data products are to be presented in an accurate, understandable, clear, and unbiased manner;
2. Utility: the AC provides quality data and information for intended use.[**]
3. Integrity: until released to the public, all AC data and information is protected from unauthorized access to ensure the information is not corrupted or falsified.

To meet these policy objectives, the AC has established the following quality management objectives (FREP 2005; GLNPO 2008):

- Resources[††] – AC management will ensure there are adequate resources allocated to quality management. Essential resources for maintaining and improving the quality of biodiversity information and research products include: appropriate staffing and training, the development and maintenance of quality management systems, appropriate use of technology, and dedicated financial resources;
- Ongoing activity - Quality management will be embedded in daily AC activities (e.g., training, Standard Operating Procedures [SOPs], scientific peer review) creating an expectation of quality and excellence;
- Systematic planning – Quality management activities are systematically incorporated into all AC activities, and monitored and planned as a standing agenda item in regular AC meetings;
- Quality system documentation – All quality management activities will have documentation to ensure users are able to evaluate the data relative to their own needs (Shampine 1993). This includes a QMP, approved by the AC Director, which describes how the AC will meet its quality objectives;
- Data Management Committee – The AC participates in the ABMI-wide Data Management Committee, which is responsible for ensuring proper data organization, management, and delivery across the ABMI.
- Cost effectiveness – Quality management activities will be implemented as cost effectively as possible without compromising data quality (DWR 1998).

8.1.2 Organizational Structure

All members of the AC team play a role in QAQC activities, with responsibilities determined by the needs of specific research projects rather than a single, centre-wide data workflow (see Figure 8.1 describing the AC organizational structure). The AC also engages with a variety of Research Collaborators who use ABMI data products or generate new data related to specific research projects. These Research Collaborators

[**] Data quality is a critical aspect to an environmental monitoring program. However, data quality can only be determined by the context in which the data are used (Ferretti 2011). Therefore, data quality is often generally defined by its "fitness of use" as determined by the user (Chapman 2005, Martin and Ballard 2010).

[††] It is also important to consider constraints in financial and human resource limitations when discussing quality management, in the sense that management of quality is not the maximization of quality at all costs, but the balance between the quantity and quality of information, which can only be achieve through a comprehensive approach.

are often actively involved in data QAQC, depending on their contributions to specific data activities (**Error! Reference source not found.**1) and are governed by contracts or grant agreements (see **Error! Reference source not found.**). Their contributions are overseen by the Research Coordinators, the Applied Ecologist, or the Bioacoustic Unit (BU) Manager, depending on the project.

The BU was established in 2015 as a collaborative initiative between the ABMI and the Bayne Lab at the Department of Biological Sciences at the University of Alberta; the AC is currently leading the ABMI's participation in the BU (Figure 8.1). The BU collects, analyzes, and reports on data collected on acoustic wildlife (such as birds and amphibians) across Alberta. It is the authority on best practices for using acoustic technology in the province, and offers a range of services to support the application of acoustic technology by the ABMI and other organizations.

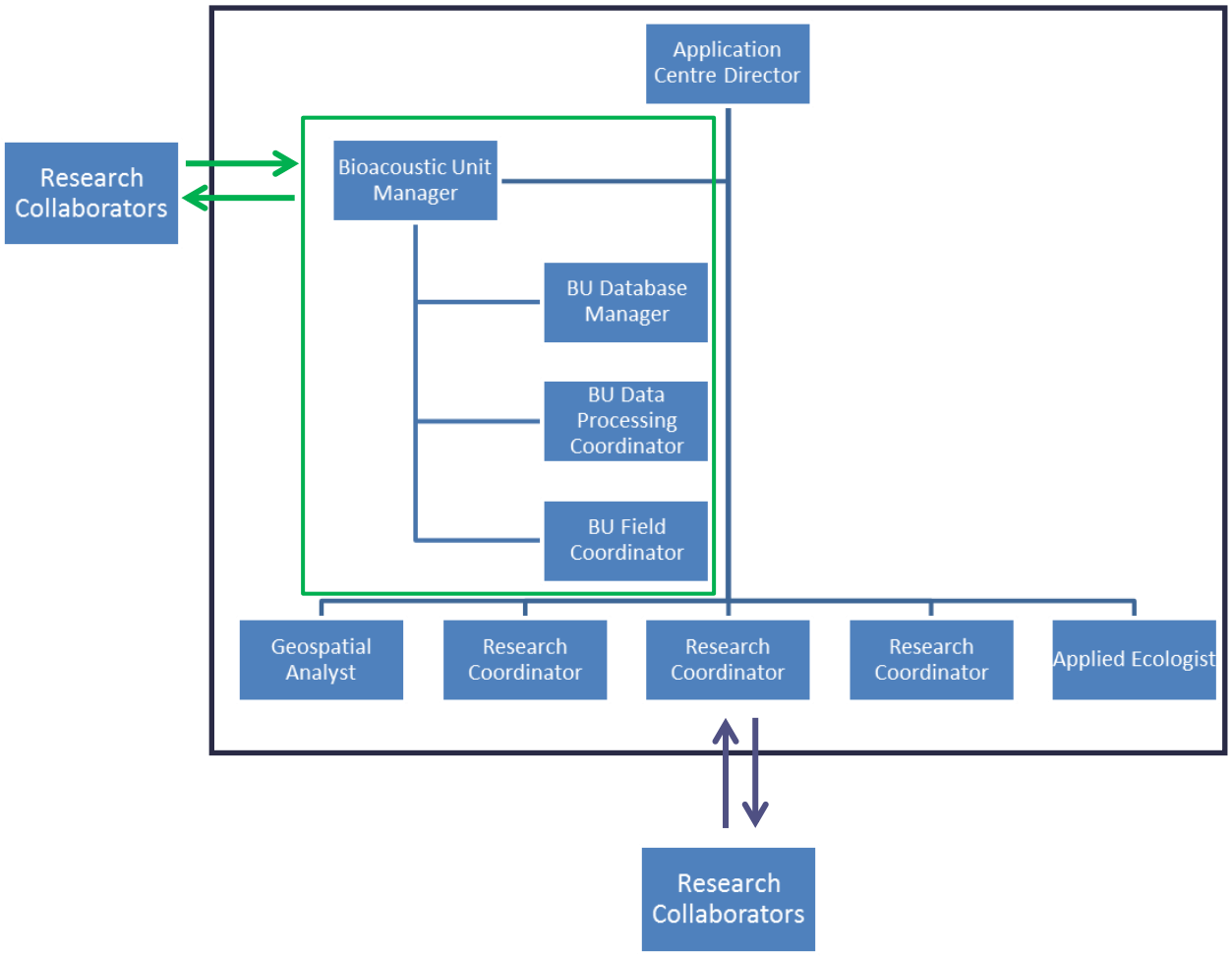

Figure 8.1. Application Centre organizational structure.

8.1.3 Staff Roles, Responsibilities, and Authorities

Error! Reference source not found. describes the current data tasks and associated quality management activities for current AC projects and the responsibilities of AC personnel.

Personnel	Data Task	Technical Activities	Responsibility
All Research Coordinators	Manage contractor services	Manage data-related contractor services, including setting data quality standards	Approve contractor services
All Research Coordinators & Managers	Manage technical contributions of contractors and collaborators	Develop work plan/deliverables; monitor progress; review invoices/deliverables to ensure they meet data quality objectives set out in grant or contract agreements	Recommend approval of deliverables and invoices to AC Director
All AC members	Data storage & back up	Regularly-scheduled (weekly) data back-ups to ABMI server	Complete update weekly
All Research Coordinators, Applied Ecologist, GIS Analyst, Research Collaborators	Processing ABMI GIS data	Process or combine ABMI layers using ArcGIS or R for project-specific analyses and develop metadata	Complete data processing and associated metadata
All Research Coordinators & Collaborators	Production of technical reports and papers	End products of data analysis; external expert review	Submit completed report to ABMI Document Archive
All Research Coordinators, Applied Ecologist, GIS Analyst	Use of external data	Review and evaluate standards provided for externally created datasets	Confirm data for use in applied research projects
Ecosystem Services Assessment (ESA) Research Coordinator	Code ESA models	Write and annotate model code, write detailed model documentation, and publish methods in peer-reviewed journal	Maintains updated code and model documentation
ESA Research Coordinator	Support web portal	Incorporate Netlogo models into online portal	Oversees model implementation in web portal
Ecological Recovery Monitoring (ERM) Research Coordinator	Train field staff	Arrange for technical training for field data collection	Oversees field staff training
ERM Research Coordinator	Collect field data	Collect species, soil, habitat data in the field; governed by project-specific protocol	Develops and maintains protocols, oversees field data collection
ERM Research Coordinator	Soil sample processing	Send soil samples to lab for processing; governed by project-specific protocol	Oversees sample transfer and return and management of sample data
ERM Research Coordinator	Lichen and moss sample processing	Provide samples to ABMI Processing Centre	Oversees sample transfer and return and management of sample identifications
ERM Research Coordinator	Collect remote sensing data	Fly Unmanned Aerial Vehicles over sites and collect multi-spectral data	Oversees collection of remote sensing data by collaborators
ERM Research Coordinator	Collect crop yield data	Collect yield data from farmers; match to site location	Collates and reviews crop yield data from farmers

ERM Research Coordinator and Ecologist	Compile data from all sources into database	Combine crop, remote sensing, field, and site coordinate data into ERM database, check for errors and omissions	Confirms completion of database
GIS Analyst	Verification of ERM site locations	Compare field notes with GIS coordinates	Confirms site locations
Beef & Biodiversity Research Coordinator	Producer Surveys	Collect grazing management practice information from farmers	Oversees data collection and collation
Beef & Biodiversity Research Coordinator	ARU deployment	Deploy Automated Recording Units (ARUs) to collect sound recordings at field locations	Oversees field data collection with support from the Bioacoustic Unit
Beef & Biodiversity Research Coordinator	Compile Data	Combine ABMI biodiversity data, producer survey data, ARU data, GoA data, and AAFC data into database	Confirms completion of database
BU Field Coordinator and Database Manager	Automated Recording Unit (ARU) preparation	Test microphones and firmware to ensure recorders are functioning properly	Confirms ARUs are functioning properly
BU Field Coordinator and Database Manager	Automated Recording Unit (ARU) deployment	Program units and deploy to site locations	Confirms accurate programming of ARUs and successful deployment
BU Database Manager	Data transfer and security	Download data from ARUs and update database; ensure adequate back-ups	Confirms completion of database and back-ups
BU Database Manager	Data QAQC	Check for missing files; correct file names; flag corrupt files; confirm file data matches expectations based on deployment/retrieval data sheets	Confirms completion of QAQC
BU Database Manager	Data export to researchers/ABMI	Export tabular data and associated metadata to end-users	Confirms data for release
BU Data Processing Coordinator	Processing audio data (human listeners)	Identify bird & amphibian species from sound files and confirm IDs	Confirms completion of identifications
BU Data Processing Coordinator	Processing audio data (computer recognizer)	Identify bird & amphibian species from sound files with computer recognizers; QAQC with human verification	Confirms completion of identifications
Rare Plants Research Coordinator	Staff training	Arrange for detailed 2-week rare plant ID training, protocol training	Oversees field staff training
Rare Plants Research Coordinator	Field data collection	Survey plant communities, collect habitat data	Oversees field data collection
Rare Plants Research Coordinator	Data transfer	Download data, compile into database	Oversees & confirms data compilation is complete

Rare Plants Research Coordinator	Data QAQC	Check data for errors, missing values, etc.	Oversees & confirms completion of QAQC
Rare Plants Research Coordinator	Public release of data	Upload data to website. Submit rare plants observations to Alberta Conservation Information Management System (ACIMS).	Approves data for public release.

8.1.4 Technical Activities

All technical activities undertaken by the AC are described in Table 8.1.

8.1.5 Quality System Implementation:

The AC Director ensures that all applicable elements of the quality system are understood and implemented by providing:

- staff training;
- adequate resources for continuous implementation;
- quarterly reviews of staff performance;
- inclusion of quality management discussions at regular staff meetings;
- explicit quality management planning in project and staff work plans, service contracts, and grant agreements.

8.2 Element 2: Quality System Components

The AC uses the following quality management practices and tools to implement its quality system.

8.2.1 Quality Management Plan

The AC QMP describes the general processes that govern data management in the AC, including the policies and objectives and the technical and management activities required to meet them. AC staff will be encouraged by the AC Director to refer to the QMP on an ongoing basis. The AC QMP is approved by the AC Director.

8.2.2 Project Work Plans

The Project Coordinator or Manager of each AC project creates, in consultation with the AC Director, a project work plan. Project work plans specify project organization, goals, objectives and milestones, deliverables, scheduling, communications, personnel and responsibilities, and budget information. Data quality provisions include specifying how data-related activities and products are documented, including deliverables such as technical reports, databases, or data layers, and associated metadata requirements. Project work plans will identify the personnel responsible for quality management activities in each project and will align with individual staff work plans.

Project work plans are reviewed annually at a minimum, to track progress, ensure data quality provisions are being followed, and to assist future planning.

8.2.3 Standard Operating Procedures and Protocols

AC projects and units use technical protocols and SOPs specific to the needs of each project or unit (Table). This documentation ensures that data are collected and managed so that they are complete, consistent and of a known and acceptable quality.

Table 8.2. Standard Operating Procedures and Technical Protocols implemented by AC projects and units.

Project/Unit	Title	Year	Location *[URL if public, SharePoint or other storage location otherwise]*
ERM	Field protocol grasslands	2014	http://abmi.ca/home/publications/201-250/236.html?mode=detail&subject=reclamation
ERM	Field protocol forests	2014	http://abmi.ca/home/publications/351-400/354.html?mode=detail&subject=reclamation
ERM	Field protocol cultivated lands	2015	Currently held by AITF and Research Collaborators – a formal copy will be posted in publications in Winter 2016.
Rare Plants	Field protocol	2014	http://www.abmi.ca/home/publications.html?keyword=rare%20plants
BU	ARU Deployment	2015	http://bioacoustic.abmi.ca/wp-content/uploads/2015/09/Lankau_2015_ARU_Deployment_Protocol.pdf
BU	Data transfer and security	2015	BU staff; currently in preparation
BU	Data QAQC	2015	BU staff; currently in preparation
BU	Processing audio data (human listeners)	2015	BU Staff; currently in preparation
BU	ARU maintenance protocols for SM2 and SM3 models	2015	BU Staff; currently in preparation
BU	ARU Deployment and Retrieval Data Sheets	2015	http://bioacoustic.abmi.ca/wp-content/uploads/2015/09/BU_ARU_PickUp_Datasheet_2015.pdf
BU	ARU Settings File (SM2 and SM3 units)	2015	http://bioacoustic.abmi.ca/wp-content/uploads/2015/09/ARU-Settings.zip

8.2.4 Data and Model Documentation

Research Collaborators publish technical reports or peer-reviewed publications that document data collection methods or modelling procedures. The AC Research Coordinators, Applied Ecologist and GIS Analyst maintain documentation of interim data products or models in development, including but not limited to model code and data processing and analysis code (e.g., NetLogo, Python, R). When data or data products from AC projects are released to the public or to collaborators, they are accompanied by appropriate documentation, as determined in project work plans.

8.3 Element 3: Quality Training System

The success of the AC QMP depends on the commitment of the personnel who implement the program on the daily basis. Through its hiring and training process, the AC ensures that all staff involved with data management have the education, experience and on-the job training required to successfully implement the quality management system.

8.3.1 Personnel Qualifications

The AC makes every effort to recruit employees capable of meeting the education, experience, and technical skill requirements of AC projects and activities. Along with other ABMI Centres housed at the University of Alberta, the AC must follow and adhere to the University of Alberta staff hiring rules and regulations. Personnel qualifications are established by the Position Classification Plan, which describes the job specifications and the education and experience necessary to fill the position. The qualifications of all job applications are reviewed by the AC Director and at least two other AC staff members to ensure applicants meet the minimum job requirements. The AC Director and at least two staff members within the AC interview qualified applicants and assess their qualifications as they relate to the posted job description. It is the responsibility of the AC Director to ensure staff members who need specialized training receive it.

8.3.2 Personnel Training

The AC Director is responsible for ensuring personnel are qualified to perform their roles, including aspects related to the quality management system. As needs are identified by the AC Director or staff, resources are made available for training and professional development, including training related to quality management (e.g., courses, seminars, conferences).

8.4 Element 4: Contractor Requirements

The ABMI AC engages a diverse group of collaborators, including academic research collaborators, independent contractors, for profit enterprises, and not-for-profit organizations, to deliver its applied research projects and the services of the BU. Each AC project and unit has specific collaborator and contractor needs, and collaborators and contractors may be involved in any step of the data and reporting cycle, including collecting field data, processing samples, creating geospatial data, data analysis and interpretation, and reporting.

The AC ensures contractors and collaborators are providing data and data products of known and acceptable quality through the following general mechanisms.

8.4.1 Project Work Plans

The collaborative projects and the BU within the AC all establish long-term (multi-year, depending on duration of confirmed funding), and annual work plans that are used to define the research program of each project and unit. These work plans are used, in part, to define data needs and collaborator roles and

responsibilities. They form the foundation for collaborator contracts and grants (below) by formalizing project- or unit- specific expectations around data and data product quality and intended uses.

8.4.2 Contracts and Grants

The AC uses contracts and grants with Research Collaborators and service providers to define expectations for the quality of data to be delivered by collaborators according to the project work plan (above) and to assess delivered products against those expectations. Relevant documents include the following:

- ABMI Agreement Template;
- Contract for Services with Individuals or Small Businesses Template;
- ABMI Grant Template;
- ABMI Data Sharing Agreement Template.

The Research Coordinators and Managers are responsible for defining the quality standards and metrics, as per the project needs, in the grant or contract and evaluating the deliverables according to those criteria. The final authority on the content of grants and contracts and on the payment of grants and contract invoices is held by the AC Director.

8.5 Element 5: Documents and Records

AC Research Coordinators and Managers are responsible for identifying and maintaining documents and records pertaining to data quality and management as required for each AC project and Unit. The AC refers to existing standards documents for guidance on the creation of documentation of data and data activities. This includes the following:

- GIS data management: a metadata standards document for GIS data, specifying what information needs to be included in the metadata of a given spatial dataset, such as a short description of the data represented, descriptions of all attribute fields, spatial reference information (i.e. coordinate system), and administrative information (source, data-sharing limitations, file format, etc.). See "Ecosystem Services Assessment 2013. GIS Metadata and Model Documentation Standards and Guidelines" for further details.
- Models: Documentation of simulation models is guided by ODD ("Overview, Design, Details") protocol,[‡‡] adapted for the types of models that are currently being developed by the AC. This standard includes an overview of the model purpose and objectives, explanations of sub-processes comprising the model, and detailed information on variables (type, name, description,

[‡‡]Grimm et al. 2006. A standard protocol for describing individual-based and agent-based models. Ecological Modelling 198:115-126.

and units), data requirements, equations used in the model, and any other pertinent information to allow readers to understand and run the models.

- External data sources: When data are acquired from external sources, including research collaborators, data sharing agreements or Memoranda of Understanding (MOU) are established that describe the data being provided and any conditions of use.
- Technical reports: Technical reports created within the AC are sent out for expert review at the discretion of Research Coordinators, Manager and/or AC Director, to ensure reports receive independent and rigorous review when necessary.

8.6 Element 6: Information Management

The AC utilizes a range of software in various data applications, depending on the specific needs of each project. The most frequently used software applications include the following:

- Geographical Information Systems: ArcGIS and Python, QGIS;
- Statistical analysis and data manipulation: R Software for Statistical Computing, STATA, Microsoft Excel, Microsoft Access;
- Modelling software: NetLogo;
- Database software: Microsoft Access, Microsoft Excel, Oracle, SQL;
- ABMI Tablet Program;
- Audio File Processing and manipulation: SongScope, Raven, Audacity, Adobe Audition;
- BU Recording Equipment: ARUs manufactured by Wildlife Acoustics;
- Project Management: Basecamp.

All AC staff maintain up-to-date software installations as they are released by the software provider, after ensuring that new software updates will not impact existing workflows. Because the majority of AC projects are short-term and independent, there are limited implications of software changes for long-term data management and quality control. However, Research Coordinators are responsible for ensuring that software versions used to conduct analyses are recorded in all data reporting and metadata.

Recording equipment used by the BU (ARUs) are maintained according to the protocols listed in Table 8.2, including repairing/replacing damaged or worn components and ensuring the firmware and settings files are current. All units are tested annually to ensure they are functioning correctly.

The AC Director ensures resources are available for staff to maintain up-to-date software, as required, and to maintain and upgrade hardware as required.

8.7 Element 7: Systematic Quality Assurance Planning

The collaborative projects and the BU within the AC all establish long-term (multi-year, depending on duration of confirmed funding), and annual project work plans that are used to define the research

program of each project and unit. These work plans formalize project- or unit- specific expectations around data and data product needs, acquisition, quality, quality assessment, and intended uses.

Depending on the nature of the project, long-term and annual project work plans outline the data operations for planned activities, including the following:

- project goals, including those related to data collection and data use;
- identification of project schedule, resources (including budget), and milestones;
- roles and responsibilities of AC staff, other ABMI staff and Research Collaborators as they pertain to data collection and management;
- expectations for data quality and related assessment methods and performance criteria, and;
- descriptions of planned data analyses and evaluations.

The AC is currently drafting a procedure for archiving completed projects.

In addition to project work plans, all AC personnel develop an annual personal work plan specifying their tasks for the year, including data activities and quality management.

8.8 Element 8: Quality Implementation of Work Processes

The AC Research Coordinators, GIS Analyst, Applied Ecologist and BU Manager are all responsible for ensuring that work is performed according to project work plans, that appropriate protocols and SOPs are in use or being prepared as required for each project, and that Research Collaborators are fulfilling their obligations under the executed contract or grant.

Annual personal work plans for each employee state their role in data quality management activities, including how much time they will allocate to each task. Personal work plans must align with project work plans to ensure all project objectives, including data quality management tasks, have sufficient staff resources to be completed.

8.9 Element 9: Quality Assessment and Response System

On an annual basis starting in 2016, the AC will convene under the leadership of the AC Director to review and assess the adequacy of the quality management system, including a review of the QMP. Both noteworthy actions or processes and areas for improvement will be identified. The outcome of this meeting will be a plan that outlines necessary actions, staff accountability, and expected implementation timelines for responding to identified issues with the quality management system.

Technical data quality management system reviews will be conducted in the course of reviewing and renewing annual project work plans, under the leadership of the Research Coordinator or Manager. Previously identified data quality objectives and assessment methods will be reported on by the individual responsible for data activities, and reviewed by the project team. Identified improvements to the project-

specific data quality management system and a plan for implementation will be documented in the subsequent project work plan.

8.10 Element 10: Commitment to Quality Improvement

All AC staff are encouraged to participate in the quality assessment processes identified above. In addition to internal AC processes, AC personnel seek out best practices for data quality management activities through communications with other ABMI centres, through both informal discussions as well as formal processes such as Data Management Committee meetings.

Appendix 1.0 MC Non-protocol Related Training

The following table lists the AITF safety training documents that staff are instructed on.

Table A1.1. List of ABMI Monitoring Centre safety training SOPs.

SOP Title	ABMI Centre	Last Update	Applicable Region *
Trucks and 4x4	Monitoring Centre	2015	All
Trailer	Monitoring Centre	2015	All
Winching	Monitoring Centre	2015	North
Working with Helicopters	Monitoring Centre	2015	Remote
Loading ATVs on Trailers	Monitoring Centre	2015	North
Loading on top-decks	Monitoring Centre	2015	North
Loading Snowmobiles on Trailers	Monitoring Centre	2015	North
Loading Argos on Trailers	Monitoring Centre	2015	North
Camping in Remote Areas	Monitoring Centre	2015	Remote
Chainsaws	Monitoring Centre	2015	North Full-Time Staff Only
Communications in the Field	Monitoring Centre	2015	All
Working Alone	Monitoring Centre	2015	All
Inflatable Boats	Monitoring Centre	2015	Wetland Crews
Field Safety Checklist	Monitoring Centre	2015	All
Navigation and Compass	Monitoring Centre	2015	All
GPS and Trimble Use	Monitoring Centre	In progress.	All
Private Land Access	Monitoring Centre/ IC	In progress.	All
AITF Corporate Policies	Monitoring Centre	In progress.	All
Biohazards	Monitoring Centre	2015	All

*These values are a general guideline only with numerous exceptions for specific regions, sites, season and a crew's assigned equipment.

The following table lists the safety training courses that are certified through third-party organizations. Certificates are issued and kept on record for a minimum of 2 years.

Table A1.2. MC training courses.

External Training*	ABMI Centre	Company Name	Certificate Course (Y/N)	Requires Period Renewal (Y/N)	Protocols or Region Training is Required For.**
Flat Water Paddling	Monitoring Centre	Paddle Canada	Y	N	Wetlands
ATV	Monitoring Centre	Alberta Safety Council	Y	Y	North
ARGO	Monitoring Centre	Alberta Safety Council	Y	Y	North Full-time Staff
Bear Awareness and Avoidance	Monitoring Centre	Alberta Safety Council	Y	N	North

Fire Safety	Monitoring Centre	Danatec	Y	N	All
H2S Aware	Monitoring Centre	Danatec	Y	N	North
Defensive Driving	Monitoring Centre	Danatec	Y	N	All
Wilderness First Aid	Monitoring Centre	Inroads Mountain Sports	Y	Y	Remote
Standard First Aid	Monitoring Centre	St. John's Ambulance	Y	Y	All
Snowmobile	Monitoring Centre	Alberta Safety Council	Y	Y	North Winter
WHIMIS	Monitoring Centre	Danatec	Y	Y	All
TDG	Monitoring Centre	Danatec	Y	Y	Wetland
Avalanche	Monitoring Centre		Y	Y	Winter site-specific
ATV Instructor	Monitoring Centre	Alberta Safety Council	Y	Y	North – 1 per Field Base or Contractor
ARGO Instructor	Monitoring Centre	Alberta Safety Council	Y	Y	As Needed
Bear Awareness Instructor	Monitoring Centre	Alberta Safety Council	Y	Y	North – 1 per Field Base or Contractor
Flat Water Paddling Instructor	Monitoring Centre	Paddle Canada	Y	Y	Wetland – 1 per Field Base or Contractor
Pleasure Craft Operator	Monitoring Centre	BOATsmart	Y	N	As Needed
Driver License	Monitoring Centre	Government of Alberta	Y	Y	All
H2S Alive	Monitoring Centre	Enform	Y	Y	As Needed
OSSA	Monitoring Centre	Keyano College	Y	Y	As Needed
CSTS	Monitoring Centre	Keyano College	Y	Y	As Needed

*Records of training are kept on file

** These values are a general guideline only with numerous exceptions for specific regions, sites, season and a crew's assigned equipment. Field Coordinators will use their experience and judgement to determine which courses are needed by specific staff and, when in doubt, will give additional training.

Appendix 2.0: Terms of Reference for Data Management Committee

Terms of Reference

ABMI Data Management Committee

September 2014

1. Proposal

It is proposed that the Alberta Biodiversity Monitoring Institute (ABMI) form a standing Data Management Committee to assist in the improvement of ABMI's data quality management.

2. Objective

The Data Management Committee's goal is ensure proper data organization, management, and delivery. In order to accomplish this, the committee is responsible for identifying and understanding ABMI's data management needs; developing strategies to improve data management shortcomings within ABMI; and implementing new policies and processes relating to any of the data services provided by the Institute.

3. Committee Membership

The Data Management Committee is comprised of representatives from all ABMI Centres. Two permanent members and one alternate will represent each Centre. The alternate will attend the meetings when one or both of the permanent members are not available. Members are expected to participate in at least three meetings per year. If a permanent member cannot attend the meeting, it is their responsibility to contact their Centre's alternate and make the necessary arrangements.

All members will be expected to come prepared for the meetings, having done preliminary readings/work when applicable.

Each of the permanent members is accountable for sharing the recommendations made by the Data Management Committee with their respective business units. It is also their responsibility to represent their business unit's interests within the committee.

Execution and implementation of workplans, strategies, or processes developed by the Data Management Committee will remain the responsibility of individual business units. Ultimately, it will fall on ABMI Executive Team to decide whether or not to follow the committee's recommendations.

4. Timeline/Schedules

The Data Management Committee will meet 3 times a year, but other meetings may be scheduled if the need arises.

Meeting will happen in September, January, and April. Tentatively all meetings will be scheduled on the 2nd Monday of each month.

5. Deliverables

Every 2 years, as part of the first meeting of the season (September), the committee will brainstorm a list of ABMI's current data management needs. These needs will be ordered and prioritized based on the members' assessment and 1 or 2 topics will be selected to be addressed in the coming year.

Achieving resolution for the selected topics will become the committee's primary mandate for the year, and meetings will be prioritized to discuss actions related to those topics.

6. Meeting Structure

- Members will alternate taking meeting minutes.
- Minutes should always include major decisions and recommendations made by the committee, specific action items agreed by the team and individual accountability for completing the assigned tasks.
- Emphasis in the agenda will be to discuss the topics/needs selected.
- Agendas will be standardized and produced by the committee Chair.
- All members are welcome and encouraged to add topics to the agenda, by contacting the Chair.
- All agenda updates need to be done at least 24hrs before the meeting, no additional information will be added to the agenda after that.

Appendix 3.0: Preparation of Standard Operating Procedures

Title: Guidance for Preparing Standard Operating Procedures
SOP Document Number: ABMI-IC-SOP-001
Version Number: 1.3
Date: 08/07/2013

Approvals

Version Number 1.1

Approved by: Jim Herbers _____ Date:
(Information Director)

Approved by: Jillian Kittson _____ Date:
(Information Coordinator)

Approved by: _____ Date:
(Domain Expert – Joan Fang)

Revision History Log

Version #	Revision Date	Author	Changes
1.0	05/05/2011	Katherine Maxcy	Drafted
1.1	05/10/2011	Katherine Maxcy	Integrated edits/comments from Jim Herbers
1.2	11/16/2011	Jillian Kittson	Document Approval/minor edits
1.3	08/07/2013	Jillian Kittson	Document Review/Edit storage, archive, and review sections/Approval

1. Introduction

As a world class monitoring program, the Alberta Biodiversity Monitoring Institute (ABMI) is an integral part of the environmental monitoring system in the province of Alberta. The ABMI's integrity and credibility as an institution depends highly on its ability to provide timely, efficient, and open access to quality data. The Information Centre (IC), as the data custodian for the ABMI, is principally responsible for managing and storing the data collected by the various data authorities (e.g., ABMI Monitoring Centre and Processing Centre at the Royal Alberta Museum), and disseminating this data to end-users, including the ABMI Science Centre and public users of the data via the ABMI website. The IC is responsible for data quality management.

As part of the IC's overall quality management system, a series of Standard Operating Procedures (SOPs) are required to provide a systematic approach to verify and validate that ABMI data is of an acceptable quality. This document provides guidance for the preparation of ABMI IC SOPs associated with data management processes and portal operations.

1.1. Overview

An SOP is a set of written instructions that describe routine or repetitive work processes performed by an organization (EPA 2007). The development and consistent use of SOPs provide employees with the information to perform a job properly, thereby promoting consistency in the quality and integrity of the end-result; in this case, ABMI data and associated products (EPA 2007). As part of an overall quality assurance framework, a system of SOPs is necessary to achieve overall data quality goals and objectives (Montana Water Quality Planning Bureau 2004). The series of SOPs produced and maintained by the ABMI's IC provides a systematic approach to verify and document that ABMI biodiversity data is consistent, complete, and of known acceptable quality.

1.2. Purpose

This guidance document describes the structure, format, and content requirements of SOPs used to guide work processes associated with ABMI data management. Included as part of this guidance document are:

- guidelines for determining which work processes require SOPs;
- requirements for SOP review and approval;
- frequency of revisions and reviews;
- document control;
- tracking and archiving; and
- SOP format.

2. SOP Process

2.1 SOP preparation

SOPs are written sets of instructions detailing procedures for all of the IC's routine and/or repetitive data management tasks (e.g., data loading procedures to the ABMI database). These instructions are summarized in a concise, simple step-by-step format, yet with sufficient detail to allow the procedure to be successfully performed by a qualified person new to the task. Flow charts or work flow diagrams are used whenever possible to illustrate the process(es) being described.

The ABMI Information Director, Information Coordinator, or domain experts (e.g., data programmers) will identify the need for an SOP. Domain experts (i.e., a person experienced with the procedure and the organization's structure) prepare the SOP. A team approach may be used for multi-tasked processes where the experiences of a number of individuals are required. Before developing a new SOP, consultation must occur with the appropriate ABMI staff and domain experts to review the needs and requirements for the SOP.

2.2 SOP Review, and Approval

SOPs must be reviewed and accepted by domain experts who perform the work and use the process. Ideally, the SOP is tested by domain experts during the review process to ensure the appropriate level of detail has been provided for in the SOP. A second party (e.g., Information Coordinator) must also review the SOP for completeness. Finally, a third level of review is performed by the Information Director to verify that the SOP complies with data quality management guidelines, and has sufficient quality controls to meets the objective(s) of the procedure. Before the SOP is finalized, approval is required by the Information Director.

Signature approval indicates that an SOP has been both reviewed and approved by management. The title page for each SOP requires three levels of review and acceptance: domain expert, Information Coordinator, and IC Director.

2.3 SOP Frequency of Revisions and Reviews

To be useful, SOPs need to be current; therefore, SOPs need to be updated and re-approved whenever procedures change. Revised SOPs will be indicated by the date/revision number on the title page.

SOPs will be systematically reviewed every year to ensure that procedures remain current and appropriate. The review date will be added to each SOP following the review. If an SOP describes a process that is no longer followed, the SOP will be withdrawn from the active file and archived.

The annual review will be scheduled and controlled by the Information Coordinator in the IC. The Information Coordinator may review the SOP or assign the task to a domain expert.

2.4 Document Control

The SOP numbering system has been developed for the ABMI IC specifically, but could be expanded to the other Centres of the ABMI (e.g., Monitoring Centre, Science Centre) if required. The SOP numbering system for the ABMI begins with this same abbreviation "ABMI". This is followed by a dash and a two-letter abbreviation for the Centre that is preparing the SOP and that is also the primary user of the SOP, including:

- AC – Application Centre
- IC – Information Centre
- MC – Monitoring Centre
- PC – Processing Centre
- SC – Science Centre

After the Centre identifier, a dash is entered followed by three digits ranging from 001 to 999, allowing for 999 Centre SOPs and a total of 4995 ABMI SOPs. See the SOP identification number of this report located at the top right hand corner of the page as an example. This report is given the number ABMI-IC-SOP-001 which fully translates to the Alberta Biodiversity Monitoring Institute (ABMI) - Information Centre (IC) – Standard Operating Procedure (SOP) - 001. The SOP naming convention distinguishes ABMI SOP documents from other documents produced by the ABMI.

Below the SOP identification number is the Version number (Version #). The version number will be tracked and changed, as necessary, by the Information Coordinator when the SOP is approved. Major revisions are indicated by the next whole number (e.g., Version 2.0, 3.0, 4.0 …). These revisions will be tracked using a revision history log which must be filled in whenever an alteration to the version number is made (including approval for the first time). Version numbers can also increase incrementally as indicated by the decimal place in the Version # (e.g. Version # 1.1, Version # 1.2, etc.) for minor modifications to the SOP. Overall, the version number allows the Information Coordinator to track the number of times a procedure has been revised; it also allows the user to verify that the current SOP is not a draft.

Below the Version # is the date the SOP was revised. As required by the ABMI's Quality Management Plan, SOPs will be reviewed annually. A record of these revisions is tracked using the Revision History Log located at the beginning of the document. This revision history allows the Information Coordinator to schedule annual reviews. It also allows users to determine if the SOP is current.

The final piece of document control information included in an SOP is page numbering. The current page and total number of pages must be included to ensure users can verify that the SOP is complete.

2.5 SOP document storage and archival system

Storage of SOPs, including current versions, old versions, and SOPs no longer in use, is managed by the Information Coordinator. The Information Coordinator is responsible for ensuring that the most recent version of each SOP is used and made available for use on the ABMI SharePoint Page (ABMI Home -> Shared Documents -> Standard Operating Procedures). The Information Coordinator will maintain copies of all SOPs (active versions, archived versions and SOPs no longer in use) on their computer in the Information Centre and on the ABMI file server at:

\\abmi-fs-srv.biology.ualberta.ca\Abmi_data\abmiserver2\D drive\SOPs for auditing purposes or for historical review. Electronic access is limited to a read-only format, thereby protecting against unauthorized changes made to the document.

A master list of all SOPs is maintained by the Information Coordinator. This file indicates the SOP number, version number, date, title, author, status, and any other important information about previous versions. Annual review of SOPs will be tracked with electronic reminders sent to the Information Coordinator email address.

2.6 SOP coordination and management

The Information Coordinator is responsible for managing the SOP system including:

- overseeing the development and review of IC SOPs;
- developing an SOP awareness and training system (as outlined in the Quality Management Plan [ABMI-IC-QMP 2013]) the intent of which is to ensure all IC personnel are trained in QA procedures, and that the QC activities as described in the SOPs are adhered to;
- performing periodic audits of SOPs to monitor and improve quality control operations;
- developing and managing the SOP document storage and archival system;
- developing and managing a SOP tracking system.

3. SOP Format

A consistent format is used for ABMI SOPs to ensure ease and efficiency of use. While the format can be adapted depending on the work process that is being described, all SOPs must contain these sections:

1. Introduction – a brief introduction to the work processes being described in the SOP
2. Summary of procedure – a brief description of the SOP and its purpose, and a point form list of steps associated with the procedure
3. Personnel responsibilities – in order to ensure the SOP is followed and enforceable, roles and responsibilities associated with specific tasks in the SOP are assigned to project managers. This is important to ensure that there is data accountability at all stages of the data management process (Martin and Ballard 2010).
4. Software requirements – given data management is largely a digital process, there are a number of pieces of software that may be used for data management tasks. A list of software requirements associated with a particular procedure must be listed.
5. Procedures – broken down into a series of steps, instructions for each task within a step are fully described in point form. Included in the series of steps are tasks specifically related to quality control activities. Quality assurance activities are always included as the last step in the Procedures section.
6. References – list of all literature and reports cited in the SOP.

A “Definitions” section is helpful to the implementation of SOPs.

4. References

ABMI-IC-QMP. 2011. Quality Management Plan – Data Processing. Version Number 1.0.

EPA (Environmental Protection Agency). 2007. Guidance for preparing Standard Operating Procedures (SOPs). EPA QA/G-6. Report available at: www.epa.gov/quality.

Martín, E. and G. Ballard. 2010. Data Management Best Practices and Standards for Biodiversity Data Applicable to Bird Monitoring Data. U.S. North American Bird Conservation Initiative Monitoring Subcommittee. Online at http://www.nabci-us.org/.

Montana Department of Environmental Quality. 2004. Guidance for preparing a standard operating procedure. Report available at: http://www.deq.mt.gov/wqinfo/qaprogram/sops.mcpx.

Appendix 4.0: Current and Completed Application Centre Projects

Ecosystem Services Assessment

Ecosystem services are benefits we receive from nature that support our health and well-being. These ecosystem services directly support many of our industries, including forestry, crop production, and cattle ranching; provide recreational outdoor activities; and make our communities more livable places. Despite this importance, many ecosystem services are difficult to measure and their economic value is difficult to assess. The Ecosystem Services Assessment (ESA) project is developing a system to assess and map the supply and value of several ecosystem services across Alberta: forest timber production, water purification, crop pollination, rangeland forage production, carbon storage, and biodiversity. Using the ABMI's specialized ecological knowledge and expertise, the ESA project is enhancing and creating knowledge to help us understand ecosystem service supply and how planning and management decisions affect the landscape and increase benefits to Albertans.

www.ecosystemservices.abmi.ca

Rare Plants Monitoring in the Lower Athabasca

To understand the status and distribution of elusive plant species in the Lower Athabasca region of Alberta, the Rare Plants project, led by Dr. Scott Nielsen at the University of Alberta, has designed techniques for surveying these rare species. The project is using a modeling and adaptive sampling approach to map habitats where rare plants are most likely to be found, and that information is then used to prioritize sampling in those areas.

http://abmi.ca/home/projects/applied-research-projects/rare-plant-monitoring.html

Rare Animals Monitoring in the Lower Athabasca

The ABMI's core biodiversity monitoring program tracks changes in groups of common plants and animals in order to understand how their populations might be changing over time. We also measure a variety of habitat characteristics and determine how our human footprint is changing over time, in order to identify relationships between human land use, habitat and species abundance, when and where they exist. But the core biodiversity monitoring program isn't optimized for tracking changes in the populations of species that are rare or elusive – these species often aren't fully captured by our core monitoring efforts. So, the ABMI's Rare Animals project was designed to address this gap.

The project was originally conceived and initiated through the Ecological Monitoring Committee for the Lower Athabasca (EMCLA). The EMCLA, a consortium of oil sands companies, government ministries and agencies coordinated by the ABMI, was established in 2010 with the goal of designing cost-efficient protocols to monitor rare and elusive vocalizing species – species that make sounds. The project is focused on several vocalizing species: owls, amphibians, and a secretive marsh bird, the Yellow Rail, which is a species of Special Concern in Canada. The overall aim of the monitoring program is to

understand these species' status, habitat preferences, and distribution across the Lower Athabasca region.

http://abmi.ca/home/projects/applied-research-projects/rare-animal-monitoring.html

Bioacoustic Unit

A collaboration between the ABMI and the Bayne Lab at the University of Alberta, the Bioacoustic Unit actively collects, analyzes, and reports on data collected on acoustic wildlife across Alberta. It is the authority on best practices for using acoustic technology in the province, and offers a range of services to support the application of acoustic technology by other organizations.

http://www.bioacoustic.abmi.ca

Ecological Recovery Monitoring Project

To understand the ecological status of reclaimed wellsites in Alberta, the ABMI's Ecological Recovery Monitoring (ERM) Project is designing a long-term monitoring program. The program will assess ecological recovery of certified reclaimed oil and gas wellsites across the province and determine how long wellsites in different types of ecosystems take to recover and become functioning ecosystems.

http://abmi.ca/home/projects/applied-research-projects/ecological-recovery-monitoring-project.html

Biodiversity Assessment of Alberta's Beef Industry

The project uses existing biodiversity data collected as part of the ABMI's long-term monitoring program, as well as spatial land cover information from ABMI's Geospatial Centre, Alberta Environment and Parks, and other sources, to assess observed biodiversity patterns in relation to different land cover and management factors in Alberta's grazing lands. Information on grazing regimes will be collected by conducting producer surveys about grazing management practices. The project also uses existing rangeland health inventory data and will be collecting new rangeland health data in order to examine how biodiversity data relates to assessments of rangeland health.

http://abmi.ca/home/projects/applied-research-projects/beef-and-biodiversity.html

Biodiversity Management and Climate Change Adaptation (Completed 2015)

Alberta's climate is becoming warmer, drier and more variable. Our goal is to develop essential knowledge and tools to support the management of Alberta's biodiversity, our species and ecosystems, in a changing climate. Identifying the potential impacts of climate change on Alberta's species, ecosystems and human communities and incorporating that knowledge into today's decisions about land use, natural resource and species management can help avoid the need for ineffective, and potentially costly, actions in the future.

www.biodiversityandclimate.abmi.ca