Final Report

Shoreline Change Analysis of an Estuarine Recreational Beach, Town of Colonial Beach, Virginia

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1. Background

1.1. Supporting Resilience Implementation

This project supports the Resilience Adaptation Feasibility Tool (RAFT) program jointly offered by UVA Institute for Engagement & Negotiation, ODU ICAR, and College of William and Mary's Virginia Coastal Policy Center. In 2019-20, the RAFT team focused on the Northern Neck region of Virginia, engaging with several communities and the Northern Neck Planning District Commission (NNPDC) to complete a feasibility scorecard, opportunities list and an action checklist for resilience planning. The Town of Colonial Beach, Virginia, was selected for a follow-up focus, resulting in a RAFT Implementation Team being established. Dr. Tom Allen joined this team in January 2021 and began the process of developing a CCRFR project to support the plan for the Town and NNPDC.

The overarching goal of this project is to fulfill needs identified in the resilience action checklist towards providing selected complete products and others that support future implementation. Team discussions have concluded assessment of available data and gaps, as well as immediate results and longer-term capabilities to develop. These existing resources include the Town's GIS database, VIMS shoreline surveys and situation reports, and NOAA topo bathymetric LiDAR. The following project tasks and deliverables are prioritized as a modular project for summer 2021. While these projects focus on Colonial Beach, there remains a research element that opens the products and methods to application in other communities. In this sense, it is a demonstration project that could be extended or replicated elsewhere. Each of the identified challenges and products thus is representative of other Virginia communities. Towards this, the project will also reflect and discuss on the extension of results and potential need and transferability to other coastal Virginia communities.

The Town continues to place a priority on assessing the long-term trends and potential solutions to this eroding recreational beach. This required collating prior VIMS shoreline surveys (maps and transects) with newer topo-bathymetric data. The additional use of elevation and bathymetry extends beyond VIMS' typical shoreline assessments and situation reports by analyzing volumetric change and shoreline change rates to better assess short vs. long-term trends, sediment transport, and giving additional context to potential mitigation or adaptation decisions. Hardened structures north and south of the town's beaches have potential impacts to the sediment budget. Further, the offshore bathymetry has not been mapped in context of beach management, and prior VIMS studies include only shorelines and representative subaerial beach profiles. Conducting a lidar change analysis of the beach and mapping the offshore bathymetry would enable volumetric change estimates and establishing more detail as to the sediment gain, loss, or transport to or from the beach.

Project tasks included:

1. Mapping the current shoreline using GPS and/or UAV aerial imagery.
2. Conducting volumetric change analysis versus the most recent LiDAR DEM and VIMS profiles, LiDAR vs. UAV DEM.
3. Deriving shoreline change rates and potential future change projections.

4. Mapping the nearshore bathymetry using ODU’s Hydrone.
5. Identifying morphological or volumetric changes in the bathymetry.
6. Summarizing findings to note trends in deposition, erosion or transport on-offshore or alongshore.

Project deliverables include:

A. Map of current shoreline.
B. Measure and report volumetric change analysis versus the most recent Lidar DEM and VIMS profiles, Lidar vs. UAV DEM.
C. Derived shoreline change rates and potential future change projections.
D. Map the nearshore bathymetry compiled by ODU’s Hydrone.

1.2. Shoreline Change Analysis

1.2.1. Mapping Shorelines

A key task of the project was to provide the Town an updated shoreline map. This was accomplished by a dedicated small Unmanned Aerial System (sUAS) mission, specifically an Unmanned Aerial Vehicle (UAV) operated by ODU. This flight took place on May 21, 2021, with subsequent analysis and digitization detailed below. The study also collated available shoreline data from VIMS, including recent high resolution aerial digitized surveys as shown in Table 1. The positional uncertainty is derived from metadata for the shoreline data or its legacy source (e.g., aerial photography.)

To undertake analysis using the USGS Digital Shoreline Analysis System (DSAS v.5), we mapped (2021) and imported (VIMS) shorelines as feature class layers in an ArcMap 10.8 personal geodatabase, projected all data into UTM meters (zone 18 Virginia North), and merged individual shorelines to form single features by year. Each shoreline was then ascribed specific required attributes.

Figure 1 illustrates an example of the digitization of the offshore “baseline” reference and casting of perpendicular, shore-normal “transects” at a regular interval. DSAS provides spatial tools to create (“cast”) the transects and then intersect the shorelines with these new features to measure inter-shoreline distances. After distances are calculated between successive years (time) and the first and last years (“end points” in time), various rate changes can be estimated and reported (e.g., meters per year.)

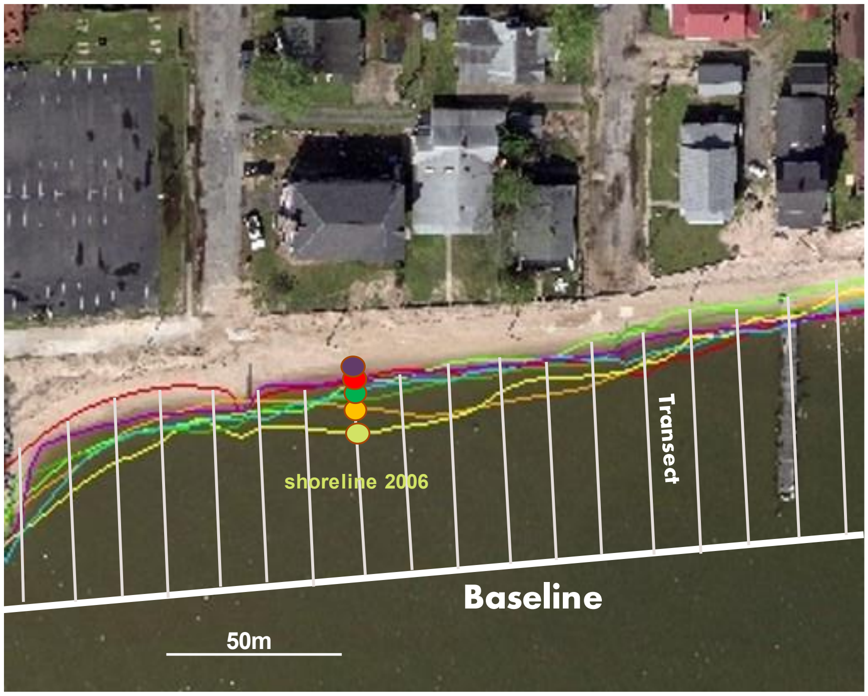

Figure 1 Shoreline Change Analysis features used by DSAS 5. This mockup shows the baseline and nominal shore-normal transects at North Beach with the intersected shorelines and transects allowing the measurement of changes and derivation of change rates (m/year)

1.2.2. sUAS Drone Mapping

1.2.3.

We used a small Unmanned Aerial System (sUAS) (specifically an Unmanned Aerial Vehicle or UAV) to collect imagery and create the most up-to-date possible source for shoreline data in May 2021. The methods for this image acquisition and processing are detailed below. The shoreline digitization and subsequent analysis are also detailed below.

1.2.3 Incorporating Error and Uncertainty

To incorporate inherent uncertainty, each shoreline has a unique error and uncertainty attributable to positional accuracy of the source imagery, methods of collection, and potential time offset from tidal coordination or anomalous water level (e.g., lagging storm surge or riverine flooding). DSAS software was used to incorporate this uncertainty from each input shoreline using the relevant positional accuracy RMSE of the source.

1.3. Shoreline Change Rates and Future Prediction

Several techniques for shoreline change rate calculation were evaluated. A final selection incorporating uncertainty reflects the capability to weight shoreline positions based on estimated error. Fluctuations in gain/loss (accretion or erosion) reflect nearly interannual variation, potential influence of adjoining beach replenishment and influence of hard structures.

DSAS includes a new method for future shoreline change prediction. This technique, which includes estimated uncertainty, was applied to predict future 10- and 20-yr shoreline positions. This approach notably does not include volumetric changes, future changes in shoreline management (e.g., renourishment) or thresholds in future processes (e.g., storminess and wave erosion or sediment transport.)

1.4. Beach Surface and 3D Volumetric Changes

Topobathy LiDAR was used to characterize beach and benthic sediment for recent historic data. These data were available in digital format from the NOAA Digital Coast online repository, collected by a RIEGL topo-bathymetric LiDAR system following Hurricane Sandy and a joint federal mapping campaign. This provided a robust *Before* baseline dataset for the beach and subaqueous surface. A robust After or current 3D surface was thus derived by combining the DEM from the UAS system and the Digital Bathymetric Model (DBM) from an autonomous surface vessel (ASV), the ODU Hydrone and its echosounder and GPS/GNSS receiver.

The opportunity to directly measure bathymetry arose at the beginning of this project with the upfit of the ODU Hydrone Autonomous Surface Vessel (ASV). The Hydrone's SonarMite single-beam echosounder available was eventually deployed off North Beach to collect bathymetry data for a mission that would allow comparison to the existing available topobathymetry DEM. Spatial patterns and volumes of erosion, deposition and relatively stability or no-change would then be derived.

Once the DEM and DBM could be seamlessly combined, the NOAA topobathy DEM and the newly created combined DEM would provide for beach and bathymetric volume change analysis. These results could inform the Town of sediment changes alongshore as well as on-offshore sediment transport. (This critical new data was subsequently a focus of a graduate student poster presented at the American Geophysical Union Fall 2021 meeting and the VAMLIS Annual Meeting in Richmond, VA, where it won best poster one a student award competition.)

2. Methods (Approach)

2.1. Study Area

Although the Town and scope of the project focused on North Beach (Fig. 2), the inclusion of a larger area and the primary public recreational beach to the south was deemed important to capture potential longshore transport trends as well as a control (e.g., to assess relative changes around the hard stabilized breakwaters and the periodically soft-stabilized 'renourished' public beach at Colonial Beach Avenue and the River Edge Hotel.) Both areas were flown and mapped by two separate UAV missions. Then, after processing orthoimagery, shorelines were digitized from these as the 2021 shoreline input to DSAS and for a final deliverable.

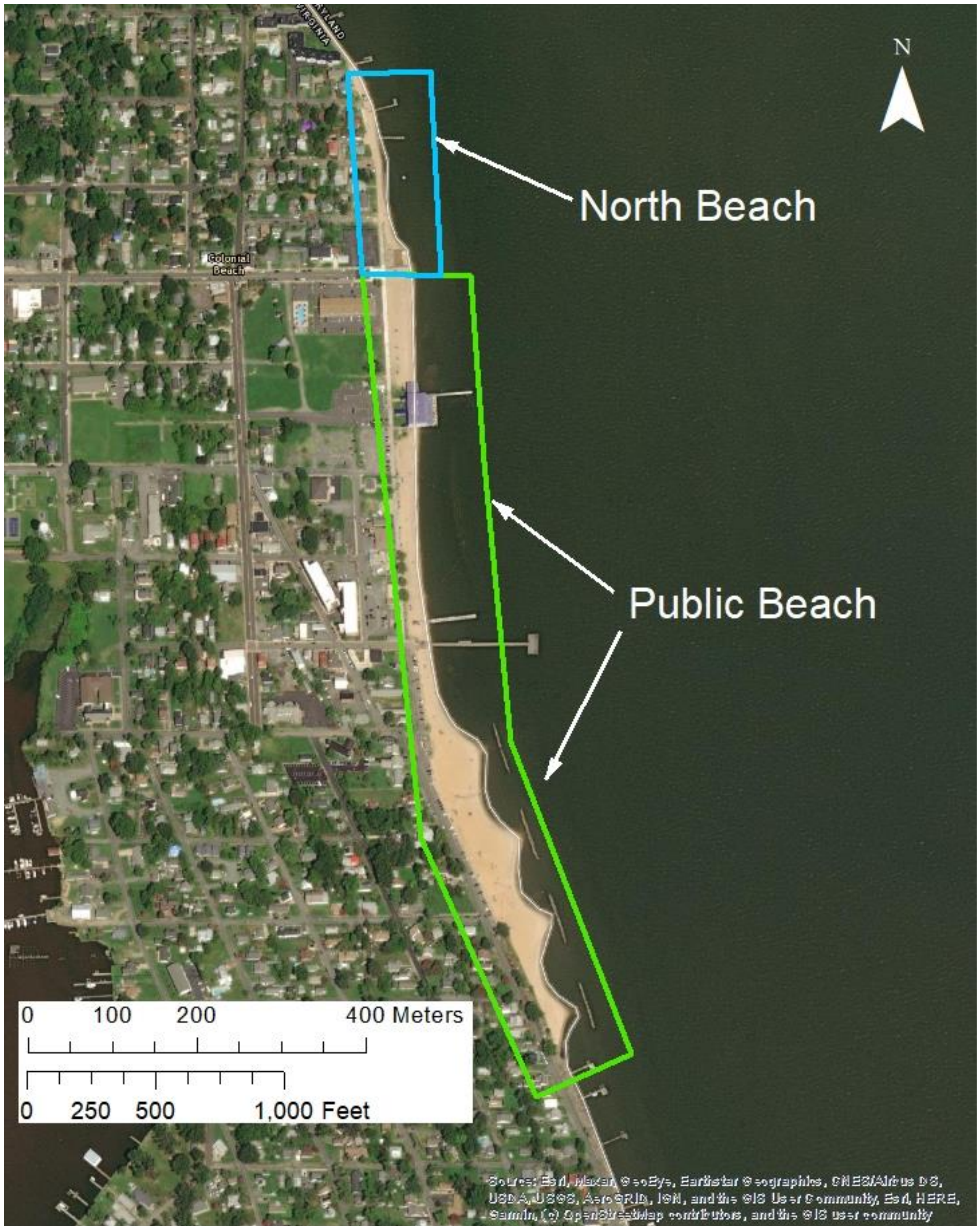

Figure 2 Study area beach locations, showing the focus on North Beach (site A) versus the larger public (site B), an intensively used recreational beach with hard-stabilization breakwaters and periodic beach replenishment.

2.2. Data Acquisition and Compilation

2.2.1 UAV Mapping Methods

Unmanned Aerial Vehicles (UAVs), commonly known as drones, were employed in this project to collect 3-band (visible spectrum) aerial imagery of two study areas, labeled Site A and B, comprising the east-facing sandy beach of the town of Colonial Beach, Virginia. A DJI Mavic 2 Pro quadcopter (FAA#

FA3TAHX7LF) with a 20-megapixel camera and weighing approximately 2 pounds was the primary vehicle used for data capture.

Image acquisition flights were performed on May 21, 2021, between 1100 and 1300, at altitudes below 400' (AGL). The flight crew was comprised of Remote Pilot in Command (RPIC) - George McLeod (FAA Remote Pilot #4135371), Person Manipulating the Controls – Christopher Davis (FAA Remote Pilot #4459040), and Visual Observer (VO) – Alex Garnand. As these flights occurred in unrestricted airspace and in accordance with FAA Part 107 rules (FAA, 2017), no special permissions or authorizations were required.

This aerial survey of Site A was covered an 8.55-acre portion of the shoreline and adjacent areas, bounded by Longfellow Avenue (north), the Potomac River (east), Colonial Avenue (south), and Washington Avenue (west). A grid flight pattern was flown to optimize image collection for the development of high-resolution orthophoto mosaics and 3D digital surface models (DSMs).

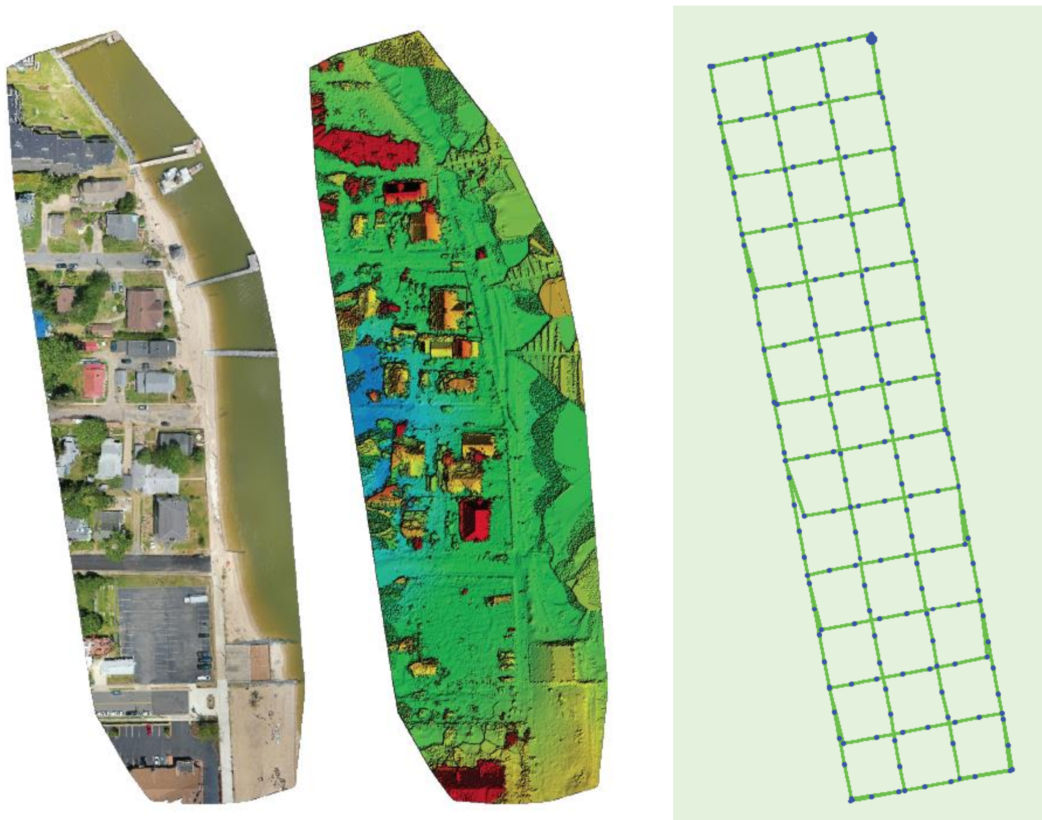

Figure 3 Orthoimage mosaic (left), digital surface model (middle) and image tiles and tiepoints (right) developed by ODU GeoSEA.

Image acquisition at Site A totaled 250 unique images (~1.72 GB). These images were post-processed using the Pix4D photogrammetric engine to create a georeferenced orthomosaic with a ground sampling distance (GSD) of 1.5cm and a DSM with an underlying point density of 926 pts/m^3.

This aerial survey of Site B was flown at a higher altitude and covered a much larger area, 23 ha (57.07 acres), of the shoreline and adjacent areas, bounded by Longfellow Avenue (north), the Potomac River (east), Lafayette Avenue (south), and Washington/Lossing Avenues (west). A parallel single-track flight pattern was flown to optimize for rapid 2-dimensional image acquisition.

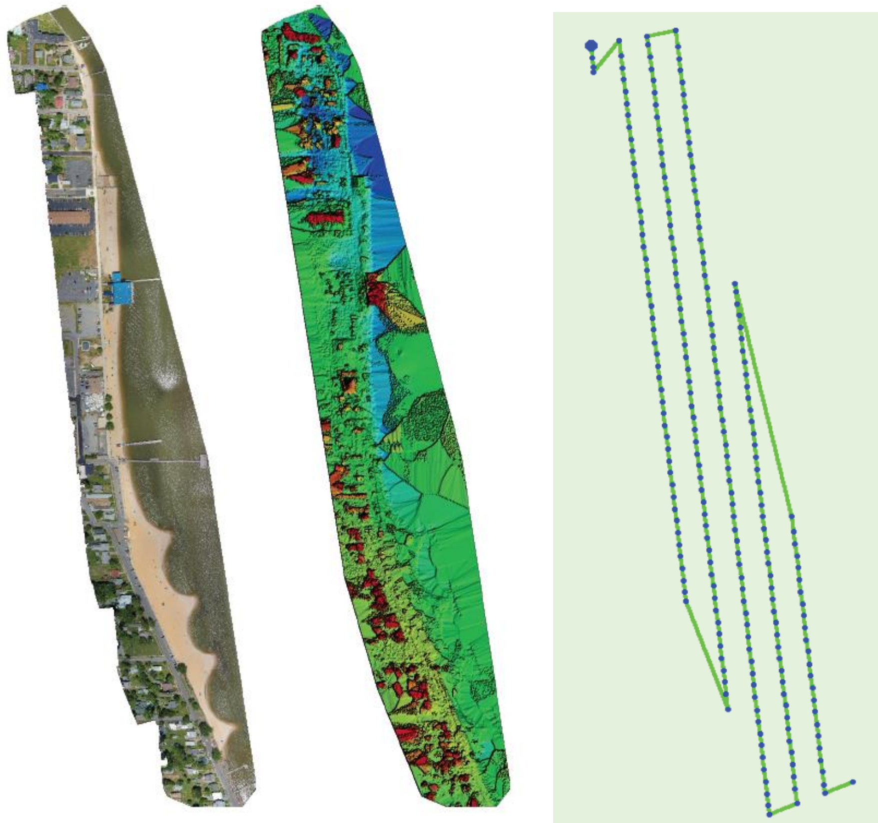

Figure 4 Study area site B to the south orthoimage (left), surface model (middle0, and flightline (right)

Image acquisition at Site B totaled 245 unique images (~2.15 GB). These images were post-processed using the Pix4D photogrammetric engine to create a georeferenced orthomosaic with a ground sampling distance (GSD) of 2.7cm and a DSM with an underlying point density of only 127 pts/m^3.

For both study sites, drone imagery and derivative data products were used to quantify the current 2- and 3-dimensional form and volume of the landforms at high resolution, thereby providing for change analysis with historic topographic maps, nautical charts, aerial photography, and topographic LiDAR.

Numerous studies have shown promise in the use of drones and drone sensor-derived products for the monitoring of site-specific topographic change and ecological impacts. Measurements derived from drone-acquired imagery processed with photogrammetric tools have been found to provide accurate and reliable estimates of human-related environmental impacts (Ancin-Murguzur et al., 2020). The generally high and highly user-configurable spatial and temporal resolution of UAV image sensor data, coupled with the ability to acquire human subjects' data remotely, makes the use of drones an extremely attractive data collection mechanism.

2.2.2 UAV Mapping Results

Figure 3 and 4 show the processed UAV orthoimagery and results analyzed by ODU GeoSEA. Given the focus of the Town on the North Beach and high erosion rates related by staff, we focused efforts on that area. In addition, GeoSEA was not contracted to deliver full areawide 3D data and corresponding bathymetry data were cost-prohibitive for temporal analysis. With site B being largely structurally controlled by breakwaters, the consensus of researchers and the town was focusing on site A for the combined volumetric analyses but to still use the imagery and historic GIS data from VIMS and topobathy LiDAR to assess shoreline change rates for the south site B.

2.3 Shoreline Digitization and Change Analysis

Using the aerial imagery from VIMS and our sUAS mission via UAV, shorelines were digitized by drawing a line along the highest water line visible in the images. As previously stated, this may not be the true mean high-water line for this year, but this is factored into the uncertainty of the shorelines. A baseline was created by drawing a line offshore at a distance that captures all shorelines and roughly perpendicular to the 2021 shoreline. Transects were cast perpendicular to the baseline (also roughly perpendicular to the shoreline) at 50 m spacing between transects, and these transects intersect all shorelines and the baseline. The baseline and transects are used in the calculation of shoreline change analysis through DSAS. Figure 5 shows the map of historic and study current shoreline digitized (deliverable A.)

Figure 5 Full study area shoreline digitization for the full study area (deliverable A) with historic shorelines included. Inset map at right shows the zoomed view of shorelines for site A. With current and historic shorelines digitized in a common spatial reference, these were added to a GIS database to analyze shoreline change rates (USGS DSAS.)

Within the DSAS calculation, a shoreline uncertainty of 6 meters was used; this is the largest uncertainty of the aerial images which was found in the metadata of the images. The uncertainty for each aerial image can be found in each dataset's metadata.

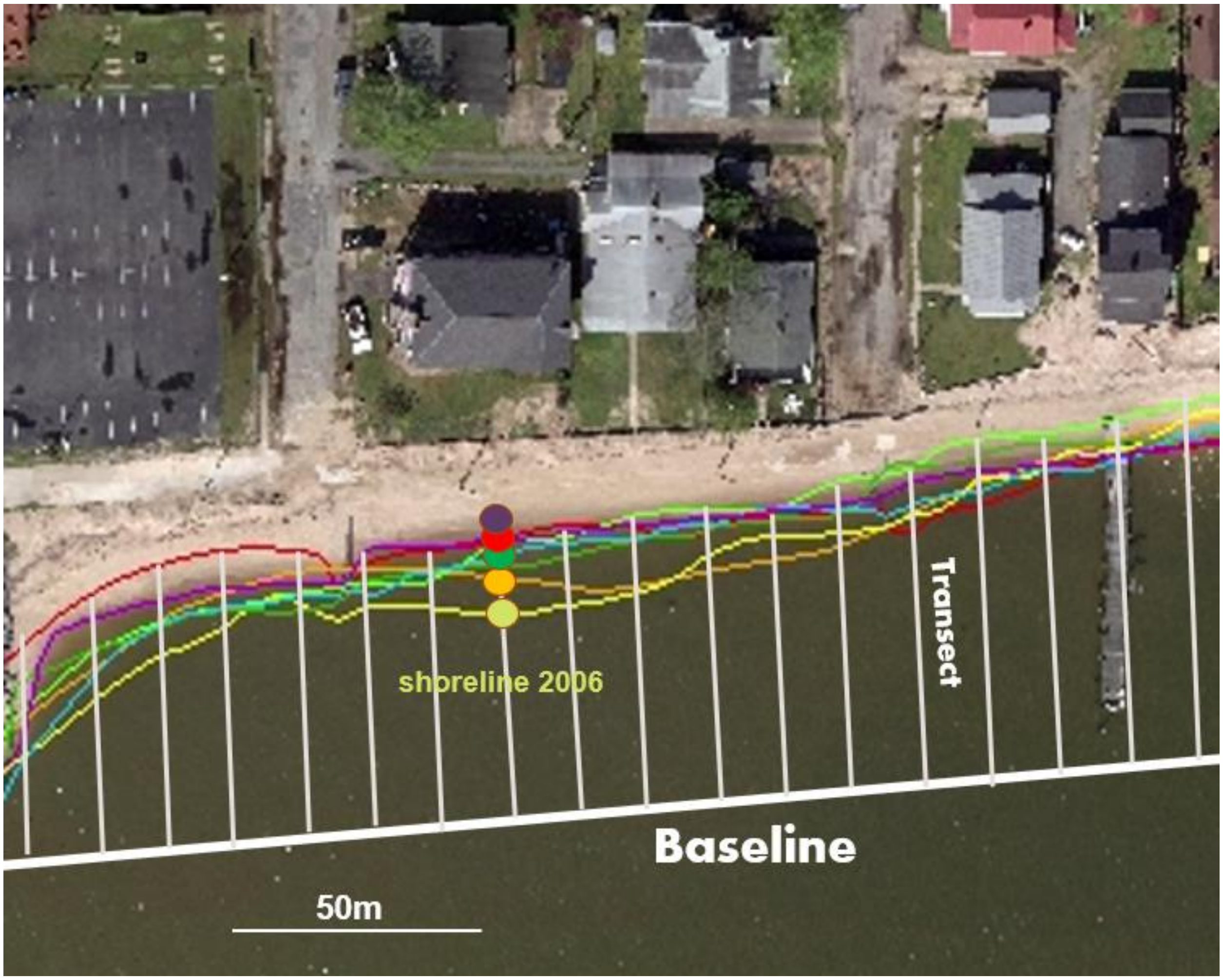

Figure 6 Methodology approach of DSAS consisted of digitizing an offshore baseline, casting perpendicular transects shoreward, and using these to intersect the historic and current shoreline positions. Each transect then has a distance and time component, allowing for calculation of shoreline change rates (SCRs.)

In the shoreline change calculation in DSAS (Fig. 6), all change statistics options were run, but only Weighted Linear Regression (WLR) rate was displayed. In a weighted linear regression, the more reliable data (i.e., data points for which the position uncertainty is small) are given greater emphasis or weight towards determining a best-fit line (DSAS Manual). With the difference in positional uncertainties and difference in sources among our dataset of aerial images, WLR calculated shoreline change rates by giving emphasis to those shorelines with smaller positional uncertainties. WLR was also chosen because it took all shorelines into account for the calculation, not just the newest/oldest or closest to shore/furthest away like some other statistical calculation options such as end point rate, net shoreline movement, or shoreline change envelope.

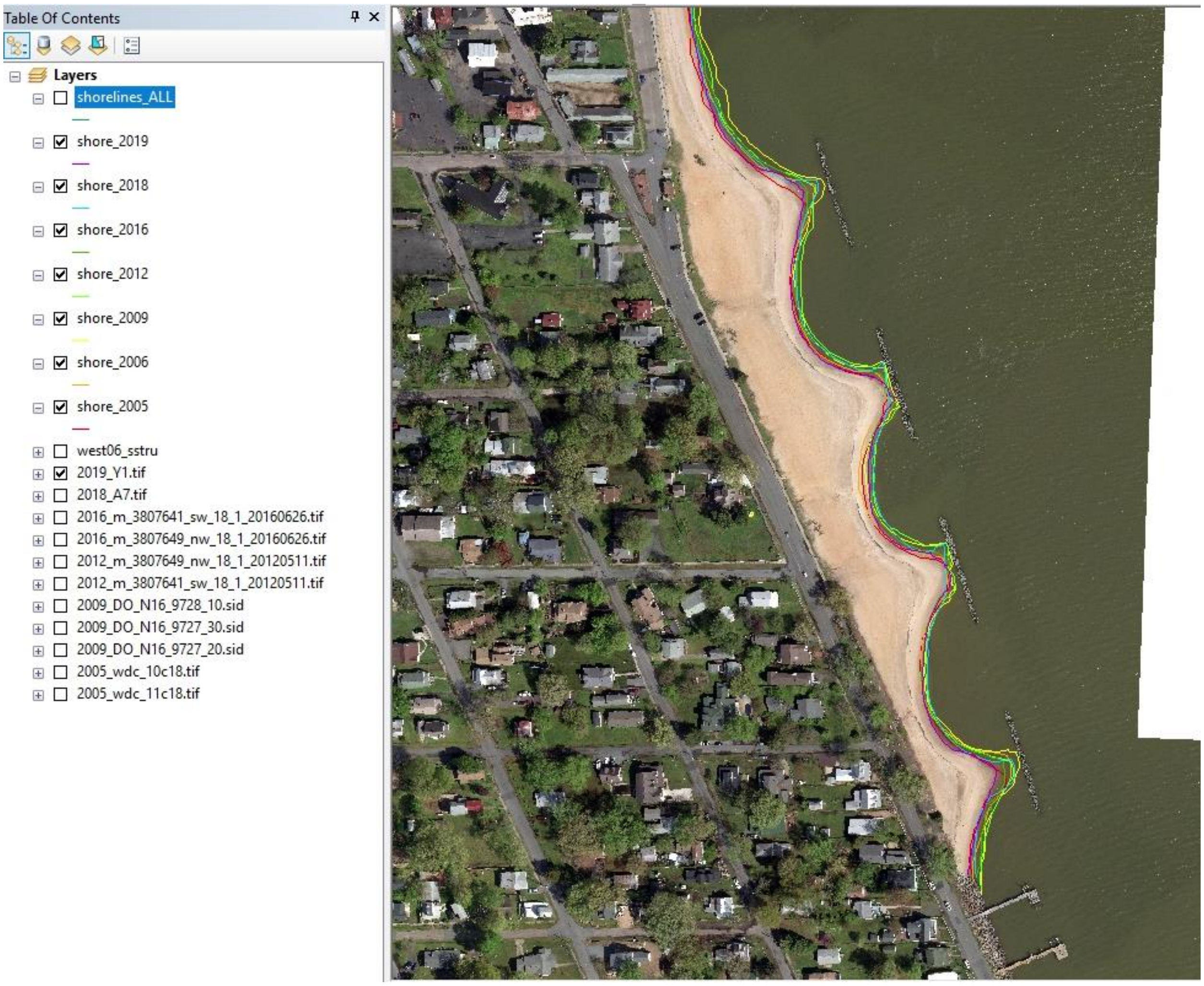

Figure 7 Site B shoreline digitization was also completed given the availability of the historic shorelines and new UAV orthoimagery. Since the UAV did not collect 3D mission data and hydrone data were cost prohibitive in time, the town and ODU consensus was to not derive volumetric analyses here. Further, a 3D UAV mission would have required direct overhead flights of beachgoers not allowed under FAA regulations.

2.4 Future Shoreline Predictions- describe the 10 and 20yr method

After historic shoreline change rates were calculated, shoreline forecasts for 10 and 20 years in the future were calculated based on the historical shoreline position data. These predictions use linear regression rate calculated by DSAS, and then estimates the shoreline position and rate for 10 years and 20 years into the future, as well as providing positional uncertainty at each time step as a band on either side of the predicted shoreline. Both sides of the positional uncertainty should be considered, however, one side may be favored in future trends based on historical trends of the shoreline.

2.5 LiDAR and sUAS DSM Change Analysis – describe the DSM and DEM and DEM of Differences method)

TBD

2.6 Bathymetry Mapping and Change Analysis

Hydrone data was collected at North Beach on August 5th, 2021, beginning at 1:18 pm and concluding at 2:24 pm, during which the tide was rising from a low tide at 11:42 am. The tide gauge used was NOAA tide gauge 8635027 Dahlgren, Virginia (https://tidesandcurrents.noaa.gov/waterlevels.html?id=8635027&units=metric&bdate=20210805&edate=20210805&timezone=GMT&datum=NAVD&interval=6&action=), located roughly 7 miles upstream (northwest) of Colonial Beach. The hydrone data was tidally corrected 0.23 meters, removing the changing tide level during data collection, and to accurately measure the depth of the water. Dahlgren tide station reports a mean tide range of 0.487m (1.6ft).

Figure 8 Missions planned and run by the Hydrone displayed in Gogole Earth Pro imagery. The various missions tested and verified the navigation, accuracy and alternative swath densities.

Figure 9 PI Allen and student Rob Stuart deploy the hydrone at North Beach in May 2021.

A Hydrone bathymetry survey was planned at ODU to include autonomous, shore-parallel tracks and ad hoc remotely operated opportunistic collections in close proximity to shallow shore and structural features such as storm water outfall pipes, rip rap, piers, and incidental features. Approximately 29,277 points were collected over roughly 1sec timestamped intervals with concurrent echosounder and onboard GPS/GNSS positioning. Positional data and soundings were subsequently linked by timestamps, adjusted by interpolated tidal corrections using the observed water levels at the Dahlgren tide station, and then used for final bathymetric mapping and spatial analysis.

Figure 10 Students and Matt Smith (Town of Colonial Beach GIS and Assets Manager, right) monitor the hydrone mission, May 2021.

The NOAA-USGS 2012 CONED Topobathy DEM (Danielson and Tyler 2016) for the area was acquired and used in separate topographic and bathymetric change analysis. This DEM in MHHW tidal datum was adjusted to NAVD88 datum for comparison to the Hydrone bathymetry (using datum offsets reported by the Dahlgren gage.) Metadata for the NOAA DEM was available from NOAA Digital Coast and VIMS metadata were critical to the historic *Before* data analysis for beach and bathymetry (https://cmap2.vims.edu/CCRMP/metadata_CCRMP/Chesapeake_Bay_TopoBathy_FGDC_Metadata.html) The vertical accuracy (RMSE) of the NOAA DEM is estimated at 15-20cm but was not locally assessed quantitatively.

A polygon was digitized extending beyond the extent of the Hydrone data approximately 10m prior to applying a spline spatial interpolation (0.5 smoothing factor) and generating a DEM at approximately 1m spatial resolution. This DEM was co-registered to the pixel size and scale of the CONED Topobathy DEM. Next, vertical changes were derived by differencing the Hydrone DEM and the Topobathy DEM to create pixel-based vertical DEM of differences. With both horizontal and vertical units in meters, this provided for visualization and volumetric analysis of changes.

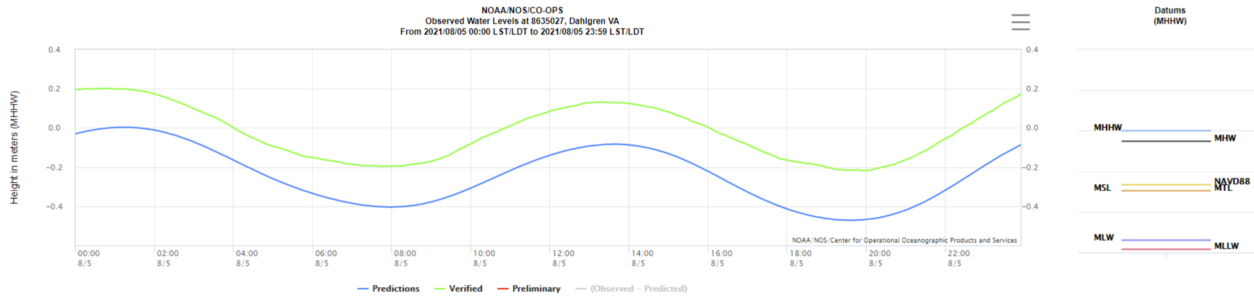

Figure 11 Tide Water level measurements at the NOAA tide gage at Dahlgren Station ID 8635027 was used to adjust the raw bathymetry of the hydrone data collection (i.e., tidal adjustment.) PI Allen developed a GIS script to automate this post-processing using coordinated timestamps from the tide gauge and hydrone GPS. https://tidesandcurrents.noaa.gov/stationhome.html?id=8635027.

3. Results and Discussion

3.1 Shoreline Changes

Shoreline changes were derived and are shown in Figures 12 and 13, including both sites A and B. Transects in DSAS are symbolized to depict the change rates using the widely used Weighted Linear Regression (WLR) technique. Results captured the noted high erosion rate at North Beach as well as unexpectedly high rates in interstitial segments along the structurally protected site B.

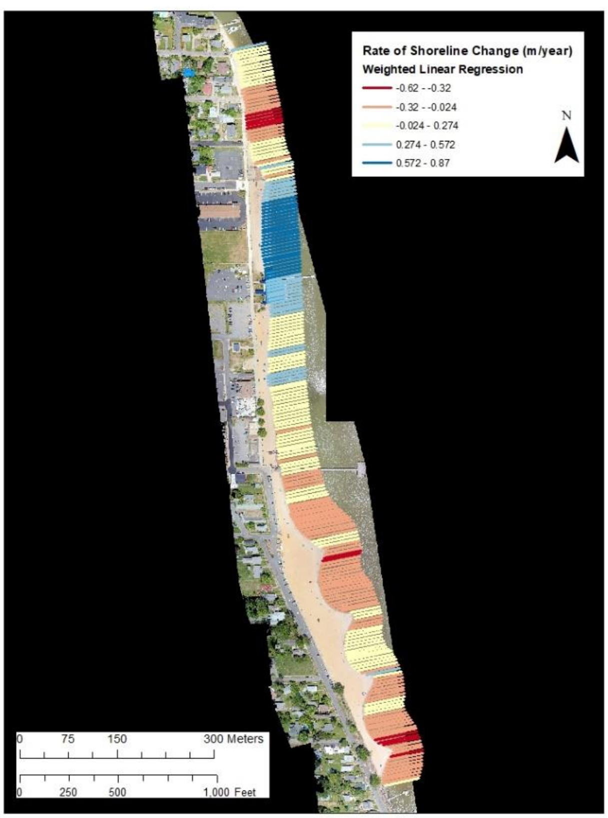

Figure 12 Map showing DSAS shoreline transects and derived shoreline change rates using the weighted linear regression technique. Hotspots of erosion are shown in oranges and reds while cool blues suggest low or even accretionary areas of change. Unsurprisingly, we quantified the locally known erosion in North Beach but also, surprisingly, indications of erosional trends around the breakwater beaches.

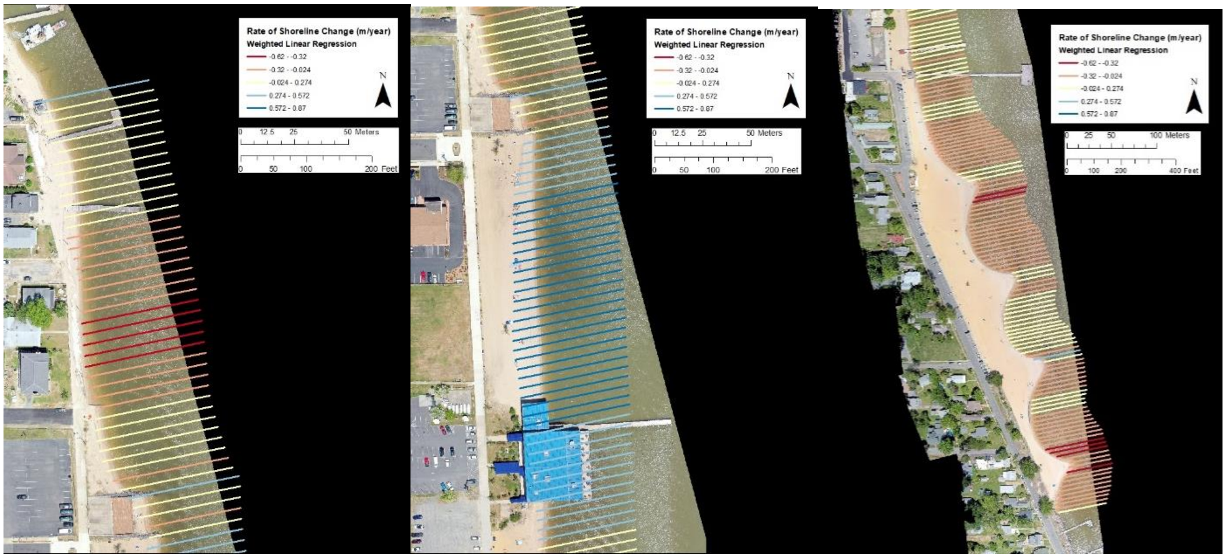

Figure 13 A series of higher resolution maps zoomed in to show transects similarly to Fig. 12. The North Beach site A (left and middle) corroborates Town observations of high rates of change. Nonetheless, results also showed some hotspots of erosional trends in the public beach to the south (right.)

3.2 Projected Future Shoreline Change and Uncertainty

Utilizing the WLR shoreline change rates, one can project future shoreline positions along transects. This approach makes significant assumptions as to static landforms on the beach and dune side (if present) and the general sediment budget. It also potentially magnifies measurement or positional error in the digitized shorelines from various sources. To overcome the latter, shoreline uncertainty is also projected using the RMSE reported metadata of the historic shoreline sources. This produces a zone of uncertainty. Figure 14 shows results of the 10- and 20-year projected shorelines, including the corresponding zones of uncertainty. This uncertainty band represents a very high confidence ~95%. The bold line represents the predicted future location for each duration, resulting from the projection of the derived weighted linear regression rate.

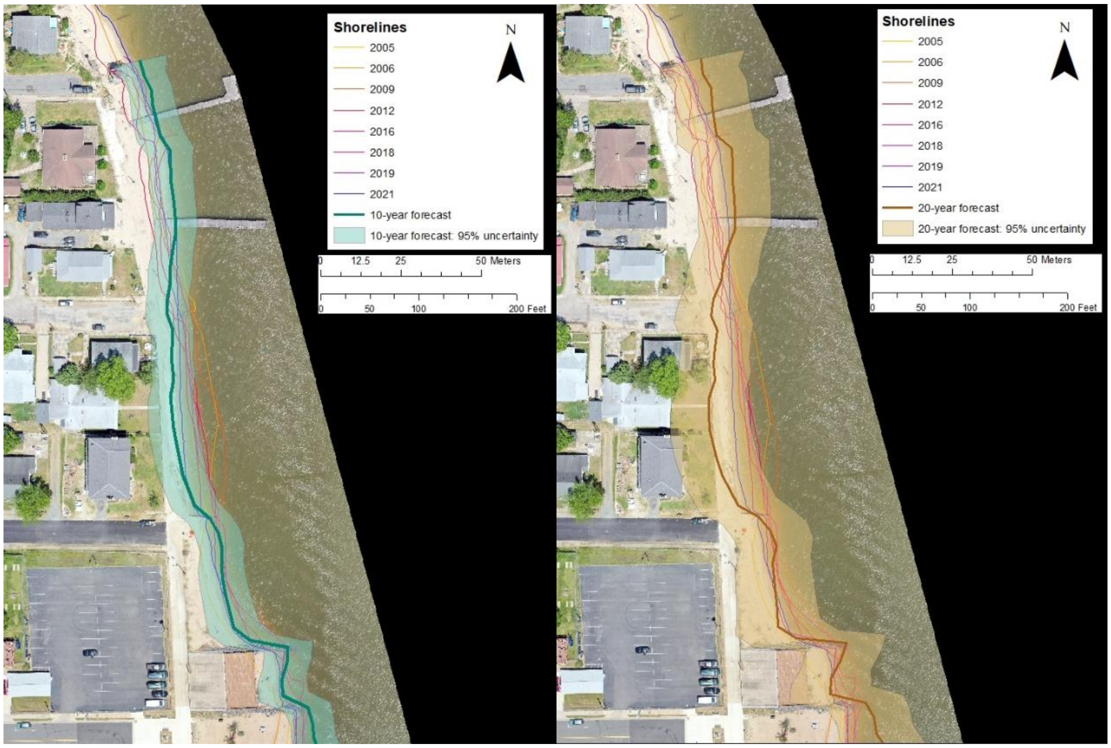

Figure 14 Maps of 10-year projected (left) and 20-year projected (right) future shorelines including zones of uncertainty derived in DSAS.

3.2 LiDAR Results

Results of the beach volume changes are depicted in three maps of Figure 15. Since each date 2012, 2016, and 2021 has a derived DEM, it is possible to examine sequential changes. The first sequence 2012-2016 indicates erosion and some accretion or built-up areas (south of North Beach), some recovery or accretion evident in the north between 2016-2021, and a generally extensive net erosion and volumetric loss of the beach over the 2012-2021 time period. This corroborates the Town's observations but further quantifies it spatially and volumetrically.

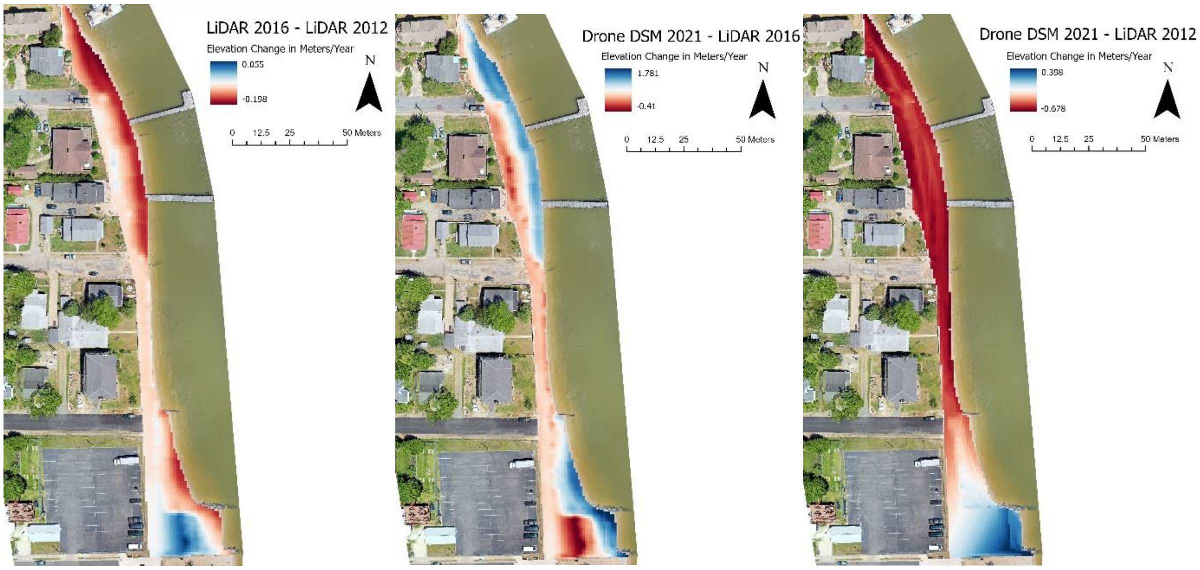

Figure 15 Time-sequential interval changes in beach elevations across the different LiDAR DEM and Drone DEM 2021 datasets depicts variability and cumulative erosion predominant change.

3.3 Hydrone Results

Results of the Hydrone survey show a robust and expected patterns in bathymetry and changes in the area, as well as as few surprises and possible anomalies. Results highlighted here focus on the CCRFR task deliverable D; mapping nearshore bathymetry. These results were greatly enhanced by the inclusion of the hydrone to capture offshore bathymetric changes. The Hydrone acquisition captured depths at 2hz interval, with numerous data from both the autonomous mission and ad hoc remote control. However, as visually evident in Fig. 16, data density of the GPS positioning was not as dense, and to avoid having to interpolate positions at a sub-second interval, only 1sec interval matching time-stamps of GPS position and echosounding data were retained. During data collection a few wakes from passing boats were observed as well as the general change in tide, which were reasonably captured by the Dahlgren gage and later removed by interpolation. A total 29,277 bathymetric points in NAVD88 datum were finally used in GIS analyses. See Fig. X. Although the greatest density of points were collected off North Beach, we included some areas off the American Legion property and private properties to the north with docks and piers at a sparser density using remote operation (in order to avoid possible collision with structures.)

All Hydrone points and topobathy DEM cells were clipped to a digitized polygon area for exclusive analysis of bathymetric change.

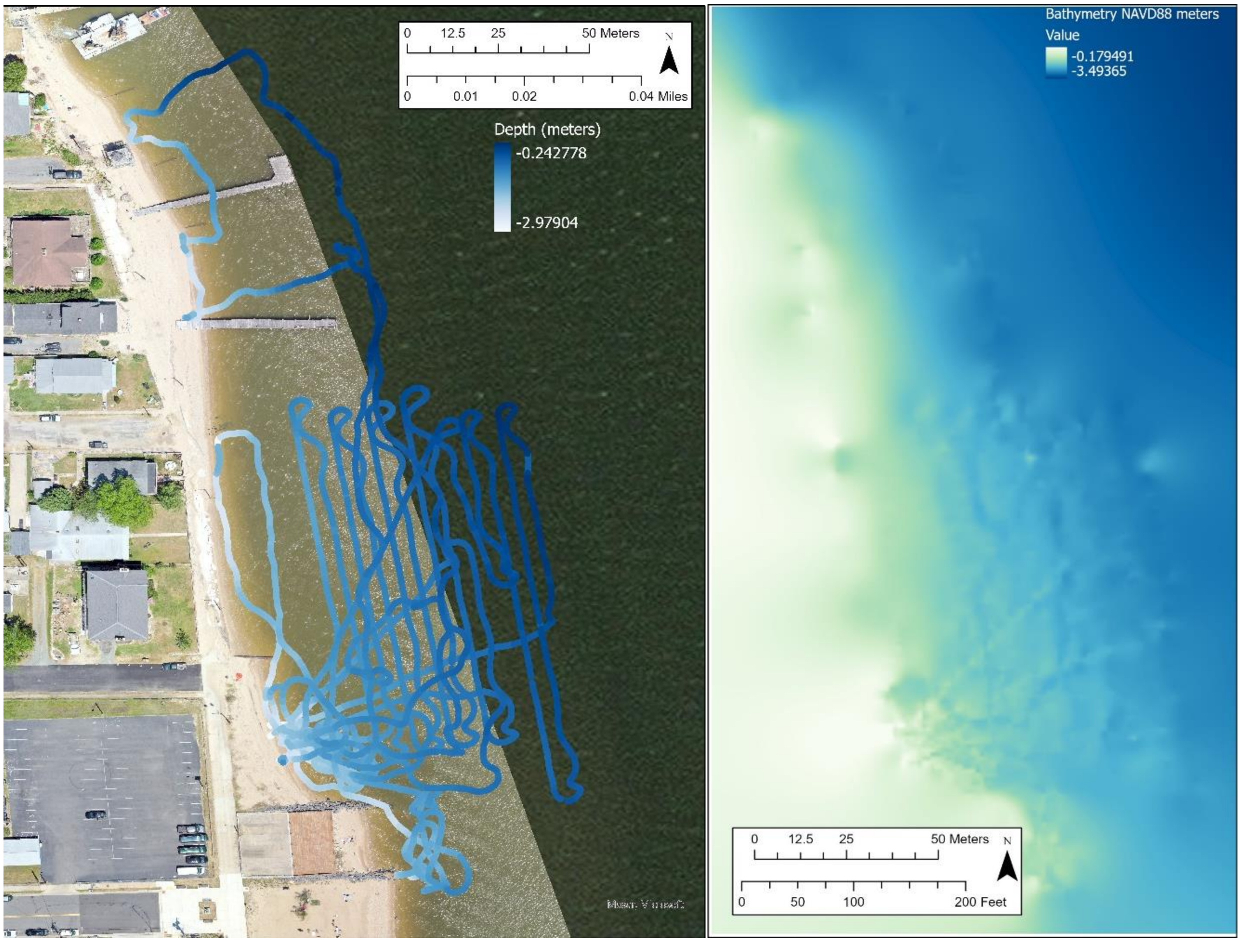

Figure 16 Final mission data for the Hydrone showing bathymetry depth points (left) after tidal correction prior to surface interpolation (right) displayed as a raster grid.

A spline interpolation was applied to the hydrone bathymetry points to create a raster grid (DEM representing bathymetry). After iterative tests, a 0.5 smoothing factor was applied and 1m pixel resolution chosen (Fig. 16.) Results of the interpolation show the expected smooth gradient from shore to offshore as well as variation alongshore near areas of potential scour along the beach, outfall pipes as well as relatively stable bedform offshore and near the groin by the American Legion property.

A few systematic or spurious areas are also evident, including some along-track bias in the bathymetry points and a few artifact errors diagonal at the beginning or end of the autonomous collection. Although these *could* be errors, they as well could be scour areas relict from the channel that was serving cruises by the town pier. The anomalously higher diagonal areas may reflect relatively lower water levels indicative of seiching or other processes at fine time intervals in the river. The Dahlgren tide gage sampling at 6min. intervals was analyzed for to assess these but did not detect such changes. It is likely that these fine spatial and temporal changes in water level may arise from currents and seiching finer than the sampling interval (and hence, time-averaged) by the gage.

In addition, the hydrone bathymetry indicated some potentially deeper pockets along the beach where wave reflection (scour) or longshore current erosion could be evident.

Bathymetric changes were measured by the DEM of difference between the Hydrone DEM and the CONED topobathy DEM using a function pixel-by-pixel in ArcGIS Pro. The resulting changes shown in Fig. 17 depict expected as well as surprising localized patterns of change. First, the overall trend is a universal net erosion (or deeper) state of water level. While substantial areas offshore show little change in depth, erosion in the north of the site and near the shoreline and upper beach face appear significant and well above the potential joint error of both data sources. In particular, areas close to shore where a sidewalk/boardwalk was broken indicate substantial deepening. This could arise directly from the DEM showing damage to this structure or caving/undermining or scour. Areas proximate the boardwalk could be a focus of wave reflection and scour as well as longshore current erosion. There is also indication of this a few meters south of a relict rip rap. In aggregate, if the water level were assumed static between the 2016 CONED DEM and the 2021 Hydrone bathymetry, the total change in bathymetry reflects a potential loss of 35,423.6 m^3 . However, this is likely an overestimate of potential erosion. Rather, the greenish-blue to dark blue areas more typically represent areas of deepening and erosion, with localized scour and sediment flux. By deepening, these areas may create a positive feedback on erosion wherein the deeper offshore water a few meters of the beach is less capable of dissipating wave energy, resulting in stronger energy dissipation on the beach and net erosion. The time interval and potential errors between the two sources, however, make it inappropriate to speculate on the potential transport of sediment. Nonetheless, these significant areas of deeper water may be important to managing beach sediment.

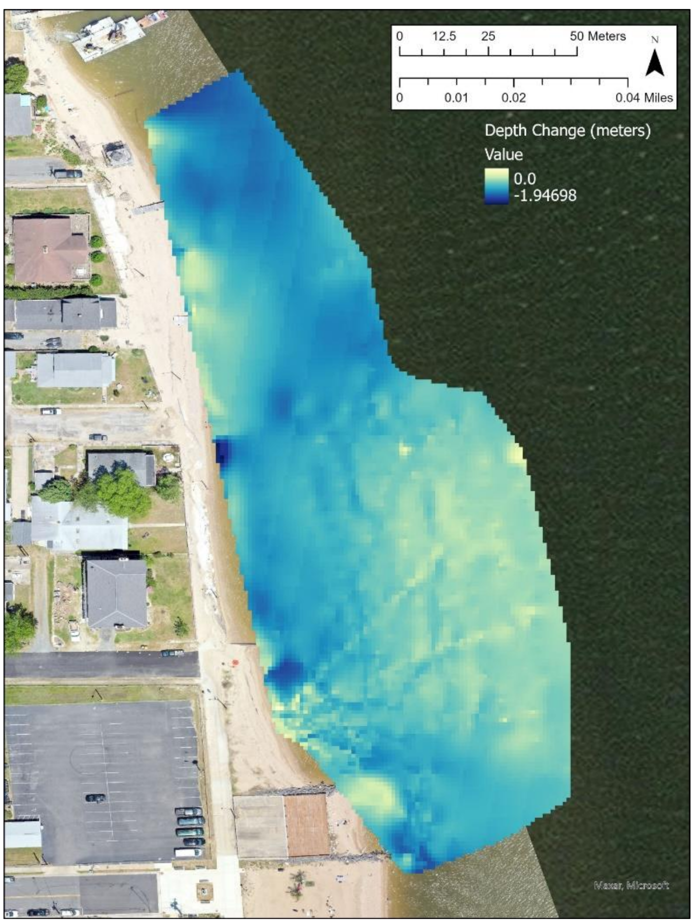

Figure 17 Map highlighting depth changes between 2012 Post-Irene topobathy LiDAR and 2021 Hydrone survey.

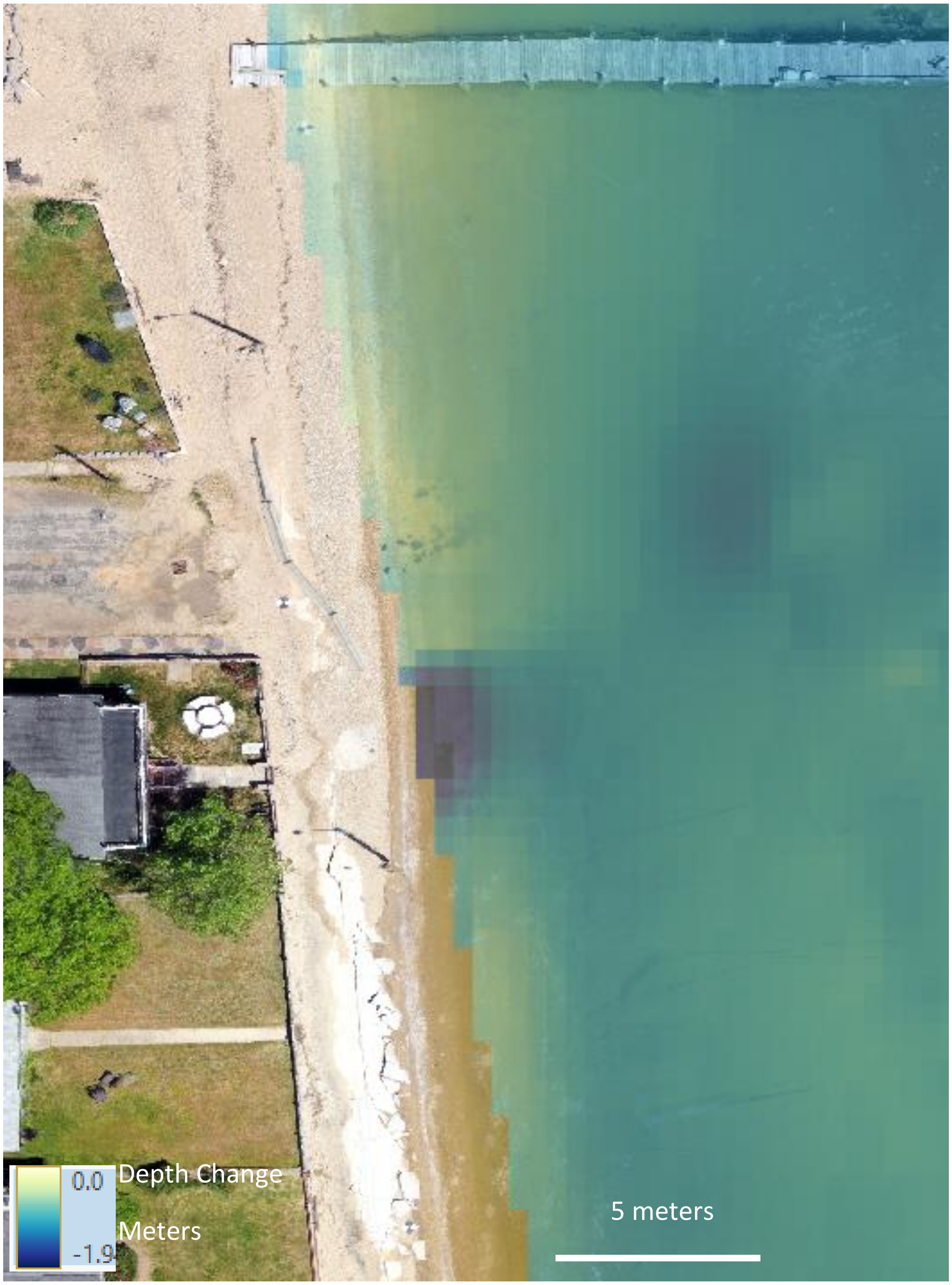

Figure 18 Zoomed view of depth change between 2012 and 2021 showing localized evident scour.

4. Conclusions and Future Work

This report describes the assimilation, new data collection, and analysis of shoreline changes in the Town of Colonial Beach North Beach study area ca. 2012-2021. Historic shoreline data were collected and enhanced by new data collection with drone imagery. Beyond typical 2D shoreline changes, the project mapped and analyzed volumetric changes, including both the beach and offshore bathymetry. Deliverables provided in the report are also available as GIS datasets with supporting metadata. The project results included:

1. Maps of current shoreline as of 2021, at fine-scale, from drone orthoimagery
2. Measurements of both beach and bathymetry changes, including 3D volumetric change.
3. Shoreline change rates and projections of future potential change.
4. Maps of nearshore bathymetry as well as bathymetric volume change.

Our results corroborate and quantify the community identified and prioritized issue of coastal erosion at North Beach. The quantification include both linear rates of change and volumetric changes. The results show rather high rates of erosion as compared to typical estuarine shorelines and a few surprising trends of erosion even within the relatively protected breakwater structures of the public access beach to the south. These results could be further analyzed to assist soft or hard stabilization projects, ranging from beach replenishments to breakwaters or hybrid projects. The projected shoreline changes identify increasing risk to the public access and some beachfront homes. The results of the Hydrone survey similarly identified substantially net erosional trends offshore. These observations raise the prospect of possible positive feedback if erosion offshore continues (i.e. potentially greater wave energy on the beach, accentuating erosion.) This somewhat speculative insight could be used to consider wider “full profile” nourishment or assist the design of structural protection.

A secondary benefit of this project is having implemented the data integration and analysis, including creating selected new scripts to automate analyses. The data can be readily distributed to the Town and county and replicated (“scaled up”) to analysis in other communities across the Bay where estuarine shoreline erosion is a concern. VIMS supports communities through dedicated shoreline situation reports, analyses, and advising. This project somewhat extends that with the quantification of historic change rates, updated methods using drone imagery and 3D data, and the bathymetric survey. Most of these new approaches are scalable and extensible inexpensively to other communities. This wider implication and future approach also prompts the question- where else might this approach be replicated? Towards this, Figure 19 presents a regional analysis of other estuarine beachfront towns and maps the relative shoreline erosion rates (from VIMS data.) This limited analysis highlights the highly erosional shoreline of the Northern Neck’s Potomac River, with secondary riverine and often bluff-adjacent shorelines. The vast extent of the bay shoreline is relatively stable (<1m erosion/yr or even decade), and although this is an historical perspective, it does highlight the distinctive erosion hazard facing the Town of Colonial beach and its neighboring communities.

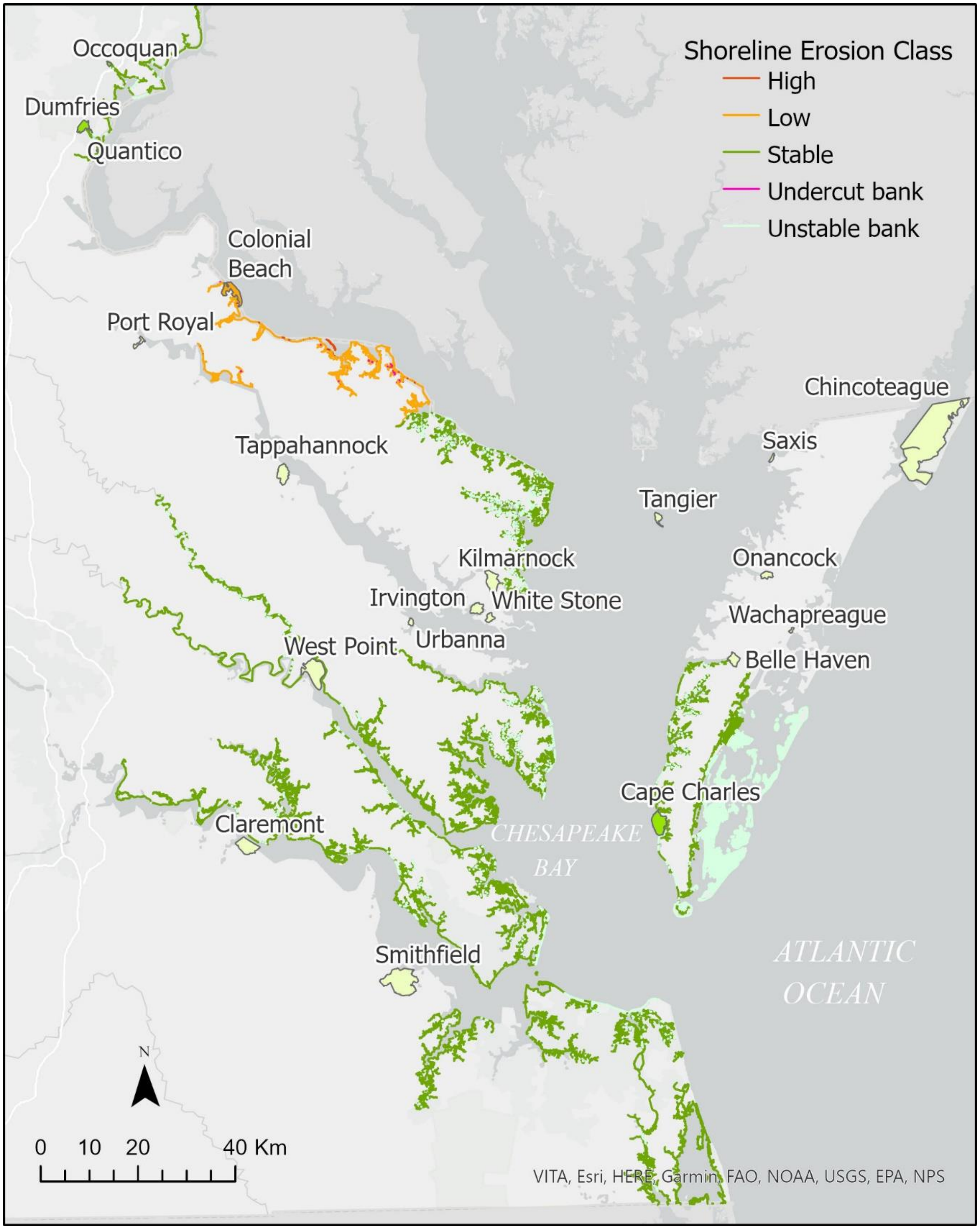

Figure 19 Map of estuarine erosion hotspots in coastal communities. The "hot" spots indicated in orange-red with less erosional areas in green. Small estuarine beachfront communities that are not structurally protected are relatively rare across the Bay but are also included. The map emphasizes the Northern Neck beaches that have experienced the most pronounced estuarine erosion, followed by riverine communities such as West Point, Claremont, and Smithfield where beaches typically adjoin bluffs that may be undercut and retreat.

5. References

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