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14. ABSTRACT
This Reclamation Science & Technology Program research project sought to modernize field data collection and advance data management via a centralized online database. The research evaluated standardized mobile application data collection and online data storage for several condition assessments—coatings, cathodic protection, hazardous materials, and mechanical—so that robust and accessible inventories can be built. The team successfully developed, tested, and implemented a GIS inspection tool. The new Materials and Corrosion Asset Inspection tool streamlines field data collection via mobile device and improves standardization for several inspection types performed across Reclamation. Overall, the Materials and Corrosion Asset Inspection tool provides as a proof-of-concept, promoting a user-friendly geospatial method of data collection, storage, and interaction. The online data management tool's report feature exports records into an editable format to aid report development. Further, the online database can be incorporated into future anticipated enterprise systems.

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Mission Statements

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Peer Review

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Acronyms and Abbreviations

AGOL	ArcGIS Online
AMD	Asset Management Division
App	Application
BORGIS	Bureau of Reclamation Geographic Information System
CARMA	Capital Asset Resource Management Application
CAP	Central Arizona Project
DOI	Department of the Interior
eGO	Enterprise Geospatial Operations
FY	Fiscal year
GAA	Geographic Applications and Analysis
GIS	Geographic information system
IT	Information technology
MCL	Materials and Corrosion Laboratory
MICA	Mobile Information Collection Application
MIPR	Military Interdepartmental Purchase Request
Reclamation	Bureau of Reclamation
RGIS	Reclamation GIS
S&T	Science and Technology
TSC	Technical Service Center
USACE	U.S. Army Corps of Engineers
UT	Ultrasonic thickness
VPN	Virtual private network

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Executive Summary

The Bureau of Reclamation (Reclamation) performs inspections of its infrastructure to ensure that adequate corrosion protection is being achieved and to determine the presence of hazardous materials that may be encountered during construction projects. Historically, approaches for in-field documentation during these inspections followed the inspector's preference, with many utilizing pen-and-paper together with a device for photo-documentation. The use of smartphones or tablets as the sole instrument is becoming increasingly common. However, with a lack of standardization or online repositories, it can be difficult to review inspection reports across facilities or agencies to obtain and analyze parallel data.

This Reclamation Science & Technology (S&T) Program research project sought to identify opportunities to modernize field data collection and advance data management via a centralized online database. The research evaluated the usefulness and appropriateness of centralized data storage for several asset inspections—coatings, cathodic protection, hazardous materials, and mechanical—so that robust and accessible inventories can be built. The first step was a review of current application-based inspection tools and inspection data to develop standardized data templates to be used during field inspections. The second step developed an ArcGIS Survey123 software application (app)-based tool with geographic information systems (GIS) for centralized storage and access to inspection data. Centralized storage allows for data query and possible implementation of inventory analyses, such as for condition-based maintenance. The final activity was beta and delta testing to finalize the Survey 123 tool and facilitation of tool implementation.

The project team and partners include specialists from Reclamation's Materials and Corrosion Laboratory (MCL), Geographic Applications & Analysis (GAA) group, Asset Management Division, and Power Resources Office, as well as field partners, including specialists from the U.S. Army Corps of Engineers (USACE) and the Central Arizona Project (CAP). Reclamation's MCL provided the primary input for the survey tool development with the GAA group executing the development.

Table ES-1 provides the online locations of the Survey123 Materials and Corrosion Asset Inspection tool components and related information, e.g., links for users to create a new ArcGIS Online (AGOL) account. The Survey123 app tool is available to Reclamation AGOL users and a link to information is given for non-Reclamation partners interested in using the tool. Access to the resulting Survey123 data tab is limited to members within the user group and member privileges can be adjusted here.

Table ES-1.—Weblinks to app-tool, AGOL tools, and useful sites; the tool, user group, data tab, and USACE AGOL require login

Description	Weblink	Comments
Survey123 App-based Tool*	https://survey123.arcgis.com/share/871e80e60a5443d992358cfba18a7518?portalUrl=https://USBR.maps.arcgis.com	Link to Survey123 tool to document inspection data; install on mobile device using app if possible; if prompted, use organization URL, enter "usbr" (for Reclamation users).
User Group^	https://usbr.maps.arcgis.com/home/group.html?id=f12dc5c4967940718fc6861eda77395a&view=list#content	Online community for survey tool users with general information for use; contact Adam Ricks or Greg Gault for support.
Survey123 Data tab^	https://survey123.arcgis.com/surveys/871e80e60a5443d992358cfba18a7518/data	The Survey123 Data tab allows users to see submitted surveys and generate reports for selected records.
Create Account	https://usbr.maps.arcgis.com/home/index.html	Link for DOI users to create an AGOL account.
Partner Info	https://intra.usbr.gov/borgis/agolstart.html#collab	Instructions for partners to gain access to AGOL system for collaboration.
USACE AGOL	https://usace.maps.arcgis.com/home/signin.html?returnUrl=https%3A%2F%2Fusace.maps.arcgis.com%2Fhome%2Forganization.html	Link for USACE AGOL site to determine if user has an account.
Authenticator	https://intra.usbr.gov/borgis/docs/mobile/EsriApp_MSAuthenticator_LoginQuickGuide.pdf https://intra.usbr.gov/borgis/docs/mobile/SetupMSAuthenticator_IndividualDevice.pdf https://intra.usbr.gov/borgis/docs/mobile/SetupMSAuthenticator_SharedDevice.pdf	Instructions for how to use Microsoft authenticator to open the installed Survey123 app on a mobile device (3 links provided).

*See Appendix A for a graphic flowchart to guide Survey123 installation and use on mobile device.
^Accessible only to AGOL users that are members of the user group.

The research progressed beyond the initial goal of investigating and making recommendations for GIS inspection tools for centralized data storage. Instead, the team successfully developed, tested, and implemented a GIS inspection tool. The new Materials and Corrosion Asset Inspection tool will streamline field data collection for several inspection types performed across Reclamation.

Overall, the Materials and Corrosion Asset Inspection tool serves as a proof-of-concept of the power of GIS data collection and storage tools. The tool promotes a user-friendly geospatial method of data collection, storage, and interaction.

1.0 Introduction

The Bureau of Reclamation (Reclamation) performs inspections of its infrastructure to ensure that adequate corrosion protection is being achieved and to determine the presence of hazardous materials that may be encountered during construction projects. Common inspections related to corrosion protection include assessment of coatings and linings, cathodic protection systems, and ultrasonic thickness (UT) testing for corrosion losses, i.e., mechanical integrity. Corrosion is defined as the degradation of the structure properties, and the purpose of inspections is to collect data to aid decision-making for maintenance and repair of such degradation. The ultimate goal of corrosion inspections is to prevent further degradation of Reclamation's steel structures and the expensive repairs that result from corrosion. Hazardous materials surveys are conducted to determine the presence of any hazardous materials (e.g., asbestos or lead) that may be encountered during project work, such as coatings removal. Knowledge of the hazardous materials present for a project improves project cost estimation (e.g., budgeting for an asbestos abatement), promotes worker safety, and ensures that all proper federal, state, and local environmental regulations are followed.

Historically, approaches for in-field documentation during these inspections followed the inspector's preference, with many utilizing pen-and-paper together with a device for photo-documentation. The use of smartphones or tablets as the sole instrument for recording inspection data is becoming increasingly common. However, with a lack of standardization or online repositories, it can be difficult to review inspection reports across facilities or agencies and obtain parallel data.

Figure 1.—Inspection team evaluating siphon pipe interior coatings using traditional data collection approaches.

This research sought to identify opportunities to modernize field data collection and advance data management via a centralized online database. The research evaluated the usefulness and appropriateness of centralized data storage for several condition assessments—coatings, cathodic protection, hazardous materials, and mechanical—so that robust and accessible inventories can be built. The first step was a review of current application-based inspection tools and inspection data to develop standardized data templates to be used during field inspections. The second step developed a software application (app)-based survey tool with geographic information systems (GIS) for centralized storage and access to inspection data. Centralized storage allows for data query and possible implementation of inventory analyses, such as for condition-based maintenance. The final activity was beta and delta testing to finalize the Survey 123 tool and facilitation of tool implementation.

The project team and partners include specialists from Reclamation's Materials and Corrosion Laboratory (MCL), Geographic Applications & Analysis (GAA) group, Asset Management Division, and Power Resources Office, as well as field partners, including specialists from the U.S. Army Corps of Engineers (USACE) and the Central Arizona Project (CAP). Reclamation's MCL provided the primary input for the survey tool development with the GAA group executing the development. Partners supported all stages of the process, including:

- Discussing capabilities, strengths, and weaknesses of existing app-based inspection tools,
- Sharing ongoing and upcoming app-based or inspection-related research efforts,
- Establishing meaningful goals for the research project,
- Reviewing research progress, providing input on research decisions, and giving feedback on the tool under development.

The project team and partners have a joint interest in developing this guidance into tools that improve inspection consistency across each agency. Including facility partners in the development of these templates helps to ensure that the adoption of the data templates is available to the broad range of non-experts that conduct these inspections. Further, the templates guide non-experts and experts in data collection to improve the quality and consistency of the data across Reclamation.

The USACE provided fiscal year (FY) 2022 funding support for the project as part of the agreement Military Interdepartmental Purchase Request (MIPR) # W81EWF20956601.

Previous work related to this project's objectives spans many disciplines, programs, and agencies. The greatest nexus is to the ongoing GIS efforts and Reclamation's Enterprise Asset Registry and Capital Asset Resource Management Application (CARMA) 2.0 projects. There are also several related research efforts funded through WaterSMART Internal Applied Science Tools. Similar efforts by the CAP and USACE also shaped this research.

1.1 BORGIS and Enterprise Asset Registry

The Bureau of Reclamation Geographic Information System (BORGIS) is an enterprise information technology (IT) system that supports the availability and integrity of Reclamation's geospatial data and services. BORGIS includes:

- Tessel, a web mapping application,
- Reclamation GIS (RGIS) Portal, an implementation of GIS company Esri's ArcGIS Enterprise that hosts web services and web mapping applications, and
- Enterprise Geospatial Operations (eGO), a web application with a searchable catalogue of Reclamation's GIS resources.

Reclamation's Asset Management Division (AMD) is leading the implementation of the Enterprise Asset Registry Project, which includes creating RGIS Portal databases that provide Reclamation's assets in a centralized location [1]. The Asset Registry will serve as the single, authoritative source for asset data for authorized Projects within Reclamation. This inventory will provide a holistic view of Reclamation's authorized Projects. Unlike past inventories it's intended to be compressive, current, broadly accessible. It will also support the development of inspection scheduling and operation and maintenance tools.

1.2 CARMA

Reclamation utilizes IBM Maximo asset management software using a customized deployment called CARMA. The primary implementation of CARMA has been Reclamation's hydropower facilities to document operations and maintenance activities. A limitation of the current installment is that it is not available Reclamation-wide. Additionally, it is not standardized across sites, making broad analysis of the data a challenge due to inconsistencies in data entry approaches.

Reclamation is about to begin a four-year project to upgrade to the MAS8.x version of the IBM Maximo Application Suite of the software, referred to as CARMA 2.0, which will expand use and improve standardization by integrating with the Enterprise Asset Registry [2]. CARMA can be used to conduct condition assessment, performance monitoring, and maintenance management. There is potential to leverage and incorporate the capabilities and lessons learned through this research project into CARMA 2.0.

1.3 CAP and USACE Partners

Both external project partners currently use or are investigating app-based inspection tools. For example, CAP developed and incorporated a tablet-based app several years ago. The app allows the inspector to input data for inspections of concrete or steel structures. It also allows the users to take photos within the app. CAP has an ongoing effort to catalog its facilities through GIS mapping along with data on key physical features.

USACE has several projects related to advancing inspection tools and inspection data management. Example areas include better inspection tools and robotics for corrosion condition assessments, structural health monitoring or automated condition assessment, and risk prediction to reduce overservicing of facilities. USACE is a pioneer in mobile app development and established the Mobile Information Collection Application (MICA) to combine photos, data, and GIS into a single device. In 2011, USACE deployed more than 50 smartphones containing MICA software to provide real-time decision support for the Mississippi River Valley flood emergency response efforts [3].

This research builds on the efforts of CAP and USACE to provide the next stage of inspection app development. Opportunities for improvement included: 1) greater flexibility for notetaking, 2) improved navigation through fewer fields or dropdowns, and 3) broader application to a variety of pipe types.

1.4 WaterSMART Internal Applied Science Tools

MCL and GAA personnel recently completed two WaterSMART Internal Applied Science Tools research projects that created GIS dashboards for data interaction and visualization. The first project created the "Cathodic Protection Dashboard," which maps cathodic protection system test data for test stations, rectifiers, and junction boxes [4]. The second project created the "Coatings Inspections and Hazardous Materials Surveys Dashboard," which maps the history of coatings inspections and hazardous materials surveys at Reclamation assets [5].

The first WaterSMART project on cathodic protection data utilized an opportunity to streamline its products with the current project. During the early project stages, WaterSMART and S&T project teams members analyzed the data overlap between the two projects and created a data schema for the Cathodic Protection Dashboard that utilizes many of the same data fields as the inspection template. As a result, data collected in the field using the cathodic protection page of the Survey123 tool can easily be appended to the hosted feature layer of the Cathodic Protection Dashboard. This allows for streamlined future data additions to the dashboard. Additionally, the coatings and hazardous materials data collection from the Survey123 tool will assist personnel with tracking data that needs to be appended to the Coatings Inspections and Hazardous Materials Surveys Dashboard; as new surveys are submitted in Survey123, dashboard managers will know that new data will need to be added to the dashboard.

2.0 Methodology

The research utilized a multi-step process to select, develop, test, revise, and distribute a mobile app-based inspection tool. Researchers reviewed the existing guidance and previous inspection reports to inform the software selection and then develop several inspection data templates. The team then utilized a process of beta testing to obtain feedback and make needed changes or updates to the tool. The last step was to finalize the tool and disseminate within the MCL group as well as to interested facilities and field offices.

Summarized reporting of the software selection and app tool initial development and testing is given here. See reference [6] for more detailed reporting.

A final step for the research approach was to review the online data management capabilities and to develop report templates to facilitate the reporting of inspection data.

2.1 Software Selection and Development

The research team investigated several factors during planning for the inspection template development. The factors had a range of impacts, including the survey software selected, off-network limitations, interaction with Asset Registry and BORGIS, and future analysis options for single and time-based datasets.

The research sought an inspection tool for use with cellular service as well as offline to collect data in locations with no or unreliable cellular service. The discussion of inspection tool needs led to the recommendation of ArcGIS Survey123 within Reclamation's instance of ArcGIS Online (AGOL). Esri's ArcGIS Survey123 application is part of the GIS company's suite of tools that Reclamation has licenses to use. Survey123 is a form-centric data input that creates geo-located point datasets using web or mobile devices, even when disconnected from internet. Survey123 website is the data management webpage to view and analyze data entered and create feature reports. Figures 2 and 3 describes the Survey123 features and the workflow to (1) create survey, (2) get data, and (3) analyze results.

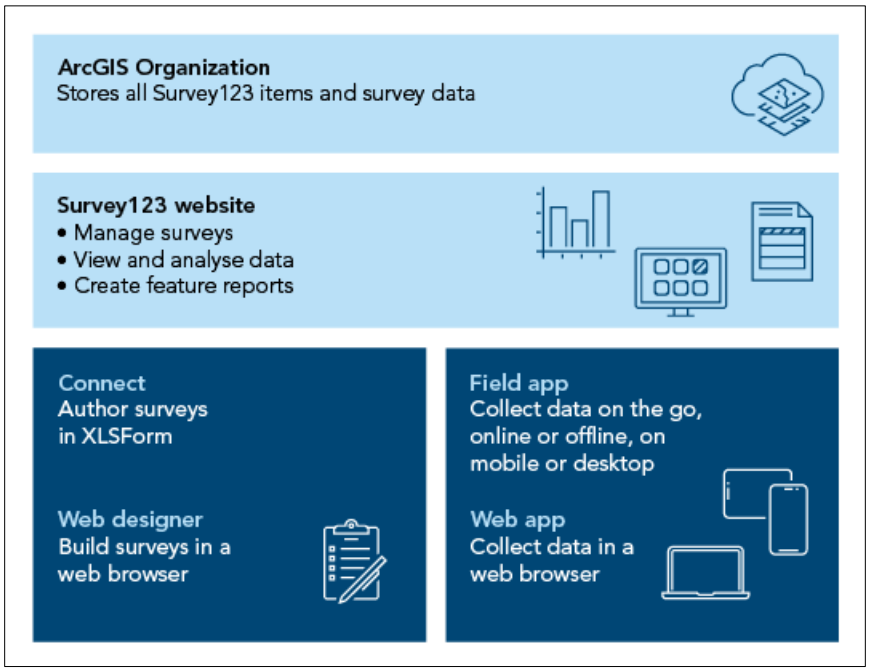


Figure 2.—Schematic showing the Survey123 relation to the ArcGIS Organization and the features of Connect, Web Designer, Field app, and Web app. Image reproduced from https://doc.arcgis.com/en/survey123/reference/whatissurvey123.htm.

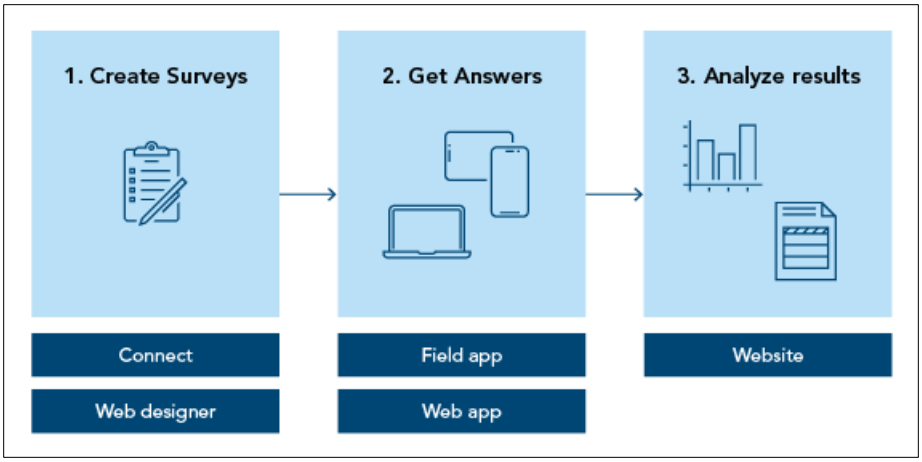


Figure 3.—Schematic showing workflow of Survey123 and the respective component(s) for each action. Image reproduced from https://doc.arcgis.com/en/survey123/reference/whatissurvey123.htm.

Survey123 components are Connect or Web designer, Field app or Web app and the Survey123 website. All Survey123 items are stored within AGOL organization. Survey123 app saves the user data to a cache during offline use and uploads the data once cellular service is available. One helpful feature of Survey123 is a set of broad options for tool development that are available to the developer. For example, Survey123 Web designer has sequencing rules that allow the data input for one field to change the successive fields that are shown to the user. This feature was utilized on the first page of the tool for documenting the Reclamation project that the inspection occurs in; the region that is selected determines the project options that appear.

GAA team members developed the first iteration of the Survey123 tool after several brainstorming meetings with the project team on inspection template needs. The MCL team drafted a spreadsheet containing the data fields, data type, and restrictions on data inputs, e.g., accepted range of values, to guide the development. The structured approach allowed for unique pages of the survey to capture location and structure information and the respective inspection data for coatings, cathodic protection, hazardous materials, and mechanical separately.

2.2 Beta Testing, Updating, and Publishing of App-Based Inspection Tool

Beta testing began after creating the initial Survey123 inspection template. Beta testing included office-based testing using the web browser version of the tool as well as the mobile app to simulate actual field testing. A developer feedback spreadsheet served to communicate the edits and revisions. The review focused on improving the user experience, e.g., shorten the survey and improve user navigation, and ensuring the inspection data and data types adequately met the documentation and reporting needs of each inspection type.

Beta testing next continued with various team members testing the tool in the field on coatings inspections, cathodic protection surveys, hazardous materials surveys, and mechanical inspections. The approach for beta testing was for inspectors to first document inspection data as usual (with this documentation approach varying between inspectors), and then to incorporate Survey123 as a

secondary data collection technique where appropriate. This duplicate documentation ensured no inspection data was lost until the survey tool was better understood and trusted, at which point it could be used as the sole documentation method. Table 1 provides the inspections utilized for field beta testing.

Table 1.—Beta testing locations and inspection types for Survey123 mobile app tool

Location	Inspection Type(s)	Description
Collbran Siphon	Coatings	The inspection captured data for each siphon pipe section containing an experimental coating installed in 1959. The data included 19 records, each with visual observations and several physical properties measured. All records were entered directly in the field in a GPS-denied environment. All were submitted after exiting the pipe and within cellular service.
Contractor Paint Shop	Coatings	The inspection was a manufacturer's site visit for a construction project. The data included observations and documentation of the contractor coating activities. Data entries were made on site, expanded upon in the hotel afterward, and then submitted.
Mni Wiconi Core Pipeline	Cathodic Protection	The inspection is an annual cathodic protection survey of a 123-mile-long welded steel pipe with 11 rectifiers and over 300 test stations. Beta testing included several dozen records on equipment items located via GPS equipment. Some records were entered in the field, while most were entered afterwards in the office.
Flatiron Powerplant	Hazardous Materials	The inspection collected coating samples on embedded pipes. Beta testing occurred in the office utilizing a subset of the field data.
Nimbus Fish Hatchery	Hazardous Materials	The inspection collected coatings and concrete samples in support of a barrier weir removal project. Again, a subset was entered in Survey123 in the office.
John W. Keys III Pump-Generating Plant	Hazardous Materials	The inspection collected coatings samples in support of a crane rehabilitation project. Beta testing again occurred in the office.

GAA team members with Survey123 editing capabilities updated the feedback spreadsheet periodically plus during working meetings. At the completion of beta testing, the Survey123 tool was recreated to incorporate all changes with a re-set to the field names produced, i.e., removing or deleting data entry fields does not remove the field name in the resulting data spreadsheet, and the recreation provided a clean slate for the organization of these field names. Further testing of this second version provided a validation to ensure optimization and functionality.

2.3 Online Data Management and Report Templates

The Survey123 website data tab allows user to view and manage data submitted and create feature reports. To aid in data reporting, it provides a report template feature for customized reporting of the different data types. It allows for multiple report templates to be uploaded to serve unique purposes. The report templates utilize the field names coded into Survey123 to populate the report based on the corresponding data field.

The project team developed a report template for each of the four inspection types (pages) in the Survey123 tool. This allows for end users to select a data record—or multiple records—that need to be reported and download. The outcome is a draft inspection report, and the anticipated benefit is that this feature will simplify the development of field inspection reports by more quickly progressing to data checking, drafting conclusions, etc.

AGOL allows for reports to be downloaded to Microsoft Word or Adobe PDF. The development process weighed the advantages of including one or both download options as it relates to a typical field inspection report workflow process and peer review requirements. In general, Microsoft Word allows for the fields and data to remain fully editable, ready for copy-and-paste into other documentation, whereas Adobe PDF has limited editing capabilities.

3.0 Results

Researchers completed development of the Survey123 Materials and Corrosion Asset Inspection tool, and it is shared DOI-wide for AGOL users to search and download. Components of the Survey123 tool are shared and organized in "Materials and Corrosion Asset Inspection Group." The default group role is member, but privileges can be elevated to group manager or owner within the user group. Group managers and owners can apply future edits or updates to the Survey123 tool and other components within the user group. Inspectors are not required to be a group member to log inspection data into the Survey123 tool.

Table 2 provides the online locations of the Survey123 Materials and Corrosion Asset Inspection tool components and related information, e.g., links for users to create a new AGOL account. The Survey123 app tool is available to Reclamation AGOL users and a link to information is given for non-Reclamation partners interested in using the tool. Access to the resulting Survey123 data tab is limited to members within the user group and user privileges can be adjusted here.

Table 2.—Weblinks to app-tool, AGOL tools, and useful sites; the tool, user group, data tab, and USACE AGOL require login

Description	Weblink	Comments
Survey123 App-based Tool*	https://survey123.arcgis.com/share/871e80e60a5443d992358cfba18a7518?portalUrl=https://USBR.maps.arcgis.com	Link to Survey123 tool to document inspection data; install on mobile device using app if possible; if prompted, use organization URL, enter "usbr" (for Reclamation users).
User Group^	https://usbr.maps.arcgis.com/home/group.html?id=f12dc5c4967940718fc6861eda77395a&view=list#content	Online community for survey tool users with general information for use; contact Adam Ricks or Greg Gault for support.
Survey123 Data tab^	https://survey123.arcgis.com/surveys/871e80e60a5443d992358cfba18a7518/data	The Survey123 Data tab allows users to see submitted surveys and generate reports for selected records.
Create Account	https://usbr.maps.arcgis.com/home/index.html	Link for DOI users to create an AGOL account.
Partner Info	https://intra.usbr.gov/borgis/agolstart.html#collab	Instructions for partners to gain access to AGOL system for collaboration.
USACE AGOL	https://usace.maps.arcgis.com/home/signin.html?returnUrl=https%3A%2F%2Fusace.maps.arcgis.com%2Fhome%2Forganization.html	Link for USACE AGOL site to determine if user has an account.
Authenticator	https://intra.usbr.gov/borgis/docs/mobile/EsriApp_MSAuthenticator_LoginQuickGuide.pdf https://intra.usbr.gov/borgis/docs/mobile/SetupMSAuthenticator_IndividualDevice.pdf https://intra.usbr.gov/borgis/docs/mobile/SetupMSAuthenticator_SharedDevice.pdf	Instructions for how to use Microsoft authenticator to open the installed Survey123 app on a mobile device (3 links provided).

*See Appendix A for a graphic flowchart to guide Survey123 installation and use on mobile device.
^Accessible only to AGOL users that are members of the user group.

3.1 Final Data Entry Fields

The survey tool development process involved creating the necessary data entry fields and determining acceptable data inputs for each field, such as selection from a dropdown list, manual entry, or a yes/no. The survey utilized multiple pages to organize the content by inspection. The first page in the survey serves each inspection. It provides data fields for the location description, a geospatial location map that can be manually entered or use the device's GPS, the Reclamation region and project the inspection is being conducted in, and the feature type and name. The next pages are for coatings inspections, cathodic protection surveys, hazardous materials sampling, and mechanical inspections, respectively. The data entry fields on these pages are collapsed by default to ease navigation to the desired page.

The following tables provide the data fields for each page of the Survey123 tool and the accepted data. In Table 3, it is of note that the "Select Region" field and "Region Projects" field pull input options from asset registry lists, which allows for consistency with other GIS data across Reclamation for these facilities. This is an example of how the input fields utilize Survey123

sequencing rules; based on the chosen region from the asset registry list, only applicable project fields will appear for user selection. Tables 4-7 display the data headings, data fields, and data entry options for the specific inspection pages in the Survey123 tool. Because individual users will only use one or a couple of the pages for their field work at a time, none of these data fields are required.

Table 3.—General inputs on page one of the Survey123 form

Data Field	**Data Entry (type, restrictions, etc.)**
Location Description	Text entry, 1,000-character limit
Geospatial Location	Map entry using device's GPS or manual entry
Select Region	Select one from drop down (information pulls from the Asset Registry)
Region Projects	Select one from drop down (information pulls from the Asset Registry based on selection from Select Region)
Feature Type	Select one from drop down (options are Pipe, Gate, Other); Other produces text entry, 255-character limit
Feature Name	Text entry, 255-character limit

Table 4.—Coatings inspection inputs on page two of the Survey123 form

Data Group	**Data Field**	**Data Entry (type, restrictions, etc.)**
Basic Inspection Data	Visual Observations	Text entry, 1,000-character limit
Basic Inspection Data	Ambient Conditions and Test Parameters	Text entry, 1,000-character limit
Basic Inspection Data	Photographs	Take image or select image, only image files allowed, maximum 50
Film Thickness Data	Film Thickness 1 (mils)	Numerical entry, between 0 and 120
Film Thickness Data	Film Thickness 2 (mils)	Numerical entry, between 0 and 120
Film Thickness Data	Film Thickness 3 (mils)	Numerical entry, between 0 and 120
Impedance Spectroscopy Data	Image of data plots	Take image or select image, only image files allowed, maximum 50
Impedance Spectroscopy Data	Impedance, 0.1 Hz (ohms)	Numerical entry, between 100 and 1,000,000,000,000
Impedance Spectroscopy Data	Phase Angle, 0.1 Hz (deg)	Numerical entry, between -90 and 0
Adhesion Data	Adhesion pull-off test (psi)	Numerical entry, between 1,000,000
Adhesion Data	Adhesion knife/crosshatch (ASTM test method and rating)	Text entry, 1,000-character limit

Table 5.—Cathodic protection survey inputs on page three of the Survey123 form

Data Group	Data Field	Data Entry (type, restrictions, etc.)
Observations	Photographs	Take image or select image, only image files allowed, maximum 50
Observations	Comments/Visual Observations	Text entry, 1,000-character limit
Rectifier Data	Rectifier ID	Text entry, 255-character limit
Rectifier Data	Tap Settings As Found	Text entry, 255-character limit
Rectifier Data	Tap Settings As Left	Text entry, 255-character limit
Rectifier Data	Voltage Output (V)	Numerical entry
Rectifier Data	Current Output (A)	Numerical entry
Rectifier Data	Shunt Reading (mV)	Numerical entry
Rectifier Data	Shunt Rating (mA/mV)	Numerical entry
Junction Box Data	Junction Box ID	Text entry, 255-character limit
Junction Box Data	Shunt Label	Text entry, 255-character limit
Junction Box Data	Shunt Reading (mv)	Numerical entry
Junction Box Data	Shunt Rating (mA/mV)	Numerical entry
Junction Box Data	Calculated Current Output (mA)	Numerical entry
Test Station Data	Test Station ID	Text entry, 255-character limit
Test Station Data	GPS Coordinates (Latitude)	Numerical entry, between -90 and 90
Test Station Data	GPS Coordinates (Longitude)	Numerical entry, between -180 and 180
Test Station Data	Voltage On Potential (mv)	Numerical entry
Test Station Data	Voltage Off Potential (mV)	Numerical entry
Test Cell Data	Start Temperature (Fahrenheit)	Numerical entry
Test Cell Data	End Temperature (Fahrenheit)	Numerical entry
Close Interval Survey	Data Collected	Select "Yes" or "No" button
Close Interval Survey	Measurement Details	Text entry, 255-character limit

Table 6.—Hazardous materials sampling inputs on page four of the Survey123 form

Data Group	Data Field	Data Entry (type, restrictions, etc.)
Expand to provide sample data	Sample ID	Text entry, 255-character limit
Expand to provide sample data	Sample Location	Text entry, 255-character limit
Expand to provide sample data	Sample Description	Text entry, 1,000-character limit
Expand to provide sample data	Material Type	Text entry, 255-character limit
Expand to provide sample data	Lab Analyses	Button selection for Regulated Metals, Asbestos, PCBs, PAHs, and Used Oil Specifications
Expand to provide sample data	Photographs	Take image or select image, only image files allowed, maximum 15

Table 7.—Mechanical inspection inputs on page five of the Survey123 form

Data Group	Data Field	Data Entry (type, restrictions, etc.)
Observations	Comments/Observations	Text entry, 1,000-character limit
Observations	Photographs	Take image or select image, only image files allowed, maximum 50
Observations	Operational Data	Text entry, 1,000-character limit
Ultrasonic Thickness Tests	Conditions and Parameters	Text entry, 1,000-character limit
Ultrasonic Thickness Tests	Measurement 1	Numerical entry
Ultrasonic Thickness Tests	Measurement 2	Numerical entry
Ultrasonic Thickness Tests	Measurement 3	Numerical entry
Ultrasonic Thickness Tests	measurement 4	Numerical entry
Ultrasonic Thickness Tests	Measurement 5	Numerical entry

3.2 Survey123 App Tool Features

The primary goal of the tool development process was to establish the user interface, or the visual aspect of the tool that users will see and interact with while logging a survey. The final Materials and Corrosion Asset Inspection Survey123 tool includes five pages of data entry options. To access the tool from a smartphone or tablet, the user should open the Survey123 app, select "Download surveys," locate the "Materials and Corrosion Asset Inspection" survey in the list or type the name into the search bar, and tap the cloud and arrow icon next to the survey name to download it to the device. See Appendix A for a graphic flowchart of these instructions.

Figure 4 shows default Survey123 pages on a mobile device. Only the first page does not have data entries set to be collapsed by default. The remaining four pages are collapsed to make navigation to the desired page easy for the user. Users can navigate backwards and forwards through the five pages using the arrows at the bottom of each screen. The checkmark at the bottom-right of page five is for the user to submit the completed survey. Once the user has finished filling out the survey and submits it, the data is either sent to RGIS Portal and is stored on a cloud or, if the device does not have cellular service, the data is stored on the device until it has service.

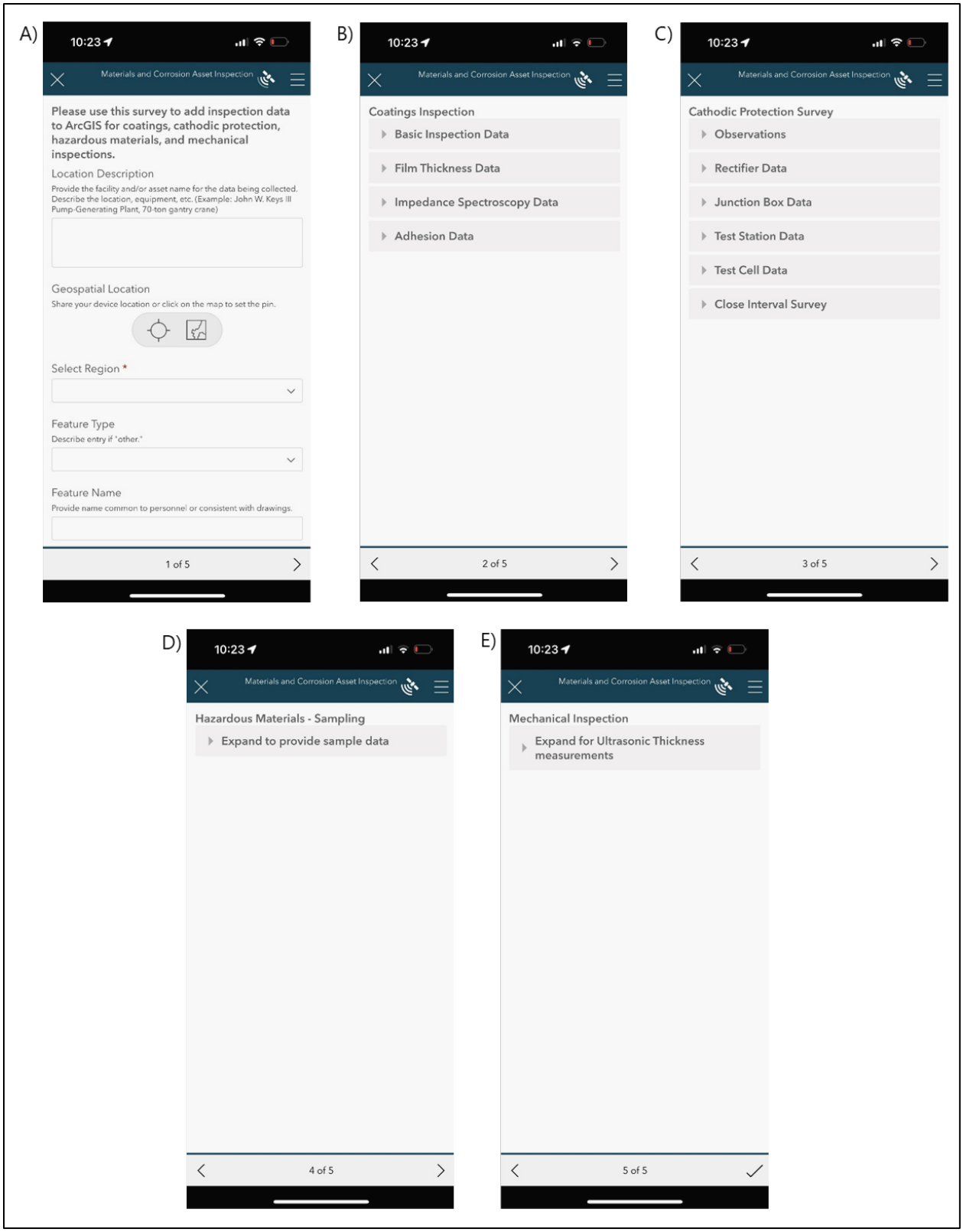


Figure 4.—Survey123 tool screenshots with default settings: A) location information (location description, geospatial location in a map, region, project, feature type, and feature name); B) coatings inspections (basic inspection data, film thickness, impedance spectroscopy, and adhesion); C) cathodic protection

surveys (observations, rectifiers, junction boxes, test stations, test cells, and close interval surveys); D) hazardous materials sampling (sample identification number, location, description, material type, laboratory analyses, and photographs); and E) mechanical inspections (observations, ultrasonic thickness tests).

While collecting data within the Survey123 tool, users can save their work as a draft and return to it later. To save a draft, users select the "X" icon at the top-left of the screen and then select the "Save in Drafts." The other options that appear are to continue the survey or to discard the changes made. A survey can be submitted by selecting the check mark in the bottom right corner of the final page.

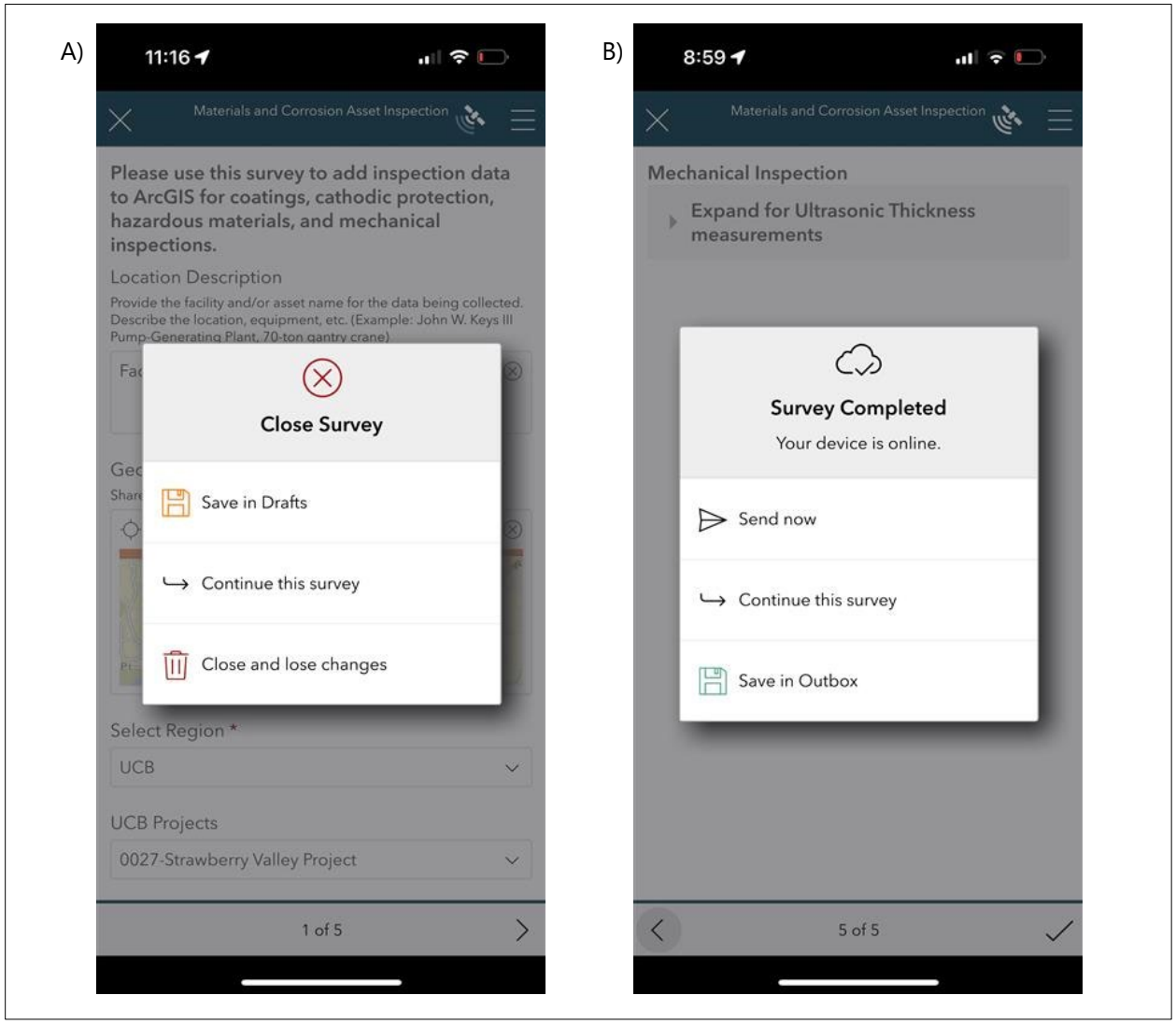


Figure 5.—Screenshots of Survey123 options for A) closing a draft survey and for B) submitting a completed survey.

3.2.1 Managing Draft Surveys

The main homepage of the Materials and Corrosion Asset Inspection tool catalogues the existing surveys based on status (Figure 6). To start a new survey, select the "Collect" option. Select "Drafts"

to resume work on previously saved surveys. These can continue to be re-opened, revised, and then saved again. Figure 6 shows a screenshot of the main homepage as well as the surveys saved as drafts. The list of draft surveys has several functionalities, including a search bar and the distance to the survey's GPS location. Figure 7 provides screenshots for additional options to sort the drafts or to show as a map view.

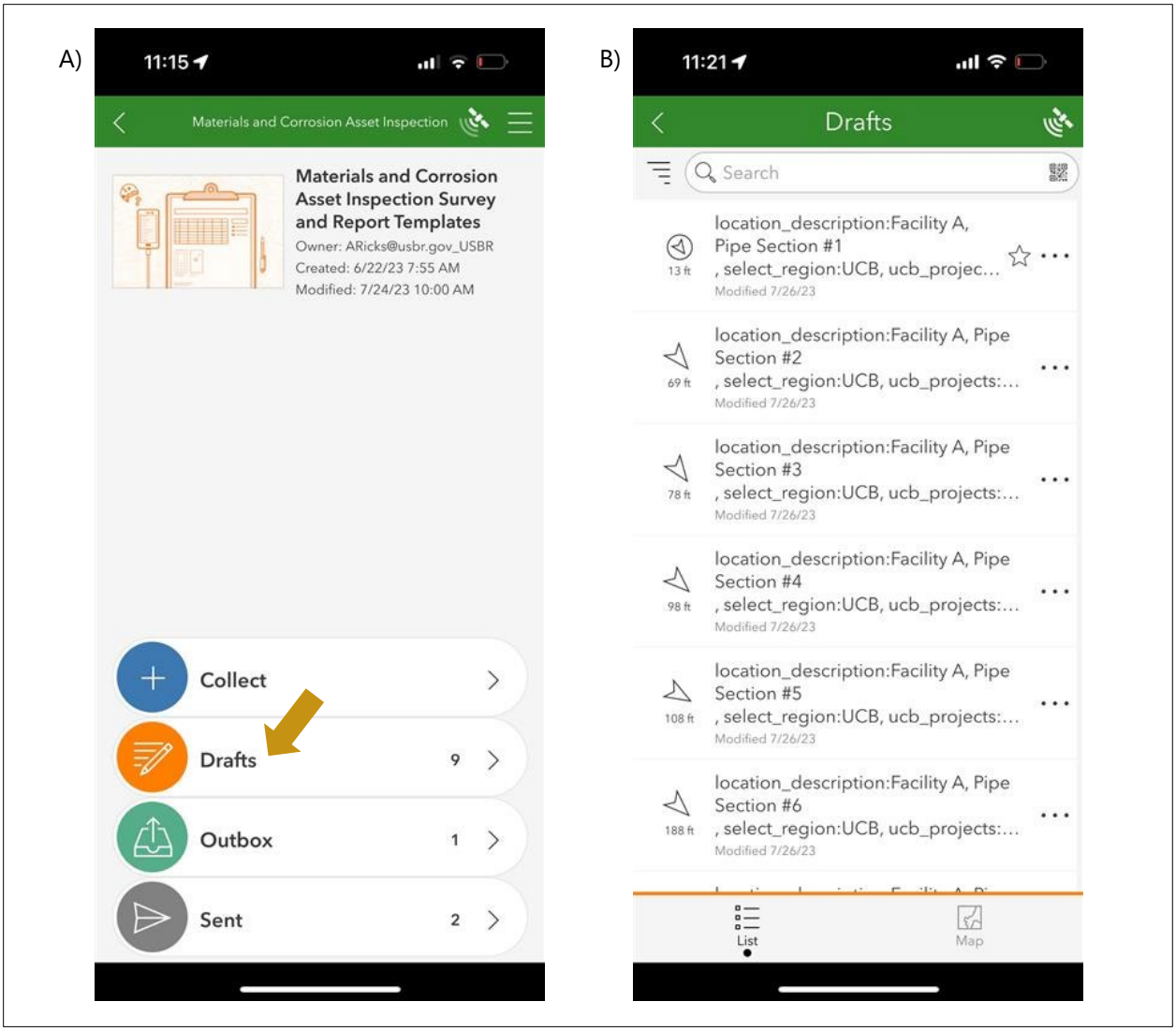


Figure 6.—Screenshots of A) the main homepage for the Survey123 tool, noting the "Drafts" option with an arrow and B) the list of draft surveys for the user to select to continue collecting data.

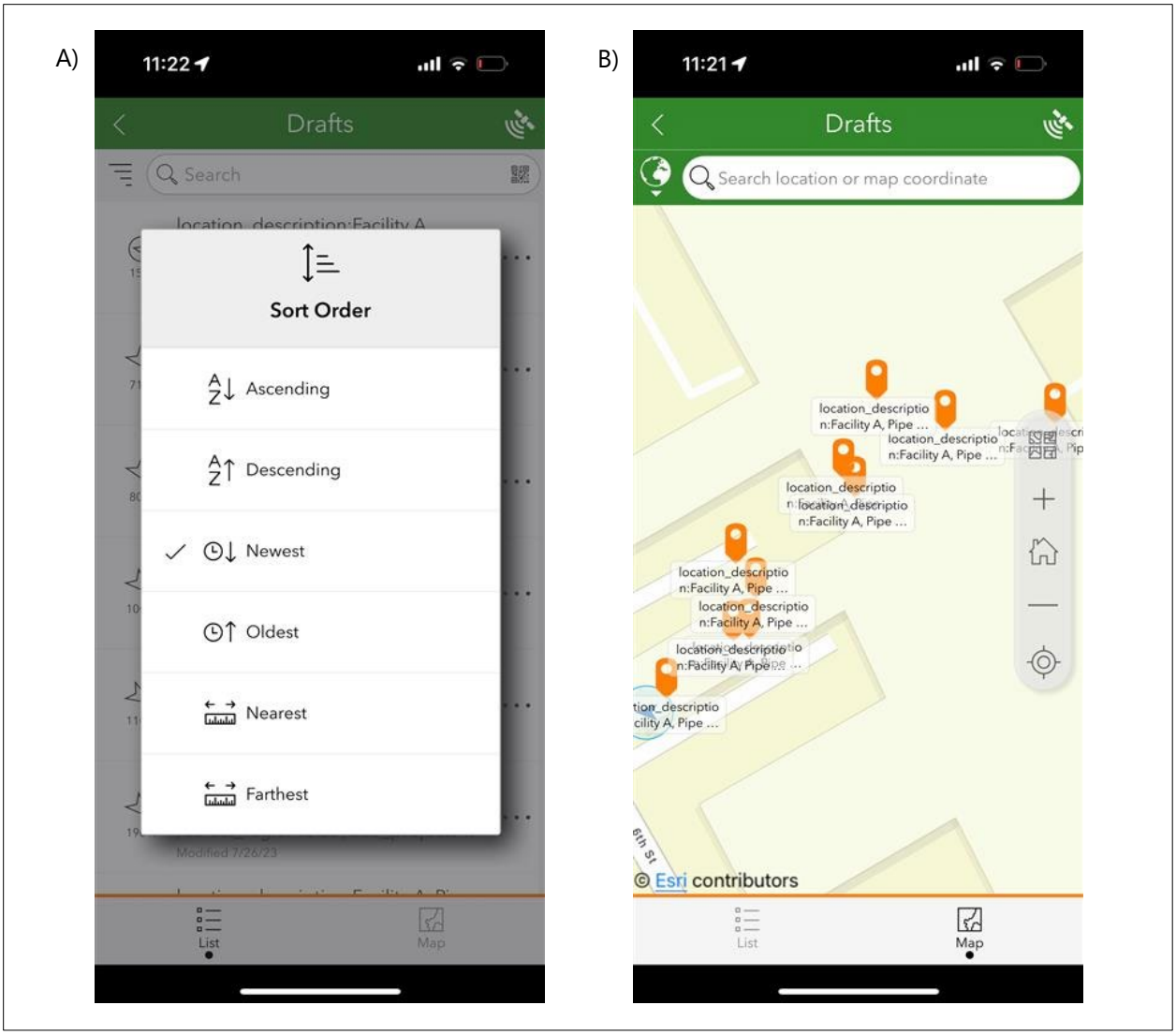


Figure 7.—Screenshots of options for managing draft surveys by A) sorting the order alphabetically, by the save time, or by distance to GPS location and B) showing as a map view instead of list.

The main homepage also shows options for Outbox and Sent. The surveys in the Outbox are completed but can also be re-opened and edited by selecting "Yes" on the menu when prompted. Similarly, the Sent surveys can also revisited. The menu options for surveys that have already been sent are "View," "Edit and resend," and "Copy sent data to a new survey." The final option allows users to use the sent data to create a new survey. Editing surveys from either the Outbox or Sent folder moves them to the Drafts list if the user chooses to save for later editing.

3.2.2 Setting a Favorite Survey

The Survey123 tool allows users to save data as a favorite by selecting the star icon labeled "Set as favorite answers" (Figure 8). This allows the user to auto-fill a new survey with desired information by selecting the option to "Paste answers from favorite." This feature saves time on inspections, such as those with multiple surveys, i.e., where general data such as Reclamation region and location are the same. Once the favorite answer is set, a new option is given to "Clear as favorite answers." New or updated favorite answers can be updated while drafting a survey provided "Set as favorite

answers" option. The survey with the favorite answers is also denoted by a star when viewing the draft surveys list (Figure 8B).

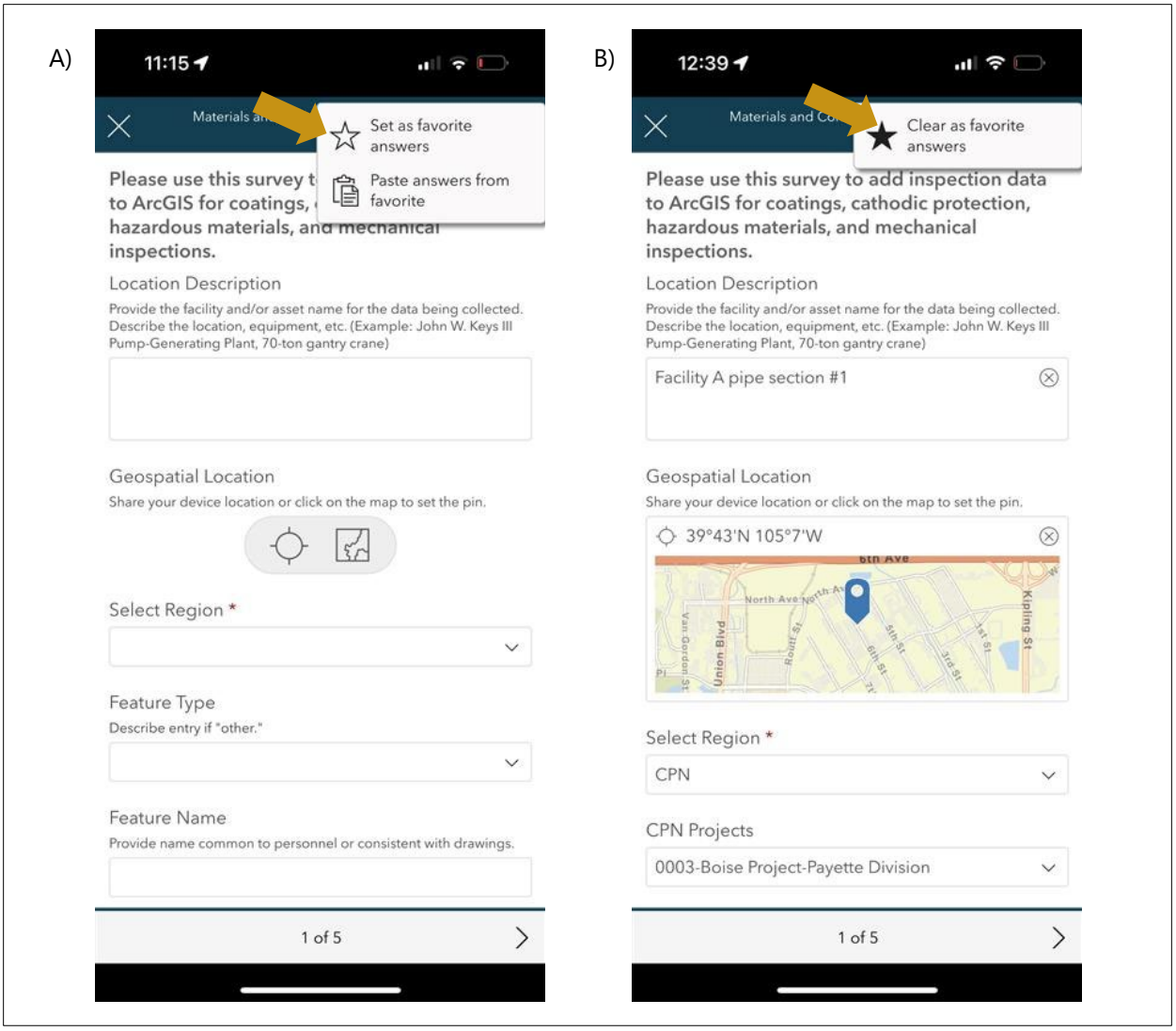


Figure 8.—Screenshot of the option for users to A) save data fields as favorite answers, which will automatically populate in later surveys when selecting "paste answers from favorite," and B) clear favorite answers.

3.2.3 Image Options

Photos can be entered into Survey123 two ways. Users can select the camera icon to open the device camera and take photos that are immediately attached to the survey. Alternatively, users can use the device photo app to collect photos and then select the folder icon in Survey123 to upload photos from the gallery. The folder icon provides upload options for "Photos" and "Files" (Figure 9).

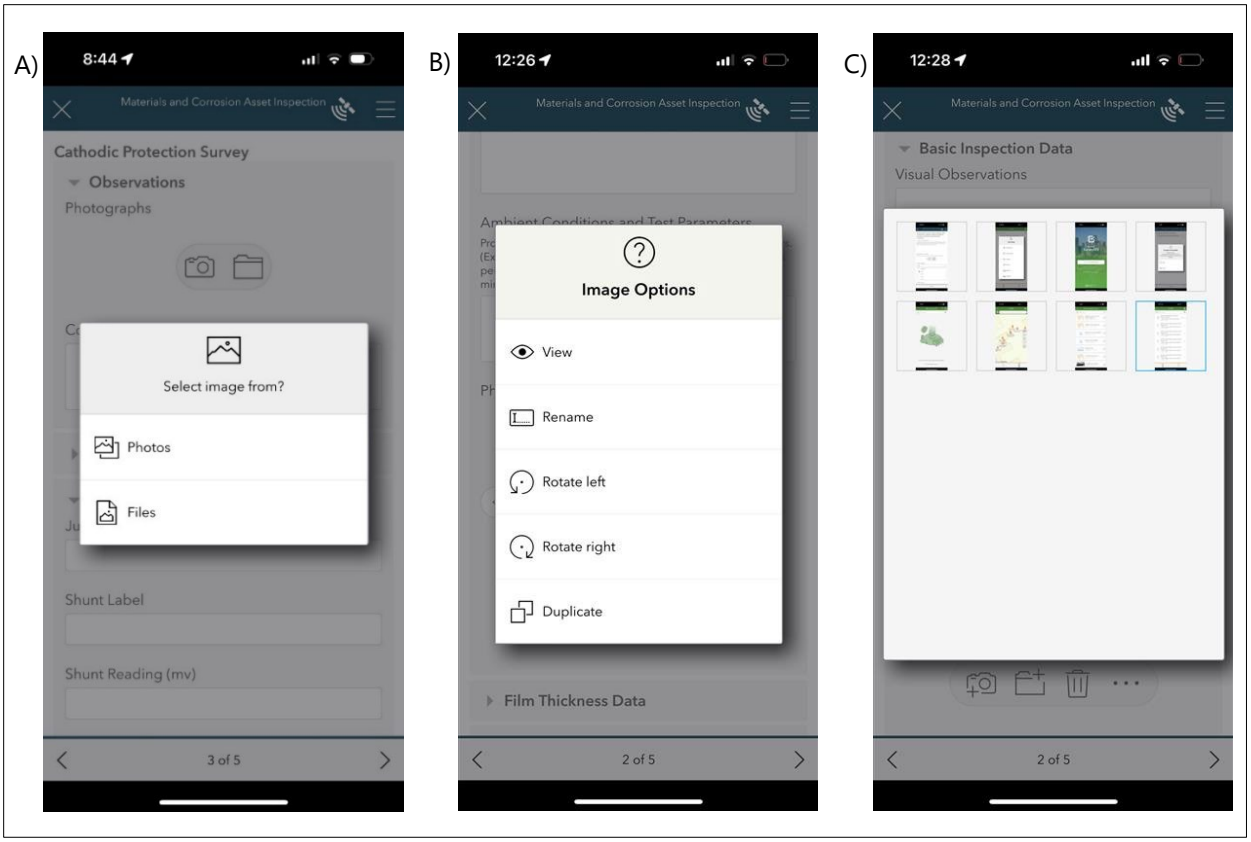


Figure 9.—Screenshots of the image options provided in Survey123: A) take a photo or upload from file, B) edit image options, and C) tile view of uploaded images.

Figure 9 also provides screenshots of additional features for images. Once uploaded, images can be viewed, renamed, rotated, and duplicated. They can also be viewed one-by-one on the screen or in a as tiles. Selected images can also be deleted.

3.2.4 GPS Options

Survey123 is compatible with external GPS devices. Users can use an external GPS device for more accurate positioning than provided by a mobile device. GPS receivers can be integrated or connected via Bluetooth. Users can configure settings for GPS devices by selecting the satellite icon in the top right corner of the Survey123 app and then the settings gear icon.

When setting the location in the survey, users can use the GPS-recorded location (internal device GPS or external GPS receiver) or manually move the location pin on the map (Figure 10). Users can view the location status by selecting the satellite icon.

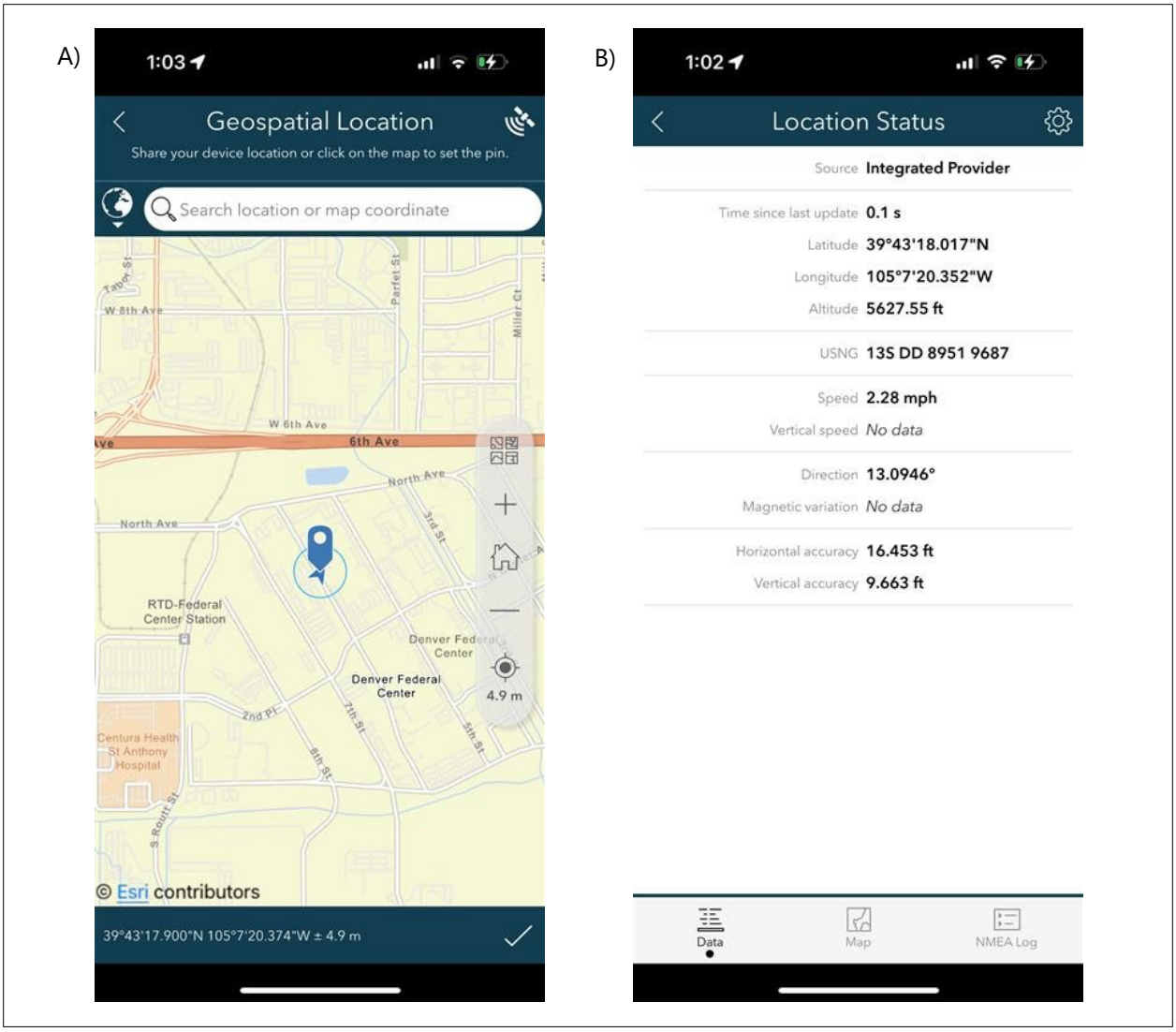


Figure 10.—Screenshots of the GPS settings for Survey123: A) GPS location map to manually adjust pin or select target icon to automatically set and B) GPS source setting viewed using the satellite icon in the app.

3.3 Survey123 Website Data Tab

The Survey123 website is the corresponding online data management platform used to view and analyze data submitted through the Survey123 tool. This can be accessed online through AGOL. The direct weblink to the Survey123 Data tab is: https://survey123.arcgis.com/surveys/871e80e60a5443d992358cfba18a7518/data.

Figure 11 provides a screenshot of the Survey123 Data tab. The user has numerous options for filtering the data that is shown by specific facilities, survey dates, etc. Further, the page also provides a "Report" tab. This feature allows users to download reports for selected data records (a single record or multiple records) using either the "Full_Record_Template," "Coatings_Template," "Cathodic_Protection_Template," "Hazmat_Template," or "Mechanical_Template." See Section 3.4 Report Templates for more information.

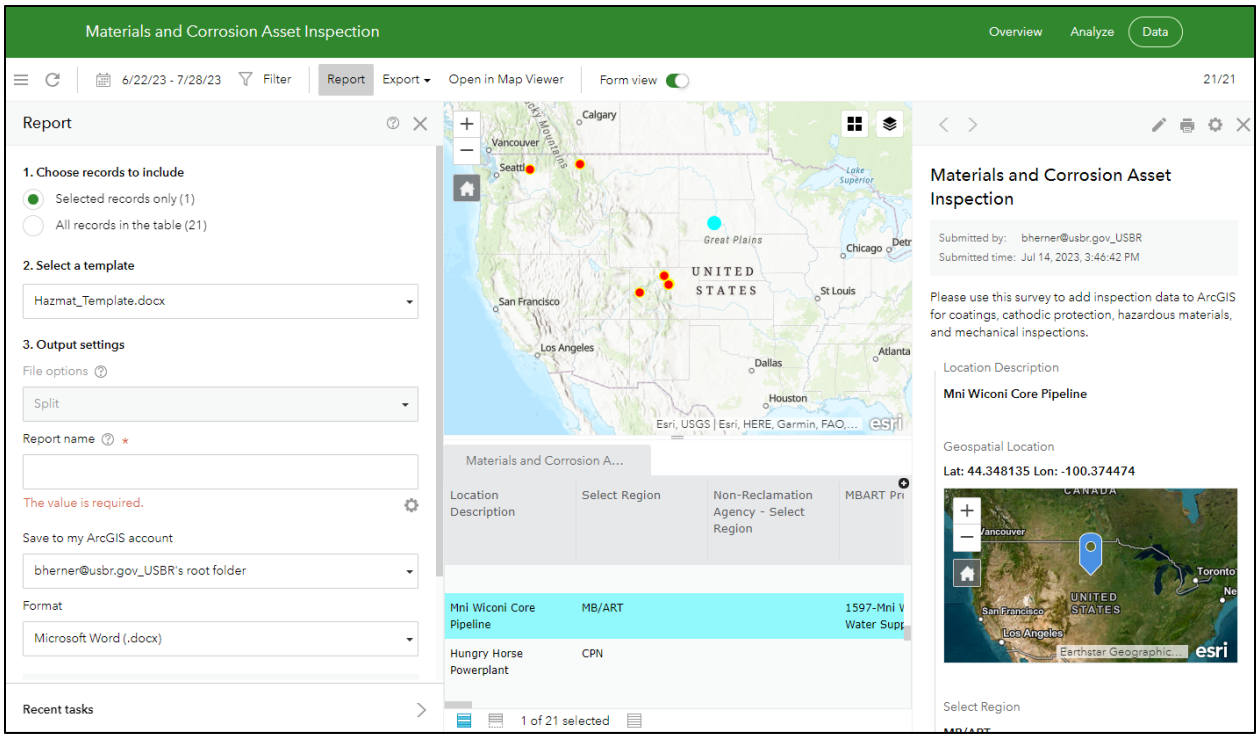


Figure 11.—Screenshot of AGOL Survey123 Data tab for the Materials and Corrosion Asset Inspection Survey123 tool for customizable data filtering, viewing survey data, and generating reports.

Photos uploaded as part of the inspection or survey can also be downloaded through the data portal. Users must first select the desired record, then scroll to the photographs section of the record in the menu bar at right. Upon selecting a photo, users can see the photo metadata and download a copy. Selecting the edit icon at top-right also allows users to revise the file name, such as to provide a draft figure caption for report downloads.

The Survey123 Data tab also provides an "Export" feature to download all data records or selected data records as various file types: CSV, Excel, KML, shapefile, and file geodatabase. To the right of the "Export" button is an "Open in Map Viewer" button; this feature opens a map where users can see point locations of data records, add other GIS data, change basemaps, measure area, length, or location, and perform various analyses.

Another option to view Survey123 data records are using Map Viewer. There are three versions of the feature layer available from the "Materials and Corrosion Asset Inspection Group"—one that is a primary layer, one that is a view of the primary layer and is editable, and one that is a view of the primary layer and is not editable but is available to be added to an ArcGIS Dashboard. These layers can be opened in the Map Viewer. The Map Viewer provides multiple options for visualizing the data geographically on the map, expanding on the customizability offered in Figure 11. The parent feature layer is in Figure 12.

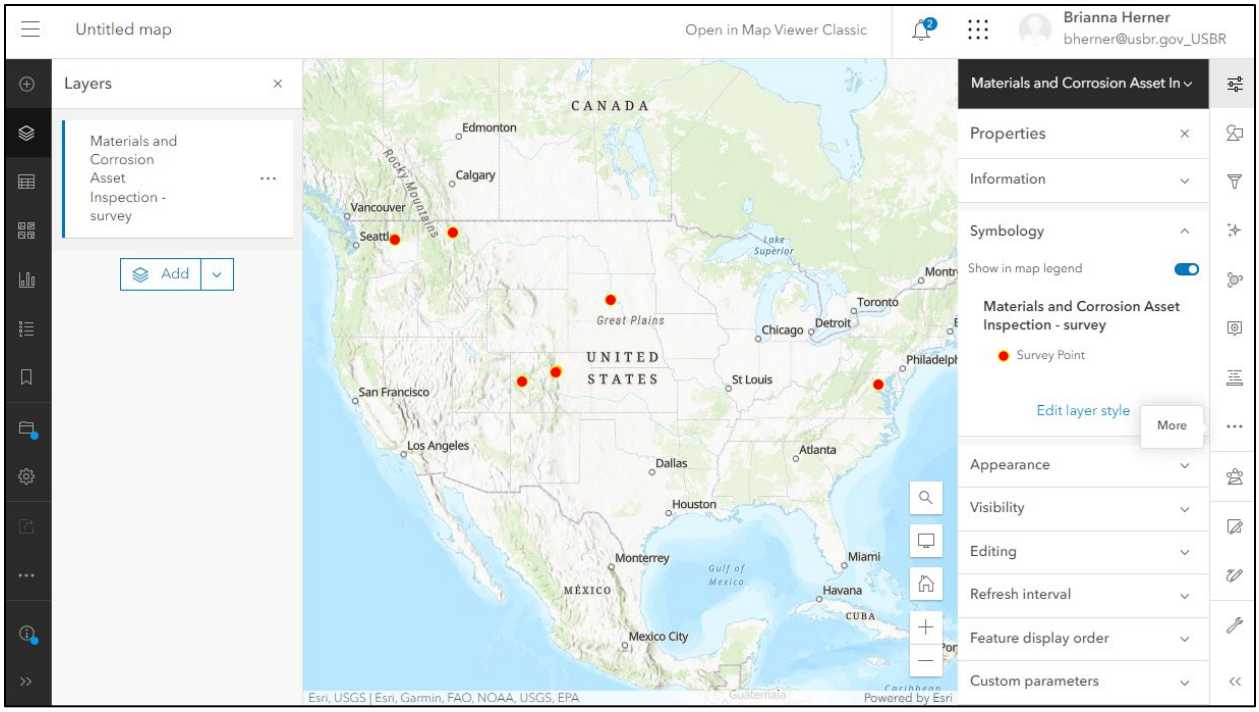


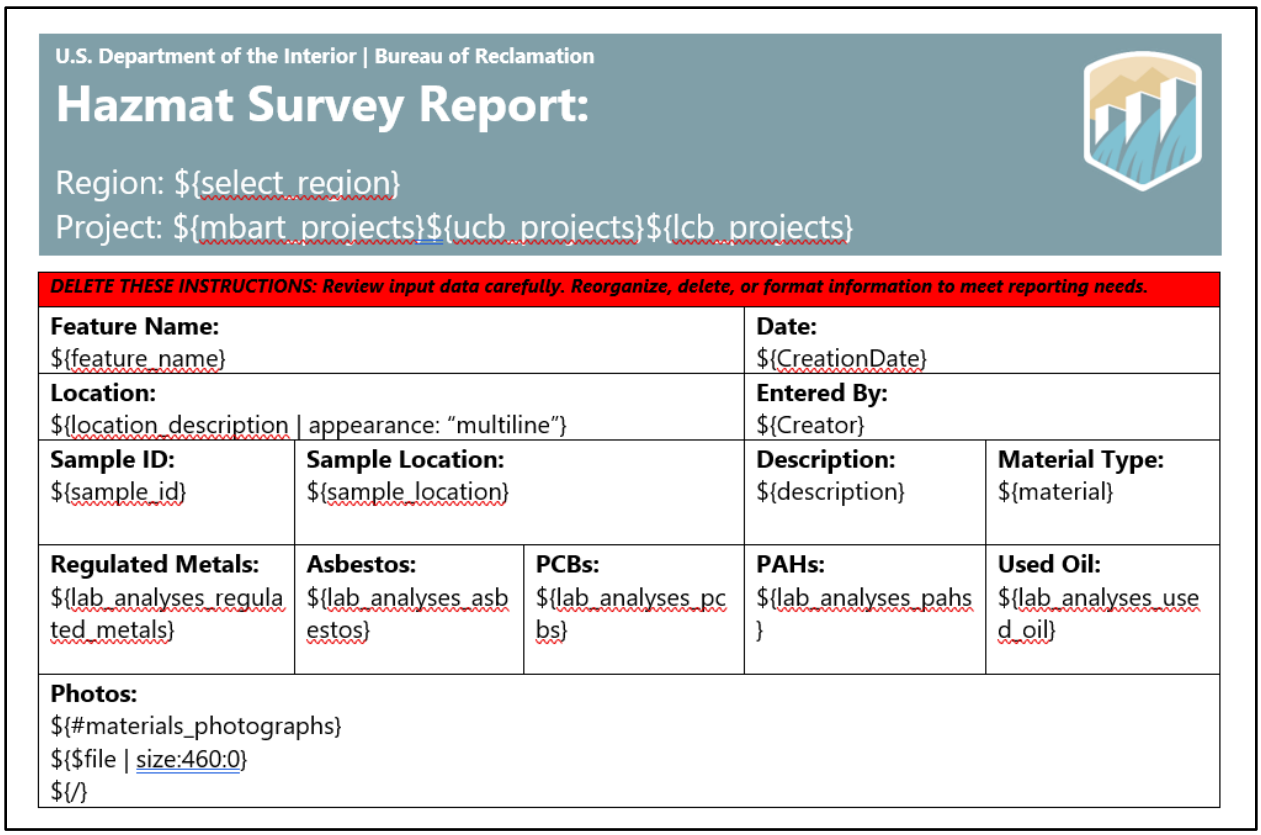
Figure 12.—Screenshot of the feature layer in the Map Viewer, accessible from the AGOL user group for additional customizable data visualization.

3.4 Report Templates

Report templates can aid in creating inspection or survey reports, such as technical memorandums. Users may generate a report of inspection data submitted from the Survey123 Data tab. Five report templates are available for the user to download. The first report template provides all data from selected records. The remaining four are specific to one inspection or survey type and provide the respective data subset: 1) coatings inspection, 2) cathodic protection survey, 3) hazardous materials survey, and 4) mechanical inspection. These templates are Microsoft Word documents and utilize Reclamation visual identity standards.

The Word report templates utilize the developer field codes from the Survey123 tool. For each data entry to appear in the report, the corresponding field code was input into a cell in Word with a descriptive heading. For example, in the hazardous materials survey report, the "Sample Location" cell includes the field code "${sample_location}" (Figure 13). When a hazardous materials report is generated in AGOL, the report (which can be downloaded as a Microsoft Word or PDF file) will populate the sample location that was entered in Survey123 in place of the field code.

Figure 14 provides an example of the full record during final testing of the Survey123 tool. See Appendix B – Templates for Online Database Report Downloads for the final versions of the five report templates loaded into AGOL.



U.S. Department of the Interior | Bureau of Reclamation

Hazmat Survey Report:

Region: ${select_region}

Project: ${mbart_projects}${ucb_projects}${lcb_projects}

DELETE THESE INSTRUCTIONS: Review input data carefully. Reorganize, delete, or format information to meet reporting needs.

Feature Name: ${feature_name}			**Date:** ${CreationDate}	
Location: ${location_description | appearance: "multiline"}			**Entered By:** ${Creator}	
Sample ID: ${sample_id}	**Sample Location:** ${sample_location}		**Description:** ${description}	**Material Type:** ${material}
Regulated Metals: ${lab_analyses_regulated_metals}	**Asbestos:** ${lab_analyses_asbestos}	**PCBs:** ${lab_analyses_pcbs}	**PAHs:** ${lab_analyses_pahs}	**Used Oil:** ${lab_analyses_used_oil}
Photos: ${#materials_photographs} ${$file | size:460:0} ${/}				

Figure 13.—The field codes in the hazardous materials report template during beta testing.

U.S. Department of the Interior | Bureau of Reclamation

Materials and Corrosion Inspection Report:

Region: UCB
Project:

DELETE THESE INSTRUCTIONS: Review input data carefully. Reorganize, delete, or format information to meet reporting needs.

Feature Name:	**Date:**
Demonstration PCCP Pipe - TEST	August 16, 2023 3:20 PM
Location:	**Entered By:**
Reclamation Technical Service Center Bldg 56 Courtyard	BMerten@usbr.gov_USBR
GPS Coordinates (latitude, longitude):	
39.7477, -105.0444	

1. Coatings Inspection

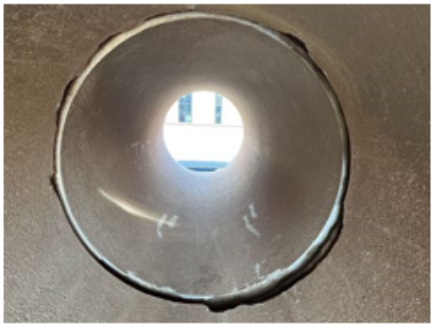
Visual Observations:
The pipe is PCCP; it is a steel cylinder with cement mortar lining and coating, wound with prestressing wires, and covered with concrete. No polymer coatings are present. Photos taken but no measurements.

Dry Film Thickness (DFT) Data (mils):		**Ambient Conditions and Test Parameters:** 100°F air temp, estimated 120°F surface temp. No testing to be performed.	
Adhesion – Pull-off (psi):	**Adhesion – Knife/crosshatch (rating):**	**EIS – Impedance, 0.1 Hz (ohms):**	**EIS – Phase Angle, 0.1 Hz (deg):**

Photos:


Frontview.jpg


Display.jpg


Pipeinterior.jpg

2. Cathodic Protection Survey

***Rectifier Data,* ID:** None

Tap Settings, As Found:	**Tap Settings, As Left:**	**Voltage Output (V):**	**Current Output (A):**	**Shunt Reading (mV):**	**Shunt Rating (mA/mV):**

Figure 14.—An example of a full record report showing only the first page of the report, i.e., the coatings inspection section, during final testing of the Survey123 tool and report templates.

4.0 Discussion

4.1 Benefits

The Survey123 tool developed under this project includes benefits of standardized data collection for Reclamation assets, cloud data storage, and report data generation. The standard data entry fields support coatings, cathodic protection, hazardous materials, and mechanical field inspections and surveys. This standardization promotes consistency in data collection across Reclamation, thus encouraging easier analysis of datasets. These benefits meet the project goals. The sections that follow outline additional benefits uncovered during the development and testing processes.

4.1.1 Streamlined Data Collection

Recording handwritten notes on paper is still common. For example, cathodic protection data is typically handwritten and later transcribe this into Microsoft Excel spreadsheets. Hazardous materials personnel also use spreadsheets to log sample data (e.g., sample identification number, sample location, a description of the material that was sampled, and what the sample will be analyzed for at a laboratory). These spreadsheets are currently copied and transposed into standard data tables in survey reports. The Survey123 tool saves time and reduces possible errors in the transcription process from handwritten data. In addition, users can export selected data records from the Survey123 Data tab as Excel files.

Another advantage of collecting field data over a phone or tablet is the ability to use the device's microphones for dictation of notes such as visual observations, which is information that can get lost after an inspection has been completed. Due to the speed advantage of dictation over handwritten notes, dictated notes also tend to be more detailed than handwritten equivalents.

Photos have historically been taken on either a digital camera, iPhone, or iPad. If the device were lost or damaged before the photos could be downloaded or uploaded, the records would be lost. In addition, this method results in photos taken without being able to provide context. The Survey 123 tool provides a method for collecting data digitally and storing images within the context of a specific inspection. For example, hazardous materials surveys require photo-documentation of the sampling process to capture sample location, material condition, and the notes on the sample collection container—which is sent to a laboratory and thus not available for reference during report writing. The Survey123 tool streamlines the assemblage of photo-documentation, observations, and data through a one-step process.

4.1.2 Online Data Storage and Reporting

The AGOL cloud data storage is an additional data repository for Reclamation, and this database can be filtered and analyzed with data collected from the tool over time. Additionally, the reports feature in the Survey123 Data tab generates downloaded content to quickly visualize data and document it for reporting purposes. The reports feature improves reporting workflow by eliminating the need to transpose handwritten notes or to paste images into a file.

4.2 Limitations

Despite the project successes, the Survey123 tool has several limitations that could not be overcome. A few limitations not described here are nuances that will improve with user experience or appear to be caused by the device or settings, i.e., model, updates, etc. The following sections include descriptions of the limitations and guidance for future relief or opportunities where applicable.

4.2.1 Data Transmission

The Survey 123 tool can operate offline or in GPS-denied environments, and it does so by storing data on the device until it has a sufficient connection to send it to AGOL; however, the tool can only send data to AGOL if cellular service or Wi-Fi is present. Data stored exclusively on the device is at risk of being lost if the device is lost or damaged before regaining connectivity—this risk is analogous to current data collection practices, e.g., data logger, instruments, field notebook, camera, etc.

Many Reclamation assets have limited cellular service, and as a result, the connectivity issue will remain a challenge for Survery123 tool use. This prevents the user from automatically setting GPS location on page 1 of the tool. The GPS location instead needs to be set manually in the map when using the tool or edited in AGOL after submitting. Figure 15 provides an image of beta testing occurring in a GPS-denied location.

Figure 15.—Beta testing of the Survey123 tool during a siphon pipe interior coating inspection.

4.2.2 Survey Logic

Survey123 is a form-based tool with fixed logic that creates a GPS-based data record. Therefore, it requires a new survey record for each location evaluated, i.e., multiple records are likely for an asset inspection that expands beyond a fixed position. For example, a cathodic protection survey along a pipeline alignment results in a submitted record for each geo-referenced point/location along the alignment. This limitation can be a substantial drawback for certain evaluation types. No work-around was identified for the existing version of Survey123 beyond significantly lengthening the survey, and no other software application was found to overcome this limitation.

The requirement for one record per location partially stems from the survey form having a fixed amount of data entry fields—an amount that would be reasonable for a specific location or area of an asset. A dataset for the entire asset could be exponentially larger. The consequence of the more simplified form is that each asset inspection is likely to result in multiple records, likely to range from a few to more than one hundred. Each record is likely to require some duplicate data entry. As discussed in Section 3.2.1 Managing Draft Surveys, the Survey123 tool allows the user to manage multiple drafts, the outbox, and sent records, which allows the user to organize the multiple survey records. Further, Section 3.2.2 Setting a Favorite Survey helps users reduces duplication of common data entry fields. The Survey123 Data tab allows users to filter to view, export, or generate reports from the multiple records for a single asset inspection or survey.

4.2.3 Inspection Routines

Asset inspections are often fast paced with large quantities of data or samples to be collect in a short period of time due to outage periods or limited facility personnel time. As a result, many beta testing efforts resulted in limited use of the Survey123 tool during the asset inspection. Survey123 tool use may not be feasible in real time for all cases, and data entry can occur or be continued after the inspection, e.g., at a hotel or while travelling.

Current routines do not incorporate all data collection into the Survey123 tool. Further, many asset inspections utilize other equipment or instruments that collect and organize data, often producing large datasets that can transfer data via Bluetooth. Asset inspections are likely to incorporate more quantitative data collection techniques in the future; therefore, it is not likely for asset inspections to be reduced to a single mobile device.

4.2.4 Data Analysis

Attempts were also made to perform statistical calculations using survey record data. For example, researchers attempted to develop report fields that would return a calculated mean and standard deviation for dry film and ultrasonic thickness data. Although limited functionality does exist for computation during report generation, it was determined to not be feasible for including in the final versions. The primary limitation is that the report template requires a hard-coded equation. Therefore, it has a fixed denominator and results an incorrectly calculated value when the number of data points collected is different than this denominator.

4.2.5 Asset Registry Data Integration

The research team also explored connecting mobile devices to a virtual private network (VPN) or Reclamation Wi-Fi. This secured access would allow users to view or access BORGIS to see assets mapped in Tessel and reference information on the asset being inspected. However, Reclamation

network is not accessible by mobile devices via VPN. Access to VPN and BORGIS would increase the resources available to the inspector during the field inspection.

The team also explored relating Asset Registry data to the Survey123 tool. This would enable users to associate inspection data with a list of asset names and related information like region and project rather than inputting by hand. Using this source of actively managed asset information could greatly improve the database quality and facilitate future integration with CARMA 2.0.

ArcGIS Dashboards provide a great tool for organizing and visualizing online databases, especially those with spatial and temporal data. The team explored automatically appending the hosted feature layer of the existing ArcGIS Dashboards with Survey123 data records and found data validation to be a significant concern. For example, each data point in the Cathodic Protection Dashboard's map widget represents a single test station with multiple years of data, allowing each to be tracked and analyzed over time. The Survey123 tool has free text data entry, and data variations in terminology or spelling will not be properly binned. For example, the Survey123 tool would accept TS10, TS-010, etc., for a test station labeled "TS010" in the dashboard, and ArcGIS would assign this as a new test station instead of appending the existing data for TS010. As mentioned above, integration with the Asset Registry could replace free text with a drop-down list of facilities, reducing possible name convention issues. If overcome, several steps could be eliminated in appending Survey123 data records to existing ArcGIS Dashboards.

4.3 Adoption and Instructions for Use

To utilize the Materials and Corrosion Asset Inspection Survey123 tool, users must first have a Reclamation AGOL account. For guidance on creating this prerequisite account, personnel may visit https://usbr.maps.arcgis.com/home/index.html. Once an account has been made, personnel interested in using the Survey123 tool should follow the below steps. See Appendix A – Survey123 Tool Graphic Flowcharts for a detailed schematic and troubleshooting.

1. Download the ArcGIS Survey123 app onto the device to be used for the asset inspection: either a government smartphone or tablet.
2. Launch the app and log into AGOL account by selecting the "Sign in with ArcGIS Online" button. Enter "USBR" as the organization's URL, then select the blue "DOI-Reclamation" box. Log in on the DOI page with a usbr.gov email and network password. If prompted, complete login using Microsoft Authenticator.
3. Once logged in, select the "Download surveys" button at the bottom of the screen, search for "Materials and Corrosion Asset Inspection" in the search bar, and select the cloud and arrow icon to download it to the device.
4. To collect data, select "Materials and Corrosion Asset Inspection" in the list of available surveys on the "My Survey123" homepage. Select the "Collect" button to launch the tool and start data collection.

The Materials and Corrosion Asset Inspection Survey123 tool provides data entry pages for four inspection and survey types, each of which has different objectives and tasks when carrying out. Table 8 provides tailored guidance for each of the dedicated uses. The information aids respective

end users and helps the adoption of this tool in a case-by-case basis and based on currently known information.

Table 8.—Targeted guidance for the listed inspection and survey types.

Type	Topic	Guidance
Coatings	Working in GPS-denied Environments	Penstock interiors are a valuable asset with limited or occasional access and would benefit from a more expansive dataset of quantitative measurements that can be analyzed over time. These inspections will require a unique survey record for many locations within the pipe—all needing to be done without connecting to AGOL.
Cathodic Protection	Generating Multiple Records	Cathodic protection inspections often occur along miles of water conveyance pipeline with test stations and rectifiers spaced at regular intervals. Rather than continuous spatial data collection along a pipeline, the tool requires one survey record per discreet location, e.g., individual test station. This results in many records for a single pipeline and thus some duplication of data entry occurs. See 3.2.2 Setting a Favorite Survey for guidance on reducing duplication of efforts.
Hazardous Materials	Saving Time in Inspections	Hazardous materials surveys are often fast paced in nature due to the large quantity of samples collected. Utilizing the Survey123 tool in real time with sample collection may not be feasible for certain hazardous materials surveys. Instead, the tool could be used by personnel in the hotel room following the day's sample collection to capture the survey information, or the tool could be used after personnel have traveled back to the office.
Mechanical	Collecting Basic Data	Reclamation has many assets requiring mechanical inspection. The Survey123 tool provides for basic mechanical observations and ultrasonic thickness data. Other methods or a new Survey123 tool dedicated to detailed mechanical investigations may be needed for comprehensive assessments of equipment operations, penstocks, etc.

5.0 Recommendations

Several recommendations resulted from this research. These are listed below and range from dissemination and adoption of the tool to future tool updating and development.

- The Survey123 tool should receive occasional review and updates based on user needs.
- The project team recommends dissemination through GIS personnel and potential users at field and facility offices. Dissemination with potential users should occur through personal interactions during asset inspections, newsletters, webinars, and workshops.
- Assess Esri's ArcGIS technology for options to directly link the Survey123 tool data to ArcGIS Dashboards, specifically the Cathodic Protection Dashboard and the Coatings Inspections and Hazardous Materials Surveys Dashboard. Advancements could allow Survey123 data to directly update dashboards.

- Incorporate lessons learned into CARMA 2.0 development and evaluate CARMA 2.0 once implemented as a potential replacement for the Survey123 tool. If replacement occurs, incorporate the Materials and Corrosion Asset Inspection AGOL database into the future shared environments.

6.0 Conclusions

The research team developed, tested, and implemented a GIS inspection tool via ArcGIS Survey123, progressing beyond the initial goal to investigate and make recommendations for GIS inspection tools for centralized data storage. The new Materials and Corrosion Asset Inspection Survey123 tool streamlines field data collection for several inspection and survey types performed across Reclamation.

A primary benefit of the Materials and Corrosion Asset Inspection Survey123 tool is its cloud-hosted database. Data collected using the Survey123 tool is stored in Reclamation's AGOL cloud, which promotes broad data accessibility and long-term storage. Inspection data logged using this tool is available through the user portal, which also serves as a back-up for data misplaced or accidentally deleted from network or other project locations. Additionally, the tool assists in standardizing data collection for coatings, cathodic protection, hazardous materials, and mechanical field inspections and surveys, thus promoting consistent data collection and allowing for future spatial or temporal analyses of large datasets. The resulting AGOL data tab also includes tailored report templates to aid organized data downloads, such as for report development.

Overall, the Materials and Corrosion Asset Inspection tool serves as a proof-of-concept for GIS data collection, storage, and interaction. It provides the groundwork to begin building a standardized database. The next stage of advancement, such as through CARMA 2.0, should incorporate the resulting database in appropriate shared environments.

7.0 Project Data

- Share Drive folder name and path where data are stored: T:\Jobs\DO_NonFeature\Science and Technology\2021-PRG-Facility Corrosion Inspection Templates and Central Database
- Point of contact name, email, and phone: Bobbi Jo Merten, bmerten@usbr.gov, 303-445-2380
- Short description of the data: documentation from app tool development, including beta testing, delta testing, AGOL report templates, interim report, conference presentation, and final report
- ArcGIS Survey123 Materials and Corrosion Asset Inspection tool available to all Reclamation users at: https://survey123.arcgis.com/share/871e80e60a5443d992358cfba18a7518?portalUrl=https://USBR.maps.arcgis.com

- Keywords: corrosion inspection, geographic information system (GIS), protective coatings, cathodic protection, hazardous materials, ultrasonic thickness, ArcGIS Survey123, asset inspection
- Approximate total size of all files: 180 MB

References

[1] D. Staton, "Enterprise Asset Registry," *Reclamation Water Operations and Maintenance Bulletin,* vol. Summer 2021, no. 252, pp. 4-5, 2021.

[2] A. Antonelli, "CARMA 2.0," *Reclamation Water Operations and Maintenance Bulletin,* vol. Summer 2023, no. 260, pp. 5-6, 2023.

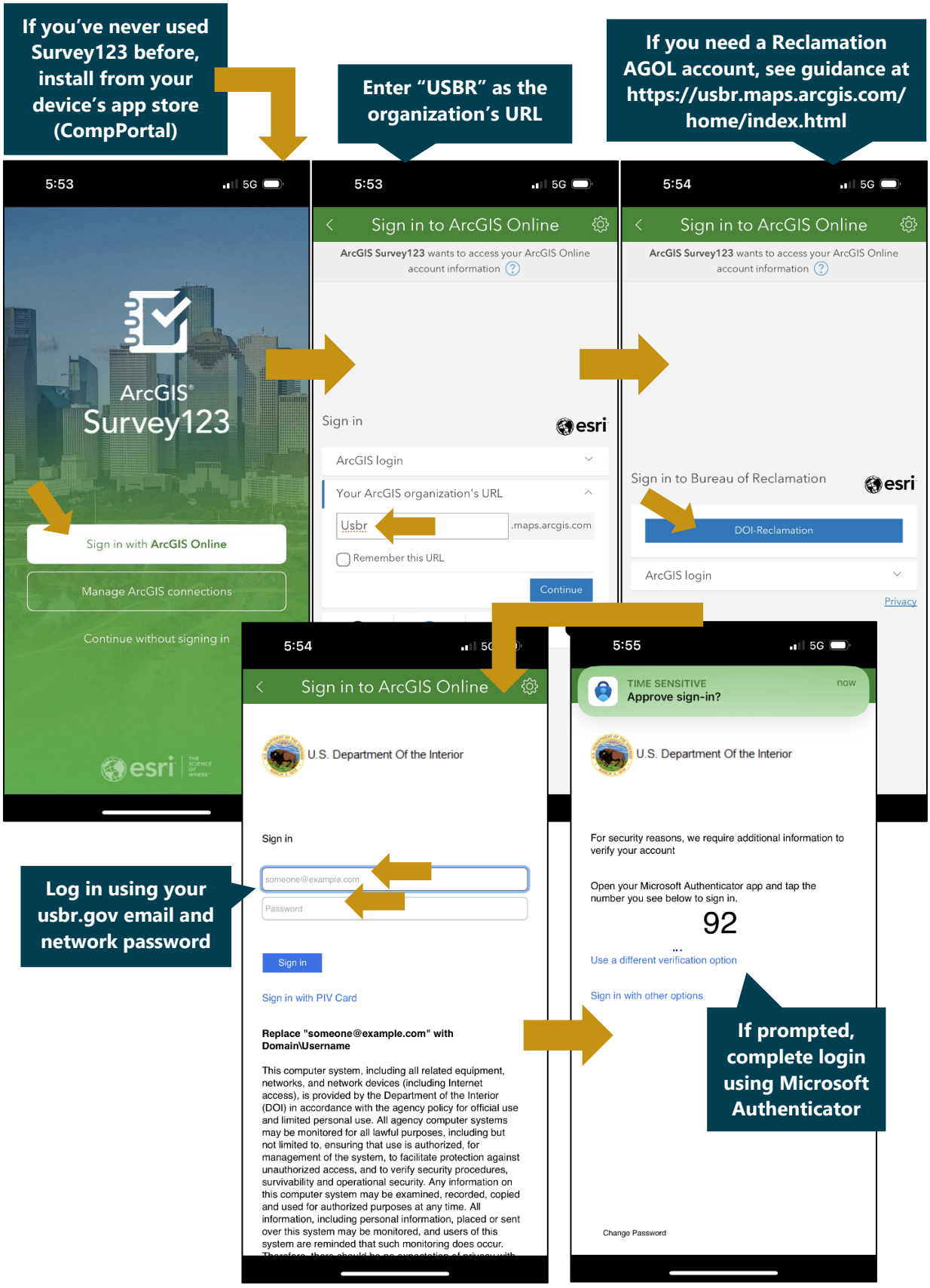
[3] "Mobile Computing - MICA and Blue Roof," U.S. Army Engineer Research and Development Center (ERDC), 20 November 2012. [Online]. Available: https://www.erdc.usace.army.mil/Media/Fact-Sheets/Fact-Sheet-Article-View/Article/476670/mobile-computing-mica-and-blue-roof/. [Accessed 2 August 2023].

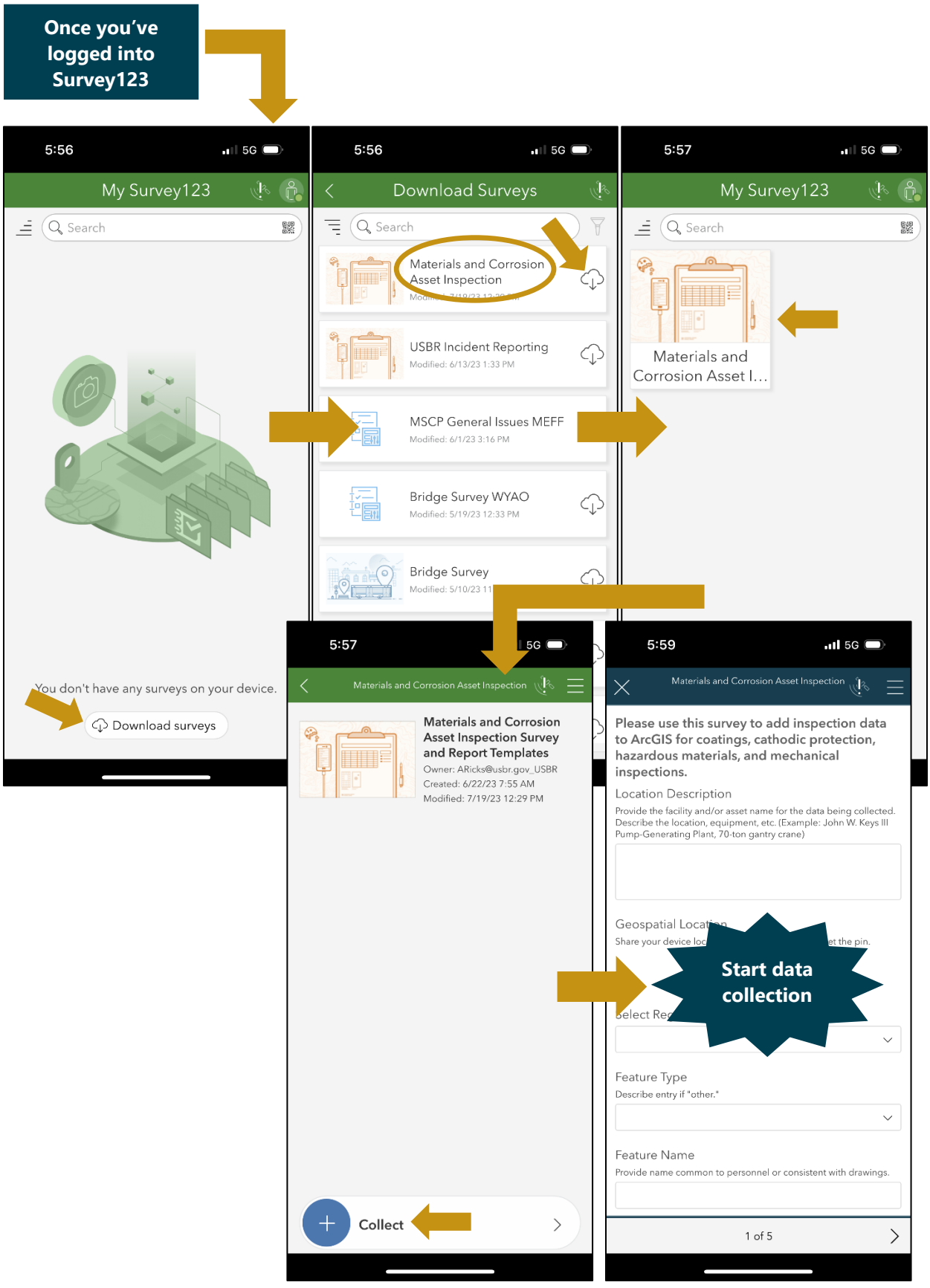
[4] B. Herner, M. Jermyn and A. Cutrell, "GIS Mapping of Reclamation's Cathodic Protection Equipment for Improved Data Collection and Monitoring for Maintenance (Final Report No. IAS-2020-0021, 8540-2022-77)," 2022.

[5] B. Herner, A. Cutrell and R. Allen, "GIS Mapping of Reclamation's Hazardous Materials Surveys for Improved Data Management, Maintenance Monitoring, and Technical Support (Final Report No. IAS-2021-004, 8540-2023-15)," 2023.

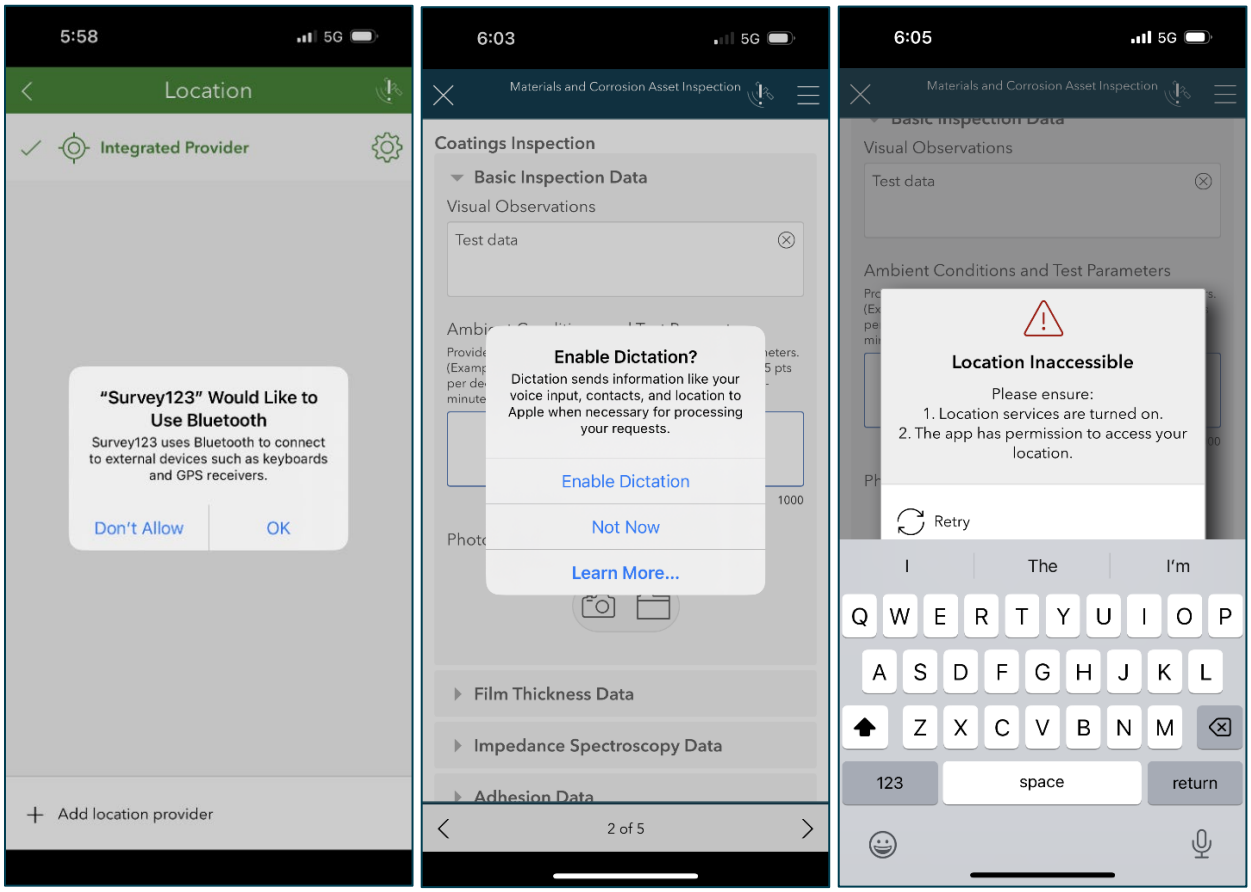
[6] B. J. Merten, "USACE-CERL and Reclamation Survey123 Facility Corrosion Inspection and ArcGIS Mapping (Technical Memorandum No. 8540-2022-73)," 2022.

Appendix A – Survey123 Tool Graphic Flowcharts


If you've never used Survey123 before, install from your device's app store (CompPortal)
Enter "USBR" as the organization's URL
If you need a Reclamation AGOL account, see guidance at https://usbr.maps.arcgis.com/home/index.html
5:53
5G
ArcGIS Survey123
Sign in with ArcGIS Online
Manage ArcGIS connections
Continue without signing in
esri
5:53
Sign in to ArcGIS Online
ArcGIS Survey123 wants to access your ArcGIS Online account information
Sign in
esri
ArcGIS login
Your ArcGIS organization's URL
Usbr
.maps.arcgis.com
Remember this URL
Continue
5:54
Sign in to ArcGIS Online
ArcGIS Survey123 wants to access your ArcGIS Online account information
Sign in to Bureau of Reclamation
esri
DOI-Reclamation
ArcGIS login
Privacy
5:54
Sign in to ArcGIS Online
U.S. Department Of the Interior
Sign in
someone@example.com
Password
Sign in
Sign in with PIV Card
Replace "someone@example.com" with Domain\Username
This computer system, including all related equipment, networks, and network devices (including Internet access), is provided by the Department of the Interior (DOI) in accordance with the agency policy for official use and limited personal use. All agency computer systems may be monitored for all lawful purposes, including but not limited to, ensuring that use is authorized, for management of the system, to facilitate protection against unauthorized access, and to verify security procedures, survivability and operational security. Any information on this computer system may be examined, recorded, copied and used for authorized purposes at any time. All information, including personal information, placed or sent over this system may be monitored, and users of this system are reminded that such monitoring does occur.
5:55
TIME SENSITIVE
Approve sign-in?
now
U.S. Department Of the Interior
For security reasons, we require additional information to verify your account
Open your Microsoft Authenticator app and tap the number you see below to sign in.
92
Use a different verification option
Sign in with other options
Change Password
Log in using your usbr.gov email and network password
If prompted, complete login using Microsoft Authenticator


Once you've logged into Survey123
5:56
My Survey123
Search
You don't have any surveys on your device.
Download surveys
5:56
Download Surveys
Search
Materials and Corrosion Asset Inspection
USBR Incident Reporting
Modified: 6/13/23 1:33 PM
MSCP General Issues MEFF
Modified: 6/1/23 3:16 PM
Bridge Survey WYAO
Modified: 5/19/23 12:33 PM
Bridge Survey
5:57
My Survey123
Search
Materials and Corrosion Asset I...
5:57
Materials and Corrosion Asset Inspection
Materials and Corrosion Asset Inspection Survey and Report Templates
Owner: ARicks@usbr.gov_USBR
Created: 6/22/23 7:55 AM
Modified: 7/19/23 12:29 PM
Collect
5:59
Materials and Corrosion Asset Inspection
Please use this survey to add inspection data to ArcGIS for coatings, cathodic protection, hazardous materials, and mechanical inspections.
Location Description
Provide the facility and/or asset name for the data being collected. Describe the location, equipment, etc. (Example: John W. Keys III Pump-Generating Plant, 70-ton gantry crane)
Geospatial Location
Start data collection
Feature Type
Describe entry if "other."
Feature Name
Provide name common to personnel or consistent with drawings.
1 of 5

Permissions to enable for Survey123



Appendix B – Templates for Online Database Report Downloads

B.1 Full Record Template

U.S. Department of the Interior | Bureau of Reclamation

Materials and Corrosion Inspection Report:

Region: ${select_region}
Project: ${mbart_projects}${ucb_projects}${lcb_projects}

DELETE THESE INSTRUCTIONS: Review input data carefully. Reorganize, delete, or format information to meet reporting needs.

Feature Name: ${feature_name}	**Date:** ${CreationDate}
Location: ${location_description | appearance: "multiline"}	**Entered By:** ${Creator}
GPS Coordinates (latitude, longitude): ${location |getValue: "y":4326 | round: 4}, ${location |getValue: "x":4326 | round: 4}	

1. Coatings Inspection

Visual Observations:
${visual_observations | appearance:"multiline"}

Dry Film Thickness (DFT) Data (mils): ${film_thickness_1}, ${film_thickness_2}, ${film_thickness_3}		**Ambient Conditions and Test Parameters:** ${ambient_conditions | appearance:"multiline"}	
Adhesion – Pull-off (psi): ${adhesion_pull_off_test}	**Adhesion – Knife/crosshatch (rating):** ${adhesion_knifecrosshatch}	**EIS – Impedance, 0.1 Hz (ohms):** ${low_frequency_impedance}	**EIS – Phase Angle, 0.1 Hz (deg):** ${low_frequency_phase_angle}

Photos:
${#coatings_photos}
${$file | size:460:0}
${$file | getValue: "name"}
${/}
${#image_of_data_plots}
${$file | size:460:0}
${$file | getValue: "name"}${/}

2. Cathodic Protection Survey

***Rectifier Data,* ID:** ${rectifier_id}

Tap Settings, As Found: ${tap_settings_as_found}	**Tap Settings, As Left:** ${tap_settings_as_left}	**Voltage Output (V):** ${voltage_output_v}	**Current Output (A):** ${current_output_a}	**Shunt Reading (mV):** ${shunt_reading_mv}	**Shunt Rating (mA/mV):** ${shunt_rating_mamv}

Junction Box Data, ID: ${junction_box_id}

Shunt Label: ${JB_shunt_label}	**Shunt Reading (mV):** ${JB_shunt_reading_mv}	**Shunt Rating (mA/mV):** ${JB_shunt_rating_mamv}	**Calculated Current Output (mA):**

1

U.S. Department of the Interior | Bureau of Reclamation

Materials and Corrosion Inspection Report:

Region: ${select_region}
Project: ${mbart_projects}${ucb_projects}${lcb_projects}

			${JB_calculated_current_output_ma}

Test Station (TS) Data, ID: ${test_station_id}

TS GPS (Lat):	**TS GPS (Long):**	**Voltage On Potential (mV):**	**Voltage Off Potential (mV):**
${gps_coordinates_latitude}	${gps_coordinates_longitude}	${voltage_on_potential_mv}	${voltage_off_potential_mv}

Test Cell Data		***Close Interval Survey***	
Test Cell Start Temperature (F): ${start_temperature}	**Test Cell End Temperature (F):** ${end_temperature}	**Data Collected:** ${data_collect_yes_no}	**Measurement Details:** ${measurement_details}

Test Comments/Visual Observations:
${cp_commentsvisual_observations | appearance: "multiline"}

Photos:
${#cp_photographs}
${$file | size:400:0}
${$file | getValue: "name"}
${/}

3. Hazardous Materials Survey

Regulated Metals:	**Asbestos:**	**PCBs:**	**PAHs:**	**Used Oil:**
${lab_analyses_regulated_metals}	${lab_analyses_asbestos}	${lab_analyses_pcbs}	${lab_analyses_pahs}	${lab_analyses_used_oil}

Photos:
${#materials_photographs}
${$file | size:460:0}
${$file | getValue: "name"}
${/}

4. Mechanical Inspection

Comments/Observations:
${commentsobservations | appearance:"multiline"}

Operational Data
${operational_data | appearance:"multiline"}

Conditions and Parameters:
${conditions_and_parameters | appearance:"multiline"}

U.S. Department of the Interior | Bureau of Reclamation

Materials and Corrosion Inspection Report:

Region: ${select_region}
Project: ${mbart_projects}${ucb_projects}${lcb_projects}

Ultrasonic Thickness (UT) Data (inches): ${utmeasurement1}, ${utmeasurement2}, ${utmeasurement3}, ${utmeasurement4}, ${utmeasurement5}	**UT Average (inches):**	**UT StDev (inches):**
Photos: ${#mechanical_inspection_photos} ${$file | size:400:0} ${$file | getValue: "name"} ${/}		

B.2 Coatings Template

U.S. Department of the Interior | Bureau of Reclamation

Coatings Inspection Report:

Region: ${select_region}
Project: ${mbart_projects}${ucb_projects}${lcb_projects}

DELETE THESE INSTRUCTIONS: Review input data carefully. Reorganize, delete, or format information to meet reporting needs.

If dry film thickness (DFT) and ultrasonic thickness (UT) are input through Survey123 app, calculate average and add to the light gray report cells. If input from other devices, revise as appropriate and add data file as appendix.

Feature Name: ${feature_name}	**Date:** ${CreationDate}
Location: ${location_description | appearance:"multiline"}	**Entered By:** ${Creator}
GPS Coordinates (latitude, longitude): ${location |getValue: "y":4326 | round: 4}, ${location |getValue: "x":4326 | round: 4}	
Visual Observations: ${visual_observations | appearance:"multiline"}	

Data Collected

Dry Film Thickness (DFT) Data (mils): ${film_thickness_1}, ${film_thickness_2}, ${film_thickness_3}		**Ambient Conditions and Test Parameters:** ${ambient_conditions | appearance:"multiline"}	
DFT Average (mils):	**DFT StDev (mils):**	**EIS – Impedance, 0.1 Hz (ohms):** ${low_frequency_impedance}	**EIS – Phase Angle, 0.1 Hz (deg):** ${low_frequency_phase_angle}
Ultrasonic Thickness (UT) Data (inches): ${utmeasurement1}, ${utmeasurement2}, ${utmeasurement3}, ${utmeasurement4}, ${utmeasurement5}		**UT Comments:** ${commentsobservations | appearance:"multiline"}	
UT Average (inches):	**UT StDev (inches):**	**Adhesion – Pull-off (psi):** ${adhesion_pull_off_test}	**Adhesion – Knife/crosshatch (rating):** ${adhesion_knifecrosshatch}

Photos:
${#coatings_photos}
${$file | size:460:0}
${$file | getValue: "name"}
${/}
${#image_of_data_plots}
${$file | size:460:0}
${$file | getValue: "name"}${/}

1

B.3 Cathodic Protection Template

U.S. Department of the Interior | Bureau of Reclamation

Cathodic Protection Survey Report:

Region: ${select_region}
Project: ${mbart_projects}${ucb_projects}${lcb_projects}${cpn_projects}${cgb_projects}

DELETE THESE INSTRUCTIONS: Review input data carefully. Reorganize, delete, or format information to meet reporting needs.	
Feature Name: ${feature_name}	**Date:** ${CreationDate}
Location: ${location_description | appearance:"multiline"}	**Entered By:** ${Creator}
GPS Coordinates (latitude, longitude): ${location |getValue: "y":4326 | round: 4}, ${location |getValue: "x":4326 | round: 4}	
***Rectifier Data,* ID:** ${rectifier_id}	

Tap Settings, As Found:	**Tap Settings, As Left:**	**Voltage Output (V):**	**Current Output (A):**	**Shunt Reading (mV):**	**Shunt Rating (mA/mV):**
${tap_settings_as_found}	${tap_settings_as_left}	${voltage_output_v}	${current_output_a}	${shunt_reading_mv}	${shunt_rating_mamv}

Junction Box Data, ID: ${junction_box_id}

Shunt Label:	**Shunt Reading (mV):**	**Shunt Rating (mA/mV):**	**Calculated Current Output (mA):**
${JB_shunt_label}	${JB_shunt_reading_mv}	${JB_shunt_rating_mamv}	${JB_calculated_current_output_ma}

Test Station (TS) Data, ID: ${test_station_id}

TS GPS (Lat):	**TS GPS (Long):**	**Voltage On Potential (mV):**	**Voltage Off Potential (mV):**
${gps_coordinates_latitude}	${gps_coordinates_longitude}	${voltage_on_potential_mv}	${voltage_off_potential_mv}

Test Cell Data		***Close Interval Survey***	
Test Cell Start Temperature (F): ${start_temperature}	**Test Cell End Temperature (F):** ${end_temperature}	**Data Collected:** ${data_collect_yes_no}	**Measurement Details:** ${measurement_details}

Test Comments/Visual Observations:
${cp_commentsvisual_observations | appearance: "multiline"}

Photos:
${#cp_photographs}
${$file | size:400:0}
${$file | getValue: "name"}
${/}

1

B.4 Hazardous Materials Template

U.S. Department of the Interior | Bureau of Reclamation

Hazmat Survey Report:

Region: ${select_region}
Project: ${mbart_projects}${ucb_projects}${lcb_projects}

DELETE THESE INSTRUCTIONS: Review input data carefully. Reorganize, delete, or format information to meet reporting needs.

Feature Name: ${feature_name}	**Date:** ${CreationDate}
Location: ${location_description | appearance: "multiline"}	**Entered By:** ${Creator}
GPS Coordinates (latitude, longitude): ${location |getValue: "y":4326 | round: 4}, ${location |getValue: "x":4326 | round: 4}	

Data Collected

Sample ID: ${sample_id}	**Sample Location:** ${sample_location}		**Description:** ${description}	**Material Type:** ${material}
Regulated Metals: ${lab_analyses_regulated_metals}	**Asbestos:** ${lab_analyses_asbestos}	**PCBs:** ${lab_analyses_pcbs}	**PAHs:** ${lab_analyses_pahs}	**Used Oil:** ${lab_analyses_used_oil}

Photos:
${#materials_photographs}
${$file | size:460:0}
${$file | getValue: "name"}
${/}

1

B.5 Mechanical Template

U.S. Department of the Interior | Bureau of Reclamation

Mechanical Inspection Report:

Region: ${select_region}
Project: ${mbart_projects}${ucb_projects}${lcb_projects}

DELETE THESE INSTRUCTIONS:** Review input data carefully. Reorganize, delete, or format information to meet reporting needs.* ***If ultrasonic thickness (UT) are input through Survey123 app, calculate average and add to the light gray report cells. If input from other devices, revise as appropriate and add data file as appendix.	
Feature Name: ${feature_name}	**Date:** ${CreationDate}
Location: ${location_description | appearance:"multiline"}	**Entered By:** ${Creator}
GPS Coordinates (latitude, longitude): ${location |getValue: "y":4326 | round: 4}, ${location |getValue: "x":4326 | round: 4}	
Comments/Observations: ${commentsobservations | appearance:"multiline"}	
Data Collected	
Operational Data ${operational_data | appearance:"multiline"}	
Conditions and Parameters: ${conditions_and_parameters | appearance:"multiline"}	

Ultrasonic Thickness (UT) Data (inches): ${utmeasurement1}, ${utmeasurement2}, ${utmeasurement3}, ${utmeasurement4}, ${utmeasurement5}	**UT Average (inches):**	**UT StDev (inches):**

Photos: ${#mechanical_inspection_photos} ${$file | size:400:0} ${$file | getValue: "name"} ${/}

1

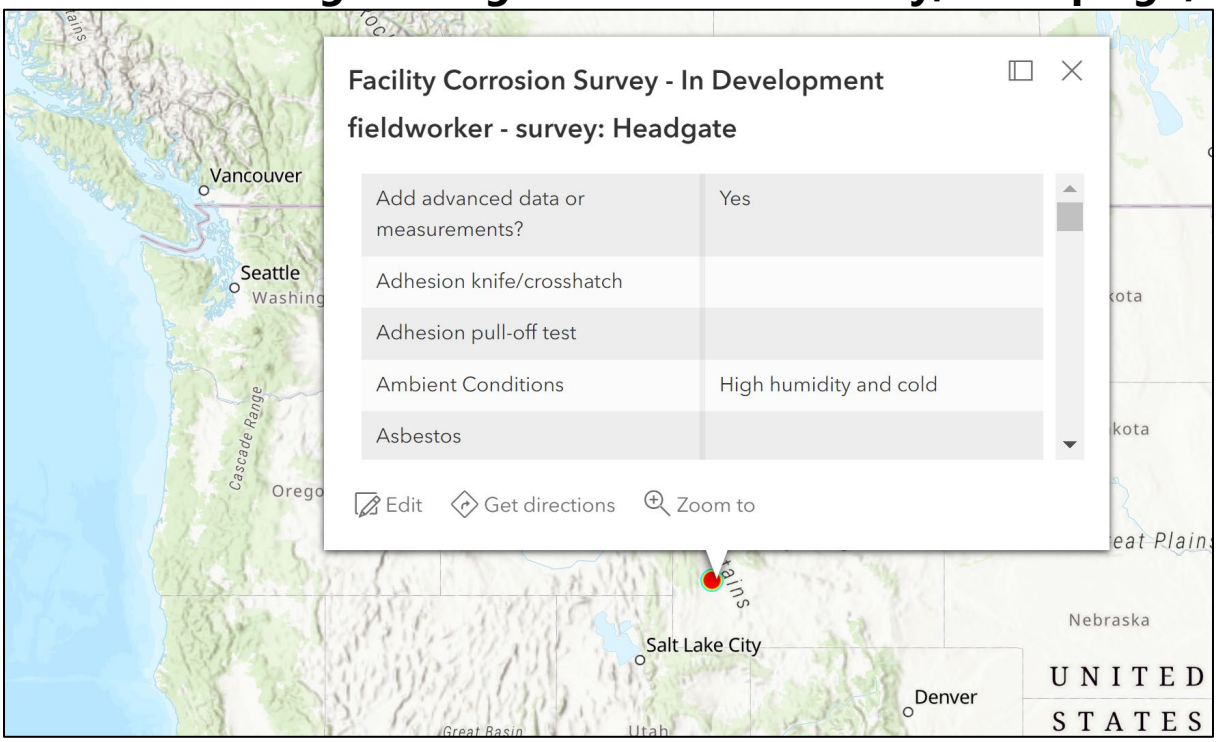
Appendix C – Interim Report, Technical Memorandum No. 8540-2022-73

BUREAU OF RECLAMATION

USACE-CERL and Reclamation Survey123 Facility Corrosion Inspection and ArcGIS Mapping

Technical Memorandum No. 8540-2022-73

U.S. Army Corps of Engineers
Engineer Research & Development Center
Construction Engineering Research Laboratory, Champaign, IL



U.S. Department of the Interior

September 29, 2022

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
09-29-2022	Research, Interim Report	May–Sept 2022

4. TITLE AND SUBTITLE
USACE-CERL and Reclamation Survey123 Facility Corrosion Inspection and ArcGIS Mapping

5a. CONTRACT NUMBER
XXXR0680R1-RR175815CERL000FC / OA979

5b. GRANT NUMBER
MIPR # W81EWF20956601 7600B

5c. PROGRAM ELEMENT NUMBER
7600A-2022-CERL-1513

6. AUTHOR(S)
Bobbi Jo Merten bmerten@usbr.gov

5d. PROJECT NUMBER
Technical Memorandum No. 8540-2022-73

5e. TASK NUMBER

5f. WORK UNIT NUMBER
86-68540

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Materials and Corrosion Laboratory
Technical Service Center
Bureau of Reclamation
U.S. Department of the Interior
Denver Federal Center
PO Box 25007, Denver, CO 80225-0007

8. PERFORMING ORGANIZATION REPORT NUMBER
8540-2022-73

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Construction Engineering Research Laboratory
Engineer Research & Development Center
U.S. Army Corps of Engineers
U.S. Department of Defense

10. SPONSOR/MONITOR'S ACRONYM(S)
USACE: U.S. Army Corps of Engineers
DOD: U.S. Department of Defense

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
8540-2022-73

12. DISTRIBUTION/AVAILABILITY STATEMENT
Report is available by request only. Email bmerten@usbr.gov.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This interim report documents the tasks completed in Fiscal Year 2022 under U.S. Army Corps of Engineers (USACE) MIPR # W81EWF20956601 on the Reclamation Science & Technology Program research project ID 22048, "Development of Facility Corrosion Inspection Templates & Planning for a Central Database.". The project team selected the Survey123 software application for development of a facility corrosion survey inspection tool and ArcGIS Online (AGOL) as a data management webpage. The survey tool allows users to document field inspection data into an app that catalogs the data in a centralized AGOL data management webpage—with or without cellular service—for coatings, cathodic protection, hazardous materials, and ultrasonic thickness testing. The next project steps are to continue development through beta testing, build a report template to generate inspection data from AGOL, and coordinate implementation as appropriate.

15. SUBJECT TERMS
Corrosion inspection, geographic information system (GIS), protective coatings, cathodic protection, hazardous materials, ultrasonic thickness

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**THIS PAGE**		17	Bobbi Jo Merten
U	U	U			**19b. TELEPHONE NUMBER** *(Include area code)* 303-445-2380

Mission Statements

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

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USACE-CERL and Reclamation Survey123 Facility Corrosion Inspection and ArcGIS Mapping

Technical Memorandum No. 8540-2022-73

prepared by

Technical Service Center
Materials and Corrosion Laboratory Group
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Cover Photograph: Screenshot of beta testing version of the Survey123 application that makes up the facility corrosion survey inspection tool (Reclamation/Bobbi Jo Merten).

Peer Review

Bureau of Reclamation
Technical Service Center
Materials and Corrosion Laboratory Group

Technical Memorandum No. 8540-2022-73

USACE-CERL and Reclamation Survey123 Facility Corrosion Inspection and ArcGIS Mapping

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Executive Summary

Reclamation performs inspections of its infrastructure to ensure that adequate corrosion protection is being achieved and to determine the presence of hazardous materials that may be impacted during projects. However, documentation for inspections is not standardized, which can make it difficult to review inspection reports across facilities or agencies and obtain parallel data.

This research investigates application-based inspection tools for use during corrosion protection field inspections in a two-phase approach. The first phase of the work is review of current application-based inspection tools and inspection data to develop standardized data templates to be used during field inspections. The second phase develops software application (app)-based survey tools with geographic information systems (GIS) for centralized storage and access to inspection data.

To develop the survey tool, the project team selected the ArcGIS Survey123 software, and the survey data will be stored and managed using the corresponding ArcGIS Online (AGOL) webpage. The survey tool will allow users to document and upload field inspection data for coatings, cathodic protection, hazardous materials, and ultrasonic thickness testing.

In fiscal year (FY) 2022, the project team utilized project funds from MIPR # W81EWF20956601 to make significant advances. Progress highlights include the following:

- Selection of ArcGIS Survey123 app and AGOL data management webpage for field corrosion inspections.
- Development of Survey123 draft Facility Corrosion Survey app inspection tool and deployment to project team for beta testing.

The next steps will continue advancing the Survey123 survey tool through feedback from beta testers. Work is also underway on a report template that will allow inspection data to be quickly populated into inspection reports with little or no additional manipulation required by the end user.

1. Introduction

The Bureau of Reclamation (Reclamation) performs inspections of its infrastructure to ensure that adequate corrosion protection is being achieved and to determine the presence of hazardous materials that may be impacted during projects. Common inspections related to corrosion protection include assessment of coatings, cathodic protection systems, and the mechanical integrity of pipe thickness, as well as hazardous materials testing, particularly for coating removal projects. Corrosion is defined as the degradation of the structure properties, and the purpose of inspections is to collect data to aid decision-making for maintenance and repair of such degradation. The ultimate goal of corrosion inspections is to prevent further degradation of Reclamation's steel structures and the expensive repairs that result from corrosion.

Current approaches for documenting these inspections generally follow the inspector's preference, with many utilizing pen-and-paper together with a device for photo-documenting. The use of smartphones or tablets as the sole instrument is becoming increasingly common. However, with a lack of standardization, it can be difficult to review inspection reports across facilities or agencies and obtain parallel data.

This research is a two-year project with two phases. The first phase is review of current application-based inspection tools and inspection data to develop standardized data templates to be used during field inspections. There are current practices on data collection for corrosion condition assessments, and the project team and partners have a joint interest in developing this guidance into tools that improve inspection consistency across each agency. As part of the first phase, this research reviewed the existing guidance and previous inspection reports to develop several inspection data templates. Including facility partners in the development of these templates helps to ensure that the adoption of the data templates can be accessible to the broad range of non-experts that conduct these inspections. The goal is for the template to improve the quality and consistency of the data across Reclamation.

The second phase develops software application (app)-based survey tools with geographic information systems (GIS) for centralized storage and access to inspection data. Centralized storage allows for data query and possible implementation of inventory analyses, such as for condition-based maintenance. The research evaluates the usefulness and appropriateness of centralized data storage for corrosion condition assessment data so that robust and accessible inventories can be built. The final activity for the second phase is to outline a recommendation, plan, and approach for implementation.

The project team and partners include specialists from Reclamation's Materials and Corrosion Laboratory (MCL), Geographic Applications & Analysis (GAA) group, Asset Management Division, and Power Resources Office, as well as field partners, including specialists from USACE and the Central Arizona Project (CAP). Reclamation's MCL is providing the primary input for the survey tool development with the GAA group executing the development. Partners are supporting all stages of the process, including:

- Sharing strengths and weaknesses of app-based inspection tools,
- Sharing ongoing and upcoming app-based or inspection-related research efforts,

- Establishing meaningful progress goals for this research project and estimating a service lifetime in which this tool will be relevant, i.e., its useful life before major updates or newer technological advancements may occur, and
- Reviewing regular research progress, providing input on research decisions, and giving feedback on the tool under development.

The U.S. Army Corps of Engineers (USACE) provided fiscal year (FY) 2022 funding support for the Reclamation Science & Technology (S&T) Program research project ID 22048, "Development of Facility Corrosion Inspection Templates & Planning for a Central Database." The research project is a 2-year effort, ending in FY 2023. This interim report documents the progress made during FY 2022 on the S&T project and the tasks accomplished as part of the agreement MIPR # W81EWF20956601.

2. Research Progress

2.1 S&T Project Kick-Off, Tasks, and Funding

Research efforts initiated in the spring of 2022, shortly after receiving S&T funding. The project kick-off included the full project team and partners. Attendees reviewed the research objectives and agreed to manage the project through bi-weekly meetings, which alternate between a full team meeting (including a progress review, updates, and feedback) and a focus session meeting. Focus sessions cover two topics separately—inspection needs and the geographic information system (GIS) options.

The contract for MIPR # W81EWF20956601 was executed on April 27, 2022. Table 1 provides the project tasks with estimated contributions from each of the two funding sources to accomplish the research objectives, as well as a detailed task description and approximate task schedule in 6-month activity intervals. This interim report supports Task 7 and will be included as an appendix in the project final report.

Table 1.—Project task, task description, schedule by fiscal year (FY), and budget breakdown for Reclamation and USACE funding.

Task No.	Task Name	Task Description	FY22 Q1–2	FY22 Q3–4	FY23 Q1–2	FY23 Q3–4	BOR Budget	MIPR Budget
0	Project Management	Coordinate proposed research strategy and tasks, periodic meetings with team members and partners, progress updates to Research Office, and change management if needed. Includes administrative support.	X	X	X	X	$ 16,000	$ 5,000
1	Prior Coatings Inspection Data Template Review	Review prior coating inspection reports to identify starting points for data templates. Review industry standard resources and best practices for standardized inspections and data collected. Document resources reviewed and findings in literature review section in final report.	X	X			$ 5,000	$ 5,000

Task No.	Task Name	Task Description	FY22 Q1–2	FY22 Q3–4	FY23 Q1–2	FY23 Q3–4	BOR Budget	MIPR Budget
2	Data Templates Drafting and End-User Reviews	Develop draft template options; begin initial review and feedback process from potential end-users. Anticipate having a basic and a detailed template with optional quantitative measurements. Adjust possible templates in coordination with Tasks 3 and 5.		X	X		$ 10,000	$ 10,000
3	Standardization of Impedance Test Method	Lead ASTM collaboration area WK67789 through test method approval; conduct small laboratory experiments to support test method finalization. Update detailed template for consistency with approved test method.	X	X	X		$ 16,000	$ -
4	Prior GIS Data Standardization Research and Existing Tools Analysis	Conduct review of prior Reclamation GIS and data standardization research and then coordinate with GIS team members to discuss possible paths forward for this GIS need. Identify strengths and weaknesses of possible approaches. Document resources reviewed and findings in literature review section in final report.	X	X	X		$ 20,000	$ 20,000
5	Develop Central Data Recommendati-ons and Field Test Templates	Coordinate with GIS team and field partners to draft recommendations. Perform several field demonstrations with the draft templates during coating inspections to get field office feedback and make iterative improvements. Develop a plan for implementation, if determined to be feasible and appropriate.		X	X	X	$ 24,000	$ 5,000
6	Distribute Inspection Templates and Facilitate Adoption	Coordinate distribution of templates as determined appropriate by team; this step is important and is considered the implementation phase of the project to ensure field offices and TSC staff are aware of and adopting the tools. This step is envisioned as several field inspections in which the end-user applies the template with support of the research team.				X	$ 7,000	$ -
7	Final Report	Develop final report. Include review of prior work, corrosion inspection templates development process, research strategy, findings, and implementation plan for central data sharing, and recommendations. Include copy of inspection templates. Facilitate final report peer reviews.		X	X	X	$ 12,000	$ 5,000
8	Data Publication	Begin the steps to publish data in the Reclamation Information Sharing Environment (RISE).				X	$ 1,000	
9	Closeout Process	Perform 508 compliance and finalization of the final report, draft bulletin, complete RISE entries, and submit all final materials.				X	$ 1,000	

Note: Q=quarter, BOR=Bureau of Reclamation, MIPR=Military Interdepartmental Purchase Request.

2.2 Current Technologies and Project Goal Refinement

Both project partners currently use or are investigating app-based inspection tools. For example, CAP developed and incorporated a tablet-based app several years ago. The app allows the inspector to input data for inspections of concrete or steel structures. It also allows the users to take photos within the app. CAP has an ongoing effort to catalog its facilities through GIS mapping along with data on key physical features.

USACE has several projects related to advancing inspection tools and inspection data management. Example areas include better inspection tools and robotics for corrosion condition assessments, structural health monitoring or automated condition assessment, and risk prediction to reduce overservicing of facilities.

This research will build on the efforts of CAP and USACE to provide the next stage of inspection app development. Opportunities for improvement include: 1) room for notes, 2) improved navigation through fewer dropdowns, and 3) broader application to pipe types.

Based on the numerous technological advancements underway in data management and machine learning, the team estimates this research project will provide an advancement with a useable life of 3–5 years. Therefore, the research will provide the groundwork for future work and the next stage of advancement.

2.3 Software Selection and Survey Tool Development

The research sought an inspection tool that can be easily used with cellular service, but that can also be used offline to collect data in locations with no or unreliable cellular service. The discussion of inspection tool needs led to the recommendation of ArcGIS Survey123 and ArcGIS Online (AGOL). Survey123 is the software that will be used to develop the survey tool where users will be able to input inspection data. AGOL is the corresponding GIS data management webpage which will store the data entered into the app and allow users to manage and view the input inspection data. Both Survey123 and AGOL were created and are managed by Esri, a commonly used company for GIS software and mapping.

2.3.1 Survey123 Selection

Survey123 is a commonly used tool that is currently in use by thousands of Department of Interior (DOI) users for data collection and mapping purposes. The survey tool can be accessed through a web browser or through a mobile app. The Survey123 app saves the user data to a cache during offline use and uploads the data once cellular service is available.

Survey123 is set up to document a single survey per location, meaning that it requires each survey to be submitted at that location before moving to the next location. For example, for a cathodic protection survey along a pipeline alignment, the data from each point/location along the alignment must be submitted individually at that point/location. This may be the most substantial drawback for the existing version of Survey123, and no other software application was found to overcome this limitation.

One helpful feature of Survey123 is a set of broad options for tool development that are available to the developer. For example, Survey123 has sequencing rules that allow the data input for one field to change the successive fields that are shown to the user.

2.3.2 Data Entry Fields

Part of the survey tool development process is coming up with the necessary data entry fields and determining what kind of data input each field will accept, such as selection from a dropdown list, manual entry, or a yes/no. Table 2 provides the team's draft initial input fields (column headers) and the type of data input that will be accepted.

The left two columns of Table 2 show how the "Region" field and "E-USBRProject" field pull input options from asset registry lists, which allows for consistency with other GIS data across Reclamation for these facilities. This is an example of how the input fields can make use of Survey123 sequencing rules because based on which item is chosen from the asset registry list, only selected applicable fields will follow.

Table 2.—Draft Initial Inputs for Survey Tool Development

Region	E-USBRProject	Feature Type	Feature Name	Inspection Type(s)
Select One	Select One	Manual Entry	Manual Entry	Yes / No
[asset registry]	*[asset registry]*	*[develop types]*		*[develop types]*
		Examples:	[# = text, default]	Corrosion - Coating Inspection
		Pipe		Corrosion - Cathodic Protection Survey
		Gate		Hazardous Materials - Sampling
		Other		Mechanical Inspection

From this starting point, each iteration worked to develop the Survey123 tool to shorten the survey and improve user navigation. Subsequent tool revisions utilized a collection form to document reviewer name, edit location, comment, and the details of the edit—i.e., a comment disposition tracking spreadsheet.

2.4 Results of Survey Tool Development

All components of the facility corrosion inspection survey tool are accessed online. To manage the users of the survey app and list information about the survey tool, the project team created an Esri-hosted User Group, or online community, called the "Facility Corrosion Inspection Templates Group." It should be noted that inspectors can still log inspection data into the Survey123 app without being a member of the User Group but becoming a group member allows access to all of the links and information published within that User Group.

Table 3 provides the online locations, or weblinks, for all components of the survey tool, including the Survey123 app, the corresponding AGOL data management webpage, and the Facility Corrosion Inspection Templates User Group. Table 3 also provides links where users can determine if they already have an AGOL account, create a new AGOL account, and find instructions on using Microsoft authenticator to open the installed Survey123 app on a mobile device.

Table 3.—Weblinks to App-tool Under Development, AGOL Tools, and Useful Sites

Item	Description	Weblink	Comments
1	Survey123 App-based Tool	https://survey123.arcgis.com/share/aac7c5516efc4efc9273f1420c569415	Link to Survey123 app to document inspection data; use organization URL, enter "usbr" (for Reclamation users)
2	User Group	https://usbr.maps.arcgis.com/home/group.html?id=f12dc5c4967940718fc6861eda77395a&view=list#content	Online community for survey tool users with general information for use; contact Adam Ricks or Greg Gault for support.
3	Create Account	https://usbr.maps.arcgis.com/home/index.html	Link for DOI users to create an AGOL account.
4	Partner Info	https://intra.usbr.gov/borgis/agolstart.html#collab	Instructions for partners to gain access to AGOL system for collaboration.
5	USACE AGOL	https://usace.maps.arcgis.com/home/signin.html?returnUrl=https%3A%2F%2Fusace.maps.arcgis.com%2Fhome%2Forganization.html	Link for USACE AGOL site to determine if user has an account.
6	Authenticator	https://intra.usbr.gov/borgis/docs/mobile/EsriApp_MSAuthenticator_LoginQuickGuide.pdf https://intra.usbr.gov/borgis/docs/mobile/SetupMSAuthenticator_IndividualDevice.pdf https://intra.usbr.gov/borgis/docs/mobile/SetupMSAuthenticator_SharedDevice.pdf	Instructions for how to use Microsoft authenticator to open the installed Survey123 app on a mobile device (3 links provided).

2.4.1 Survey Tool User Interfaces

The primary goal of the tool development process is establishing the user interface, or the visual aspect of the tool that users will see and interact with while logging a survey. Figure 1 shows a screenshot of the appearance of the Survey123 tool for the Facility Corrosion Survey during beta testing. The weblink for the tool is listed in Table 3 as Item 1.

Figure 1.—Screenshot of draft Facility Corrosion Survey in Survey123.

Figure 2, below, presents a screenshot of the "Content" tab of the User Group webpage, which is listed as Item 2 from Table 3. The screenshot shows the content as two large icons, a clipboard and world map, which are links to the Survey123 form and corresponding AGOL data management webpage, respectively. Note that the Survey123 form requires an additional step to click on the "Open in Survey123" button to open the published survey.

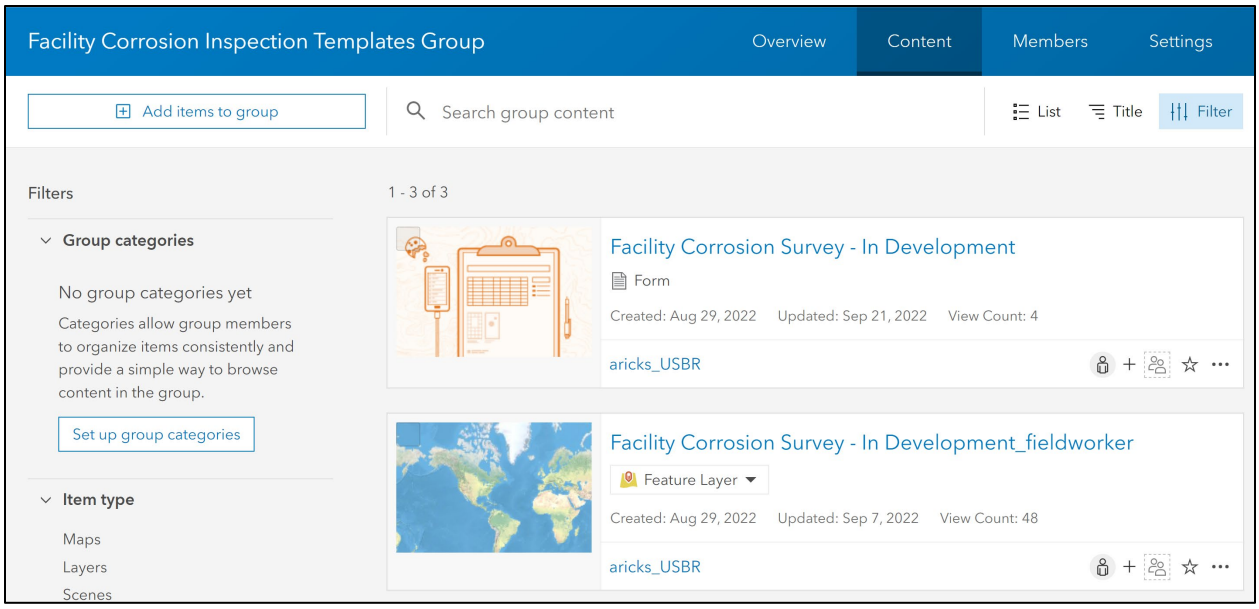

Figure 2.—Screenshot of "Facility Corrosion Inspection Templates" User Group webpage with main links to survey and data sites.

The User Group webpage in Figure 2 also allows the user to select other tabs in the upper right-hand corner. The "Members" tab shows the current member list with options to revise member roles, add new members, etc. The "Overview" tab provides useful information, including the Survey123 link and instructions for using the Microsoft authenticator to access the app (Items 1 and 6 from Table 3, respectively).

The Survey123 published form is available through a web browser or by installing the Survey123 app, such as on an iPad or iPhone device. The user must use the survey tool app—as opposed to the browser—to have the benefit of collecting data without cellular service. The current understanding is that draft surveys are stored for up to 7 days; the user must connect to cellular service before the end of this period for the data to upload to AGOL.

2.4.2 ArcGIS Online Mapping

AGOL is the corresponding online data management platform used to manage, store, and view data submitted through the Survey123 app. AGOL can be accessed online at the User Group (Item 2 in Table 3) by clicking on the world map icon, as shown in Figure 2. The direct weblink to the AGOL data management webpage is:
https://survey123.arcgis.com/surveys/aac7c5516efc4efc9273f1420c569415/data

Figure 3 provides a screenshot of the data management webpage. The user has numerous options for filtering the data that is shown by specific facilities, survey dates, etc. Further, the page also provides a "Report" option, and the development of a report template is forthcoming.

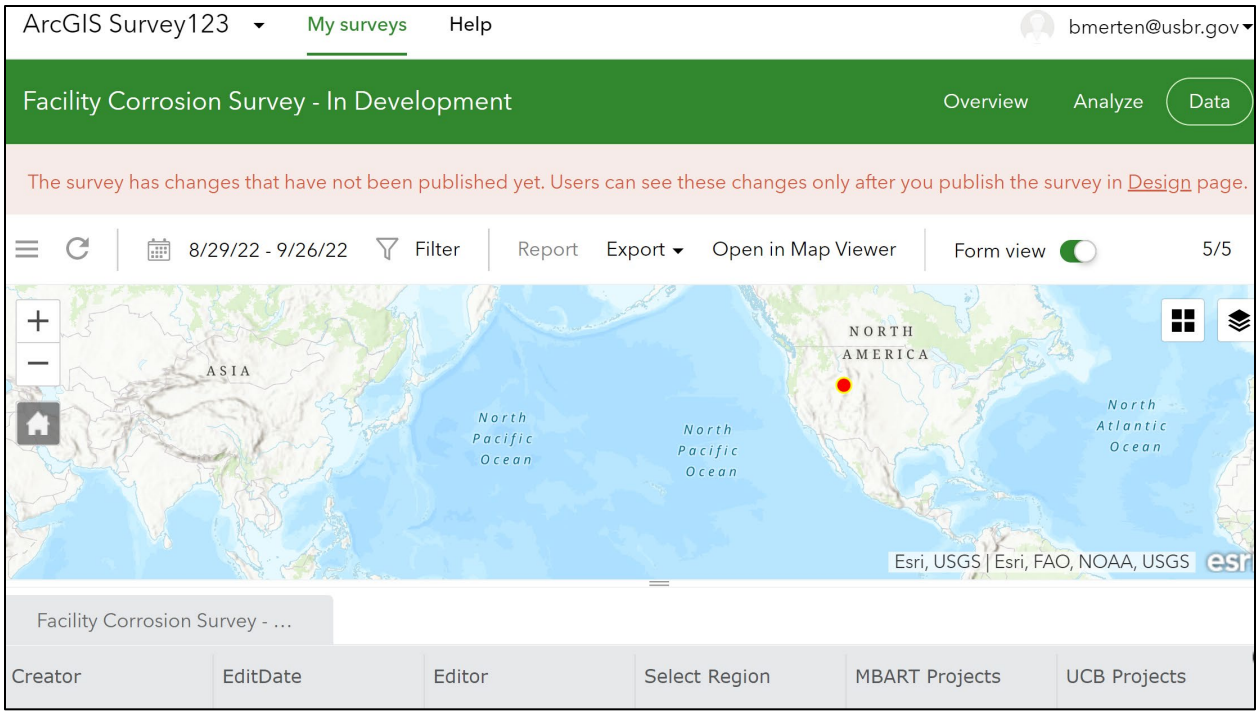

Figure 3.—Screenshot of AGOL Survey123 data portal, "Facility Corrosion Survey – In Development," for customizable data filtering and viewing of survey data.

Another option to view AGOL data is the Map Viewer, available by selecting the "Open in Map Viewer" option shown in Figure 4. The Map Viewer provides multiple options for visualizing the data geographically on the map, expanding on the customizability offered in Figure 3.

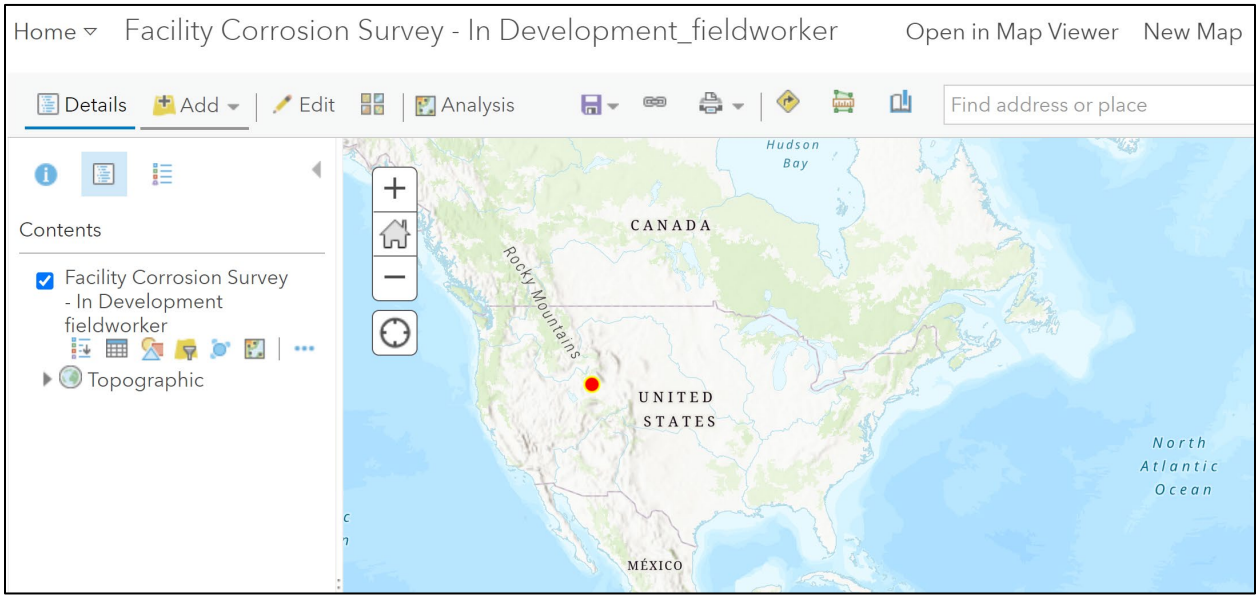

Figure 4. —Screenshot of the Classic Map Viewer, accessible from AGOL Survey123 for additional customizable data visualization.

3. Next Steps

3.1. Survey123 Beta Testing

In FY 2023, the project team will continue the Survey123 beta testing and development updates to enhance tool usability. This beta testing will likely continue through spring of 2023, which should allow time for various team members and partners to log a number of different inspection types on a variety of structures.

If additional funding were available, the primary use would be to increase the number of beta-test inspections. The current approach for beta testing is for inspectors to first document inspection data as usual (with documentation approach varying between inspectors), and then to incorporate Survey123 as a secondary data collection technique where appropriate. This duplicate documentation ensures no inspection data is lost until the survey tool is better understood and trusted, at which point it can be used as the sole documentation method. To facilitate this beta testing process, research funds will support the extra time required for data entry into the Survey123 tool, which may range from about a half-day to several staff days depending on the inspection and the number of people involved. So additional research funds would support an increased number of beta-test inspections, thereby providing a greater amount of feedback and user data for the project team to review and apply toward the research project.

3.2. Data Management Webpage and Report Template

Based on the progress made in FY 2022, the project team is progressing beyond the original planned scope described for Tasks 4 and 5 in Table 1. Beyond simply investigating and making recommendations on GIS tools for centralized data, the team has begun building an AGOL data management webpage and is actively demonstrating its attributes and usefulness for corrosion inspection data management.

Final steps for the project, which will occur during FY 2023, include review of the data management webpage for improvements. This exercise will become more meaningful once more beta-test data from more inspection locations are available. The team will also draft an inspection report template with the goal of adding a feature to the data management webpage that can generate draft reports from the data collected in Survey123. Traditional inspection reports are serving as the starting point for the template. Future iterations of the report template will occur as time allows, with the goal being to maximize functionality of the feature, thereby increasing the benefit of using AGOL and Survey123 as inspection tools. The ideal end-product is a feature that can reliably and quickly populate inspection data into inspection reports with little or no additional manipulation required by the end user. This would provide a significant time savings for inspectors upon their return to the office.

3.3. Implementation

The final project step is to evaluate whether the survey tools (app and data management webpage) are ready for release and adoption. If they are found to be ready, the team will coordinate an implementation approach. If the team finds need for additional technological advances or

modifications that precede tool release and adoption, the final report will clearly identify the next steps needed.

4. Conclusion

The project team utilized project funds from MIPR # W81EWF20956601 to make significant advances in FY 2022. Progress highlights include the following:

- Selection of ArcGIS Survey123 app and AGOL data management webpage for field corrosion inspections.
- Development of Survey123 draft Facility Corrosion Survey app inspection tool and deployment to project team for beta testing.

Project next steps will continue advancing the Survey123 tool through feedback from beta testers. Work is also underway on a report template that will allow inspection data to be quickly populated into inspection reports with little or no additional manipulation required by the end user.