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## Great Bay Estuary Submerged Aquatic Vegetation (SAV) Monitoring Program for 2019 - 2023 Quality Assurance Project Plan

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Great Bay Estuary Submerged Aquatic Vegetation (SAV)  
Monitoring Program for 2019 - 2023  
Quality Assurance Project Plan

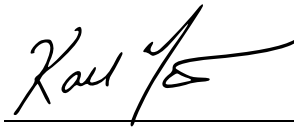
May 2019

*Prepared by:*

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Seth Barker, Photointerpretation Consultant, East Boothbay, Maine  
Claire Kiedrowski, Cornerstone Energy Services, Inc.

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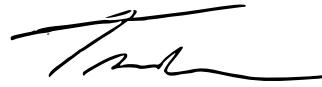
Project Manager:



**July 19, 2019**

Signature / Date  
Kalle Matso, PREP/UNH

PREP QA Officer



**July 19, 2019**

Signature / Date  
Trevor Mattera, PREP/UNH

Aerial Survey Contractor:



**July 19, 2019**

Signature / Date  
Claire Kiedrowski, Cornerstone Energy Services

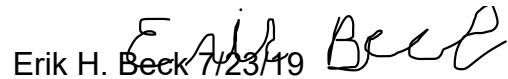
Photointerpretation Contractor:



**July 19, 2019**

Signature / Date  
Seth Barker, Independent Contractor

USEPA Project Officer:



Signature / Date  
Erik Beck, US EPA

USEPA QA Officer:

Nora J Conlon 07/23/2019

Signature / Date  
Nora Conlon, US EPA

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### A3 – Distribution List

Table 1 presents a list of people who will receive the approved QAPP, the QAPP revisions, and any amendments.

Table 1: QAPP Distribution List

Name	Project Role	Organization	Telephone Number and E-mail Address
Kalle Matso	Project Manager	Piscataqua Region Estuaries Partnership	(603) 781-6591; kalle.matso@unh.edu
Trevor Mattera	PREP QA Officer	Piscataqua Region Estuaries Partnership	603.862.1310; trevor.mattera@unh.edu
Claire Kiedrowski	Aerial Survey Contractor	Cornerstone Energy Services	(207) 942-5200, x350; CKiedrowski@CornerstoneEnergyInc.com
Seth Barker	Photointerpretation Contractor	Independent contractor	(207) 633-3735; seth.l.barker@gmail.com
Erik Beck	USEPA Project Officer	US Environmental Protection Agency	617-918-1606; beck.erik@epa.gov
Nora Conlon	USEPA Quality Assurance Officer	US Environmental Protection Agency	617-918-8335; conlon.nora@epa.gov

Based on EPA-NE Worksheet #3

### A4 – Project/Task Organization

The project will be completed by the Piscataqua Region Estuaries Partnership (PREP). Funding for the project will be provided by the NH Department of Environmental Services (NHDES).

The Project Manager will: be responsible for coordinating all program activities and communicating with EPA; manage all contractors and field staff, be responsible for “stop/go” decisions in the field, and coordinate data analysis and will be responsible for all final products. The PREP QA Officer will ensure that all QA steps are adhered to, and will be responsible for reports summarizing any deviations from the procedures in the QA Project Plan, the results of the quality control (QC) tests, and whether the reported data meet the data quality objectives of the project.

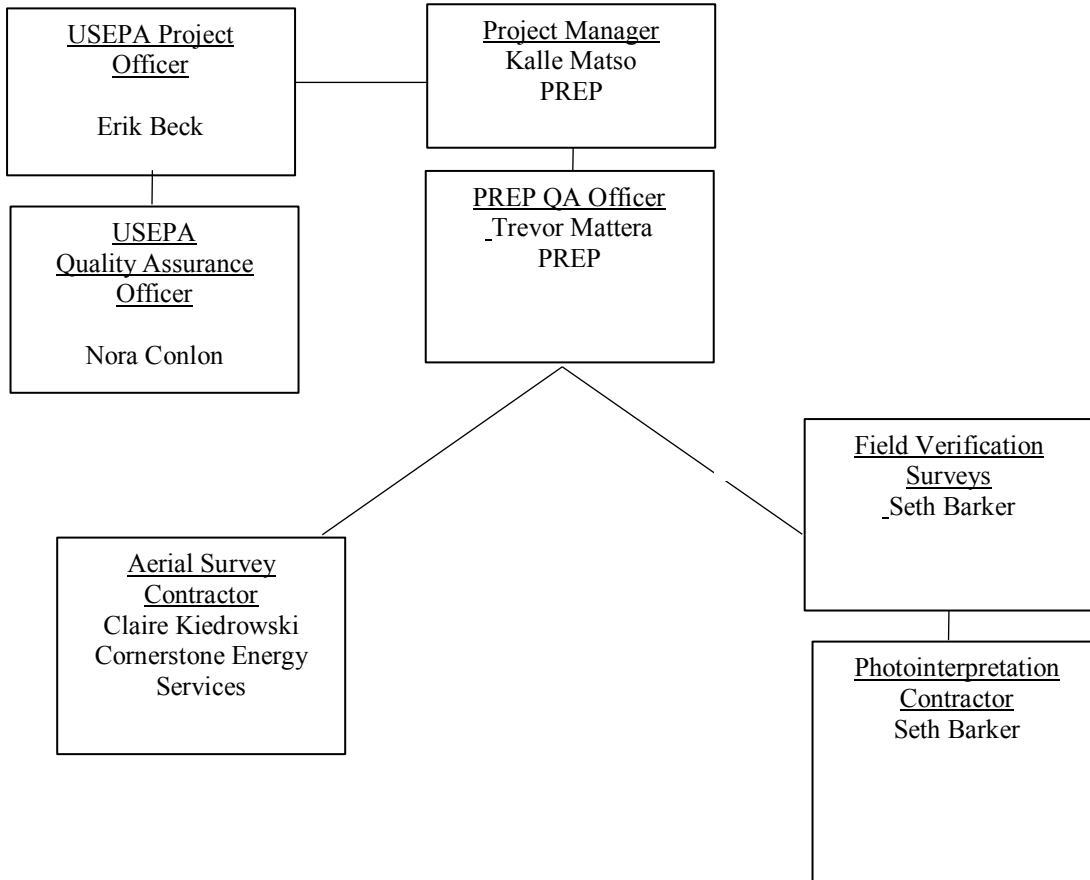
The project has three components: (1) an aerial survey; (2) field verification; and (3) photointerpretation of the aerial imagery. PREP will hire contractors to assist with all three components of the project.

The Aerial Survey will be completed by Cornerstone Energy Services, Inc. Claire Kiedrowski of Cornerstone will be responsible for all work tasks for the aerial survey.

The field verification will be completed by PREP with assistance from contractor Seth Barker. The Photointerpretation component of the project will be conducted by Seth Barker under a contract with PREP. The work will consist of field surveys to calibrate the interpretation of the aerial imagery to map boundaries of SAV beds.

The principal users of the data from this project will be the PREP, NHDES, and EPA as well as other interested parties. The Project Manager will submit a report to the partners at the end of the project with the final data and the QA/QC reports. Figure 1 shows an organizational chart for this project.

Figure 1. Organizational Chart.

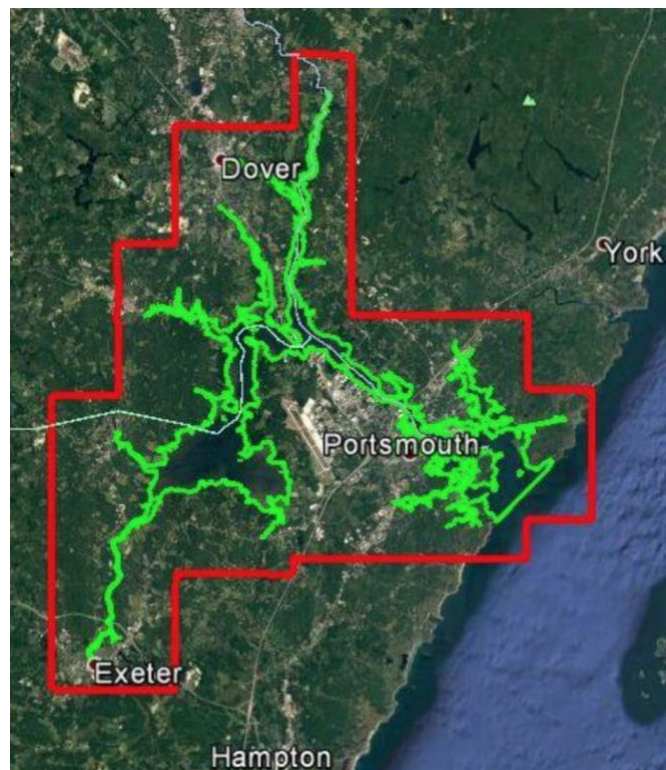


### A5 – Problem Definition/Background

Submerged aquatic vegetation (SAV), including seagrasses such as eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*) are essential to estuarine ecology because they filter nutrients and suspended particles from water, stabilize sediments, provide food for wintering waterfowl, and provide habitat for juvenile fish and shellfish, as well as being the basis of an important estuarine food web. Healthy SAV both depends on and contributes to good water quality. Therefore, PREP tracks the presence of SAV in the Great Bay Estuary as an indicator of estuarine health. Note that seaweeds also provide some of these functions, but they are not considered SAVs as they are not vascular, rooted plants.

The objective of this project is to map SAV habitat in the Great Bay Estuary during the summer growing period. The Great Bay Estuary is 21 square miles of tidal waters located in southeastern New Hampshire. The area for SAV mapping encompasses downstream portions of all tidal rivers and to the mouth of Portsmouth Harbor. The mouth of Portsmouth Harbor is defined by lines extending from Odiorne Point in Rye, NH to White Island to Horn Island to Searwards Point on Gerrish Island in Kittery, ME. The total area to be mapped is approximately 21 square miles. The study area in which SAV will be mapped for this project is shown in Figure 2.

Figure 2: Study Area for 2018 SAV Mapping



Maps of SAV in the estuary will be used by PREP and other coastal resource managers to evaluate trends in SAV populations over time and other resource decisions.

Although mainly focused on eelgrass, past aerial seagrass surveys have noted the presence of widgeon grass, especially in the tributaries (Personal Communication, Fred Short, 2015). Widgeon grass is very difficult to distinguish from eelgrass (without field verification steps that are beyond the scope of this work) and yet it provides many of the same functions and services as eelgrass. Therefore, we will not attempt to distinguish between these two seagrasses. Until other studies prove otherwise, we will continue to assume that more than 95% of the seagrass is eelgrass, and less than 5% of the seagrass is widgeon grass.

## **A6 – Project/Task Description**

The main tasks for the project are:

### 1. Hire Contractors

The Project Manager will set up contracts for the Aerial Survey, Field Verification, and Photointerpretation work tasks.

### 2. Prepare QA Project Plan

A QA Project Plan for SAV mapping will be produced by PREP. This QA Project Plan is for the years 2019 through 2023 mapping effort. At this time, it is unclear whether surveys will take place every year or every other year during this time period.

### 3. Acquire Aerial Imagery of the Estuary (and portions of contributing tributaries)

The Aerial Survey Contractor will plan and execute an aerial over-flight between mid-June and early September to collect aerial imagery during periods of suitable conditions (see Section A7). Raw images (no orthorectification) will be delivered to the Photointerpreter within 21 days of image acquisition, no later than 10/1 of the given year. (Early September is the latest that the flight will occur; if the flight occurs earlier—for example, on June 20, then the raw images will be delivered to the Photointerpreter within 21 days of that date.) These raw images are for internal use only and are not to be distributed. Note that field verification can be effectively implemented with the raw imagery, not the orthorectified imagery; the detailed field notes and orthorectified imagery are later used to provide sufficiently accurate maps. Final orthorectified images for UNH and State use will be delivered by December 31 of the given year. A draft aerial survey report will be provided by 11/30 of the given year.

### 4. Photointerpret Aerial Imagery

The Photointerpretation Contractor will review the aerial imagery and, based on field visits (see below) to the estuary and published guidance, will map SAV beds in the estuary. SAV will be categorized as present or absent; SAV coverage less than 10% cover will be deemed “absent:” more than 10% = “present.” A draft report will be provided by 2/1 of the year following the flight. The final report will be prepared by 3/1 of the year following the flight.

### 4b. Field Verification Survey

The Photointerpretation Contractor will visit sites where the preliminary imagery shows areas that could be interpreted in various ways. To increase the accuracy of the maps, the Contractor will visit these sites in the field to verify whether SAVs are present. See Section B1 for details.

### 5. Prepare Quality Assurance Reports

The PREP QA Officer will prepare a QA Report based on the final report from the Photointerpretation contractor. The QA Report will evaluate whether or not the data quality objectives for the project have been met (see Section A7 and B5). Quality Assurance and Control for the aerial survey will be handled



internally by the aerial survey contractor. Process and accuracy statements will be documented in the accompanying FGDC-compliant metadata to ensure that the data quality meets the objectives for the project (see Sections A7 & B5).

## 6. Issue Final Reports, Data Management, and Archiving

After completing the quality control tests and verification/validation process (see Sections D1-D3), the Project Manager will make the final reports available to the public on the PREP website (scholars.unh.edu/prep). See Section C2 for lists of information that will be included in the final reports. GIS datasets for aerial imagery and final SAV maps will be made available for download from the NH GRANIT Clearinghouse. All data associated with the project will be archived with PREP as electronic files.

Table 2 shows an approximate timeline for all of the tasks for this project.

Table 2: Project Schedule Timeline. Dates written assuming that flight happens in 2019. For years 2020 through 2023, the same days and months will apply to new years.

Activity	Dates (MM/DD/YYYY)		Product	Due Date
	Anticipated Date(s) of Initiation	Anticipated Date(s) of Completion		
Hire contractors	3/1/19	5/1/19	Executed contracts	5/15/19
QAPP preparation or update	3/3/19	5/1/19	Approved QAPP or approved changes to existing QAPP	5/15/19
Acquire aerial imagery	6/15/19	9/9/19	Raw aerial imagery	9/30/19
Delivery prelim images - rectified	7/15/19	10/10/19	Orthorectified – only for photointerpreter use.	9/30/19
Aerial Survey Report	7/30/19	11/20/19	Draft Aerial Survey report	11/30/19
QA Report for Aerial Survey	12/1/19	12/31/19	QA report	12/31/19
Final Ortho Tiles for State Use	10/1/18	12/31/19	Final Deliverable: Orthos w/metadata	12/31/19
Photointerpretation work	9/30/19	3/1/20	SAV bed boundaries	3/1/20
Field Verification Survey	9/9/19	11/1/20	SAV bed boundaries	3/1/20
Draft Photointerpretation Report	1/1/20	2/1/20	Draft report	2/1/20
QA Report for Photointerpretation	3/1/20	4/1/20	QA report	4/1/20
Final Photointerpretation Report	1/1/20	3/1/20	Final report and files	3/1/20

Based on EPA-NE Worksheet #10.

### A7 – Quality Objectives and Criteria

Data quality objectives for the aerial imagery, field verification surveys, and the photointerpretation are summarized in 3, Table 4, and 5, respectively.

Table 3: Data Quality Objectives, Criteria, and Quality Control Protocols for the Aerial Survey

Data Quality Objective	Criteria	Protocol
Imagery Completeness	4-band source imagery obtained for 100% of study area. (i.e., less than 100% will fail to meet objectives)	Extent of imagery will be compared to study area.
Ground Pixel Resolution	Less than or equal to 0.30 meters (1 foot)	Pixel size of imagery will be compared to criteria.
Spatial Accuracy	Horizontal positional accuracy less than or equal to 0.62 meters (2 feet) Root Mean Square Error following guidance from NSSDA*	The positions of 20 known locations in the orthorectified imagery will be checked against the known coordinates.
Environmental & Timing Conditions	Environmental & timing conditions met during flight - 6/15/ to 9/9/ of the given year - 7 AM to 10 AM - Low spring tide (+/- 2 hrs) - Low sun angle (22-50°) - Low cloud cover (<10%) - Calm winds (<10 mph) - Sufficient water clarity (confirm day before and morning of flight that bottom features are distinguishable at appropriate tidal stage). **	Environmental & timing conditions during flight will be compared to criteria.

\*Root Mean Square Error (RMSE). A measure of the difference between locations that are known and locations that have been interpolated or digitized. RMSE is derived by squaring the differences between known and unknown points, adding those together, dividing that by the number of test points, and then taking the square root of that result. Following guidance from the National Standard for Spatial Data Accuracy (NSSDA), the spatial accuracy will be calculated as the 95% confidence level using the circular map accuracy standard (Accuracy = 1.7308 \* RMSE). See <http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3> for methods.

\*\*The following people will communicate by email and cell phone in order to determine that environmental conditions are met: Kalle Matso, Claire Kiedrowski, Seth Barker and the airplane pilot (regarding sun angle, cloud cover, winds, and tides; PREP staff (regarding water clarity). Water clarity is one of the critical factors that must be assessed during the lead time before aerial photography is attempted. Poor water clarity can stem from a multitude of conditions and if present can make it difficult or impossible to reliably map eelgrass distribution. In a large estuary such as the Piscataqua River Estuary water clarity is seldom uniform. This requires a strategic approach to assess conditions throughout the estuary in advance of an overflight.

For this project we will observe water clarity for at least five locations throughout the region. These areas will include (but not be limited to) Little Harbor, the mouth of the Piscataqua River (Fort Foster), Little Bay (Cedar Point or Fox Point), Adams Point, and an interior location in Great Bay (Great Bay SeagrassNet Site/Transect C). Water clarity will be assessed with a Secchi disk and if the Secchi disk finds bottom and is still observed, the visible bottom depth. Observations will be taken several days before planned flight and on the day before the flight if weather events (wind and/or rain) or other environment factors such as plankton blooms are suspected to contribute

to the possibility of deteriorating water clarity. A Secchi disk reading of at least 2 meters is desired but it is possible that it may not be obtained in Great Bay. It also is anticipated that Secchi disk readings well above two meters will be observed at more coastal locations. In addition to taking Secchi disk readings, observers will note whether bottom features are distinguishable at the appropriate tidal stage. “Distinguishable” means that the human eye can differentiate between eelgrass, seaweed and unvegetated bottom. Several initial runs will be taken to start to build a database of background observations in anticipation of the actual flight. In addition, observations will be compared to previous measures of water clarity (Kd values) where present. Note: the Secchi disks and previous Kd values will help us quantify observations; however, the final determination of whether water clarity is sufficient will be based on qualitative descriptions of water clarity at the five sites. This decision will be made by Kalle Matso with input from Seth Barker. The determining question will be: Will the flight produce imagery of a high enough quality to allow the Photointerpreter to distinguish unvegetated areas from areas that have at least 10% seagrass, (with the understanding that the Photointerpreter will also use field verification to aid in interpretation of imagery)?

Table 4: Data Quality Objectives, Criteria, and Quality Control Protocols for Field Verification Surveys

Data Quality Objective	Criteria	Protocol
Spatial Accuracy	Field GPS units should have a reported accuracy less than or equal to 3 meters using NAD83 datum.	Check reported accuracy of field GPS units.
Comparability	Field observations should be collected using a standardized protocol. (NOAA 2001)	Check that protocols from the QAPP were used for field observations.
Completeness	Field observations should be made at planned locations and should ideally represent various conditions in SAV beds.  At least 80% of the field verification stations should be visited.	Check field verification observation locations against planned locations.  Check that 80% of field verification stations were visited.

Table 5: Data Quality Objectives, Criteria, and Quality Control Protocols for Photointerpretation

Data Quality Objective	Criteria	Protocol
Mapping completeness	SAV presence-absence mapped for 100% of study area	Extent of mapped SAV will be compared to study area.
Minimum Mapping Unit (MMU)	100 square meters	The area of the smallest delineated SAV beds will be compared to the criteria. If SAV beds smaller than 100 sq meters can be clearly discerned, they will be mapped but flagged as being below the MMU.
Spatial Accuracy	Less than or equal to 5 meters	The bed edge measured at 10 field verification locations will be compared to mapped edge. See Section B2 for methods.

## **A8 – Documents and Records**

### QA Project Plan

The Project Manager will be responsible for maintaining the approved QA Project Plan and for distributing the latest version to all parties on the distribution list in section A3. A copy of the approved plan will be made available on the PREP publications web page (<http://scholars.unh.edu/prep/>).

### Reports to Management and the Public

The Project Manager will provide final reports from the Aerial Survey and the Photointerpretation to the partners and will post it on the PREP website. See Section C2 for details about the final reports. All final GIS datasets will be made available for public download on the NH GRANIT GIS clearinghouse ([www.granit.unh.edu](http://www.granit.unh.edu)).

### Archiving

The QA Project Plan and final reports will be kept on file with PREP (in electronic formats) for a minimum of 10 years and/or the duration of the EPA grant.

## **B1 – Sampling Process Design**

The project has three components: (1) an aerial survey; (2) a field verification survey; and (3) photointerpretation of the aerial imagery.

### Aerial Survey

The Aerial Survey will be coordinated by Cornerstone Energy Services. Four-band aerial orthorectified imagery will be collected for the study area. A total of 170 images with a ground resolution of 0.3 meters (1 foot) will be collected from 9 flightlines at approximately 9,000 feet altitude (see Figure 3). The imagery will be overlapping with 60% forward lap and 30% sidelap. The imagery will be collected between June 15<sup>th</sup> and September 9<sup>th</sup>, when all conditions meet the criteria listed in Section A7 (Table and 6). A draft of the imagery will be provided to the Project Manager within 21 days of the flight. See Table 2 for all other dates and deadlines.

### Field Verification Survey and Photointerpretation

Seth Barker will visit a minimum of 10 sites where draft imagery shows SAV habitat and a minimum of 10 sites where the “signature” is confusing. (See “Completeness” in Table 4). Weather for field verification days need only be calm enough for safe boat travel. The rationale for choosing the specific sites is dictated by the need to capture the diversity of signatures (particular appearances) that indicate the presence of seagrass versus mud or seaweed habitat. More than 10 sites for each category may be needed, depending on the variety of signatures evident in the imagery. A minimum of five additional sites will be selected where SAV was previously mapped but is no longer visible in the aerial photography. The rationale is to ensure that actual SAV habitat was not mistakenly missed due to issues such as turbidity. Again, the number of sites depends on the number of areas where things have changed from previous years. Additional sites will be selected as needed to capture the diversity of signatures.

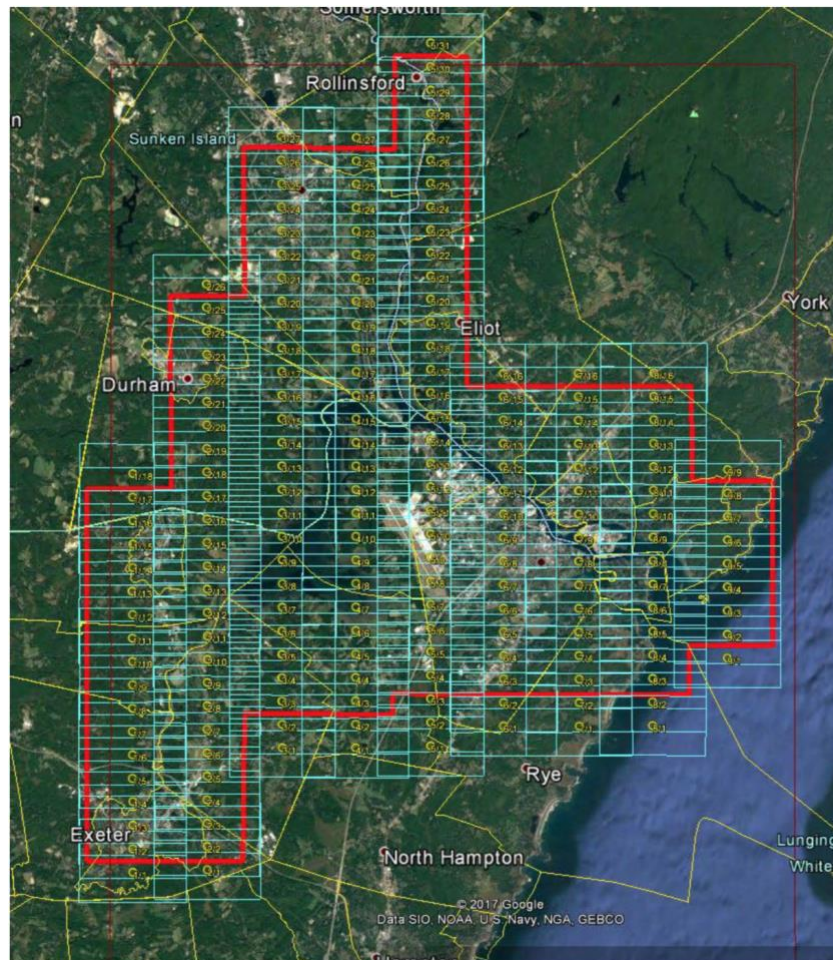
Field observations will be made using a drop camera and high accuracy GPS within 60 days of the aerial survey. The locations (stations and transects) to be visited will be determined by the Contractor by reviewing previous SAV maps and from the draft imagery. As an alternative and in areas where SAV is known to persist, SAV maps from previous years will be used to select stations and transects. It is anticipated that seven days of field work will be necessary.

### Changes from Previous Surveys

Percent cover assessments were used through 2015. However, for upload to the NHDES EMD database, the percent cover assessments failed the NHDES QA/QC for GIS and database acceptability in 2013 (Wood 2014). Therefore, beginning in 2016, aerial monitoring of SAV distribution has focused on presence/absence only. The presence/absence assessment is completely comparable with previous work. (EPA-approved QAPPs for 2003 and 2010 – 2014 can be found at: [scholars.unh.edu/prep](http://scholars.unh.edu/prep). Any other years between 2003 and 2016 are based on previously approved QAPPs.)

In 2017, the minimum mapping unit was adjusted (from 200 meters to 100 meters) to make it more accurate in terms of how the photointerpretation process actually works; there is no impact on comparability.

Figure 3: Flightlines for Aerial Survey. The yellow line is the project boundary, overlapping images are shown in cyan and photo centers and flight lines are shown in red. Ground sample resolution for the raw imagery is 0.30 meters.



## **B2 – Sampling Methods**

The project has three components: (1) an aerial survey; (2) a field verification survey; and (3) photointerpretation of the aerial imagery.

### Aerial Survey

Aerial imagery will be collected using an Intergraph Digital Mapping Camera. The Intergraph Digital Mapping Camera captures panchromatic—meaning that all visible bands are combined into one band—color, and color infrared imagery in a single pass. During the flight mission, a GPS supported navigation system interfaces with the camera control software, differential GPS, and inertial mapping unit (IMU) sensors to capture positional data.

The imagery will be georeferenced using direct georeferencing from the airborne GPS and IMU measurements. If this process does not provide the positional accuracy required for the project (see Section A7), a traditional aerotriangulation process will be used using scaled ground control.

Digital orthophotographs will be created from aerial imagery from the digital camera, exterior orientations from either direct georeferencing or aerotriangulation, and digital elevation models from LiDAR or USGS datasets for the study area. Individual images will be orthorectified using specialized orthorectification software. The orthorectification process will use a bi-cubic convolution algorithm. Images will be radiometrically balanced to ensure consistency across flight lines. The projection for the orthophotographs will be New Hampshire State Plane-Foot with a horizontal datum of NAD83. (Although a very small part of the remotely sensed area is in the State of Maine, only the NH system is used in order to simplify processing. (See Appendix C for more details.)

### Field Verification Survey

The following protocol will be used for field verification observations.

1. Record station number and time. Record water depth from boat depth finder if available.
2. Record observations at station and/or along transect on the standardized field sheet
  - Classify the SAV cover as either absent or present, using Appendix A as a guide.
  - Record observations of features that may provide confusing signatures in the aerial photography (e.g., seaweeds). (While seaweeds are often noted in field notes, they will not be “mapped”; only SAVs will be mapped.)
3. Save photographs and video collected at the station and record filenames on field datasheet (see Appendix B).
4. Record any other observations from the site on the field sheet.

### Photointerpretation

The Photointerpretation Contractor will perform field work to guide the photointerpretation. Field observations will be made by the Photointerpretation Contractor along transects using a drop camera and high accuracy GPS within 60 days of the Aerial Survey. Transects will be recorded in a GPS as routes and observations will be taken using a drop camera along the route. Multiple observations of presence/absence, relative density using cover categories described in Section B4, presence of seaweeds, and other features will be made. These observations will be georeferenced and used in a GIS to clarify and correct interpretations of SAV distribution.

The methods that will be used for the actual photointerpretation are described in Section B4.

The following protocol will be used for edge mapping for “spatial accuracy” (see Table 5).

1. Use underwater video camera and visual inspection (where water depths and clarity permit) to locate the boundary of the SAV bed. In areas where the SAV boundary is gradual, the point at which SAV is visually estimated to have less than 10% cover will be defined as the boundary.
2. Mark the boundary using GPS every 5-10 meters along a 50-meter boundary. Record coordinates from GPS in DD.DDDDDD format.
3. Coordinates will be routinely recorded in a GPS file and available after the field visit. Coordinates will be hand written only if not recorded in a GPS file.
4. The above steps can be done using preliminary imagery. When improved imagery is available, a subset of the study area will be re-assessed (digitally, that is, not by boat) in terms of GPS points and boundary edges in order to fulfill the data quality objectives noted in Table 5.

### **B3 – Sample Handling and Custody**

Not applicable. No samples will be collected.

### **B4 – Analytical Methods**

Digital orthophotographs will be photointerpreted using methods from Short and Burdick (1996), NOAA (1995), and NOAA (2001) to delineate the boundaries of SAV beds. The boundaries of SAV beds will be interpreted from orthophotos and polygons will be created using GIS. Observations made during site visits by the Photointerpretation Contractor (see Section B2) will be used to assist in the location of polygon boundaries. The visual guides that will be used for determining the 10% cover class cut-off from the aerial imagery are provided in Appendix A. These guides have been widely used as aids for interpretation and mapping, including in Chesapeake Bay.

Topology rules will be created in a GIS to identify and correct gaps and overlaps between polygons. The projection for the SAV bed shapefile will be New Hampshire State Plane-Foot with a horizontal datum of NAD83.

### **B5 – Quality Control**

#### Aerial Survey

Quality Assurance and Control will be handled internally by the aerial survey contractor, according to Appendix C. Process and accuracy statements will be documented in the accompanying FGDC-compliant metadata to ensure that the data quality meets the objectives for the project (see Sections A7 & B5).

#### Field Verification Survey

The Project Manager will check that the data quality objectives were met using the criteria and methods from Table in Section A7.

#### Photointerpretation

The Project Manager will check that the data quality objectives were met using the criteria and methods from Table in Section A7.

### **B6 – Instrument/Equipment Testing, Inspection, Maintenance**

All equipment used for the Aerial Survey shall be inspected prior to the flight to ensure proper operation. Drop cameras and GPS units for the Field Verification Survey shall be inspected, charged, and cleaned before each field day.

### **B7 – Instrument/Equipment Calibration and Frequency**

The Aerial Sensors/Camera(s) used to acquire project imagery shall have current USGS certification, or in the case of digital sensors a current Product Characterization Report.

### **B8 – Inspection/Acceptance Requirements for Supplies and Consumables**

Not applicable.

### **B9 – Non-direct Measurements**

Information on tides, sun angles, weather, water clarity, and precipitation will be used to decide on the date for the aerial survey. The data sources that will provide this information are:

- Tides: NOAA Tide Predictions at Fort Point, Dover Point, and the Squamscott River span the study area.
  - Fort Point (Portsmouth Harbor)  
<http://tidesandcurrents.noaa.gov/noaatidepredictions/NOAATidesFacade.jsp?Stationid=8423898>
  - Dover Point  
<http://tidesandcurrents.noaa.gov/noaatidepredictions/NOAATidesFacade.jsp?Stationid=8421897>
  - Squamscott River  
<http://tidesandcurrents.noaa.gov/noaatidepredictions/NOAATidesFacade.jsp?Stationid=8422687>
- Sun Angles: Sun angles for Portsmouth, NH are available from <http://aa.usno.navy.mil/data/docs/AltAz.php>.
- Weather: Weather predictions for Portsmouth, NH are available from <http://forecast.weather.gov/MapClick.php?CityName=Portsmouth&state=NH&site=GYX&textField1=43.0568&textField2=-70.782&e=1>
- Water Clarity: See Section A7.
- Precipitation: Precipitation data and forecasts are available from the sources listed below.
  - Northeast River Forecast Center – 48-hour forecasts of precipitation  
<http://www.erh.noaa.gov/nerfc/fcstprecip.shtml> .
  - National Weather Service - Daily weather observations, including daily precipitation, in Rochester NH <http://www.erh.noaa.gov/box/dailystns.shtml>.



- U.S. Geological Survey - Streamflow in the Lamprey River  
[http://waterdata.usgs.gov/nh/nwis/uv/?site\\_no=01073500&PARAMeter\\_cd=00065,00060,72020](http://waterdata.usgs.gov/nh/nwis/uv/?site_no=01073500&PARAMeter_cd=00065,00060,72020)

### **B10 – Data Management**

Aerial photographs and orthophotographs from the Aerial Survey will be stored on hard drives by the Aerial Survey Contractor. The final imagery files will be transferred to the Project Manager on external hard drives. Raw and preliminary images will be delivered directly to the Photointerpreter by the Aerial Survey Contractor via thumb or disk drive. The Project Manager will deliver the external drives to the Photointerpretation Contractor and to the NH GRANIT clearinghouse. The orthophotographs will be uploaded to the NH GRANIT GIS clearinghouse for public distribution. The following file formats will be used for the imagery:

- Draft imagery as a composite true-color compressed file in SID format, geolocated using direct georeferencing and assuming an average elevation.
- Final imagery as orthorectified 4-band (red, green, blue, and near infrared), 8-bit imagery for the entire area in uncompressed GeoTiff format using ¼ quadrangle tiles (1:24,000 scale) and a composite true-color compressed file in SID format.
- The imagery will be projected in New Hampshire State Plane-Feet NAD83 and shall have metadata meeting FGDC standards.

SAV bed boundaries from the Photointerpretation Contractor will be delivered on thumb or hard drives to the Project Manager in shapefile format compatible with ArcGIS in New Hampshire State Plane-Feet NAD83 projection. The shapefiles will be stored in a dedicated project directory on the PREP computers. The shapefiles will also be uploaded to the NH GRANIT GIS clearinghouse for public distribution. Field verification information collected by the Photointerpretation Contractor—including video and still imagery as well as field sheets—will be included.

### **C1 – Assessments and Response Actions**

The Project Manager will be in frequent communication with contractors during the project. The Project Manager will ask about difficulties encountered and ensure that protocols from the QA Project Plan are being followed. At a minimum, the Project Manager will complete the following checks while the project is proceeding.

- Review QC Plan for Aerial Survey contract
- Review Field Sampling Plan for Photointerpretation contract
- Review QC Plan for Photointerpretation contract
- Conference with Aerial Survey Contractor before flight windows
- Conference with Photointerpretation Contractor after first day of field work
- Review of draft imagery provided by Aerial Survey Contractor
- Review draft report from Aerial Survey Contractor
- Review draft report from Photointerpretation Contractor

- Review and approve any other reports provided by contractors

The Project Manager will initiate appropriate response actions after each check, if needed.

## **C2 – Reports to Management**

The final report for this project will focus on the Photointerpretation of Aerial Imagery for SAV Habitat Mapping and will contain the following:

- Introduction
- Methods
  - Methods for field surveys
  - Methods for photointerpretation and mapping of SAV beds
  - Methods for quality control checks
- Results
  - Summary of the area of SAV cover (in acres) in the Great Bay Estuary
  - Maps showing the location of SAV beds in the Great Bay Estuary at a scale of 1:24,000.
- References
- Appendices/Attachments
  - NSSDA Report for PREP Orthophotography (provided by the aerial survey contractor)
  - Raw field survey data
  - Quality-assured SAV bed boundaries as an ArcGIS shapefile (compatible with ArcGIS10) in New Hampshire State Plane-Foot NAD83 projection with project metadata meeting FGDC standards.

## **D1 – Data Review, Verification and Validation**

The final reports from the Aerial Survey Contractor and the Photointerpretation Contractor will be provided to the Project Manager. The Project Manager will review the reports and will provide copies of the reports to the public as well as the EPA Project Officer.

The Project Manager will be responsible for independently assessing that the data quality objectives from Section A7 have been met for each report using the criteria and methods from Sections A7 and B5. For each of the final reports, the Project QA Officer will prepare a QA Report that documents the results of quality control tests. The QA Report for the Photointerpretation contract will include all Field Verification Survey data used to assess the data quality objectives.

## **D2 – Verification and Validation Procedures**

For each of the final reports, the Project Manager will review the QA Report from the Project QA Officer to see if there have been deviations from the QA Project Plan and if the data quality objectives have been met. Any decisions made regarding the usability of the data will be left to the Project Manager; however, the Project Manager may consult with project personnel and partners, if necessary.

### D3 – Reconciliation with User Requirements

The Project Manager will be responsible for reconciling the results from the final reports from the Aerial Survey Contractor and the Photointerpretation Contractor with the requirements of the study (the ultimate use of the data). Results that are qualified by the Project Manager may still be used if the limitations of the data are clearly reported to decision-makers. The decision-making process will be:

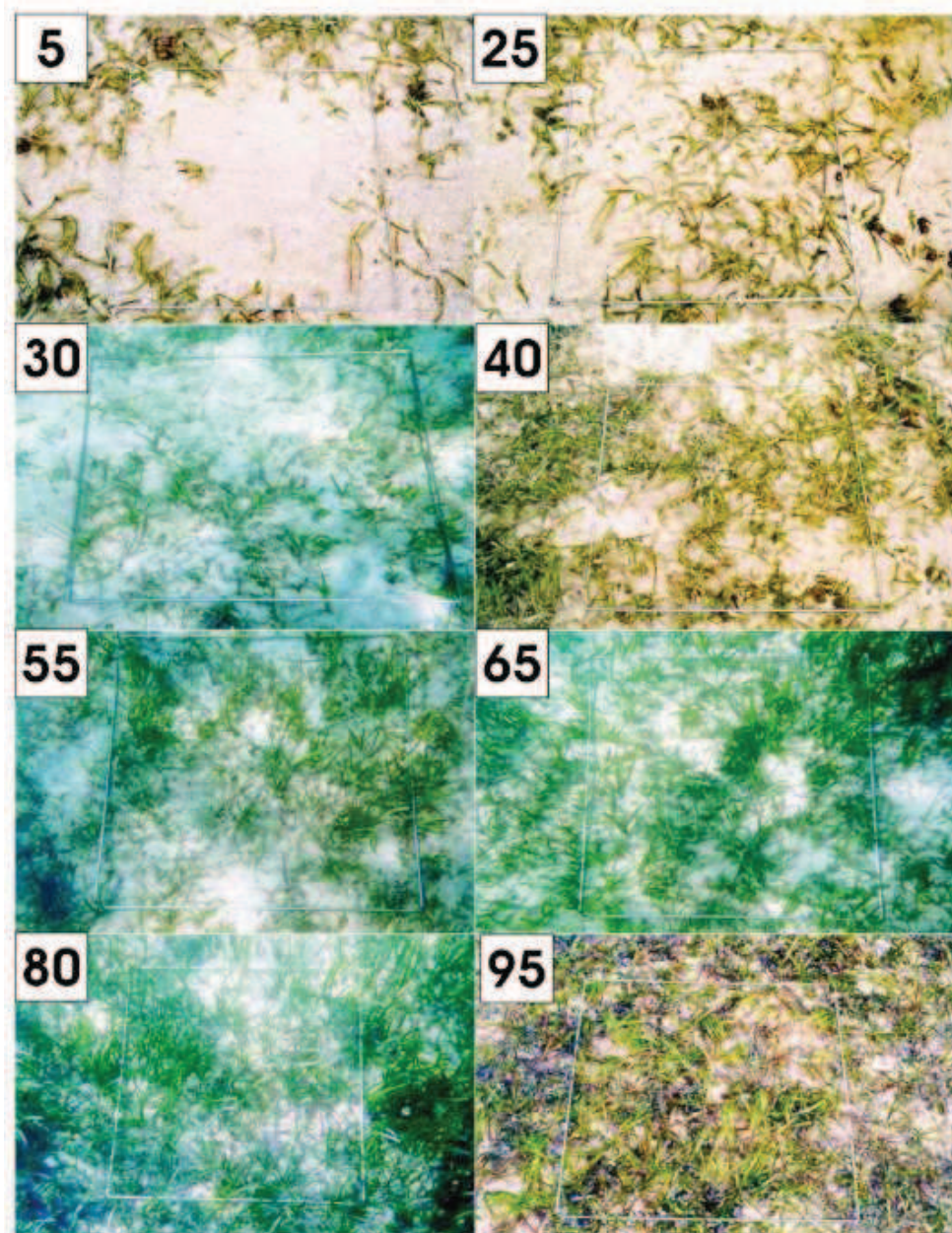
1. The Project Manager will review data with respect to sampling design.
2. The Project Manager will review the QA Report from the Aerial Survey Contractor.
3. If the data quality objectives from Section A7 are met, then the user requirements have been met and the SAV maps can be used without qualification.
4. If the data quality objectives from Section A7 have not been met, the Project Manager will consult with project personnel and partners and make a recommendation about whether the SAV maps are still usable for their intended purpose or whether the data need to be qualified or rejected. The Project Manager may also initiate appropriate corrective actions to improve the quality of the data, if possible. Corrective actions may include providing comments on the draft report from the contractor and asking for revisions.
5. The Project Manager will document this decision-making process in a memorandum that will be appended to the QA Report.
6. The QA Report will be attached to the final report from the contractor to document any QA concerns and qualify the data, if needed.

### References

- National Oceanic and Atmospheric Administration (NOAA). 1995. NOAA Coastal Change Analysis Program (C-CAP): Guidance for regional implementation by J.E. Dobson, E.A. Bright, R.L. Ferguson, D.W. Field, L.L. Wood, K.D. Haddad, H. Iredale, J.R. Jensen, V.V. Klemas, R.J. Orth, and J.P. Thomas. NOAA Technical Report NMFS 123. <http://www.csc.noaa.gov/crs/lca/pdf/protocol.pdf>
- National Oceanic and Atmospheric Administration (NOAA). 2001. Guidance for Benthic Habitat Mapping: An Aerial Photographic Approach by Mark Finkbeiner [and by] Bill Stevenson and Renee Seaman, Technology Planning and Management Corporation, Charleston, SC. NOAA/CSC/20117-PUB. [http://www.csc.noaa.gov/digitalcoast/\\_pdf/bhmguide.pdf](http://www.csc.noaa.gov/digitalcoast/_pdf/bhmguide.pdf)
- PREP. 2017. State of Our Estuaries Report. Piscataqua Region Estuaries Partnership, University of New Hampshire, Durham, NH. Available at [www.stateofourestuaries.org](http://www.stateofourestuaries.org).
- Short FT and Burdick DM (1996) Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. *Estuaries*, 19:730-739.
- Trowbridge P (2013) Trowbridge, Philip, "Great Bay Estuary Eelgrass Monitoring Program for 2013 Quality Assurance Project Plan" (2013). PREP Publications. 389. <http://scholars.unh.edu/prep/389>
- Wood, MA (2014) Memorandum: Quality Assurance of 2013 Great Bay Estuary Eelgrass Monitoring Program". Quality Assurance Project Plans. 3. <http://scholars.unh.edu/qapp/3>

## Appendix A Visual Guides for Seagrass Percent Cover in Quadrats

### Seagrass percentage cover photo guide



Source: SeagrassNet Short, F.T., McKenzie, L.J., Coles, R.G., Vidler, K.P., Gaeckle, J.L. 2006. SeagrassNet Manual for Scientific Monitoring of Seagrass Habitat, Worldwide edition. University of New Hampshire Publication. 75 pp.

## Plant Survey Standard Cover Classes and Midpoints for Estimating Abundance

One method for obtaining abundance values for vegetation surveys is to estimate the percent of a plot occupied by the target plant. To assess percent cover, one estimates the area of the plot frame (1m<sup>2</sup>) that is covered by all of the leaves, branches, and stems of the target species. Visual estimates may vary from one person to another. This variability can be significantly reduced by using standard cover classes and midpoint abundance values. The following figures illustrate 9 standard cover classes to use. For each plot, first identify and list the species present, then for each species determine which figure best describes its cover. Record the midpoint value on the data sheet.



(Trace to 1%)  
Use 1%



(11% to 19%)  
Use midpoint 15%



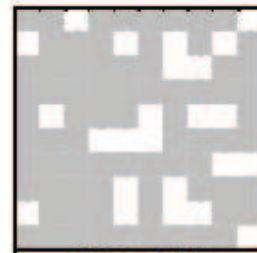
(46% to 64%)  
Use midpoint 55%



(2% to 4%)  
Use midpoint 3%



(20% to 30%)  
Use midpoint 25%



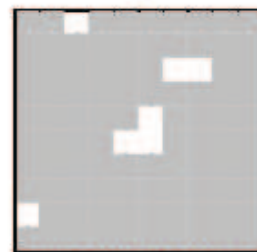
(65% to 87%)  
Use midpoint 76%



(5% to 10%)  
Use midpoint 7%



(31% to 45%)  
Use midpoint 38%

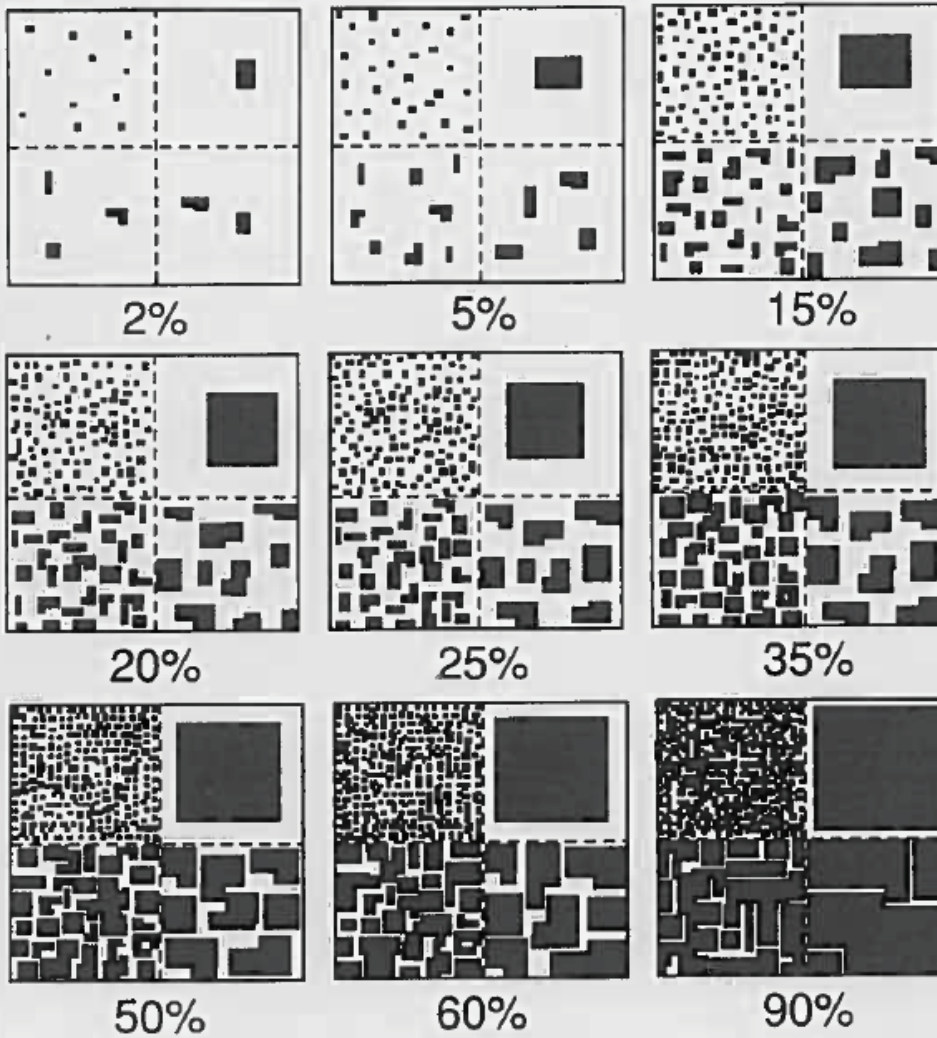


(88% to 100%)  
Use midpoint 94%

Carlisle, B.K., J.D. Baker, A.L. Hicks, J.P. Smith, and A.L. Wilbur. 2004. Cape Cod Salt Marsh Assessment Project; Final Grant Report, Volume 1: Relationship of salt marsh Indices of Biotic Integrity to surrounding land use, 1999 Boston, MA. Massachusetts Office of Coastal Zone Management.

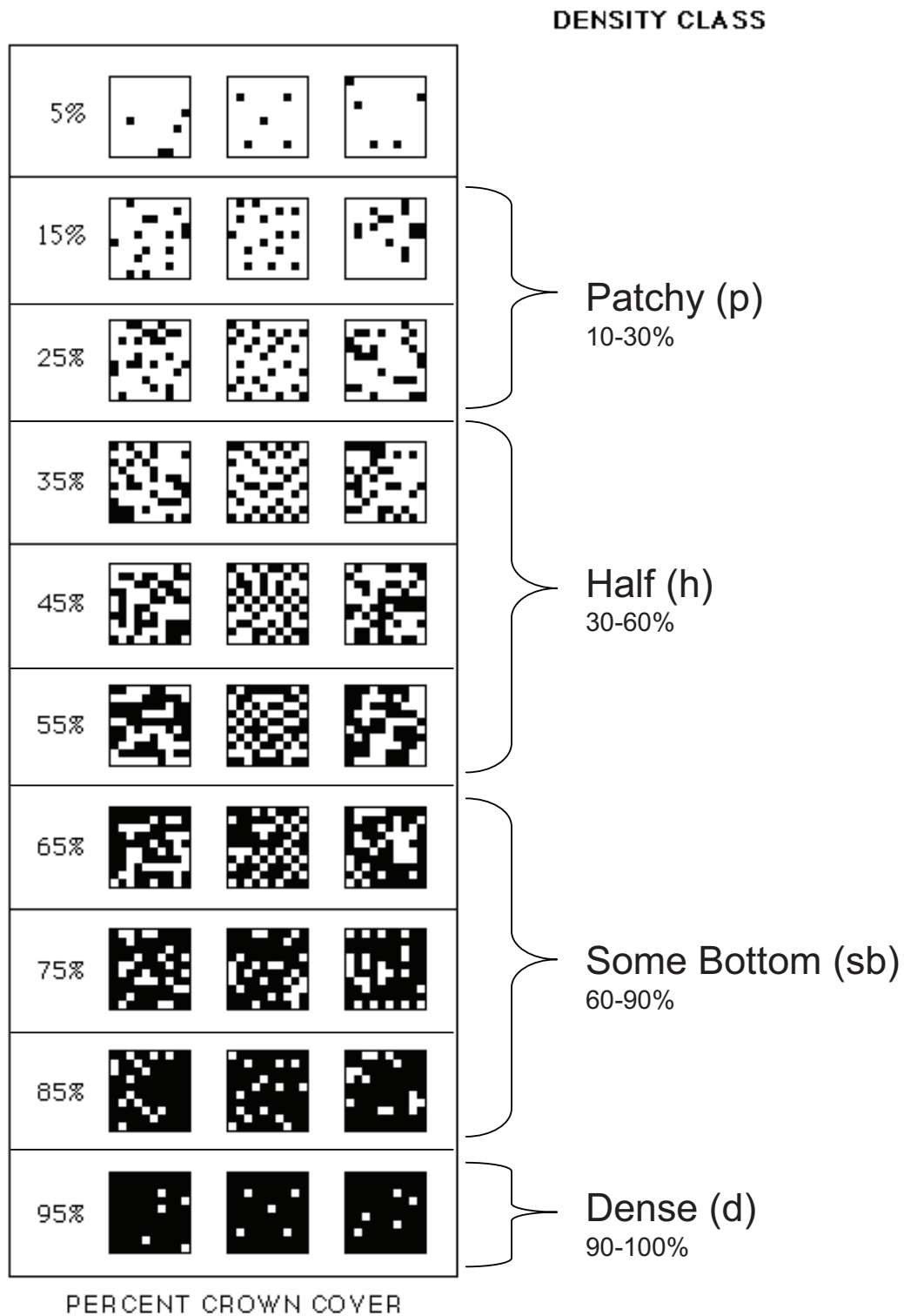
## EXAMPLES OF PERCENT OF AREA COVERED

The following graphic can be used for various data elements to convey "Amount" or "Quantity." **NOTE:** Within any given box, each quadrant contains the same total area covered, just different sized objects.



Source: USDA/NRCS. Field Book for Describing and Sampling Soils. September 2002.

# Visual Guide for Eelgrass Percent Cover for Photointerpretation



Source: [http://web.vims.edu/bio/sav/sav11/crown\\_density.html](http://web.vims.edu/bio/sav/sav11/crown_density.html)

# Appendix B

## Field Data Sheet -SAV

## Ground Truth Monitoring

Station Number		Date MMDDYY						
Crew Chief		Crew Member 1						
Crew Member 2		Crew Member 3						
Purpose for Visit								

Weather Condition	<input type="checkbox"/> Sunny <input type="checkbox"/> Partly Cloudy <input type="checkbox"/> Overcast <input type="checkbox"/> Rainy <input type="checkbox"/> Windy <input type="checkbox"/> Foggy							
Sea Condition	<input type="checkbox"/> Calm <input type="checkbox"/> Choppy <input type="checkbox"/> Rough							
Time On Station	:	(HH : MM EDT)						
Water Depth	.	(meters, one decimal place)						

Latitude		.							DD . DDDDDD format
Longitude		.							DD . DDDDDD format

### Drop Camera Observations

SAV Cover	<input type="checkbox"/> Less than 10% <input type="checkbox"/> More than 10% <input type="checkbox"/> Not Present								
Algal Cover	<input type="checkbox"/> Less than 10% <input type="checkbox"/> More than 10% <input type="checkbox"/> Not Present								
Filenames for Photos or Video									
Notes									



**Field Data Sheet - SAV**

**Ground Truth Monitoring**

<b>Station Number</b>		<b>Date</b>	<b>MM</b>	<b>DD</b>	<b>YY</b>						
-----------------------	--	-------------	-----------	-----------	-----------	--	--	--	--	--	--

**Edge Mapping**

Marker	Latitude (DD . DDDDDD)							Longitude (DD . DDDDDD)						
1		.							.					
2		.							.					
3		.							.					
4		.							.					
5		.							.					
6		.							.					
7		.							.					
8		.							.					
9		.							.					
10		.							.					
<b>Notes</b>														



**Cornerstone**  
Energy Services

AERIAL IMAGERY, MAPPING, & GIS

6 State Street, Suite 301 / Bangor ME 04401  
207.942.5200, x350 / 866.836.8834 x350 toll free

## **Appendix C**

# **Task 2: Quality Control Plan For Acquisition of Aerial Imagery For Habitat Mapping for Summer 2019**

**Job #: TBD**

**May 9, 2019**

## I. Introduction

Our overall quality assurance plan starts at the project planning stage and ends with a customer satisfaction de-brief upon completion of the project. The general principle of *“Do it right the first time”* is followed throughout the project.

The key elements of a project are defined up front, when the contract is first negotiated. This ensures that the project is completed on time, within budget, and that the deliverables meet with the client’s expectations.

### A. Customer Satisfaction

The initial step of the project involves the contractual negotiations whereby the Project Team becomes more familiar with the client’s project: specifications, final end use of any mapping products, time schedules, coordination with other projects or uses of products, contract terms, fee for services, change order procedures, specific technologies that will be used, QA/QC procedures that will be followed, etc. Having a thorough understanding of each of these components, and how they all relate to one another, results in no surprises during the project life cycle.

It is during this initial stage (Project Kickoff Meeting) that a complete project schedule and an allocation of labor hour requirements are finalized, to ensure that adequate resources are available to meet client needs and expectations.

### B. Built-in Product Quality

On the technical side, a series of specific questions have been developed for each phase of a project. This ensures that the necessary elements of a project have been addressed not only by the customer, but also by the project team. This information, along with the specifications, is then passed directly to the technical/production people so that all project specific information has been transmitted to the appropriate individuals and that all production people are aware of upcoming projects and schedules. These instructions are provided to the team in writing and subsequently discussed in team and one on one meeting with the project leads.

Each technical task that the project team performs is structured with specific procedures to guarantee generation of a quality product. The QC process for mapping projects is linear in nature because the processes are linear in nature. Therefore, before each phase can be started, the previous phase has to pass certain QC criteria. This protocol is followed for each phase of the project.

At the start of each project, production procedures (checklists, progress charts, QC testing and reporting mechanisms) are developed. A portion of the project is then created and all production processes exercised, including QC procedures. This sample project data is then submitted to the customer for final approval. Any changes are noted and improvements to the production process implemented. At this point, production begins.

The next step in the production process is to complete the feedback loop by informing the production personnel of the QC analysis and results. Production personnel are given complete access to QC data so that they can improve their individual processes to conform to project standards.

After approximately 10-15% of the project has been completed, supervisory personnel meet with production staff members to identify bottlenecks or other challenges in the production process. This results in better, more highly automated routines to speed the process and improve the quality of the work product. Notable by-products of these meetings are the continued education and training of production staff, which leads to fewer human errors as production progresses.

## **II. Quality Assurance and Quality Control Procedures**

Quality Assurance (QA) and Quality Control (QC) are two separate, but closely linked processes that ensure that the project deliverables meet the project specifications. Quality Assurance is a written plan of the procedures and processes that are to be followed for each task. These processes and procedures have been designed and proven to be effective in producing a quality product in a repeatable and sustainable fashion.

Quality Control is a process of evaluating, or testing, the final product to identify any defects. This process involves different people using different software/processes (than what was used to produce the product) to evaluate the product for conformance to specifications. QC involves using a structured and rigorous approach to the evaluation. Generally, if any part of the project specifications can be quantified, or measured, then it should be evaluated. Acceptance criteria are developed to provide a pass/fail analysis of each item. Both automated and manual review techniques are employed: automated routines for 100% review, and manual reviews for a random sample of products.

The linkage between QA and QC occurs after the results of the QC are known. If any defects are discovered, we determine why the QA plan did not prevent the defects and the plan is appropriately modified and implemented. This process is initiated after each QC cycle if defects are found. This method of constant and continual improvement results in highly consistent products with high quality. Both production and QC team members participate in the analysis and improvement of the process to make sure that

all team members are up-to-date on the latest techniques and procedures for the entire project.

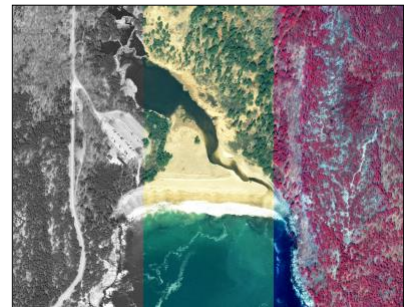
### III. Tasks

#### A. TASK 1: Collect Aerial Imagery for the Piscataqua Region Estuaries

Task 1 involves the collection of digital 4-band imagery with a nominal 1 foot resolution. Also included is a preliminary set of orthophotographs produced using the ABGPS/IMU data and assuming an average elevation.

The mission will be flown using the Intergraph Digital Mapping Camera (DMC). The Cornerstone Project Team selected the DMC due to its superior accuracy, image clarity, and versatility. Flight lines and exposure stations for this project will have been pre-planned by Cornerstone according to the specifications listed in the RFP.

Multiple flights over the same area are not required because the DMC simultaneously captures panchromatic, color, and color infrared imagery in a single pass. The DMC system is a complete end-to-end digital imaging system. It has an integrated workflow, from mission planning and preparation to the creation of deliverable products. During a flight mission, a Global Positioning System supported navigation system interfaces with the camera control software, differential-GPS, and inertial measurement unit (IMU) sensors to capture positional data to the 0.62 meters (2 foot) accuracy required for the project.



The DMC captures imagery suitable for engineering-level planimetric and topographic mapping as well as superior ortho image products and it has been documented that the DMC's accuracy and image quality exceeds other digital imaging systems.

Cornerstone will work closely with both PREP Project Manager and the aerial survey firm, Geomni (formerly Richard Crouse & Associates/RCA), to schedule potential acquisition dates and times. We will continue to actively monitor the conditions along the coast so that everyone is kept up-to-date with the status of image acquisition and its specific parameters. The Cornerstone Project Team is very familiar with tracking tides and solar sun angles based on client criteria.

Geomni's Maine and New Hampshire flight operations are based out of Old Town Maine. ***This proximity to New Hampshire and southern Maine ensures that a decision to fly can be made quickly and early while acquisition conditions are optimal.***

The flightplan is shown below in Figure 1 and consists of 6 flight lines with 99 images flown at approximately 9,000 feet about ground level at a pixel resolution of 0.29 meters. The flightplan is based on mapping limits provided by PREP.

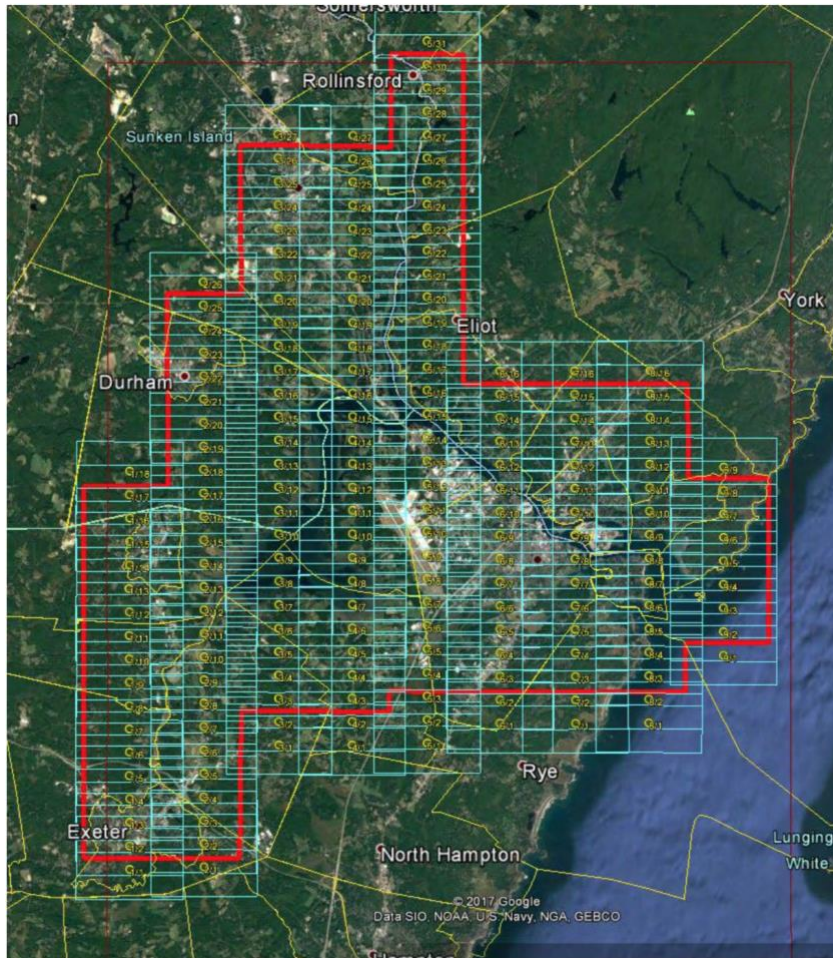


Figure 1. Flightplan layout consisting of 9 flightlines and 186 images. The yellow line is the project boundary, cyan lines are overlapping images lines, and red circles/line are image centers and flightline. Ground sample resolution for the raw imagery is 0.29 meters.

### Quality Assurance

Project specifications for not only the flight, but also the derivative project deliverables, will be conducted with the flight crew and staff so that they have a complete understanding of this important project.

Geomni, working closely with Cornerstone and PREP, will collect aerial imagery that meets or exceeds the following specifications.

- Mapping location: The Great Bay Estuary, Little Harbor, and the New Hampshire Coastline. See attached description and map.

- 4-band source imagery (red, green, blue, and near infrared) and will be of sufficient resolution to support production of digital orthorectified images to a ground pixel resolution of 0.30 meters (nominal 1 foot).
- Orientation: Vertical.
- Ground Pixel Resolution: 0.30 meters (1 foot).
- Spatial accuracy: Digital orthorectified imagery shall have a horizontal positional accuracy not to exceed 0.62 meters (2 feet) Root Mean Squared Error. A digital elevation model of sufficient accuracy and resolution shall be used in the orthorectification process to ensure compliance with the accuracy specification for the final imagery product.
- Overlap: The extent of image coverage over the project area shall be sufficient to ensure void areas do not exist within the defined project area.
- Camera Station Control: Camera position shall be recorded at the instant of exposure for each image using airborne, differential GPS. Camera attitude shall be recorded at the instant of exposure for each image.
- Sensor Calibration: A current Product Characterization Report will be provided.
- Environmental Conditions:
  - June 15 to September 9, 2019,
  - Early morning (7:00 am – 10:00 am)
  - Low spring tide (+/-2 hours of low tide at Adams Point in Great Bay)
  - Low sun angle (>30 degrees ideal, >50 degrees unacceptable. Flight window was extended to >22 degrees, to accommodate ideal tide conditions. Flight lines shall be planned, and imagery acquired, in such a way so as to minimize sun glint over areas of interest.)
  - Low cloud cover (>10% cover is unacceptable)
  - Calm winds (<10 mph)
  - No preceding rain events (TBD by PREP Project Manager)
  - Low turbidity / good water clarity (TBD by PREP Project Manager).

Flight maps will be prepared using a well established and trusted flight planning software. Project limits furnished by the client will be used to determine the area coverage. Digital output from the flight planning software is transferred electronically into the flight navigation and the DMC image capture system.

The Flight Contractor, Geomni, will obtain prior authorization from the PREP Project Manager for the date of the aerial survey. The Flight Contractor will also coordinate with Pease International Tradeport regarding flight restrictions near the Portsmouth International Airport.

A contacts list was generated to discuss status of water, ground, tide, sun angle, and weather conditions prior to flight:

**Contact List:**

<b>Name</b>	<b>Organization</b>	<b>Work Phone</b>	<b>Mobile Phone</b>	<b>Email</b>	<b>Role</b>
<b>Kalle Matson</b>	PREP / NH Dept. of Environmental Services	(603) 781-6591	(603) 781-6591	<a href="mailto:Kalle.Matso@unh.edu">Kalle.Matso@unh.edu</a>	Project Manager
<b>Claire Kiedrowski</b>	Cornerstone Energy Services	(207) 942-5200, x350	(207) 266-7087	<a href="mailto:ckiedrowski@Cornerstoneenergyinc.com">ckiedrowski@Cornerstoneenergyinc.com</a>	Project Manager, Mapping Director
<b>Jeremy Whittemore</b>	Cornerstone Energy Services	(207) 942-5200, x356	(207) 465-6828	<a href="mailto:jwhittemore@Cornerstoneenergyinc.com">jwhittemore@Cornerstoneenergyinc.com</a>	Mapping Coordinator
<b>Seth Barker</b>	Independent Contractor	(207) 633-3735	(207) 315-1924	<a href="mailto:seth.l.barker@gmail.com">seth.l.barker@gmail.com</a>	Aerial Interpreter
<b>Vilia Bates</b>	Geomni	(207) 827-5979	(207)323-4366	<a href="mailto:vbates@verisk.com">vbates@verisk.com</a>	Flight Contractor Contact

**QC for Aerial Imagery and AGPS/IMU capture**

- Pre-flight
  - The digital flight maps will be checked for proper coverage, sidelap, overlap, and flight height by Cornerstone personnel.
  - Teleconference meetings to discuss appropriate flight conditions will be documented by Cornerstone and distributed to each party.
  - Images will be automatically inspected to verify that it is in the 4-band format, with a nominal ground resolution exceeding 1 foot ground resolution. Performed by Geomni.
- Post-flight
  - Flight logs will be inspected to verify that all environmental conditions have been met along with proper time considerations. Performed by Geomni.
  - When the flying mission has been successfully completed and the images have been processed suitable to work with them as individual images, they will be imported into ArcMap and inspected for cloud shadow, density, clarity and image consistency. Images will also be checked for acceptable overlap, and sidelap. Tilt, and crab angle will be reviewed by inspecting the IMU rotational angles. Performed by Cornerstone.
  - The AGPS/IMU data will be verified post-flight by importing photo center positions into ArcMap and checked for proper coverage, overlap and sidelap. Performed by Cornerstone.



- Again, the images will be visually inspected to verify that it is in the 4-band format, with a nominal ground resolution exceeding 1 foot ground resolution. Performed by Cornerstone.

There are two sets of deliverables with Task 1: the first is a preliminary set of raw and rectified images and the second is the final orthorectified images along with photo center information and supporting documents.

#### **Preliminary Deliverables:**

Raw Images, AGPS/IMU data, and preliminary orthophotos. Within 21 days or sooner (the intent is as soon as possible) of acquiring the imagery, Cornerstone will provide PREP and Aerial Interpreter with raw images, AGPS/IMU data, and preliminary orthophotos for the study area to be used in the ground truth survey. We will use AGPS/IMU for geopositioning and an average elevation terrain model (the same across all images) will be used to generate 4-band orthophotographs with a 1 foot resolution. They will not be mosaicked. These images are not to be distributed but are meant solely for the aerial interpreter.

The images shall be in a JPEG format with JGW world file and will be georeferenced using direct geo-referencing from the airborne GPS (AGPS) and inertial measurement unit (IMU) used in the aerial acquisition phase.

#### **Quality Control Checks and Procedures for Digital Raw Images and Preliminary Orthophotographs**

- Check that imagery covers project area.
- Preliminary check on quality of imagery.
- Check for proper image format(s).
- Check coordinate system and units.
- If applicable, check that all images were orthorectified and are readable with at least two software packages.

#### **Delivery Materials**

- Raw images. Within 21 days of image acquisition, deliver raw images with AGPS/IMU only as the geo-referencing in TIF and/or JPEG formats.
- Deliver preliminary images orthophotographs in SID and/or JPEG formats using direct geo-referencing.

### **Final Deliverable Materials**

The final deliverables will be will be verified for completeness prior to shipping.

- Digital Camera Product Characterization Report.
- ArcGIS shapefile(s) showing photo centers and times of all photographs.
- Raw imagery data with camera station control data in the New Hampshire State Plane Coordinate System referenced to NAD83. Elevations will be referenced to NAVD88 via NAD83 ellipsoid heights, and geoid modeling. Units will be US Survey Feet.
- Raw images on external disk drive.
- QC summary report.

### **B. TASK 3: Prepare and Deliver Digital Files to PREP**

Task 3 involves the preparation of orthorectified multi-band imagery and RGB composite true color imagery mosaicked in uncompressed GeoTiff format.

#### **1. Direct geo-referencing or AT**

##### **Quality Assurance**

Cornerstone proposes to use direct geo-referencing for the positioning of the imagery. In this scenario, ground control points are not used because the aircraft is equipped with integrated Airborne GPS (AGPS) and IMU systems. The AGPS calculates the exposure centers for each photo. The IMU unit provides the roll, tip, and yaw of the aircraft at the instance of exposure. In essence, each photo center is a control point with this approach.

To verify the geo-positioning, Cornerstone proposes to obtain scaled ground control check points surrounding the project area. We will scale a minimum of 20 coordinates from photo-identifiable points from New Hampshire's GRANIT Statewide GIS Clearinghouse and the Maine GIS Geolibrary such as the recent 2012 and 2016 orthophotographs in York County. We will compare scaled coordinates with the directly geo-referenced coordinates to ensure that we meet the 0.62 RMSE as specified for the horizontal accuracy. Points will be well distributed over the entire project area: points will enclose the project area as well as a number of them will be sprinkled throughout the middle. Points will be selected after Cornerstone receives the imagery.

If we do not meet the positional accuracy requirements, then we are prepared to follow a traditional workflow of running the aerotriangulation (AT) process. Typically, the aerotriangulation (also called bridging) process is used to densify the

ground control network and the AGPS, and to extend the limited control into every frame of photography. The process involves measuring points on each stereo model, tying the stereo models into strips, and then tying the strips into a block. The block is then transformed to fit the existing scaled ground control. A sophisticated least squares algorithm is then used to adjust all of the measurement values simultaneously to achieve a best fit solution.

The above bridging process would be used to the extent possible on this project. However, water photos cannot be bridged in the above manner unless sufficient land features are present. Where typical bridging is not possible, we will rely on the AGPS exposure center coordinates, and the photo rotations derived from the inertial measurement unit (IMU). On land features that are present, we will scale coordinates of photo-identifiable points from New Hampshire's GRANIT Clearinghouse, and will add such points to the aerotriangulation solution for that area. This process is discussed in the "*Guidance for Benthic Habitat Mapping*" in the section Alternative Sources of Control.

#### **Quality Control Checks**

- If Direct georeferencing
  - Check points from scaled imagery
- If Aerotriangulating (AT)
  - Check model ties
  - Check flight ties for blunders.
  - Check ground control residuals.
  - Check RMSE of final block adjustment

#### **Delivery Materials**

The final deliverables will be will be verified for completeness prior to shipping.

- If Direct geo-referencing
  - Exterior orientation parameters (X, Y, Z, Omega, Phi, Kappa).
  - Listing of check points and their coordinates
- If Aerotriangulation (AT)
  - Report and listing of the refined plate coordinates; pass point and flight tie residuals, final coordinates of all pass points, flight ties, and ground control, and exterior orientation parameters (X, Y, Z, Omega, Phi, Kappa).
- ArcGIS shapefile(s) showing photo centers and times of all photographs.

## **2. Digital Elevation Model**

#### **Quality Assurance**

Digital Elevation Models (DEM) are a necessary element to create digital orthophotographs. Cornerstone will obtain the best, freely available LiDAR data or USGS DEMs that cover the project area and use these in the orthorectification process. We propose to use the following composite data: a new composite DEM will consist of LiDAR data compiled from Coastal NH (2011, NOAA), FEMA 2006, and NRCS 2013 datasets and will be obtained from New Hampshire's GRANIT website.

The DEM will be imported into our softcopy system and edge matching will be verified in stereo using photogrammetric software and hardware. In areas of gaps or overlaps, Cornerstone will correct the area in stereo using our softcopy system. The Digital Elevation Model will be of sufficient accuracy and resolution for the orthorectification process to ensure compliance to the spatial accuracy of the RFP.

#### **QC of Digital Elevation Model**

- Stereo visual inspection and correction, if necessary.

#### **Delivery Materials**

- None

### **3. Orthophotography & Mosaicking**

#### **Quality Assurance**

Ortho-rectified multi-band (red, green, blue, and near infrared) imagery will be created from the following raw data sources: aerial imagery from the digital camera, exterior orientations from either direct geo-referencing or aerotriangulation, and the Digital Elevation Model (DEM).

The individual images will be orthorectified using specialized orthorectification software. The orthorectification process will use a bi-cubic convolution algorithm, which produces a quality orthophotograph. Output pixel resolution for each image will be 1 foot (0.30 meters) and the projection will be the New Hampshire State Plane Coordinate System with horizontal datum of NAD83.

Images will be mosaicked into a seamless database using OrthoVista software. This software package also provides tools for radiometrically balancing of the images, to ensure image consistency and enhancement across flight lines. We will review the radiometric balance options with PREP to ensure optimal viewing of the eelgrass and salt marshes. Changes in color balance across the project will be gradual (if at all). It is understood that abrupt tonal variations are not acceptable.

Once the images are color corrected and mosaicked, they will be tiled to a layout suitable for PREP. The geo-referenced mosaic images will be in uncompressed

GeoTIFF format. As the images are loaded into your GIS package, they will automatically be placed in the correct geographic position.

Deliverables will also include a 3-band (red, green, blue) true-color composite.

#### **QC for Orthophotography**

- DEM will be verified before the orthorectification process.
- Imagery locations will be checked against checkpoints and existing vector data. A minimum of 20 check points that are distributed throughout the project area will be evaluated to determine the accuracy of the final product. Existing data sets (vector maps, high resolution/quality digital orthophotographs, etc) as well as the initial points used to verify the quality of the direct georeferencing or AT will be used to extract suitable points. RMSE's for both the x and y component of the check points will be computed assuming that the RMSE of the x and y components are roughly equal. The 95% confidence level using the circular map accuracy standard ( $Accuracy = 1.7308 * RMSE_r$ ) will be applied. The results will be reported in the standard NSSDA report format showing all computations. This step is in addition to the step checking the horizontal accuracy in Task 3, Subtask 1 (Direct Georeferencing or AT).
- Individual inspection of the imagery for pleasing and consistent color balancing suitable for eelgrass habitat monitoring.

The final deliverables will be will be verified for completeness prior to shipping.

#### **Delivery Materials**

- Digital media on hard drive
- Ortho images in uncompressed GeoTIF/TFW format
- Index of tile layout in ArcGIS format
- Composite image in SID format
- Orthophoto metadata meeting FGDC standards
- Clearly stated materials to deliver to GRANIT clearinghouse.

### **C. TASK 4: Quality Control Report**

Task 3 involves the preparation of the Quality Control Report that demonstrates that the imagery meets or exceeds the specifications from Task 1 according to the procedures specified in the Quality Control Plan from Task 2.

#### **Quality Assurance**

The QC reports and check lists from the previous tasks will be assembled.

#### **Quality Control**

The assembled reports will be reviewed to make sure all required items are a “pass”.