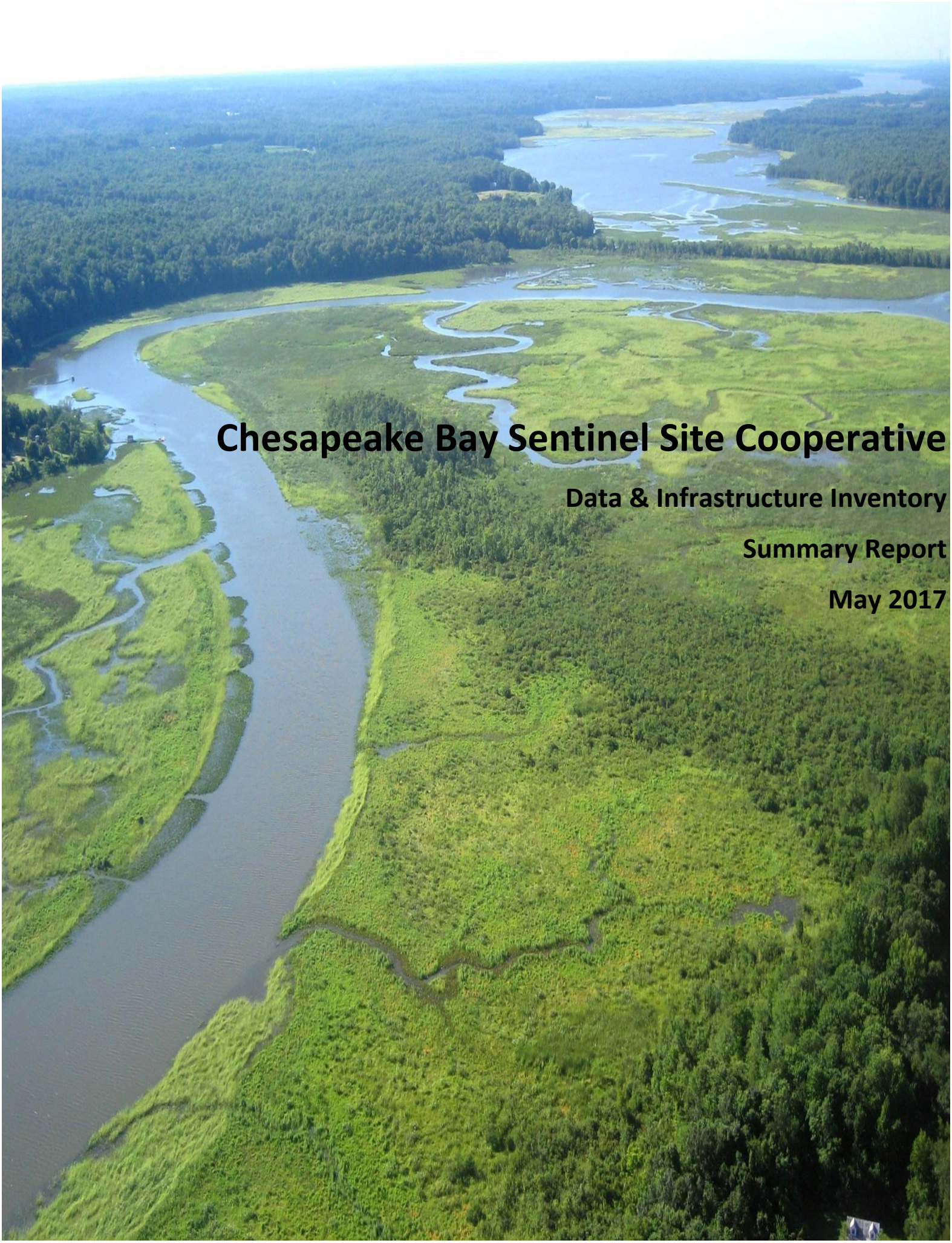

Chesapeake Bay Sentinel Site Cooperative

Data & Infrastructure Inventory

Summary Report

May 2017

COVER PHOTO: AERIAL VIEW OF JUG BAY WETLANDS SANCTUARY IN MARYLAND

Acknowledgments

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Glossary of Acronyms

CBP	Chesapeake Bay Program
CBSSC	Chesapeake Bay Sentinel Site Cooperative
CNHP	Colonial Historic National Parkway
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DIC	Dissolved Inorganic Carbon
NAVD88	North American Vertical Datum of 1988
NERRS	National Estuarine Research Reserve System
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
SET	Surface Elevation Table
TSS	Total Suspended Sediments
UMCES	University of Maryland Center for Environmental Sciences
USFWS	United States Fish & Wildlife Service
USGS	United State Geological Survey
UVA	University of Virginia
WMA	Wildlife Management Area

Introduction

The natural and built environments that fringe the Chesapeake Bay face an ever-increasing threat from rising sea levels. Scientists and managers tasked with the conservation, preservation and enhancement of natural areas across the Bay face a growing need for reliable and accurate site-level information on sea level rise and ecosystem vulnerability. Establishing the Chesapeake Bay Sentinel Site Cooperative, or CBSSC, is a recent effort to facilitate collaboration across multiple partners involved in data collection and synthesis of Bay-wide ecosystem-based information from coastal marshes. The Cooperative focuses on measuring the impacts of sea level rise and is strengthened by collaboration with coastal managers, decision makers and community liaisons. These partners work together to apply the science produced at sentinel sites to coastal management and resilience efforts.

Each Chesapeake Bay Sentinel site collects long-term data on marsh elevations, water levels, water quality, emergent vegetation and weather. A sentinel site (Figure 1), as defined by NOAA, is "an area within the coastal and marine environment that has the operational capacity for intensive study and sustained observations to detect and understand changes in the ecosystems they represent" (Hensel et al forthcoming). Specifically, "a sentinel site will have a system comprised of at least (1) a local, high accuracy vertical control network; (2) high accuracy local water level sensor(s); (3) long term coastal habitat monitoring infrastructure, including but not limited to Surface Elevation Tables (SETs). The key is to relate changes in water levels to observable changes in the ecosystem" (Hensel et al forthcoming). The CBSSC extends from the mouth of the bay just north of Virginia Beach to the bay's source, east of Havre de Grace, Maryland, where it meets the Susquehanna River.

CBSSC sentinel sites cover a diverse range of wetland types, including tidal freshwater marshes, back-barrier lagoons, estuarine brackish marshes and actively managed wetlands. The "founding" sentinel sites are shown in Figure 2 and detailed in the following section, *History & Structure of the CBSSC*. The CBSSC also connects to — and relies on — broader observing networks, such as NOAA's Chesapeake Bay Interpretive Buoy System (CBIBS), the Virginia Estuarine and Coastal Observing System (VECOS) run by the Virginia Institute of Marine Sciences (VIMS), and the Eyes of the Bay network run by Maryland's Department of Natural Resources.

The mission of the Chesapeake Bay Sentinel Site Cooperative is to integrate science findings from local observations across the Chesapeake Bay to improve planning and management decisions regarding sea level rise and ecological changes.

The purpose of this report is to provide an inventory of each sentinel sites' capacity to collect data on sea level rise and associated ecological changes. By developing this inventory we gain a stronger understanding of what information is collected spatially and temporally across the Chesapeake Bay. Knowing this information allows regional scientists and managers to refine research questions and management priorities within, across and beyond sentinel sites. The inventory can also help to identify site-specific and regional data gaps across the CBSSC network. In addition, the inventory may serve as a platform for future regional collaborations.

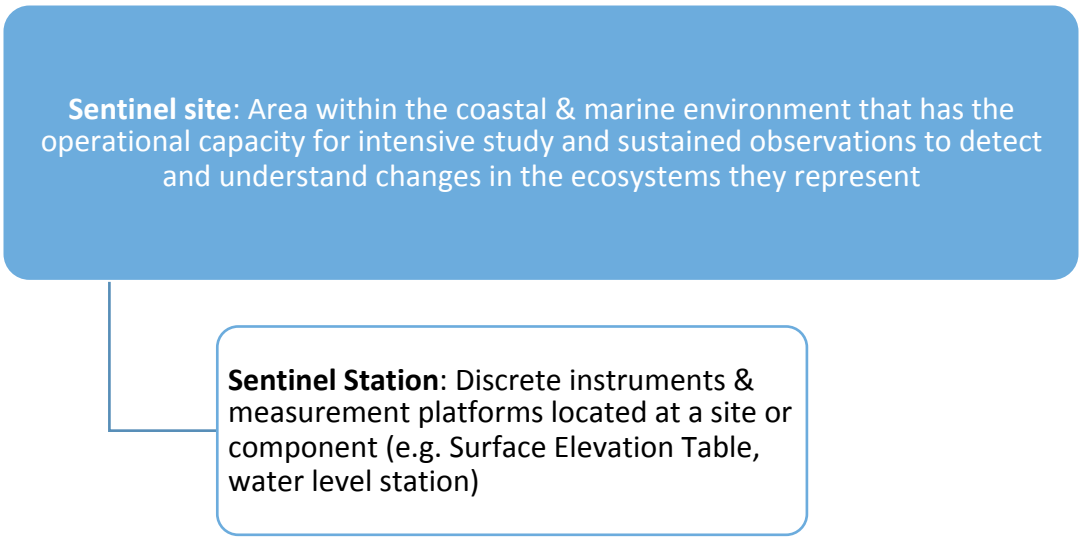


Figure 1. Composition of a Sentinel Site, as defined by NOAA.

History and Structure of the CBSSC

As outlined in the FY13-FY17 CBSSC Implementation Plan, the Cooperative was formed in 2012, with an initial emphasis on supporting resilience to sea level change and coastal inundation. Building from NOAA's sentinel site model under the National Estuarine Research Reserve System (NERRS), an initial network of 10 sentinel sites came together to begin collaborative conversations. These sites included the four sites that comprise the Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERR-VA): Goodwin Islands, Catlett Islands, Sweethall Marsh and Taskinas Creek; three sites that comprise the Chesapeake Bay National Estuarine Research Reserve in Maryland (CBNERR-MD): Jug Bay Wetlands Sanctuary, Otter Point Creek and Monie Bay; Assateague Island National Seashore; the Virginia Coast Reserve/Long-Term Ecological Research Program (VCR-LTER); and Blackwater National Wildlife Refuge. In 2015, the Cooperative officially added the Smithsonian Environmental Research Center (SERC) and the Paul S. Sarbanes Ecosystem Restoration Project at Poplar Island as sentinel sites.

Together, these 12 sites are considered the "founding" sentinel sites and are depicted in Figure 2. Since the original survey (Appendix A) was intended to just capture metadata from these founding sites, the 79 question-long survey captured information from these sites only.

As the CBSSC expanded its reach across the Chesapeake Bay, additional organizations, institutions and agencies grew interested in active involvement in the Cooperative. Much of this interest can be traced to the October 24th SET & Wetland Monitoring Workshop that took place in Cape Charles, VA. The meeting, described in greater detail on page 35, took a deeper dive into Surface Elevation Table (SET) data collected across hundreds of instruments around the Bay. The data producers were specifically interested in pooling elevation trend data from the SET Metadata Inventory (Appendix C) to examine landscape level "signals". This group was involved in numerous updates to the SET metadata inventory as a result and their input on other sections was welcomed in the development of this report. For these reasons, the SET section reflects an expanded collection of sites in addition to the "founding" sites. Each of these sites is at various stages of build out. In the SET section of this report, Table 6 outlines all of the sentinel sites depicted throughout this report. In some cases multiple agencies and organizations are involved in on-going monitoring activities. For example, Blackwater NWR is federally owned and operated by USFWS with majority of the data collected and managed by Refuge staff with the exception of SETs which are managed and monitored by USGS staff. For specifics regarding an individual site, please consult with the contact listed for each site in the SET Metadata Inventory (Appendix C).

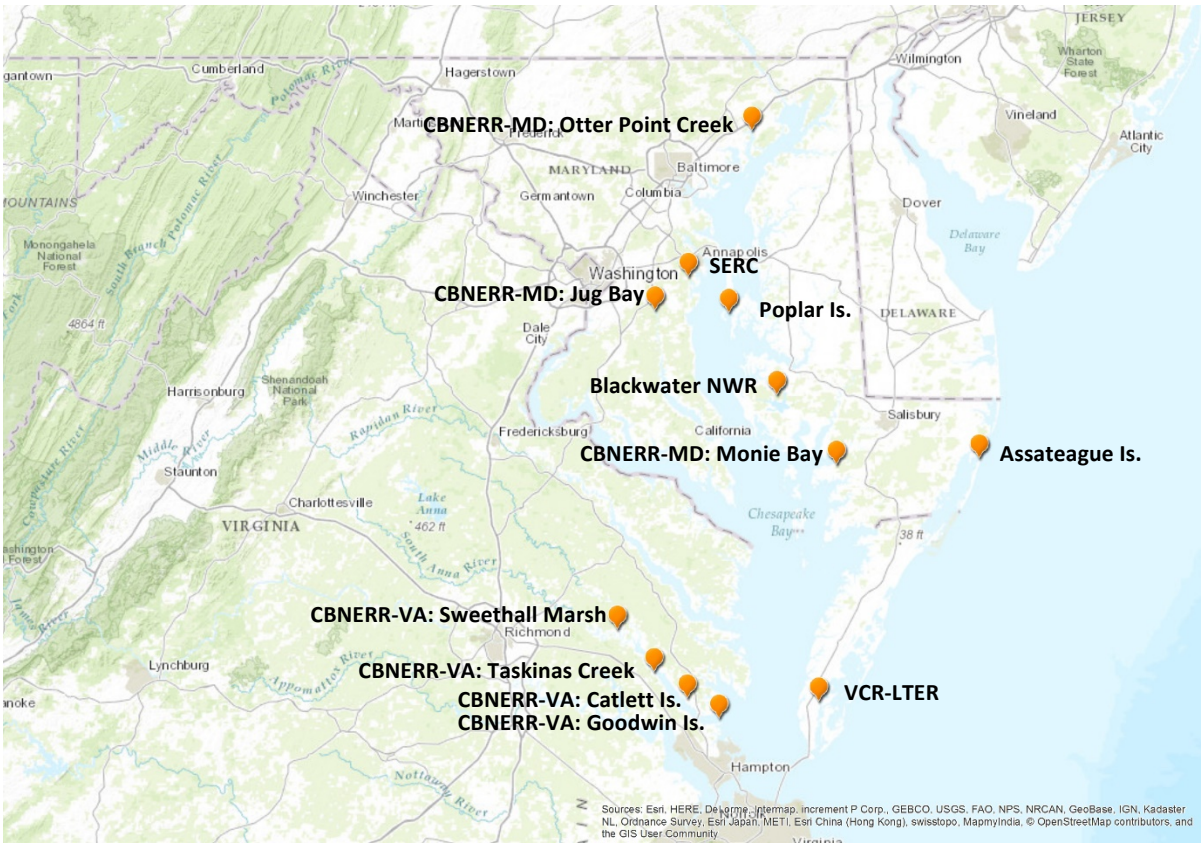


Figure 2. Map of the founding Chesapeake Bay sentinel sites.

Project Genesis

Since the Cooperative's inception in 2012, no comprehensive inventory exists on sentinel site data collection and coastal infrastructure across the sites. This gap in knowledge was recognized as a barrier to creating integrated, collaborative synthesis products and formulating sound questions and management priorities. By collecting and aggregating this information, the CBSSC Management Team, led by the CBSSC Coordinator, sought to catalog infrastructure and data gaps and look to standardize data collection protocols. For example, the team has identified a need to better understand relative sea level trends across all sites. In addition, it was hoped the inventory would illuminate areas where spatial and temporal comparison could be made within and across sentinel sites.

Methods

The Cooperative Management Team, made up of members from across the sentinel sites and participating agencies, worked together to develop the survey questions. Using Survey Monkey, we created a series of questions for each sentinel site regarding: 1) core sentinel site observational infrastructure (e.g. water level gauging, emergent vegetation plots); 2) site-specific ecological characteristics; 3) management implications and applications of data. The survey was divided into 13 sections to capture details on the sentinel site monitoring elements and applications (see Appendix A). The survey contained 79 questions[1] and was disseminated to each site-level representative (see Appendix A for Survey Monkey questionnaire). Each representative was provided three weeks to complete the survey and supplemental Excel tables that were shared separately. Survey Monkey responses were only generated for the 12 founding sentinel sites (Figure 2).

Once responses were collected, the data was collated into a spreadsheet for side-by-side comparison. Information from the surveys was summarized and follow up questions identified for each respondent. The Sentinel Site Cooperative Coordinator spoke with many of the representatives from each location via phone and in-person to fill in any gaps in responses.

Throughout the data collection process, challenges were identified. Collaborative efforts often present unique challenges when it comes to accessing data and receiving responses in a timely fashion. Due to the *pro* bono nature of this inventory effort, delay in receiving information slowed progress at times. Additionally, respondents had different interpretations of how to answer survey questions which caused some issues with cross-comparisons.

Anticipated Uses of this Inventory

It is anticipated that the inventory described in this report will serve as the foundation for the following:

- CBSSC Syntheses: Recognizing the wealth of data that exists among the sites, there is great potential to harness the collaborative nature of the Cooperative to identify and secure grant monies to advance science syntheses. These syntheses would aim to provide a broader Chesapeake-wide perspective. This inventory has identified where gaps in observational coverage exist among sites.
- Strategic Plan to fill identified observational gaps.
- Cooperative-wide data sharing policy.
- Centralized Database: Through partnerships with the Mid-Atlantic Regional Ocean Observing System (MARACOOS) and the North Atlantic Landscape Conservation Cooperative (NALCC), centralized

[1] The Survey did not ask for details on Surface Elevation Tables (SETs) since a recent inventory exists (Appendix C)

databases can be assembled and combined in such a way that is accessible and useful for management decisions.

Key Issues of Management Concern

At the end of the survey, each site representative was asked to list up to five issues of management concern for their sentinel site. Survey results clearly indicate that long-term marsh sustainability and vulnerability is of paramount concern. Specifically, sites are concerned with the ability of marshes to adapt to rising sea levels through landward migration and vertical elevation gains achieved through various ecological and geomorphic processes (e.g. sediment accretion, belowground biomass development). Additional concerns include the ability of sentinel sites to provide storm buffering capabilities as well as their response to critical water quality stressors such as low dissolved oxygen levels, harmful algal blooms and water clarity. Impacts from invasive species as well as salinity intrusion were also expressed as a concern.

TOP MANAGEMENT CONCERNS

1. ABILITY TO ADAPT TO SEA LEVEL RISE
2. SHORELINE BUFFERING CAPABILITIES
3. WATER QUALITY STRESSORS

Results

Funding

In order to better understand how each monitoring element is supported financially, sites were asked to identify their funding source for every sentinel site monitoring element included in the survey. Table 1 indicates a patchwork nature of funding sources across the monitoring elements. Table 2 lists funding sources across the sentinel sites. Since sentinel sites are each constructed under their respective agency or organization's mission and priorities, it is no surprise that the future of funding for sentinel stations varies from site to site. Much of the support comes through annual grant awards as part of a site's operating base. The stability of this funding is never guaranteed, however, and if cuts are made to grant awarding programs, certain monitoring elements may

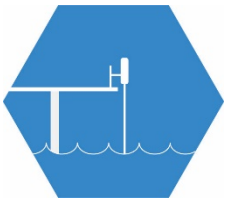
take a back seat. For example, there is currently no money to support the reading of SET instruments maintained by the University of Maryland along the Nanticoke and Upper Patuxent Rivers.

Table 1. Funding breakdown by monitoring element

	Operational (base)	NOAA Grant	EPA	USACE	Endowment	Other Grant $
Water Level	X	X	X	X	X	X
Emergent Vegetation	X				X	X
Water Quality	X	X	X		X	X
Groundwater	X					X
Weather stations						X
SETs	X	X		X		X

Table 2. Funding breakdown by sentinel site

	Operational (base)	NOAA Grant	EPA	USACE	Endowment	Other Grant $
CB NERR- VA	X	X	X			X
CB NERR- MD	X	X				
Assateague Island	X					
Blackwater NWR						
SERC	X				X	X
VCR-LTER						X
Poplar Island				X		X



Water Level Gauging

Sea level rise manifests itself differently along the coast, making it important to obtain local water level information. Water-level monitoring stations at each sentinel site continually measure water level surface, providing a long-term dataset for scientists to use.

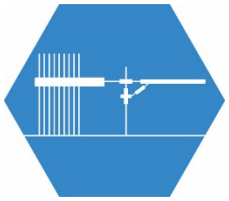
Water level gauging is conducted for a variety of reasons across the sites, including marsh and sea level rise modeling, inundation analysis and to aid in bathymetric map corrections. Each of the Cooperative's sentinel sites has at least one gauge to monitor water levels. More than half of the water level sensors at sites rely on pressure sensors that make up one probe/port of water quality monitoring sondes (e.g. YSI sondes). Two sites (Assateague Island National Seashore and Sweet Hall Marsh) have high-quality microwave sensors installed. Some sentinel sites utilize the data from these local stations to calculate tidal datums while others utilize datums derived from nearby NOAA National Water Level Observation Network (NWLON) stations.

Data from local site gauges is publically available at all sites with the exception of SERC, which is expected to become available in the near future.

In order to understand the management implications of water level data, sentinel sites were asked to list up to 5 past, current, or intended uses of water level data. Table 3 outlines these uses. The most common use, as indicated by the survey results, is for inundation and storm surge analyses.

Table 3. Sentinel site use or intended use of water level data

Use	# of sites
Inundation/Storm Surge Analysis	4
Marsh Modeling	2
Development of Marsh Indices	2
SLR/Water Level Monitoring	2
Hydrodynamic Modeling	1
Submerged Aquatic Vegetation Habitat Requirements (light penetration)	1
Bathymetric Map Correction	1
Marsh Flooding Regimes	1
Barrier Island Vegetation	1
Lagoon Circulation	1
Marsh Biogeochemical Processes	1
Marsh Plant Stand Stock	1
Development of Local Datums	1
Sedimentation Studies	1



Surface Elevation Tables

Surface elevation tables (SETs) are mechanical devices permanently installed in wetlands that allow scientists to measure small changes in surface elevation precisely and accurately (Figure 3). This instrument allows scientists to better understand how coastal marshes respond to sea level rise. SETs are commonly used with marker horizons—thin layers of feldspar clay applied to the surface of the marsh—to track changes in accretion (the accumulation of sediments on the marsh surface over time). Understanding the rate of vertical land motion is critical to understanding system response to elevated sea level and coastal change.

There are over 500 SETs recorded across two updates made to the SET inventory in 2016 and 2017 (Appendix C). The inventory captured a variety of attributes for each instrument, including the frequency of SET monitoring, geomorphic and hydrologic setting, and dominant plant species. The original inventory dates back to 2014 before a full-time coordinator was assigned to the Cooperative. Under the full-time coordinator, two updates took place in October 2016 and in January 2017 to rectify portions of the survey to allow for easier comparisons across sites. Unfortunately, a small handful of sites did not contribute updates in January 2017, so these SETs were omitted from the report results for 2017. Each section clearly identifies the date from which the update is extracted.

The 2017 updated inventory indicates that just over half of the SETs have referenced surface elevations relative to NAVD88. These surface elevations were collected via digital level and GPS receivers (including Real-Time Kinematic GPS set-ups).

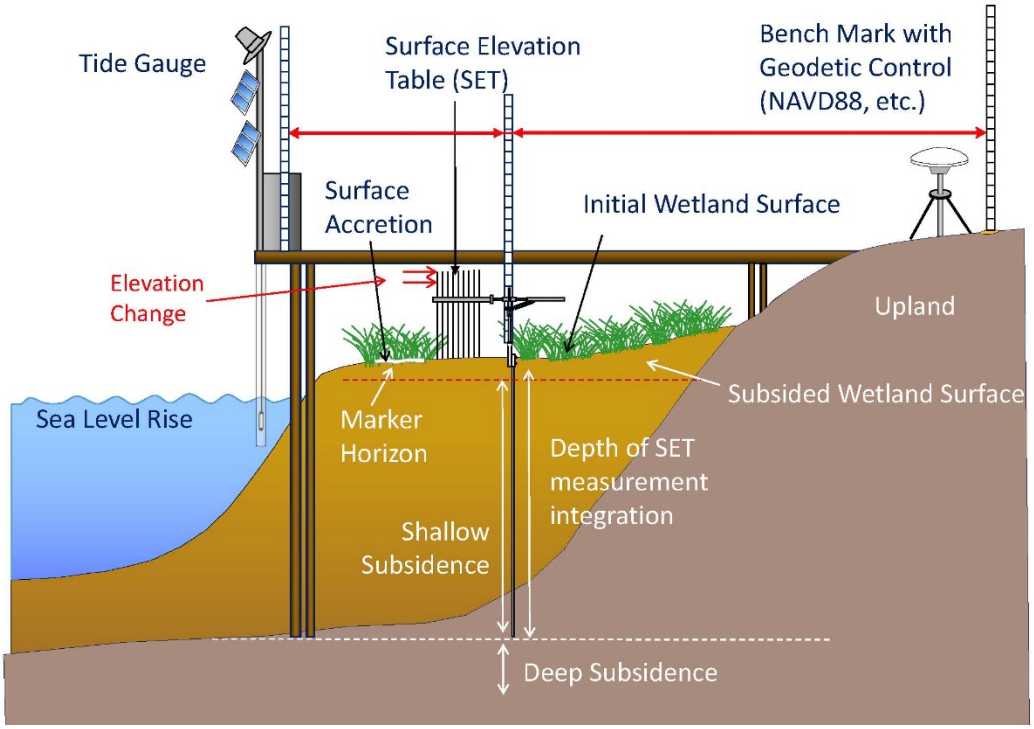


Figure 3. Depiction of sentinel site monitoring elements, including the SET. Credit: NOAA, NGS

Purpose for Installing SETs

Chesapeake Bay SETs were installed across the Bay at different times and for different reasons. Many SETs were installed to answer specific research and management questions, as outlined in Table 4. The inventory captures a variety of attributes for each instrument, including the frequency of SET monitoring, which occurs predominantly twice per year or annually.

Table 4. Purpose for installing SETs at sites

Sentinel Site	Purpose
SERC	To measure and understand the effects of elevated CO2, warming, nitrogen pollution, invasive species on elevation
Poplar Island	To answer: • Are marshes keeping pace with sea level rise? • Do high and low marsh have similar rates of elevation change? • What is the source of accretionary material? • Do interior and creek bank locations in the low marsh have different rates of elevation change?
CBNERR-MD	Monitor long-term changes in marshes with rising sea levels To answer: • How does ditch plugging affect water levels and the marsh's ability to accrete (specific to UMD/CBNERR collaborative science sites)
CBNERR-VA	To better understand long-term changes in the marshes under rising sea levels, local land subsidence, salt water intrusion, enhanced storm damage and the spread of invasive species
VCR-LTER	To test hypotheses related to bird habitat; better understand processes contributing to transgression and processes contributing to marsh edge erosion
Cove Point	To better understand how accretion and erosion at a created marsh compares to more pristine marshes
Parkers Creek	To serve as the control marshes for the Dominion Cove SETs
Nanticoke River	To examine whether tidal freshwater marshes are losing elevation more rapidly than other marshes (to test the hypothesis that tidal freshwater marshes are subsiding more rapidly due to the effects of increased saltwater intrusion, higher decomposition rates from the introduction of higher sulfate loads)
Upper Patuxent River	To examine if manipulations in porewater salinities and increased flooding result in subsidence or changes in plant communities
Kingman and Kenilworth Marshes	To evaluate restoration efforts at these sites
Dyke Marsh	To gather data on elevation dynamics to inform potential restoration of the marsh

Uses of SET Data

Sites were also asked to list up to 5 past, current or intended uses of SET data (may be different from the original purpose for installing the instruments). Table 5 outlines those uses.

Table 5. Past, current, or intended uses of SET data.

Use
Examine if sites are keeping pace with SLR
Calculate effects of global change on soil carbon sequestration rates
Understand if low marsh areas are gaining elevation at different rates than high marsh
Evaluate the effectiveness of restoration interventions
Education and Outreach
Development of marsh indices
Development of Marsh Equilibrium Models (MEMs)
Understand marsh transgression/migration
Contribute to local/regional subsidence studies
Compare sediment transport processes (includes understanding created vs. natural marshes)
Examine if man-made structures such as revetments enhance or disrupt marsh processes
Contribute to the creation of a coastal resilience tool
To provide useful information to guide managers with land management

Gap Analysis

There is a noticeable geographic gap in the distribution of SETs in the northern portion of the Bay as well as on the western shore between the York and Potomac Rivers (Figure 4). There is a need to develop a plan of action on how to address these geographic gaps with the CBSSC Management Team.

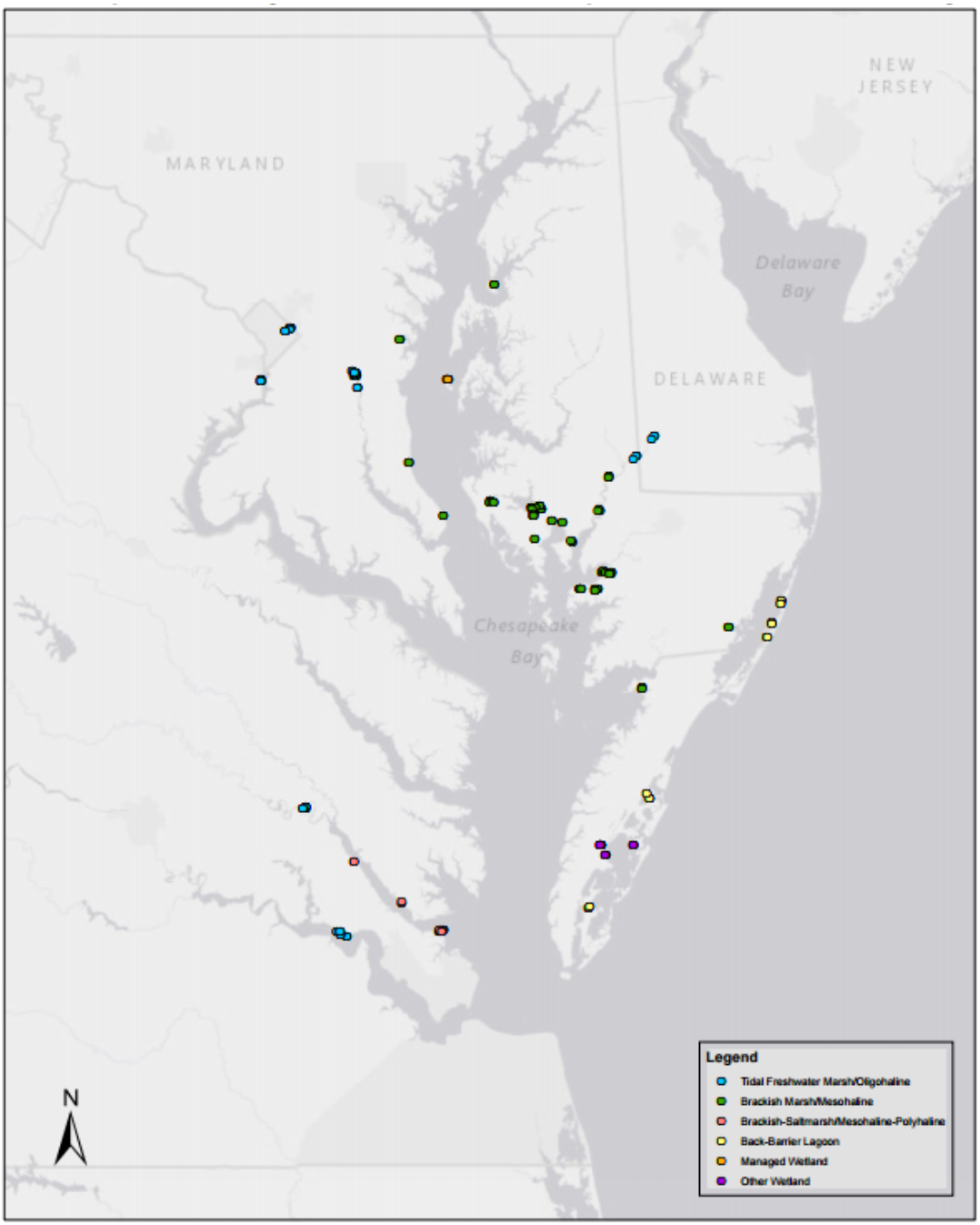


Figure 4. Distribution of SETs across the Chesapeake Bay (October 2016).

Table 6. Number of SETs per site (combines inventories from 2016 and 2017).

Organization/Affiliation	Sentinel Site (Location)	# of SETs
CBNERR-MD	Otter Point Creek	0
CBNERR-MD	Jug Bay Wetlands Sanctuary	24
CBNERR-MD	Monie Bay	18
CBNERR-VA	Goodwin Islands	17
CBNERR-VA	Catlett Islands	13
CBNERR-VA	Taskinas Creek	2
CBNERR-VA	Sweet Hall Marsh	12
NPS	Assateague Island National Seashore	16
NPS	CNHP: Jamestown Island	12
NPS	Dyke Marsh	9
NPS	Kenilworth Marsh	5
NPS	Kingman Lake	5
NASA	Wallops Island*	3
SERC	Kirkpatrick Marsh	48
USFWS	Blackwater NWR	145
USFWS	Chincoteague NWR*	24
USFWS	Eastern Neck NWR	4
USFWS	Wallops Island NWR*	3
UVA	VCR-LTER	48
UMCES	Poplar Island	30
UMCES	Cove Point	2
UMCES	Knapps Narrows	3
UMCES	Parkers Creek	4
UMCES	Nanticoke River	10
UMD	Upper Patuxent River	5
UMD	Deal Island WMA	24
UMD	EA Vaughn	12
USGS	Audubon Property-Farm Creek	2
USGS	Fishing Bay WMA	8
USGS	Saxis WMA	4
	Total	**512**

* added to inventory in 2017

Age of SET Records

The longest continuously read SET is found at the Virginia Coast Reserve Long-Term Ecological Research site (VCR-LTER) with a record spanning 18 years (Figure 5).

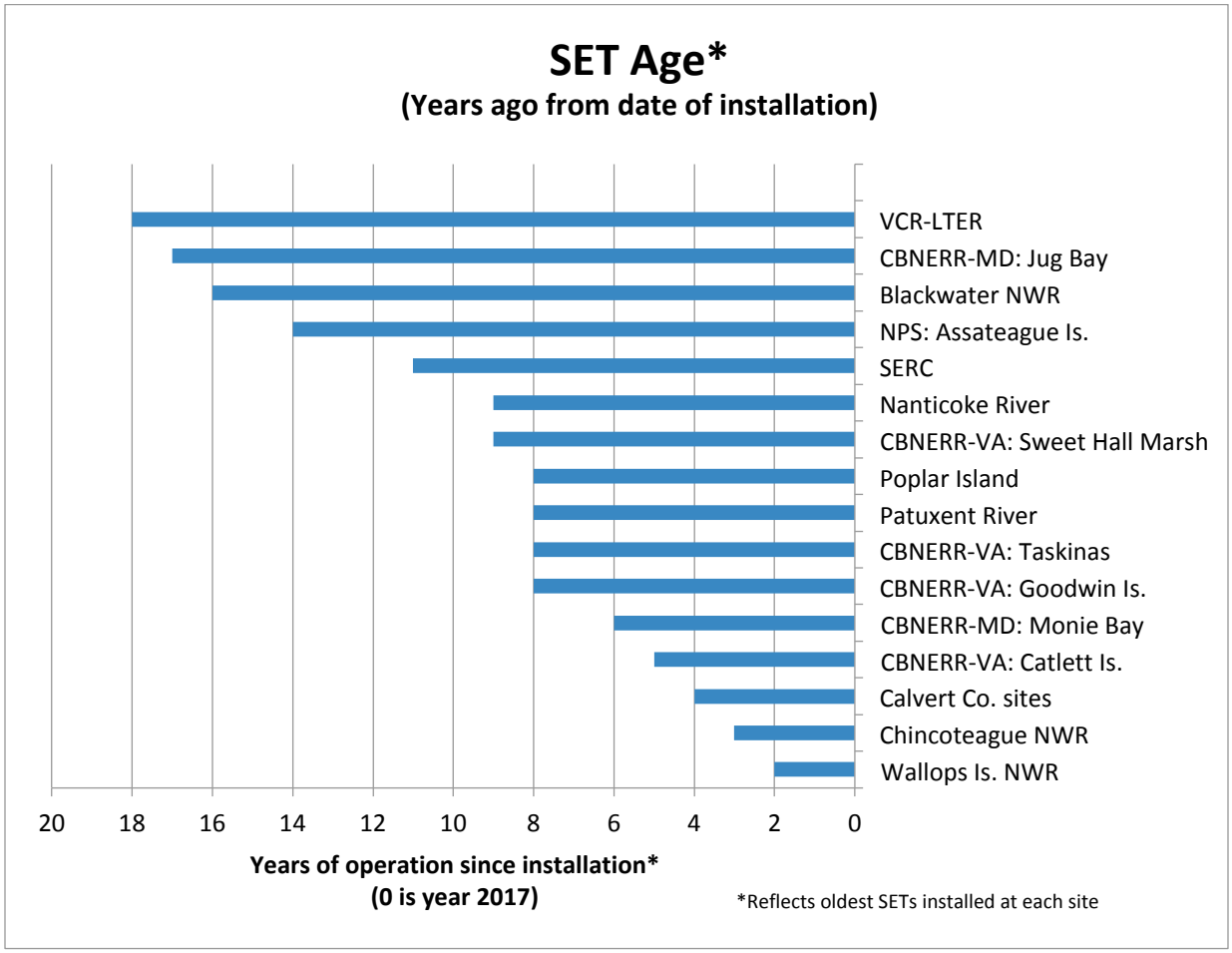


Figure 5. SET Age (October 2016)

Sampling Frequency by Geomorphic Setting

SET users were asked to indicate the *most* representative geomorphic setting in which their SETs are located. As guidance, SET users were asked to choose from a list of 20 geomorphic settings adapted from Cahoon et al. 2009. These options include tidal freshwater marsh, estuarine brackish marsh, estuarine embayment, and back-barrier lagoon (a full list of options can be found in Appendix C). Table 7 organizes sites, including the number of

instruments at each, that fall within these geomorphic settings and how frequently the SETs are sampled. Bi-annual sampling is the most common sampling frequency for sites across the CBSSC.

Table 7. SET sampling frequency sorted by geomorphic setting and number of instruments monitored at sites (January 2017).

Habitat Type	Not currently measured	2-3 times per year	Every 4-12 months	Bi-annual (2 times per year)	Annually	Every 2-3 years	Sampling Frequency TBD
Tidal Freshwater Marsh	CBNERR-MD: Jug Bay (7) Nanticoke River (1)*	CBNERR-MD: Jug Bay (5)	CBNERR-VA: Sweet Hall Marsh (12)	CBNERR-MD: Jug Bay (24) NPS: Dyke Marsh (9) NPS-CNHP: Jamestown Island (12) NPS: Kingman Lake (5)			
Back-barrier Lagoon Marsh				Assateague Island N.S. (16) Chincoteague NWR (18)	VCR-LTER (35) VCR-LTER: Watchapreague (7)	VCR-LTER (6)	NASA-Wallops Is. (3)
Estuarine Brackish Marsh	Nanticoke River (10)*		SERC (48)	CBNERR-MD: Monie Bay (12) Wallops Is. NWR (3)	Knapps Narrows (3) Poplar Island (30) CBNERR-MD/UMD:Deal Island (24) CBNERR-MD/UMD: EA Vaughn (12) CBNERR-MD/UMD: Monie Bay (6)		
Estuarine Embayment			CBNERR-VA: Taskinas Creek (2) CBNERR-VA: Goodwin Island (17) CBNERR-VA: Catlett Island (13)	Parkers Creek (4)			
Other: Created tidal marsh inside rock revetment				Cove Point (2)			
Other: Moist Soil Management (Managed Impoundment)				Chincoteague NWR (6)			

*Nanticoke River sites were sampled 2 times per year between the years 2007 and 2014.

SET Type

Over 70% of the SETS included in the January 2017 SET update are the deep rod variety (Table 8). The 48 SET instruments installed at SERC are deep-shallow rod combined instruments to accommodate experimental manipulations.

Table 8. SET Type (January 2017)

SET Type	
Deep Rod (~2 m to 25m+)	240
Shallow Rod (<1m to 2m)	30
Original (~2m to 9m)	54

Hydrologic Zones

SET users were also asked to categorize their SETs according to hydrologic zone (choices are outlined in Appendix C). Sites were asked to identify the hydrologic zone that best describes where the SET is situated in the marsh (Table 9). Selecting just one choice proved difficult for some of the survey respondents, so any analyses conducted by hydrologic zone should be carefully considered and the data contributor closely involved in any subsequent analysis. Among the SETs surveyed in the January 2017 update, there is a fairly uniform number of SETs spread out across the high, mid and low intertidal zones (85, 97 and 96, respectively). Only 2 instruments are located in the fringe or supratidal zone. These instruments are found at Goodwin Island. Five instruments are located in a mudflat, one at Poplar Island and four at Kingman Lake. All five instruments found in the upland-maritime forest zone are located at Goodwin Island. Given the lack of instruments found in this transition zone and Cooperative-wide interest to better understand marsh transgression, sites concerned with marsh persistence may consider targeting these areas for the installation of new SETs. Tied together with vegetation transect data, sites can track elevation change over time alongside measures such as species distribution and abundance. All six of the instruments listed as "other" are SETs found in managed impoundments at Chincoteague National Wildlife Refuge.

Table 9. SETs per Hydrologic Zone (January 2017)

Hydrologic Zone	
High Intertidal	85
Mid Intertidal	97
Low Intertidal	96
Fringe (Supratidal)	2
Mudflat	5
Upland-Maritime Forest	5
Other: Managed Impoundment	6

Experimental Manipulation

As described earlier in this section, many of the SETs were installed to help answer specific research questions. Survey respondents were asked to indicate whether the marsh surrounding the instrument was treated or manipulated in any way. Table 10 provides a breakdown of these SET treatments. Sites with past or ongoing experimental treatments are located at Assateague Island National Seashore, Smithsonian Environmental Research Center (SERC), University of Maryland Center for Environmental Studies (UMCES) managed sites, Poplar Island, and Maryland's CBNERR. Treatments vary among sites and according to specific research questions posed by site researchers. UMCES-monitored sites use high and low nutrient treatments, Assateague Island monitors SETs within horse exclosures, the Deal Island and E.A. Vaughn Wildlife Management Areas contain SETs located in ditched marshes, the University of Maryland conducted salinification experiments along the upper reaches of the Patuxent River, and SERC conducted elevated CO_2 experiments to simulate climate change effects. Within the 27 SETs on Poplar Island, there a multiple treatments being tested in a restoration setting including high vs. low nutrients, interior low marsh vs. creek bank low marsh and distance from inlet.

Table 10. SET Treatment Types (October 2016)

Treatment	
None/control	229
Restoration	27
Saltwater	5
Ditched	18
Horse exclusion	4
Low nutrient	3
High nutrient	27
Ambient CO2	7
Ambient CO2 + N	8
Elevated CO2	9
Elevated CO2 + N	6
Elevated CO2 + ambient N	8
Burned	28
Fertilized	12

Emergent Vegetation

Scientists measure plant traits such as height, percent cover, stem density and biomass to understand how wetland vegetation responds to changing sea levels. Vegetation is often seen as a key indicator of marsh health and integrity.

All of the founding sentinel sites within the Cooperative have emergent vegetation plots. Exact number of plots were not captured by the inventory, only estimations were provided. Each sentinel site contains between 60 and 200 plots; totaling more than 1,200 vegetation plots.

Vegetation monitoring has a long history with monitoring dating back to 1987 at SERC and 1999 at the VCR-LTER. The sampling frequency and aspects measured varies across the sites, as highlighted by Table 11.

Table 11. Sampling Frequency of emergent vegetation and aspects measured

Sentinel Site	*# of collection points*	*Stem Density*	*% Cover*	*Height*	*Biomass*	*Species Diversity*
Assateague Island National Seashore	450		2 yrs	2 yrs		
Blackwater National Wildlife Refuge	72		3 yrs			
CBNERR-MD: Monie Bay	30	2 yrs	2 yrs	2 yrs		
CBNERR-MD: Jug Bay	70	1/yr	1/yr	1/yr		
CBNERR-MD: Otter Point Creek	75	2 yrs	2 yrs	2 yrs		
CBNERR-VA: Goodwin Island	65	2 yrs	2 yrs	2 yrs		2 yrs
CNERR-VA: Catlett Islands	30	2 yrs	2 yrs	2 yrs		2 yrs
CNERR-VA: Taskinas Creek	62	2 yrs	2 yrs	2 yrs		2 yrs
CBNERR-VA: Sweethall Marsh	90	2 yrs	2 yrs	2 yrs		2 yrs
Poplar Island	100		1/yr	1/yr	1/yr	1/yr
Smithsonian Environmental Research Center	200	1/yr		1/yr	1/yr	
Virginia Coast Reserve-LTER	100				1/yr	1/yr

Uses of Emergent Vegetation Data

In order to understand the management implications of emergent vegetation data, sentinel sites were asked to list up to 5 past, current, or intended uses of emergent vegetation data. Table 12 outlines these uses. The most common use, as indicated by the survey results, is in the identification of shifts in the vulnerability of species composition due to changes in sea level.

Table 12. Past, current, or intended uses of emergent vegetation data

Use	# of sites
Identify shifts in vulnerability of species composition due to SLR	3
Assess vulnerability of critical habitats	2
Ground-truth data habitat maps	2
Evaluate change in marsh vertical elevation due to SLR	2
Develop marsh indices	1
Develop marsh equilibrium models	1
Evaluate change in horizontal marsh migration	1

Dominant Plant Communities

Figure 6. Diversity of dominant vegetation species in the CBSSC.

Together, the sentinel sites contain an impressive array of plant communities. This diversity is important when considering habitat quality for many species, including migrating and resident birds and invertebrates. The root structures and zone of tolerance for these species have a large impact on the viability and survivability of marshes within the Cooperative. Although not the dominant species across the sites, the invasive common reed *(Phragmites australis)* is present at most all of the sites. The presence and spread of Phragmites continues to be of concern to many of the sites. Outlined, below, is a list of dominant plant species as reported in the January 2017 SET inventory update.

The Jug Bay component of the CBNERR-MD is considered a **tidal freshwater marsh**, with a reported 16 plant species, the most abundant are green arrow arum (*Peltandra viginica),* yellow pond-lily (*Nuphar lutea),* and cattail (*Typha)*.

The Sweet Hall Marsh component of the CBNERR-VA is considered a **tidal freshwater marsh** community with a reported 12 species. The most abundant species are green arrow arum (*Peltandra viginica)* and annual wildrice (*Zizania aquatica)*.

The Goodwin Islands and Catlett Islands components of the CBNERR-VA are **estuarine embayment marsh island systems**. These sites contain both short and tall forms of smooth cordgrass (*Spartina alterniflora*), saltmeadow cordgrass *(Spartina patens),* blackrush *(Juncus roemerianus)*, and maritime forest species.

The Taskinas Creek component of the CBNERR-VA is considered an **estuarine brackish marsh**. The most abundant species are smooth cordgrass (*Spartina alterniflora*), saltmeadow cordgrass *(Spartina patens),* and inland saltgrass *(Distichlis spicata).*

The Monie Bay component of the CBNERR-MD is considered an **estuarine brackish marsh**. The most abundant species across this site is needlerush (*Juncus roemerianus),* smooth cordgrass *(Spartina alterniflora), and* saltmeadow cordgrass *(Spartina patens)*.

EA Vaughn is considered an **estuarine brackish marsh**. The most abundant species are smooth cordgrass (*Spartina alterniflora*), saltmeadow cordgrass *(Spartina patens),* and saltmarsh loosestrife (*Lythrum lineare).*

The Deal Island Wildlife Management Area site is considered an **estuarine brackish marsh.** The most abundant species across this site is needlerush (*Juncus roemerianus),* and smooth cordgrass *(Spartina alterniflora).*

Poplar Island and its reference sites at Knapps Narrows are considered **estuarine brackish marshes**. The dominant plant species at both is smooth cordgrass (*Spartina alterniflora).* Poplar Island is a massive restoration site where dredge material is beneficially re-used and placed within construction cells. At Poplar Island, *Spartina* is planted following dredge material application.

Blackwater Wildlife Refuge is considered an **estuarine brackish marsh**. Dominant plant species include bulrush (*Schoenoplectus americanus).*

The Smithsonian Environmental Research Center is considered an **estuarine brackish marsh.** Dominant plant species include bulrush (*Schoenoplectus americanus),* saltmeadow cordgrass *(Spartina patens),* saltgrass (*Distichlis spicata)* and the invasive common reed *(Phragmites australis)*.

The VCR-LTER sites (including Watchapreague) are considered **back-barrier lagoon marsh**. The dominant species present at these sites is smooth cordgrass (*Spartina alterniflora)* (both tall and short forms).

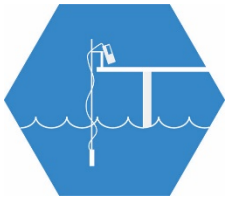
Assateague Island National Seashore is considered a **back-barrier lagoon marsh**. The dominant plant species are smooth cordgrass (*Spartina alterniflora)* and glasswort *(Salicornia)*.

Cove Point is considered a **created tidal marsh inside a rock revetment** and its reference site at Parkers Creek is considered an **estuarine embayment**. The dominant plant species at these Calvert County sites are smooth cordgrass (*Spartina alterniflora*) and saltmeadow cordgrass *(Spartina patens).*

Sites along the Nanticoke River span a gradient from **tidal freshwater marsh** to **estuarine brackish marsh**. The dominant species across these sites are halberdleaf tearthumb *(Polygonum arifolium)* and salt reedgrass *(Spartina cynosuroides).*

Jamestown Island (part of the NPS Colonial National Historic Park Sites) is considered a **tidal freshwater marsh**. The dominant plant species include green arrow arum (*Peltandra viginica)* and salt reedgrass *(Spartina cynosuroides).*

Kenilworth Marsh and Kingman Lake (NPS) are both considered **tidal freshwater marsh**. While Kingman Lake is un-vegetated, Kenilworth Marsh is dominated by green arrow arum (*Peltandra viginica) and* cattail *(Typha).*



Water Quality Monitoring

Water quality is a major driver of ecosystem change. Researchers and managers monitor parameters such as temperature, total suspended solids, dissolved oxygen, pH, conductivity, chlorophyll, and nitrogen. Consistent water quality sampling is achieved through the deployment of water quality sondes and/or discrete sampling at fixed location across the sentinel sites.

Water quality data is currently transmitted and available for download from Assateague Island, SERC, Poplar Island, CBNERR-MD and CB ERR-VA (excluding Catlett Islands). Table 13 provides a look at the parameters collected at each site.

Table 13. Parameters collected via sonde and/or discrete sampling station across surveyed sites

Site	DO	Temperature	Salinity	Conductivity	Chlorophyll *a*	Fluorescence	TSS	Turbidity /Secchi Depth	pH	Nutrients (e.g. NO_2, NO_3, NH_4, PO_4)	DOC or DIC
SERC	X	X	X		X		X			X	
Poplar Island	X	X	X	X			X	X	X	X	
CBNERR-MD: Jug Bay	X	X	X	X	X	X	X	X	X		
CBNERR-MD: Monie Bay	X	X	X	X	X		X	X	X	X	
CBNERR-MD: Otter Point Creek	X	X	X	X	X		X	X	X	X	
CBNERR-VA	X	X	X	X	X	X	X	X	X	X	X
VCR-LTER		X	X	X	X			X	X	X	
Cove Point	X	X	X	X			X	X		X	X
Parkers Creek	X	X	X	X	X						
Nanticoke River			X	X							
NPS: Assateague Is.	X	X	X		X			X	X		
NPS: Jamestown, Kingman Lake, Dyke Marsh	X	X	X		X			X	X		

Uses of Water Quality Data

In order to understand the management implications of water quality data, sentinel sites were asked to list up to 5 past, current, or intended uses of water quality data. Table 14 outlines these uses. The most common use, as indicated by the survey results, includes obtaining dissolved oxygen criteria for the site.

Table 14. Past, current, or intended uses of water quality data

Use	# of sites
Dissolved Oxygen Criteria	3
Modeling	2
Harmful Algal Bloom Detection	1
Salinity Intrusion	1
Impaired Water Listing	1
Fish Kills	1
Ecosystem Response to Hydrological Budget	1
Emergency Response	1
Middle and High School Curriculum	1
Development of water quality standards for Chesapeake Bay tributaries	1

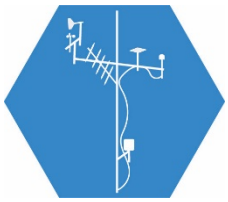
Groundwater Monitoring

The number of groundwater wells at the sentinel sites varies greatly across the Cooperative. The Catlett Islands component of the CBNERR-VA, the Monie Bay component of the CBNERR-MD and Blackwater National Wildlife Refuge currently do not collect any groundwater data. The installation of groundwater wells is planned for CBNERR-VA Catlett Islands in the near future. For the remaining sites, characteristics include water level/depth, salinity/conductivity, temperature, as well as nutrients such as SO_4, H_2S, CL, NH_4, CH_4 (collected at SERC). Poplar Island uses dialysis samplers to measure dissolved nutrients in sediments, including chloride, sulfide and iron. Assateague Island and the VCR-LTER conduct continuous monitoring of wells. The CBNERR-VA sites (excluding Catlett Islands), SERC and Poplar Island, conduct groundwater monitoring on either a seasonal or annual basis. Three groundwater wells were installed at Jug Bay Wetlands Sanctuary (a component of the CB NERR-MD), but were recently removed in 2016 due to malfunction.

Data is publically available for SERC and VCR-LTER and is planned for Assateague Island in the near future. Data is not publically available for CBNERR-VA sites or Poplar Island, but it may become available in the future. In order to understand the management implications of groundwater data, sentinel sites were asked to list up to 5 past, current, or intended uses of groundwater data. Table 15 outlines these uses. The most common use, as indicated by the survey results, includes understanding salinity intrusion and on-site inundation.

Table 15. Past, current, and future intended uses of groundwater data

Use	# of sites
Salinity Intrusion	4
Inundation	4
Plant Production/Recruitment	3
Invasive Species	1
Changes in Biogeochemistry	1
Increased CO2	1
Nitrogen and phosphorous available in root zone	1



Real-time Meteorological Data

Weather stations at each sentinel site measure temperature, precipitation, wind speed, wind direction, relative humidity and barometric pressure. This vital information helps scientists and managers understand estuarine circulation, plant productivity, storm frequency and intensity and drought indices. Many sentinel sites also rely on weather stations located outside their site boundaries to account for gaps in weather information and data.

There are a total of eleven meteorological stations across the sentinel sites. Four of CBNERR components do not possess an on-site weather station. These components include Monie Bay, Otter Point Creek, Catlett Islands and Goodwin Islands. The longest-running station belongs to the VCR-LTER with a record of 27 years.

In order to understand the management implications of meteorological data, sentinel sites were asked to list up to 5 past, current, or intended uses of weather data. Table 16 outlines these uses. The most common uses, as indicated by the survey results, include storm surge modeling and supporting the understanding of plant reproduction and site water quality.

Table 16. Past, current and future intended uses of meteorological data

Use	# of sites
Storm Surge Modeling	2
Plant Reproduction	2
Water Quality	2
Storm Runoff	1
Photosynthetically Active Radiation for SAV	1
Storm Frequency and Intensity	1
Wind Data for High Water Levels	1
Estuarine Circulation	1
Carbon Study	1
Mercury Deposition	1
Atmospheric Corrections for water level data	1
Atmospheric Nutrient Loading	1

Vertical Control Network

Each sites' monitoring elements document change within a geospatial context. To ensure that sensors are physically stable and to enable correlations between data sets, sites need a stable vertical reference framework throughout their properties to which these elements can be connected. Stable bench marks are therefore established within the site, and using various surveying techniques, precise heights are established on these marks and the heights are extended to the monitoring elements. Data from one sensor can therefore be vertically related to other elements in the system. In this way, water level datums such as Mean High Water, emanating from a site's water level sensor, can be related to vegetation zones being monitored for sensitivity to flooding.

Three of the **Chesapeake Bay NERR components in Virginia** have permanent survey monuments in their local vertical control network. The Catlett Islands component does not contain permanent survey monuments but rather uses SETs as local control marks. There are plans within the spring/summer of 2017 to install 2 upland benchmarks on the Timberneck portion of Catlett Islands to enhance the vertical control network at this site. The most recent surveys of these networks took place in 2011 and 2012. CBNERR-VA has utilized digital leveling, RTK GPS surveying, static GPS surveying and leveling to connect instruments within its network.

Assateague Island National Seashore, has survey monuments in place and was last surveyed in early 2015. The site has utilized digital leveling, RTK GPS, and static GPS to connect instruments within its network.

The Smithsonian Environmental Research Center has survey monuments in place across its site and was last surveyed in 2014. SERC last conducted a survey of their vertical control network in 2014. The site has utilized digital leveling and RTK GPS to connect instruments within its network.

The **VCR-LTER** has survey monuments in place across its site and was last surveyed in 1992. There are plans to survey using static GPS and digital leveling to connect instruments within its network in 2017.

Poplar Island has survey monuments in place across its site and was last surveyed in 2016. The site has utilized digital leveling and RTK GPS to connect instruments within its network.

One of the **Chesapeake Bay NERR components in Maryland** has surveyed monuments in place (Jug Bay Wetlands Sanctuary). Otter Point Creek and Monie Bay do not have vertical control networks established yet but there are plans to survey Monie Bay in the first half of 2017. Jug Bay Wetland Sanctuary has utilized RTK GPS and leveling to connect instruments within its network.

The majority of sites utilize in-house staff to conduct vertical control surveys. Poplar Island relies on the U.S. Army Corp of Engineers, NOAA's National Geodetic Survey, and Maryland Department of Natural Resources to conduct surveys. Re-surveying is not done at any consistent interval of time at any of the sites.

Digital Elevation Models and Aerial Imagery

Digital Elevation Models or DEMs are three-dimensional representations of the Earth's surface or features. A total of 29 DEMs were created across sites within the VCR-LTER, CB NERR-VA, SERC and Assateague Island National Seashore. DEMs are used for habitat mapping, geomorphological monitoring, vegetation analysis, running marsh equilibrium model, and the development of marsh indices. The development of additional DEMs could be an important priority for sites moving forward as these models provide valuable insights into the viability and future vulnerability of these systems to rising sea levels.

Aerial imagery is instrumental in conducting change analyses and observing shifts in habitats over time. Historical assessments can provide a look at shoreline erosion over time and high resolution images can also help managers understand changes in vegetation distribution and condition over time.

Aerial imagery collected across the sentinel sites dates back more than 79 years to 1937. The resolution of the images varies greatly between 1:5,000 to 1:40,000.

The Cooperative's sentinel sites identified the need for aerial imagery with six inch to one-foot resolutions as well as hyperspectral imagery to discriminate between species (Table 17).

Table 17. Imagery needs as expressed by site-level representatives

Gap	# of sites
High Resolution (1 foot or better)	4
Leaf on/off imagery	2
Hyperspectral to discriminate between species	1
Quickbird Multispectral	1
Multi-Temporal Hyperspectral	1

Discussion

The results of this inventory indicate a rich and robust monitoring network in place across the Cooperative sentinel sites. By continuing to fill gaps in the infrastructure and improve technologies, the network only stands to strengthen and the ability to generate science syntheses improves. Over the past 2 years, discussion on how to improve the network and understand marsh ecosystem processes fostered closer collaborations among researchers and managers.

Maintaining Vertical Control Networks

Recent conversations regarding water level sensor stability at CBSSC sentinel sites raised major questions about local data quality. In some cases, the level of accuracy needed to answer research questions about sea level rise and coastal response is not met by local site data. As tidal ranges are less than one meter across the Bay, small changes in water level can make the difference between dry land and flooded land. Thus, accurately measuring elevation requires robust data obtained from high quality instruments that are well maintained and surveyed on a regular basis. This report discovered that most sites do not maintain any kind of schedule for re-surveying their vertical control network. Routine surveying becomes opportunistic mainly due to time restrictions and budgetary and personnel constraints. Multiple cases of benchmark instability were raised over the course of the past year, likely due to suspected deep subsidence beneath the marshes. Further complicating this is the challenge that sensors are in some cases handled by third-party technicians. If communication channels

between groups are not properly maintained, routine tasks such as re-surveying go incomplete or un-reported. When (and if) sites discover errors in their data, it is often difficult to salvage. Alarmed by the potential problem of unstable benchmarks, a SET & Wetland Working Group recently formed to address some of these challenges. The group outlined some potential solutions, detailed below.

Potential solutions:

1. Work collaboratively with subject matter experts from across the federal agencies and academia to develop Standard Operating Procedures (SOPs). SOPs would outline a specific survey schedule for the sites to follow, steps to complete when changing out instruments and to ensure stability of instruments.
2. Facilitate conversations with third-party technicians tasked with maintenance of instruments to ensure that any changes or adjustments are properly communicated and conveyed to sentinel site representatives.
3. Work collaboratively with NOAA to develop a support tool to aid sites in understanding the level of accuracy sites can assign to data collected and how the accuracy may dictate the application of those data.
4. Seek new funding streams to support:
    a. Higher quality sensors;
    b. Additional staff time for instrument maintenance and surveying; and
    c. Technical assistance for field staff, especially from within NOAA's Center for Operational Oceanographic Products & Services (CO-OPS)

Marsh Migration and Erosion

During the January 2017 SET Inventory update, site representatives were also asked to include some notes on observed changes to marshes taking place across their sites. Three questions demonstrate some interesting responses that warrant further study:

- **Is there transgression occurring on the upland edge? (Y, N or not sure)** In addition to keeping pace with rising sea levels via vertical accretion, marsh systems migrate into upland adjacent lands (i.e. transgression) where slopes will allow. Ten out of 14 respondents report that there is some transgression occurring on the upland edge of their sites (SERC, Poplar Is., Jug Bay, Goodwin Is., Catlett Is., Taskinas Creek, Sweet Hall Marsh, VCR-LTER, Dyke Marsh and Monie Bay). The remaining four respondents are unsure if transgression is occurring at their sites (Cove Point, Parkers Creek, Nanticoke River sites and the Upper Patuxent River).
- **Have you witnessed any changes taking place in the uplands adjacent to site wetlands? (e.g. tree die-off, invasion by Phragmites) Please be specific.** Changes in species distribution, tree die-off and invasive species presence may greatly influence marsh migration. At Poplar Island, *Phragmites australis* is controlled. The site has witnessed *Spartina patens* moving up into the dikes adjacent to the marshes. At Jug Bay, the marsh is migrating into the forested wetland and there is some die-off of Ash trees (likely

due to the Emerald Ash Borer). At Goodwin Is. and Catlett Is. there is both tree die-off and invasion by *Phragmites australis*. At Sweet Hall Marsh tree die-off is observed. The VCR-LTER sites are observing tree die-off along the edge of marshes. Dyke Marsh, Kingman Lake and Kenilworth Marsh all have problems with the invasive *Phragmites australis* and have experienced plenty of tree die-off but mainly due to Emerald Ash Borer infections. Kingman Lake also has an issue with goose herbivory and control measures are planned for the near future.

- **Is the leading edge/shoreline of your site eroding, prograding or stable?** In addition to further investigating changes taking place along the upland edge of sites, there is a need to better understand changes taking place along the seaward edge or shoreline of the sites. Increased erosion can become particularly problematic when marsh expansion is inhibited by hardened infrastructure (e.g. buildings, roads, etc.), steep slopes, or invasive species such as the aggressive *Phragmites australis*. If erosion continues unabated, sites could become "squeezed" and continue to diminish in size as sea levels rise. Only two sites (Jug Bay and VCR-LTER) reported some progradation occurring along the shoreline of their sites. Six sites indicated that some sections within their sites are stable or "relatively stable". These sites include SERC, Poplar Island, Jug Bay, Sweet Hall Marsh, VCR-LTER and Monie Bay. Erosion has been observed at Goodwin Island, Poplar Island, Jug Bay, Catlett Island, Taskinas Creek, and the VCR-LTER. There is suspected erosion occurring at Monie Bay, although this change was not confirmed. Sites along the Nanticoke River and the Upper Patuxent River are not monitored for erosion-type processes and the survey respondent was unsure how the marshes are responding laterally. There is "severe" erosion taking place at Dyke Marsh along the Potomac River.

Conclusion and Next Steps

The marshes of the Chesapeake Bay are important ecosystems providing a range of services including storm surge abatement, critical nursery habitat for juvenile fish and crabs, carbon sequestration and filtering nutrients from the surrounding watershed. They are an integral part of the Bay's landscape and culture. Without them, life would be vastly different.

Sea levels will continue to rise throughout the 21st Century, further stressing many of these low-lying systems. Sentinel Site data arms site-level managers with the information they need to develop and guide restoration and conservation planning and land acquisition efforts. Together, these sites have the potential to form a compelling narrative on the overall resilience of these systems to coastal change and encourage Chesapeake Bay managers to think about how to ensure their future resilience from local and regional perspectives.

This Data and Infrastructure Inventory serves as the catalyst for future work within the CBSSC. Already, the Cooperative has convened a meeting of scientists and managers to discuss the drivers of elevation change and wetland vulnerability to sea level rise across sites. An October 2016 workshop represented the first time a broad network of scientists, managers and field technicians gathered together to collectively examine and discuss coastal wetland change as it relates to sea level rise at locations around the Chesapeake Bay. The workshop brought together 27 participants representing 15 agencies and academic institutions.

The workshop included ten presentations from scientists scattered across the Bay each highlighting SET data and trends. Each presenter provided a quick overview of their site, sea level rise rates, average rate of change and any information on ancillary data or drivers (e.g. TSS) that helps put their SET data into perspective.

A high level analysis of the presentations illuminated two interesting trends in need of further investigation:

1. Elevation gain/loss is much more variable in oligohaline and tidal freshwater systems than for mesohaline or polyhaline sites; and
2. High marsh is gaining less elevation than low marsh

Further, the concept of "elevation capital" was discussed many times as a characteristic that promotes marsh resilience. The group discussed expanding the resilience conversation to include the prospect of upslope migration (i.e. transgression). The upland topography and other barriers (e.g. infrastructure) might be conceptualized as "migration capital" and considered in tandem with "elevation capital" to develop a useful framework for understanding marsh adaptation and resilience. A number of sites across the region have begun to examine upslope migration, also known as transgression. The Coordinator of the CBSSC is currently working to assemble a Marsh Migration Summit to gather researchers, managers, practitioners and policy makers now faced with understanding how, if and when marshes will move and the implications of this lateral movement to land preservation, land use and zoning, habitat quality and the provision of ecosystem services.

The October workshop also catalyzed the formation of a SET & Wetland Monitoring Working Group whose mission is to share best practices, lessons learned and advancements in the field to work together to produce science syntheses useful to CB management and decision-makers. The workgroup met again in late March 2017 to continue working through issues of sensor stability, the establishment of vertical control networks and to further examine SET elevation trends over time and evaluate the potential drivers of this change.

This new working group is one example of how new science and management challenges may be addressed by the Chesapeake Bay Sentinel Site Cooperative (CBSSC). The importance of this inventory is to provide scientists and policy-makers with a clear understanding of the current scientific data being collected across the CBSSC. With this information, we can identify pressing temporal and spatial questions that can make use of this rich data set and identify the gaps that must be filled in order to answer tomorrow's questions.

References

Cahoon, Don, D.J. Reed, A.S. Kolker, M.M. Brinson, "Coastal Wetland Sustainability", *Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region,* Chapter 4, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.1. 2009.

Chesapeake Bay Sentinel Site Cooperative Implementation Plan, http://www.vims.edu/cbnerr/ChesapeakeBay_SentinelSiteCooperative_IP_FY13FY17_FINAL.pdf, February 2013.

Hensel, Phillipe and Artara Johnson, "Accurate Elevations for Sea Level Change Sentinel Sites", *NOAA Technical Report, NOS NGS Forthcoming*, August 2014.

Appendix A:

- Data and Infrastructure Inventory (spreadsheet containing all responses from respondents)
- Survey Monkey Questions (Pdf version of survey questions)

Appendix B: Distilled Spreadsheet (a distilled version of the survey responses)

Appendix C:

- 2017 Update of SET Metadata Inventory
- 2016 Update of SET Metadata Inventory

Appendix D: Supplemental Information fields (listed below)

SET Data Categories

- Sentinel site
- SET Geographic Location
- Geomorphic Setting
- Site label
- SET ID
- Marker Horizon ID

- Data Ownership
- Property Ownership
- Latitude
- Longitude
- Waterbody
- Installation Date
- Sampling Frequency
- Last Date Sampled
- Surface Elevation NAVD88
- Surface Elevation Tidal Datum
- Surface Elevation Ellipsoid
- Hydrologic Zone
- SET Type
- Dominant Plant Community
- Treatment
- Contact Email
- Contact Phone Number

Aerial and Satellite Imagery

- Sentinel Site
- Type of aerial/satellite imagery
- Source
- Resolution of imagery
- Use of imagery
- Notes

DEM

- Sentinel Site
- Type of DEM
- Source
- Use of DEM
- How imagery was manipulated/enhanced for your site-specific use
- Installation Date (YYYYMMDD)
- Reserve Site

Water Level Sensors

- Sentinel site
- Site name/label

- Is your WL sensor a dedicated WL sensor or part of a water quality sonde?
- Is the gauge surveyed in a control network? (Y/N)
- How was the gauge surveyed in the control network?
- If the gauge is removed for any reason, is it re-surveyed into the network upon return? (Y/N)
- Describe the type of gauge
- Date of installation (MM/DD/YYYY)
- Sampling frequency of instrument

Water Quality Sondes

- Sentinel site
- Site name/label
- What brand/model is installed?
- When was the sonde installed? (MM/DD/YYYY)
- Sampling frequency of the instrument.
- What parameters does the sonde measure?
- What is the geographic relation of the sonde to the other sentinel site infrastructure?
- Date of installation (MM/DD/YYYY)
- Sampling frequency of instrument
- Notes

Real-Time Meteorological Data

- Sentinel site
- Site name/label
- List of components of the weather station
- What parameters does the station measure?
- When was the station installed? (MM/DD/YYYY)
- What is the sampling frequency of the instrument?
- What is the geographic relation of the weather station to other sentinel site infrastructure?

Appendix E: Publically Accessible Sentinel Site Data

- VCR-LTER: http://www.vcrlter.virginia.edu/home1/dataCatalog
- CB NERR- VA: http://cdmo.baruch.sc.edu/data/availableTwo.cfm
- CB NERR- MD: http://cdmo.baruch.sc.edu/data/availableTwo.cfm
- SERC: http://serc.si.edu/gcrew/datamain.aspx
- Assateague Island National Seashore: data is worked up every 5 years and available upon request
- Blackwater Wildlife Refuge: not available
- Poplar Island: not available

Appendix F: Data Sharing Policies

- VCR- LTER: http://www.vcrlter.virginia.edu/data/docs/IMPolicy_VCRLTER06.pdf
- CB NERR- VA: http://cdmo.baruch.sc.edu/data/policy.cfm
- CB NERR- MD: http://cdmo.baruch.sc.edu/data/policy.cfm
- Assateague Island National Seashore: https://irma.nps.gov/Portal
- Poplar Island: available by request to cenab-pa@usace.army.mil
- SERC- http://serc.si.edu/gcrew/datamain.aspx
- Blackwater Wildlife Refuge: not available