QAPP : LIVING SHORELINE AND SUBMERGED AQUATIC VEGETATION COMPATABILITY STUDY

Project ID: **CBIG Contract # 14-22-3015 CBG 9001**

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580 Taylor Ave.
Annapolis, MD 21401

A. PROGRAM MANAGEMENT

A1. Approval Sheet

Concurrence

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EPA Region 3

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Approval

EPA Region 3

Name: Durga Ghosh Title: R3 Delegated Approving Official Organization: CBP / USGS	Signature: Durga Ghosh Date: 09/27/2022

Note: This approval action represents EPA's determination that the document(s) under review comply with applicable requirements of the EPA Region 3 Quality Management Plan [https://www.epa.gov/sites/production/files/2020-06/documents/r3qmp-final-r3-signatures-2020.pdf] and other applicable requirements in EPA quality regulations and policies [https://www.epa.gov/quality]. This approval action does **not** represent EPA's verification of the accuracy or completeness of document(s) under review, and is **not** intended to constitute EPA direction of work by contractors, grantees or subgrantees, or other non-EPA parties.

Revision History

This table shows changes to this controlled document over time. The most recent version is presented in the top row of the table. Previous versions of the document are maintained by Quality Manager.

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A3. Distribution List

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A4. Project/Task Organization

Most individuals participating in this project are with Maryland's Department of Natural Resources Resource Assessment Service (RAS) and Chesapeake and Coastal Watershed Services (CCS) units. Staff at Anne Arundel Community College are also participating as subcontractors that will provide SAV seed processing and storage services.

Brooke Landry, Natural Resource Biologist, Maryland Department of Natural Resources, Resource Assessment Service (RAS) will serve as the project leader and Field Operations Manager (FOM). She will be responsible for project coordination, supply acquisition, field data collection and validation, analysis, interpretation, and reporting. She will be responsible for general oversight of the project and will write the draft and final report.

Becky Golden, Program Manager, Maryland Department of Natural Resources, Resource Assessment Service (RAS) will assist with field data collection and data analysis and will assist with report preparation.

Becky Swerida, Reserve Biologist, Chesapeake Bay National Estuarine Research Reserve

Maryland Department of Natural Resources, Chesapeake and Coastal Watershed Services (CCS) will provide logistical support and information regarding living shoreline site data and construction status, and assist with field data collection when available.

Dave Goshorn, Assistant Secretary, Aquatic Resources, Office of the Secretary, Maryland Department of Natural Resources will serve as the project QA/QC manager and be responsible for maintaining the official, approved QA Project Plan.

Ari Engelberg, Implementation Project Officer, Maryland Department of Natural Resources, Chesapeake and Coastal Services (CCS) will serve as a CCS point of contact for this project, review and approve progress reports, and serve as general grant manager.

Wesley Gould, Implementation Project Officer, Maryland Department of Natural Resources, Chesapeake and Coastal Watershed Service (CCS) will provide living shoreline construction and design information and participate in report preparation and review, internal DNR communication of results, and incorporate information gleaned into future living shoreline designs.

Gabe Cohee, Restoration Program Manager, Maryland Department of Natural Resources, Chesapeake and Coastal Watershed Services (CCS) will provide living shoreline construction information and participate in report review and internal DNR communication of results.

Nicole Carlozo, Natural Resource Resiliency Planner, Maryland Department of Natural Resources, Chesapeake and Coastal Watershed Services (CCS) will provide living shoreline construction information and participate in report review and internal DNR communication of results.

Michael Norman, Laboratory Manager and Biology Center Director, Anne Arundel Community College, along with his students will provide seed processing and storage services on a subcontractor basis.

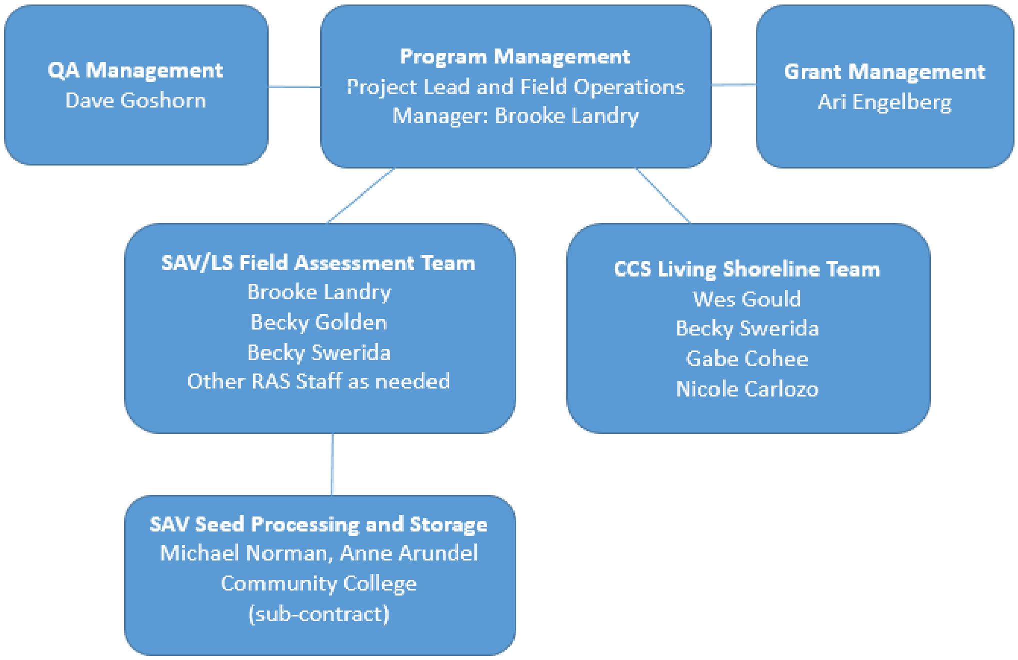

Figure 1. SAV/LS Compatibility Study Project Organization Chart

A5. Problem Definition/Background

Submerged aquatic vegetation (SAV) is one of the Chesapeake Bay's most important habitats and resources. SAV provides food and habitat, as well as nursery grounds, for commercially and recreationally important finfish and shellfish (Heck et al.2003; Beck et al. 2001; Wyda et al. 2002), and resident and migrating waterfowl depend on SAV for sustenance (Perry et al. 1981, 2007; Straub et al. 2012). SAV absorbs excess nutrients (Kenworthy et al. 1982; McGlathery et al. 2007), reducing the prevalence of algae blooms, and reduces wave and current energy (Koch 2001; Koch and Gust 1999; Gurbisz et al. 2016), which promotes the settlement of suspended solids, reduces erosion and increases water clarity. More recently, its contribution to global carbon sequestration has been highlighted (Duarte et al. 2005, 2010; Fourqurean et al. 2012), with blue carbon now recognized as an important tool for mitigating climate change (Laffoley and Grimsditch 2009; Crooks et al. 2011; Mcleod et al. 2011). Also with regard to climate change impacts, SAV has been found to play a vital role in buffering the effects of acidification throughout the Chesapeake Bay (Su et al. 2020).

Recent studies (Landry and Golden 2018; Patrick et al. 2016, 2018) assessing the local and system-wide impacts of hardened shorelines on nearshore habitats have shown that armoring shorelines – either with riprap revetments or bulkheads – negatively impacts SAV habitat and resilience indicators at both the local and system scales. With sea level rise (SLR) predicted to reach up to 2 additional feet in the next 30 years, options to protect shorelines without resorting to harmful hardening practices will be necessary to protect SAV and ensure long-term land-water connectivity and migration corridors for SAV, as well as the animals that utilize its habitat. Living shorelines have exhibited tremendous potential in filling this need, particularly in their ability to maintain connectivity and protect shorelines from erosion, and recent work by Palinkas and Staver (in preparation) has demonstrated that living shorelines do not impact SAV at the system scale. More work is necessary, however, to fully understand the impacts that living shorelines may have on SAV habitat at the local scale. Depending on the living shoreline design, some SAV burial or other impacts resulting from the alteration in nearshore hydrologic dynamics may occur. Our intention is to improve our understanding of localized living shoreline impacts on SAV and potential SAV habitat. A secondary objective is to determine if the incorporation of SAV restoration into living shoreline designs is a feasible option to reduce long-term or permanent impacts to SAV at the local scale.

Approach: We will conduct a Before-After-Control-Impact (BACI) study to assess the effect of living shoreline construction and placement on SAV habitat at three new living shoreline construction sites and control sites in Maryland's tidal waters. The type, design, and geographic location (and consequently salinity regime) of the living shorelines included in the study will be dependent on the construction schedules of projects funded by the Resiliency through Restoration grant program.

In addition to assessing direct impacts on SAV habitat, we will determine if incorporating SAV restoration through seeding into living shoreline designs may be a potential option for reducing long-term or permanent SAV impacts at living shoreline sites. If direct SAV restoration at living shoreline sites proves to be a feasible and beneficial option, SAV restoration may become a more standard component of living shoreline design with SAV mitigation efforts taking place at the living shoreline site itself rather than out-of-kind creation or monetary compensation.

Anticipated Benefits: Because living shorelines are the preferred method of erosion control in Maryland (Tidal Wetland Regulations for Living Shorelines formalize the requirements of the Living Shorelines Protection Act passed by the Maryland General Assembly during the 2008 Legislative Session), it is necessary to fully understand their impact on SAV and potential SAV habitat. This project will improve our understanding of living shoreline impacts and the potential for SAV restoration at living shoreline construction sites. It is anticipated that this study will answer lingering questions regarding the impacts of living shorelines on adjacent SAV and improve regulatory confidence in approving living shoreline permit applications for sites that may include SAV impacts. It has been established that hardened shorelines, particularly vertical bulkheads, interrupt land-to-water connectivity and negatively impact SAV at both the local and system-wide scales. As sea level rises and Maryland's shorelines are subject to increased wave energy and storm surge, it will be necessary to move from a "harden-everything" approach to an approach more closely rooted in nature-based solutions.

A6. Project/Task Description

Overview Project and Task Schedule

Dec 2021 – August 2022: **Quality Assurance Project Plan (QAPP) Development**. Draft the QAPP, submit to the EPA for review, and integrate any required revisions or additions into a final version accepted by the EPA.

Dec 2021 – August 2022: **Site selection**. Identify pre-construction living shoreline sites and corresponding control sites to be used for the study.

August 2022 – Mar 2023: **Year 1 monitoring**.

- August 2022 – September 2022: Survey SAV or potential SAV habitat at each living shoreline site and control site prior to living shoreline construction.

- October 2022 – March 2023: During living shoreline construction fall/winter/spring 2022-2023 (this is dependent on the construction schedule and weather), the sites will be visited by RAS or CCS staff. No in situ measurements will be taken at this time as it will be outside of the SAV growing season. Control sites will also not be surveyed at this time. This site visit is intended to ensure that construction is occurring as planned and that any deviations from the original plans are noted.

Apr 2023 – Feb 2024: **Year 2 monitoring & Seed Collection, Processing, and Storage.**

- April 2023 – August 2023: Survey each living shoreline site and control site post-construction to determine if SAV is passively recruiting.
- July 2023 – Feb 2024: Identify potential donor SAV beds for seed collection. Collect, process, and store SAV seeds in preparation for Year 3 seeding. Seed processing and storage conducted by sub-contractor.

Mar 2024 – Jun 2024: **Year 3 monitoring and final report.**

- Mar 2024 - April 2024: Survey each living shoreline site and control site post-construction to determine if SAV is passively recruiting. At each site, conduct SAV restoration using appropriate seeds and seeding methodology as dictated in *Small-scale SAV Restoration in Chesapeake Bay: A Guide to the Restoration of Submerged Aquatic Vegetation (SAV) in Chesapeake Bay and its Tidal Tributaries* (Jasinski et al. 2021).
- May 2024 – June 2024: Survey each living shoreline and control site in May and again in June to determine planting/germination success. Write final report of research results.

It is anticipated that a thorough review of living shoreline impacts on SAV would take several years; SAV and SAV restoration efforts should be monitored for multiple growing seasons. Here we offer a modest approach that will narrow that official timeline to three growing seasons and three sites with the understanding that long-term impacts will not be monitored as part of this study. However, RAS staff and the SAV component team will continue to monitor the sites separate from this contract for subsequent years.

Site Identification and Selection

The project lead will work with CCS staff to identify Resiliency through Restoration living shoreline projects that will be constructed in Maryland during the fall/winter of 2022/2023. Up to six potential sites will be physically assessed for site selection. Three sites will ultimately be selected for inclusion in the study and ideally each will be large enough to accommodate one area for active SAV restoration and one area where active SAV restoration/seeding will not be conducted to determine if natural recruitment or recovery is equally effective. The area of SAV restoration will be scaled relative to the size of the living shoreline project so it cannot be determined in advance of site selection. Nearby control sites will also be selected to determine if SAV impacts are unique to the living shoreline site and due to construction/restoration or based on system-wide conditions (ie. changes in water quality/clarity).

Because living shoreline construction permits are frequently denied due to the presence of SAV, the selected living shoreline sites will not necessarily include SAV prior to construction but SAV should be present nearby within the system and the area to be altered will be appropriate SAV habitat (stable sediment, shallow enough for light penetration). Potential study sites will be evaluated and identified via GIS/map-based assessments by late-July 2022 and on-site assessments and final selections will occur by the end of August 2022.

Pre-Construction Surveys

Year 1 monitoring will commence and take place during the SAV growing season (this is the BEFORE component of the BACI study). The project lead will work with CCS staff to secure living shoreline project plans and conduct SAV surveys in the footprint of the project. Five transects will be surveyed at each site and its corresponding control site. Surveys will be conducted using snorkel or SCUBA gear by SCUBA-certified biologists (Brooke Landry, Becky Golden). Distance between transects will depend on the width of the project. If for example, a living shoreline project is anticipated to have a 100 meter (m) wide footprint, transects will be placed at 25 m intervals. Each transect will be 100 m long and SAV (if present) will be surveyed within 0.25 m^2 quadrats placed at 5 m intervals, for a total of 20 quadrats per transect. Habitat conditions will still be monitored if SAV is absent at site.

At each *site, transect,* and *quadrat,* relevant physical and biological information will be measured and recorded. Basic water quality parameters (conductivity, dissolved oxygen, temperatures, pH and turbidity) will be measured in situ using a YSI ProDSS.

Control sites that correspond with each living shoreline construction site will be surveyed in the same manner as the living shoreline site. In the example above where the future living shoreline site footprint is 100 m wide, the control site will be 100 m wide and along the same shoreline with similar fetch. Transects will be set 25 m apart and quadrats will be surveyed every 5 meters. Control sites will be established along natural shorelines – not hardened shorelines.

During living shoreline construction fall/winter/spring 2022-2023 (this is dependent on the construction schedule and weather), the sites will be visited by RAS or CCS staff. No in situ measurements will be taken at this time as it will be outside of the SAV growing season. Control sites will also not be surveyed at this time. This site visit is intended to ensure that construction is occurring as planned and that any deviations from the original plans are noted.

Post-Construction Surveys
Following completion of construction of each living shoreline site, the AFTER component of the BACI study will take place the following growing season (summer 2023). Each living shoreline site will be surveyed and transects and quadrats will be placed as in 2022 at each site and identical parameters will be measured. This AFTER survey will serve to determine how exactly the construction of the living shoreline changed the bathymetry and sediment characteristics of the site and to determine how SAV habitat was affected and if SAV is passively recruiting to the site following IMPACT.

SAV Restoration Component
Seeds of appropriate SAV species (as determined by the salinity at the site and species present within the system) will be collected during the 2023 growing season during 2-3 collection events depending on the number of species identified for restoration. Seeds will be collected, transferred, processed, and stored according to the instructions and protocols established in *Small-scale SAV Restoration in Chesapeake Bay: A Guide to the Restoration of Submerged Aquatic Vegetation (SAV) in Chesapeake Bay and its Tidal Tributaries* (Jasinski et al. 2021). Processing and over-winter storage will be conducted by Michael Norman and his students at Anne Arundel Community College on a sub-contract basis as identified in the project budget.

In spring of 2024, the project lead will work with project team members to set up exclosures within the adjacent subtidal areas of each living shoreline to conduct SAV restoration by seeding. Half of the adjacent subtidal area at each living shoreline site will be dedicated to SAV restoration. Seeds will be placed at the density and using the protocol recommended by Jasinski et al. (2021).

Final SAV Survey
During the summer 2024 growing season, post-construction and restoration site surveys, as well as control site surveys, will be conducted in the same manner as previously described. This final survey to assess restoration success and/or natural recruitment of SAV to the living shoreline and control sites post construction will conclude the field component of this study, though longer-term monitoring will be conducted by RAS staff outside of this study to determine long-term success of the restoration effort.

Data analysis and reporting:
A nested Analysis of Variance (ANOVA) will be used to determine if SAV density or species composition are significantly impacted by living shoreline installation. Metrics and diversity averaged among quadrants and transects will be analyzed pre- and post- impact for each site to test for short-term impacts. The null hypotheses are: 1) average SAV density metrics and diversity will not significantly differ pre- and post- impact at any living shoreline site; 2) average SAV density metrics and diversity will not differ significantly between living shoreline sites and control sites. An ANOVA will also be used to determine if there is a difference in SAV growth between SAV restoration plots and non-SAV restoration plots at living shoreline sites. The null hypothesis is: there is no difference between restoration plots and non-restoration plots in SAV growth post-construction at living shoreline sites. The final report will include an analysis of the data collected, an evaluation of the results, and recommendations for incorporation (or not) of SAV restoration in living shoreline projects.

A7. Quality Objective and Criteria

The goal of this project is to obtain the data necessary to more fully understand the impact of living shoreline construction and placement on SAV habitat in Maryland's portion of Chesapeake Bay and to determine the feasibility of incorporating SAV restoration into living shoreline designs. Collecting accurate, precise, representative, complete, and comparable data will be of the utmost priority. All data will be collected by highly trained DNR staff that have been conducting similar SAV surveys for decades using internationally recognized SAV monitoring methods. Basic water quality parameters (conductivity, dissolved oxygen, temperatures, pH and turbidity) will be measured in situ using a YSI ProDSS. Table 1 addresses accuracy, detection limits, and sensitivity for each parameter sampled for, where applicable. Survey locations will be dependent on the Resiliency through Restoration grant program project implementation schedule. Established SAV restoration protocols that have been described by Jasinski et al. (2021) for Chesapeake Bay SAV will be followed to maximize the potential for SAV restoration success at living shoreline sites. Data quality objectives for this project are summarized in Table 2.

Table 1. Specifications for the YSI ProDSS Sonde Sensors

Parameter (units)	Sensor Type	Range	Accuracy	Resolution	Calibration	Maximum Depth
Dissolved Oxygen (% saturation)	Optical Luminescense - Lifetime Method	0 to 500%	0 to 200 (+/-1% of reading or 1% air saturation, whichever is greater) 200% to 500% (+/-8% of reading)	0.1% or 1% air saturation (user selectable)	1 or 2 points	100 m
Dissolved Oxygen (mg/L, ppm) temp comp range -5 to 50°C	Optical Luminescense - Lifetime Method	0 to 50 mg/L	0 to 20 mg/L (+/-0.1 mg/L or 1% of reading, whichever is greater) 20-50 mg/L (+/-8% of reading)	0.1 or 0.01 mg/L (user selectable)	1 or 2 points (user selectable)	100 m
Temperature (°C, °F, K)	Thermistor; Combination Sensor with Conductivity	-5 to 70°C (23 to 158°F)	+/-0.2°C	0.1°C or 0.1°F (user selectable)	None	100 m
Turbidity (FNU, NTU)	Nephelometric - Optical, 90° Scatter	0 to 4000 FNU	0 to 999 (0.3 or +/-2% of reading, whicever is greater) 1000 to 4000 (+/-5% of reading)	0.1 FNU	1, 2, or 3 points (user selectable)	n/a
Conductivity* (µS, mS)	Four Nickel Electrode Cell	0 to 200 mS/cm	0 to 100 mS/cm (+/-0.5% of reading or 0.001 mS/cm, whichever is greater) 100 to 200 mS/cm (+/-1% of reading)	0.001, 0.01, or 0.1 mS/cm (range dependent)	1 point	100 m
pH (mV, pH units)	Glass Blub Comination Electrode, Ag/AgCl Reference Gel	0 to 14 units	+/-0.2 units	0.01 units	1, 2, or 3 points (user selectable)	100 m

Table 2. Data quality objectives, criteria, and quality control protocols for this project.

Data Quality Objective	Criteria	Protocol
Bias	SAV percent cover, canopy height, and presense of reproductive structures should be comparable across members of the field assessment team within ±10%.	Field assessment team members will "calibrate" their assessments of percent cover by reviewing published examples of visual representations of different percent covers (Short 2017). Field estimates will then be made by consensus of the field team. The field assessment team will also review photographs and SAV maps from previous years before the field season begins.
Spatial Accuracy	GPS units should have a reported accuracy less than or equal to 2 meters	Transect and quadrat locations will be recorded using a Garmin GPSMap78. Transect locations will then be staked in the field using screw anchors. The minimum accuracy tolerance of the unit will be set to reject saving any waypoints with spatial accuracy less than 0.03m, thereby assuring spatial accuracy requirements are met or exceeded.
Comparability	Field data should be collected using standardized methods.	Check that protocols from the QAPP were used for field observations. The QA Manager should use filtering functions to check field assessment team's spreadsheets for data entry errors. All percent cover values should fall into one of the categories specified in the sampling methods. A minimum of 10% of field observations should be checked against electronic spreadsheets. Water quality data collected using the YSI ProDDS will follow collection and calibration protocols established in DNR's Shallow Water Monitoring Program QAPP (Parham et al. 2021).
Completeness	Field observations should be made for SAV percent cover, canopy height, reproduction, epiphyte occurrence, and in the case of restoration surveys, shoot counts. In addition, environmental data collection should include Secchi depth, water depth, sediment type, conductivity, dissolved oxygen, temperature, pH and turbidity.	Check field observations for completeness. Document reasons for any deviations from sampling protocol.

A8. Special Training/Certification

All individuals involved in field surveys are SCUBA certified through nationally recognized agencies (i.e. PADI or NAUI). Copies of dive certification cards and DAN Diver Insurance cards will be kept on file with the QA/QC project manager. Familiarity with equipment and protocols used will be performed in advance of field surveys by the team leader.

- Brooke Landry is an expert in the field of SAV ecology and plant identification and has been performing SAV surveys since 2002 using the equipment and similar protocols described in this document.
- Becky Golden is an expert in the field of SAV ecology and plant identification and has been performing SAV surveys since 2001 using the equipment and similar protocols described in this document.

The data will be validated by DNR's Quality Assurance (QA) Manager, Dave Goshorn, for quality assurance and who will report back to Brooke Landry, Project Leader. All training and certification records are kept in the C2/RAS wing of DNR/Tawes State Building and can be verified.

A9. Documents and Records

SAV, water quality, and physical data collected in the field will be recorded on pre-prepared waterproof datasheets and later transcribed into digital Excel files. These datasheets will include date, time of sampling, weather conditions, parameters sampled for, and crew names. All original datasheets will be copied to maintain back-ups. Copies will be stored with Becky Golden and originals will be stored with project lead, Brooke Landry in the Resource Assessment Service wing (C2) of Maryland's Department of Natural Resources and held in accordance with the Department's records management and retention strategy. Data will also be saved in Microsoft Excel and shared among team members using Google Sheets. Data will additionally be backed up on the DNR RAS Shared Drive. The QA/QC Manager will be responsible for an annual review of the Quality Assurance Project Plan. The QAPP will be revised and resubmitted to EPA Region 3 if changes are necessary.

B. DATA GENERATION AND ACQUISITION

B1. Sampling Process Design (Experimental Design)

Experimental design overview

This study will include two components. The first component will be to assess the effect of living shoreline installation on SAV habitat and will employ a Before-After-Control-Impact (BACI) experimental design. The second component of this study will be a small-scale SAV restoration effort at the living shoreline sites to better understand feasibility of incorporating SAV restoration into living shoreline designs.

BACI Design
BACI designs are useful in evaluating human-induced versus natural effects on ecological variables. We will survey SAV habitat at sites permitted for living shoreline construction and installation. Surveys will take place during the summers before and after the living shoreline installation to determine if the construction and installation had an impact on the adjacent SAV habitat. Simultaneously, we will survey SAV habitat at nearby control sites. This will allow us to determine if changes in SAV habitat are due to natural, system-wide impacts rather than local, human-induced impacts. Control sites will be selected based on similarities to the living shoreline site. They will be within the same tributary, within 1 km of the living shoreline site, and will have a similar fetch, slope and shoreline alignment to the extent possible.

Site Selection
Three living shoreline sites will be included in this project and all will be in Maryland's tidal waters, including portions of the Chesapeake and Atlantic Coastal Bays. Living shoreline and control sites will be selected in spring/summer of 2022 and surveyed in summer of 2022 prior to living shoreline installation. These sites have not yet been determined - site selection will be dependent on the construction schedule of projects supported by the Resiliency through Restoration grant program. The project lead will work with CCS project team members who are familiar with the proposed living shoreline projects and their permit and construction status to identify up to six sites for visual assessment and to determine which are most appropriate for inclusion in the study. CCS staff will provide living shoreline project plans. The living shoreline selected for inclusion will be scheduled for construction/installation during the fall and winter of 2022-2023.

Sites will be prioritized for inclusion based on:
1. **SAV presence** (if SAV is present prior to construction, impacts to SAV habitat during and after construction will be more readily observed, so SAV presence will be prioritized).

2. B**athymetry** (the impacted area will be suitable SAV habitat, so sites less than 2 meters deep with a gentle slope will be prioritized).

3. **Sediment characteristics** (some sediment types, such as peat or anoxic mud, are less conducive to SAV growth so sandy sediments or those with a sand/mud combination will be prioritized).

4. **Fetch** (fetch is related to site-specific wave and current energy which affects SAV distribution, so lower fetch sites will be prioritized).

5. **Size** (the living shoreline needs to be large enough to divide the area in half and conduct an SAV restoration project that is at least 20 m^2, so larger/longer sites will be prioritized).

Control sites will be selected based on similarities to the living shoreline site. They will be within the same tributary, within 1 km of the living shoreline site, and will have a similar fetch, slope and shoreline alignment to the extent possible. Control sites will be established along natural shorelines – not hardened shorelines – to avoid confounding the impacts observed.

SAV presence and tributary-specific distribution will be determined using publicly available data from the Virginia Institute of Marine Science (VIMS) SAV Aerial Survey Program (http://web.vims.edu/bio/sav/). These SAV maps and aerial images will also be used to identify potential control sites prior to visual assessments. Visual assessments of SAV presence, bathymetry, sediment characteristics, fetch, and project size at both the living shoreline sites and the control sites will all be conducted in-situ for final determination of inclusion in the study.

Pre-Construction Surveys
Once living shoreline and control sites are identified, Year 1 monitoring will commence and take place during the 2022 SAV growing season (April – October). This is the BEFORE component of the BACI study. SAV surveys will be conducted during the SAV growing season and each living shoreline and control site will include four 100 meter transects. Transects will be oriented perpendicular to the shoreline running shoreward to channelward and placed at even intervals along the linear square footage of the proposed living shoreline site. Distance between transects will depend on the width of the project. If a living shoreline project is anticipated to have a 100 meter (m) wide footprint, transects will be placed at 30-35 meter intervals. Each transect will be 100 meter long and SAV habitat will be surveyed within 0.25 m^2 quadrats placed at 10 meter intervals, for a total of 11 quadrats per transect (Fig. 2). Surveys will be conducted using snorkel or SCUBA gear by SCUBA-certified biologists (Brooke Landry, Becky Golden). All SAV surveys will be in-situ, visual assessments. No actual SAV biomass or water samples will be collected for this component of the study.

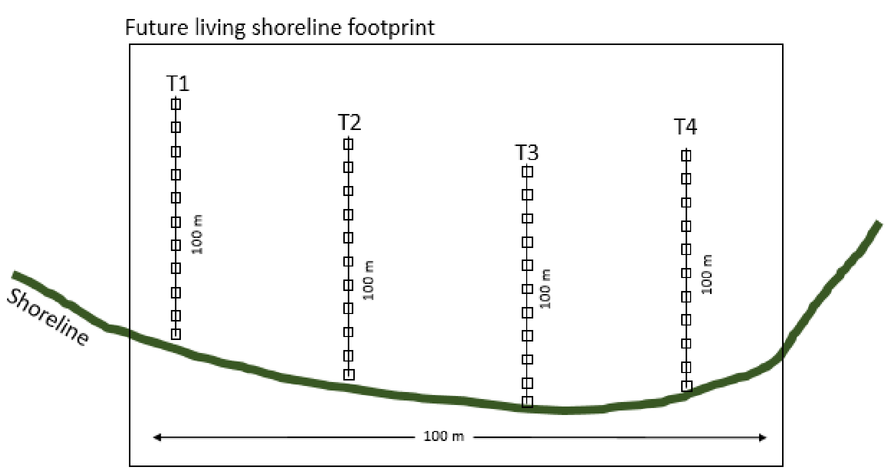

Figure 2. Schematic of future 100 meter wide living shoreline site. Transects are placed 30-35 meters apart and run perpendicular to shore. 0.25 m2 quadrats are placed every 10 meters along the length of transect.

At each transect, the following parameters will be recorded or measured:

1. **Date and time**

2. **Coordinates at beginning and end of transect** in decimal degrees using a handheld Garmin GPSMap78. Transects should begin at Mean Low Water (MLW) and end 100 meters out from the beginning point.

3. **Secchi depth** using an 8" Secchi disk with attached measuring string at beginning, middle, and end of transect.

4. **Conductivity, dissolved oxygen, temperature, pH, and turbidity** (using a YSI ProDSS) at middle of transect.

At each survey point along the transect, the following physical parameters will be measured and recorded:

1. **Waypoint** and corresponding latitude and longitude (take a GPS point at each quadrat using handheld Garmin GPS)

2. **Water depth** (measure water depth using a pre-marked PVC depth stick at each quadrat and correct to MLW using the predicted tide table)

3. **Sediment/substrate type** (identify if bottom is sand, mud, peat, gravel/rocky, or combo)

At each survey point along the transect, the following biological parameters within a $0.25m^2$ quadrat will be measured and recorded on pre-prepared waterproof datasheets:

1**. Total SAV cover (including macroalgae)** – measured from 5% to 100% in 5% increments, with the presence of very few plants (<5% cover) assigned a value of 1% cover

2. **Cover of each species present, including macroalgae** - measured from 5% to 100% in 5% increments, with the presence of very few plants (<5% cover) assigned a value of 1% cover. Percentages should be assigned based on how much of the quadrat is occupied by that species, not by how much of the total SAV is made up of that species. For example, if the total SAV is 50% of the quadrat and it's all widgeon grass, widgeon grass should be assigned a value of 50%, not 100%.

3. **Canopy height** - defined as the height in centimeters of 80% of the <u>leaf material</u> (not reproductive structures) of the dominant species, ignoring the tallest 20% of the leaves.

4. **Presence/absence of reproductive structures** (flowers, seeds, seed pods) – defined as the presence or absence of any reproductive structures of each species observed in the quadrat.

5. **Epiphyte loading** (measured as low, medium, and high and defined as the abundance of epiphytes on 80% of the leaf material of the dominant species, ignoring the most and least fouled 20%)

Control sites that correspond with each living shoreline construction site will be surveyed in the same manner as the living shoreline site. In the example above where the future living shoreline site length is 100 m wide, the control site will be within 1 km of the living shoreline site, and will have similar bathymetry, sediment characteristics, and fetch. Transects will be set 30-35 m apart and quadrats will be surveyed every 10 meters. Control sites will be established along natural shorelines – not hardened shorelines – to avoid confounding the impacts observed.

During living shoreline construction fall/winter/spring 2022-2023 (this is dependent on the construction schedule and weather), the sites will be visited by RAS or CCS staff. No in situ measurements will be taken at this time as it will be outside of the SAV growing season. Control sites will also not be surveyed at this time. This site visit is intended to ensure that construction is occurring as planned and that any deviations from the original plans are noted. Pictures will be taken from all possible angles and stored with the datasheets and data for this project. No in-situ measurements will be taken at this time as it will be outside of the SAV growing season. Control sites will also not be surveyed at this time as it is outside of the SAV growing season.

Post-Construction Surveys
Following completion of construction/installation of each living shoreline site, the AFTER component of the BACI study will take place the following SAV growing season (summer 2023). Each living shoreline and control site will be surveyed and transects and quadrats will be placed as in 2022 at each site; identical parameters will be measured. This AFTER survey will serve to determine how exactly the construction of the living shoreline changed the bathymetry and sediment characteristics of the site and to determine how SAV habitat was affected and if SAV is passively recruiting to the site following IMPACT.

SAV Restoration
Year 2 of the study will involve seed collection, processing, and storage for the SAV restoration component of the study. The selected living shoreline sites will ideally be large enough to include an adjacent subtidal SAV restoration plot that is at least 20 m^2 in half of the impacted area following construction and installation. The other half of the adjacent subtidal area will not be seeded and observed to determine if natural recruitment is as beneficial as direct seeding (Fig. 3). As it is generally recommended to wait one year post construction at living shoreline sites to allow the site to settle, SAV restoration won't be attempted until spring 2024. The BACI component of the study will allow us to determine if changes in SAV at the site are related to the installation of a living shoreline while the SAV restoration component will allow us to determine if it is feasible and beneficial to incorporate SAV restoration into living shoreline designs.

Seeds of appropriate SAV species will be collected during the 2023 SAV growing season during 2-3 collection events depending on the number of species identified for restoration.

If selected living shoreline sites are in the tidal fresh or oligohaline, *Vallisneria americana* (wild celery) will be used for restoration. If in the mesohaline, either *Ruppia maritima* (widgeon grass), *Stuckenia pectinata* (Sago pondweed), or *Potamogeton perfoliatus* (redhead grass) will be used. To the extent feasible at mesohaline sites, the dominant species present in the area will be used, but determination will also be made based on the availability of suitable SAV donor beds. Donor bed suitability and seed "readiness" will be determined following seed collection protocols described in *Small-scale SAV Restoration in Chesapeake Bay: A Guide to the Restoration of Submerged Aquatic Vegetation (SAV) in Chesapeake Bay and its Tidal Tributaries* (Jasinski et al. 2021).

Seeds will be collected, transferred, processed, and stored according to the instructions and protocols established in Jasinski et al. 2021. Processing and over-winter storage will be conducted by Michael Norman and his students at Anne Arundel Community College on a sub-contract basis as identified in the project budget.

In spring of 2024 (Year 3), the project lead will work with project team members to set up exclosures within the adjacent subtidal area of each living shoreline site (Fig. 3) to conduct SAV restoration by seeding. Half of each living shoreline site will be dedicated to SAV restoration, but the exact placement and layout of the restoration project cannot be determined until the sites have been selected. Exclosures will be erected using mesh fencing and PVC poles as described in Jasinski et al. (2021). The purpose of the exclosure is to reduce wave energy at the restoration site, contain seeds, and exclude predators such as blue crabs, turtles, and waterfowl that may be inclined to feed on the seeds and young, emergent shoots. Seeds will be placed by hand at the recommended density, time, and using the protocol recommended by Jasinski et al. (2021).

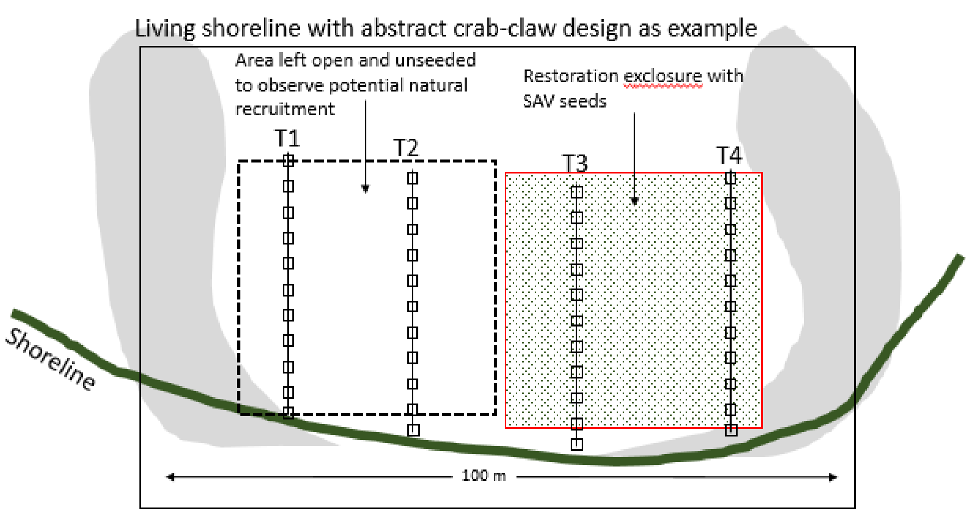

Figure 3. Living shoreline with abstract crab-claw design as an example. Half of the site will be dedicated to SAV restoration (red square) while the other half is left opened to observe potential natural SAV recruitment.

Final SAV Survey
SAV will be surveyed at living shoreline and control sites in summer 2024 in the same manner as described above along five transects. Additionally, the entire site – inside and outside of the restoration plot exclosures - will be scanned for SAV emergence so that shoots emerging beyond the transect lines can be quantified. If shoots are observed, surveys will be conducted in 15 haphazardly-placed 0.25 m^2 quadrats both inside and outside of the exclosure boundaries for a total of 30 quadrats per living shoreline site. SAV percent cover, individual species % cover, total SAV shoot count (shoots counted in the entire 0.25 m^2 quadrat), and canopy height will be recorded to determine germination success and initial success of the restoration effort inside the restoration plot and the coincident recovery/recruitment of SAV outside of the restoration plot.

This final survey to assess restoration success and/or natural recruitment of SAV to the site post construction will conclude the field component of this study, though longer-term monitoring will be conducted by RAS staff outside of this study to determine long-term success of the restoration effort.

B2. Sampling Methods

All SAV surveys will be in-situ, visual assessments. No actual SAV biomass or water samples will be collected for the BACI component of the study. Water quality parameters will be measured in situ following the water quality data collection protocols described in the QAPP for Maryland's Shallow Water Monitoring Program (Parham et al. 2021).

For the SAV restoration component of the study, seed collection will be conducted by hand from boats or while wading, depending on the location of the donor bed. SAV seeds or seed pods will be temporarily held in mesh bags or baskets and transported to Anne Arundel Community College for processing and storage following the protocols described in Jasinski et al. 2021. During transportation, wet newspaper will be used to keep seeds from desiccating.

B3. Sample Handling and Custody

Living Shoreline and Control Site Data
Data observations collected during living shoreline and control site surveys will be recorded on pre-prepared waterproof data sheets using #2 pencils. As each page of the data sheet is filled, a picture of the page will be taken using the project lead's iPAD or underwater camera. Completed datasheets will be stored in a secured plastic folder in the field and the folder will be stored in the equipment and sample locker on the boat or in the truck and transported to the RAS wing of DNR. Datasheets will be rinsed, dried, and stored in the project lead's work file cabinet and in accordance with the Department's data management and retention policy. Data will be transferred from the field datasheet into an Excel spreadsheet by the project lead. The Excel file will be converted to a Google Sheets document and shared with team

members for review and collaboration. Back-up copies will be maintained in the SAVGROUP folder on the RAS shared file drive.

All SAV data observations will be non-invasive and collected in-situ.

SAV Seed Collection
The species used for SAV restoration will be dependent on the location of the living shoreline sites selected. If in the tidal fresh or oligohaline, *Vallisneria americana* (wild celery) will be used. If in the mesohaline, either *Ruppia maritima* (widgeon grass), *Stuckenia pectinata (*Sago pondweed), or *Potamogeton perfoliatus* (redhead grass) will be used. To the extent feasible at mesohaline sites, the dominant species present in the area will be used, but determination will be made based on the availability of suitable SAV donor beds.

Seeds will be collected, transferred, processed, and stored according to the instructions and protocols established in Jasinski et al. 2021. Processing and over-winter storage will be conducted by Michael Norman and his students at Anne Arundel Community College on a sub-contract basis as identified in the project budget.

B4. Analytical Methods

A nested Analysis of Variance (ANOVA) will be used to determine if SAV density or species composition are significantly impacted by living shoreline installation. Metrics and diversity averaged among quadrants and transects will be analyzed pre- and post- impact for each site to test for short-term impacts. Change in total SAV % cover, the % cover of individual SAV species, the frequency of occurrence of total SAV and each SAV species, and species richness will all be evaluated and assessed for significant difference between the Before/After periods and the Control/Impact sites.

The null hypotheses are: 1) average SAV density metrics and diversity will not significantly differ pre- and post- impact at any living shoreline site; 2) average SAV density metrics and diversity will not differ significantly between living shoreline sites and control sites.

Species richness is defined as the total number of species observed at each treatment. The Shannon Weiner Index and Pielou's evenness, which account for both species richness and relative abundance of each species to determine how well a species is represented within a community, will be calculated from the total SAV percent cover and individual species percent cover for each transect. Frequency of occurrence (number of quadrats where observed/total number of quadrats) for each species or genera at each site will also be calculated and evaluated.

An ANOVA will also be used to determine if there is a difference in SAV growth between SAV restoration plots and non-SAV restoration plots at living shoreline sites. The null hypothesis is: there is no difference between restoration plots and non-restoration plots in SAV growth post-construction at living shoreline sites.

The final report will include an analysis of the data collected, an evaluation of the results, and recommendations for incorporation (or not) of SAV restoration in living shoreline projects.

B5. Quality Control

Team members surveying SAV and collecting water quality data using the Secchi disk and handheld YSI ProDSS will be trained on all aspects of data collection and overseen by the project lead. For initial quadrat and transect sampling by team members other than the project lead/FOM, observations will be verified upon visual inspection of quadrat by the FOM to ensure consistency. Datasheets will be reviewed in the field following each survey to ensure that all data has been recorded and that data entries "make sense."

The Project QA Officer will check that the data quality objectives are met using the criteria and methods from Table 1 in Section A7. The FOM will verify that the field crews are following the protocols correctly during field sampling. Databases of results will be checked for transcription errors and bad data using two methods. First, the entire data set will be checked against the entries in each field data sheet. Second, the Project QA Officer will discuss outlier occurrences with the Project Manager to determine if there are outliers in the data set. The Project QA Officer and the Project Manager will examine the outliers to determine whether these data should remain in the dataset.

B6. Instrument/Equipment Testing, Inspection, and Maintenance

The FOM will be responsible for checking the batteries in the GPS and digital underwater camera before traveling to sampling sites each day that the equipment is in use. The GPS, camera, and a spare set of batteries will be taken into the field in a waterproof container. The project lead/FOM will also transfer photographs from the camera to a computer at the end of each sampling day to ensure that the camera has sufficient memory available to store new pictures on the next sampling day or to ensure that incase of accident or malfunction, that there is minimal loss of image data.

The FOM will be responsible for ensuring that the YSI ProDSS has been checked for damage and calibrated prior to each field season and then prior to each site survey. Calibration protocols will be the same as identified in the QAPP for Maryland DNR's Shallow Water Monitoring Program (Parham et al. 2021). To avoid damage, the YSI will be transported into the field in its carrying case and stored inside the case when not in use. Spare batteries will be taken into the field in the same hard case used to transport the YSI Sonde or in another waterproof case to avoid corrosion. Upon return to the office, YSI probes will be cleaned with tap water and a small amount of water will be placed in the calibration cup until next use.

Field inspection and Testing

1. At every site where the YSI ProDSS will be used, the travel cup is taken off before the boat leaves the dock, placed in the probe protecting cup, and wrapped in a wet towel (DI water). The YSI is returned to the cup following docking.

2. At each site a QA/QC surface measurement is taken before lowering into water to ensure accuracy.
    a. The local DO is not to exceed +/-2% of 100.0%, if this occurs, re-rinse using DI water, re-calibration of the YSI is necessary if the value does not fall within this range.

3. YSI is rinsed with DI water after every site, taking care to rinse the conductivity port (Kopp and Neckles 2009), placed in a wet towel (DI water) to keep ports moist, and into a protective case for safe travel between sites.

B7. Instrument/Equipment Calibration and Frequency

The FOM will be responsible for ensuring that the YSI ProDSS used for water quality parameter measurements has been checked for damage and calibrated prior to each field season and prior to each survey. Calibration protocols will be the same as identified in the QAPP for DNR's Shallow Water Monitoring Program (Parham et al. 2021). To avoid damage, the YSI ProDSS will be transported into the field in its carrying case and stored inside the case when not in use. Spare batteries will be taken into the field in the same hard case used to transport the YSI ProDSS or in another waterproof case to avoid corrosion.

B8. Inspection/Acceptance of Supplies and Consumables

The FOM will prepare field equipment for daily use, ensuring proper calibration is completed, software is updated, and/or power sources are optimized for peak performance (i.e., charged/cycled). Standards purchased for YSI sonde calibration are developed by YSI and are labeled with the date opened.

B9. Non-direct Measurements

Information on tides will be used to determine the dates and times optimal for surveys to occur and seeds to be collected. NOAA Tide Predictions for Chesapeake Bay will be used: http://tidesandcurrents.noaa.gov/noaatidepredictions/

SAV abundance and distribution data from the VIMS SAV interactive map will be used to assist with overall site condition review and control site locations: https://www.vims.edu/research/units/programs/sav/access/maps/index.php

B10. Data Management

Data observations collected during living shoreline and control site surveys will be recorded on pre-prepared waterproof data sheets using #2 pencils. As each page of the data sheet is filled, a picture of the page will be taken using the project lead's iPAD or underwater camera. Completed datasheets will be stored in a secured plastic folder in the field and the folder will be stored in the equipment and sample locker on the boat or in the truck and transported to the RAS wing of DNR. Datasheets will be rinsed, dried, and stored in the project lead's work file cabinet and in accordance with the Department's data management and retention policy.

Data will be transferred from the field datasheet into an Excel spreadsheet by the project lead. The Excel file will be converted to a Google Sheets document and shared with team members for review and collaboration in a project-specific Google Drive folder. Back-up copies will be maintained in the SAVGROUP folder on the RAS shared file drive.

The field assessment team will assign filenames to photographs taken during construction and any taken during the surveys using the sample-labeling scheme: site name, transect, and date and those will be stored in the same Google Drive as the data.

The project leader will provide the Project QA Officer with copies of all electronic files by sharing a copy of the Google Drive folder link (although they will have permanent access) within one month of the completion of the field work for the current field season.

C. ASSESSMENT AND OVERSIGHT

C1. Assessments and Response Actions

Assessments (e.g. data quality) can be scheduled for any time that is mutually convenient for the user groups (RAS, CCS), the QA Manager, and our team. Brooke Landry will oversee and provide regular checks, including verifying field procedures, throughout the season and during data analysis. Regular check in with CCS according to the QAPP and contract agreement will occur quarterly.

Furthermore, in order to confirm that field sampling, field analysis and laboratory activities are occurring as planned, the Project QA Officer and Field Operations Manager/Project Leader will confer after the first sampling event each year to discuss the methods being employed and to review the quality assurance samples. This audit will involve a review of the data generated and an assurance that the protocols described are being followed. At this time, all concerns regarding the survey protocols and analysis techniques will be addressed and any changes deemed necessary will be made to ensure consistency and quality of subsequent sampling. The Project Leader will have the authority to resolve any problems encountered. Assessment frequencies and responsible personnel are shown in the following table.

Table 3. Assessment and Response Action Table

Assessment Type	Frequency (Annual Basis)	Person Responsible for Performing Assessment	Person Responsible for Responding to Assessment Findings	Person Responsible for Monitoring Effectiveness of Corrective Actions
Field sampling audit	Once after first sampling day	FOM with Project QA Manager	FOM with Project QA Manager	FOM with Project QA Manager
Field analytical audit (GPS, Camera, YSI)	Once after first sampling day	FOM with Project QA Manager	FOM with Project QA Manager	FOM with Project QA Manager
Data Quality Assurance	Annually	Project QA Manager	Project QA Manager	Project QA Manager

C2. Reports to Management

Quarterly and semi-annual reports will be submitted, incorporating all of the surveying, analysis, and restoration conducted to that point. Following the final quarterly report, a final report will be created that includes all of project data as well as analysis of the data, results, discussion, conclusions, and recommendations.

Reporting will occur as follows:

- Interim Progress Reports: quarterly reports will be made to Chesapeake and Coastal Services via Grants Gateway web portal and will describe all of the surveying, analysis, and restoration conducted to that point.
- Final Report: a draft final report will be submitted for review to Chesapeake and Coastal Services. This report will include:
    - An executive summary
    - A summary of all methods used, analytical techniques and results.
    - Implications of the work for comprehensive conservation and living shoreline design implementation.
    - Recommendations for future restoration and shoreline and SAV protection activities.
    - If necessary, amend the draft final project report in response to comments provided by CCS.

- Present a final report and oral presentation if requested to CCS and submit the final report (Adobe PDF format) and all associated data to CCS via Grants Gateway and email to interested parties and the Project Team.

D. DATA VALIDATION AND USABILITY

D1. Data Review, Verification, and Validation

Data collected in the field (on datasheets and handheld devices) will be reviewed during collection, upon return to the office, and again after data has been input electronically to ensure consistency. Data will be input by trained staff and crosschecked prior to analysis by the Project Lead. Inconsistent values will be removed before analysis, such as negative and otherwise impossible values. All data generated from field work will be reviewed and analyzed by the Project Lead.

D2. Verification and Validation Methods

Data validation and verification will include checks on:

- Completion of all fields on data sheets; missing data sheets
- Completeness of QC checks (e.g. number and type of QC checks performed vs. number/type proposed)

D3. Reconciliation with User Requirements

The Project Lead will be responsible for reconciling the results from this study with the ultimate use of the data. Results that are qualified through the QA process may still be used if the limitations of the data are clearly reported to decision-makers. Data for this project are being collected as part of a limited survey effort. It may not be possible to repeat surveys without disrupting the BACI time series.

Therefore, the Project Lead will:
1. Review data with respect to sampling design.
2. Compare the QA memorandum with the QAPP.
3. If the data quality objectives from Section A7 are met, the user requirements have been met. If the data quality objectives have not been met, corrective action will be established by the Project Lead.

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