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3. Abstract:

Coastal parks are at risk from climate change impacts of sea level rise and surge caused by large storms. The best estimates of how much sea level will rise, where inundation will be most severe, and the expected frequency and intensity of large storms are changing rapidly as climate scientists and coastal geomorphologists study the dynamics of coastal systems and refine their models. The goal of our project is to estimate risk at specific locations -- sentinel sites -- in northeastern coastal national parks. Sentinel sites will be identified by the parks and may be infrastructure such as roads and structures, or locations of special interest such as important cultural or natural resources. Our process requires establishing an accurate elevation measurement at sentinel sites and assessing the probability of inundation at these sites using the best available models. Elevations at sentinel sites will be obtained using RTK GPS to within 2-4 cm accuracy. In order to survey sentinel sites, a backbone of high-accuracy geodetic control must be established in each coastal park. The backbone control network is required to serve as base station locations when conducting RTK surveys of the sentinel sites. The first phase of this project is to review existing geodetic control from records maintained at the NOAA OPUS repository, NOAA National Geodetic Survey database, and the NPS Denver Service Center for their suitability as backbone or sentinel locations. When the review is complete we will know which monuments need to be visited in the field to verify their condition, assess their stability, and judge their suitability as backbone control sites. This assessment will be used to determine where new survey monumentation will have to be added to complete the high-accuracy geodetic backbone for each park. All suitable geodetic monuments that we identify will be entered into a GIS database for use in an NP Map application. This will be the initial version of a monumentation database that is planned to include all national parks. Once the backbone and sentinel sites are in place, we will use the high-accuracy elevation data at sentinel sites to assess risk from sea level rise and storm surge using the best available models for the coastal Northeastern United States. Sea level rise modeling is an extremely fertile area of research. New models, new climate data, and better projections are being developed at a rapid rate. However dynamic the predictions of sea level rise and storm surge might be, they will always require assessment against accurate elevations at locations of concern in coastal parks. Our system of backbone and sentinel sites will allow rapid and accurate assessment of inundation risk as newer models are developed for many decades into the future.

4. Introduction

a. Problem Statement:

Many areas of the coastal national parks of the northeastern United States are vulnerable to impacts from storm surge and sea level rise (Thieler and Hammer-Klose 1999). To assess which regions and resources within parks are most at risk, comparison can be made of the elevation of the resources and predicted elevation of sea level rise and storm surge under various modeling scenarios. At present, there are incomplete or inaccurate elevation data for critical park resources, therefore, it is impossible to measure risk from inundation to sea level rise and storm surge. We will resolve this problem by developing a network of critical resources called sentinel sites and accurately measure their elevations. These data can then be compared to inundation models to determine which sentinel sites are most at risk. In order to measure elevation at sentinel sites, and backbone of high accuracy geodetic control sites must be established within the parks we are studying. We will establish these geodetic backbone networks using existing geodetic control and new control monuments where none exists.

b. Background:

The Department of Interior is developing a strategy to evaluate habitats, infrastructure, and resources at risk from the effects of global climate change (DOI Task Force on Climate Change 2008). In coastal ecosystems, sea level rise (SLR) and an increase in storm frequency and intensity are two major impacts expected to result from climate change (Anthony et al. 2009, Zhang et al. 2004, McGranahan et al. 2007, Casenave and Nerem 2004). Earth scientists and coastal geologists are continually refining their predictions of sea level rise; the current range is on the order of 25 – 145 cm by the year 2100 for the northeastern United States (Table 1, reviewed in Vinhateiro 2008). Many climate change models predict an increase in the frequency of large storms such as hurricanes, monsoons and Nor'easters (Bender et al. 2010, Oouchi et al. 2007). Surge from large storms is exacerbated by sea level rise. Storm surge heights can be significant for intense events; for example, surge levels reached 9 m during Hurricane Katrina in the Gulf Coast in 2005 (Fritz et al. 2007). As evidenced most recently on the Louisiana and Mississippi coasts, large storms can have significant impacts to coastal infrastructure and ecosystems.

Table 1. *Projected 21st century sea level rise (modified from Vinhateiro, 2008) for southern New England based on eustatic sea level rise estimates and local isostatic sea level changes.*

Author	*Predicted Sea Level Rise for Southern New England (RI)*		*Notes*
	2050	*2100*	
Titus and Narayanan 1995	15 cm	34 cm	Most likely range
NOAA 2007	12.9 cm	25.7 cm	Extrapolating historic trend 50-100 years into the future (Newport RI)
IPCC 2007	18-32 cm	33-74 cm	Dependent upon emissions scenarios
UCS 2006	10-25 cm	25-99 cm	Dependent upon emissions scenarios
Rahmstorf 2007	20-45 cm	65-145 cm	Based on IPCC TAR warming scenarios
Overpeck et al. 2006, UCS 2006		Several meters	Dependent upon the stability of Greenland and continental ice sheet

Evaluating resources at risk in coastal National Parks typically involves creating detailed elevation maps of parks and determining what areas fall within elevations that would be inundated under various risk scenarios from sea level rise or storm surge. Unfortunately, the elevation data currently available for coastal parks are not always accurate enough to conduct these map-based assessments where critical elevations for inundation fall within the range of accuracy for the vertical dimension of the terrain model (reviewed in August et al. 2009). The USGS National Elevation Dataset currently available for the entire country is only accurate to ± 2.4 m (Gesch 2007). Mapping-grade GPS technology produces elevation measurements accurate to 10-30 m. Survey (geodetic)-grade GPS technology can accurately measure elevation to within centimeters, but the cost of the necessary equipment and time required to collect large numbers of highly accurate elevations is prohibitive. Many coastal parks have extensive LiDAR elevational data but these are typically accurate from 15 cm to 1 m (Gao 2007) which yield elevation models with vertical accuracy of 30 cm to 2 m (1 - 6 feet, National Standard for Spatial Data Accuracy). Thus, care must be taken to not over-extend the vertical accuracy of DEM's when creating terrain models and extrapolating inundation zones from them. The dilemma is clear, it is inappropriate to evaluate inundation risk in locations at the SLR or storm surge margins using coarse-scale elevation data that are many times less accurate than the magnitude of expected flooding.

The problem this project will address is to assess risk at high value locations in coastal parks using high-accuracy elevation data and best available sea level rise and storm surge models. The cm-accurate elevation data at sentinel sites will permit risk assessment over short time periods into the future or using models with narrow ranges of precision.

c. Specific Objectives to be Addressed:

We propose to use existing and enhanced geodetic control in the northeastern coastal parks to develop and implement a procedure for evaluating risk from sea level rise and storm surge. We will use locations for which cm-accurate elevation data exists as a baseline for our assessment. We will add to the existing control network "sentinel sites" at locations where Park managers determine there are critical infrastructure, habitats, cultural sites, and populations of species of concern. We will measure the location and elevation at sentinel sites to within 2-4 cm using survey (geodetic) grade GPS technology using one or more carrier phase survey measurement techniques (e.g., kinematic, real time kinematic, static, rapid static; USACE, 2003). We will make use of the National Geodetic Survey's (NGS) Online Positioning User Service (OPUS) and the Continuously Operating Reference Station (CORS) network for static and rapid static positioning solutions. Using best available sea level rise and storm surge models, we will estimate the probability of inundation at geodetic control locations and sentinel sites in the coastal regions of the parks. Furthermore, we will develop digital terrain models of susceptible areas in coastal parks using the best available LiDAR data. These terrain models will provide a general view of potential inundation zones from sea level rise and storm surge, but will not be as accurate as the geodetic control and sentinel sites.

d. Environmental Planning:

We will file appropriate permit applications for ground disturbance to establish new monumentation and relocate existing monumentation.

e. Principal Project Managers:

The URI Environmental Data Center has served as the National Park Service's northeast region Field Technical Support Center (FTSC) since 1996. The project personnel identified in this proposal have all worked on FTSC projects and are familiar with the northeastern coastal parks and park GIS managers. Furthermore, the EDC works closely with the Northeast and Coastal Barrier Network (NCBN) monitoring program and have ready access to data managed by that initiative. URI leads the North Atlantic Coast Cooperative Ecosystems Studies Unit (NAC CESU) which will serve as the cooperative basis for this project.

Peter August and Charles LaBash will administer this project. Both are experienced GIS analysts and have over a decade of experience working on National Park Service geospatial data projects. LaBash has conducted field research in the coastal parks listed here and is very experienced in GPS data acquisition. He is currently coordinating the Rhode Island segment of the USGS Northeastern US coastal LiDAR data collection mission. August and LaBash will assist in developing all protocols for the project, contribute to the design of the content management system, and coordinate sentinel site evaluation.

Michael Bradley will direct the field and database aspects of the project. He has extensive experience in using all levels of GPS technology and has many years of experience working with geodetic control in coastal parks. He will supervise field crews, assist in the development of project procedures, and help design the data system to store the information gathered here. He will also oversee development of the sentinel site assessment methodology.

Roland Duhaime oversees project development and implementation for the URI EDC National Park Service Field Technical Support Center. He has almost 14 years experience working in northeastern parks and interacts with the regional and national GIS leadership for the NPS. Duhaime will assist us by serving as a liaison between the EDC and Park personnel.

5. Study/Implementation Plan

a. Approach and Methods:

This project will occur in a number of phases.

Phase 1: Inventory and Verification. The coastal parks of the northeastern United States have rich networks of monumented geodetic control. By "monumented geodetic control" we refer to locations that are permanently marked with a brass disk, metal rod, cement or stone platform, or other permanent structure for which an accurate survey of location and elevation has been performed by a licensed professional surveyor. Much of the monumentation in the National

Parks has been established by NOAA's National Geodetic Survey (NGS). Additional monumented geodetic control has been added to the parks by surveys contracted by parks or researchers; many of these records are maintained by the NPS Denver Service Center (DSC).

Monumented geodetic control points represent a valuable information resource for evaluating inundation risk from sea level rise and storm surge in coastal parks. But, to be useful for such an analysis, a control point must possess the following: (1) accurate measurement and recording of horizontal and vertical position, (2) a monumented platform that is clearly indicated and undisturbed which unambiguously shows the precise location of the surveyed position, and (3) clear directions to locate the monumented site in the field. The initial phase of our project will be to inventory monumented geodetic control for coastal parks in the northeast region (CACO, ASIS, ACAD, FIIS, GATE, COLO, BOHA, GEWA, ELIS, STLI). We will focus on control in those areas that are identified as sensitive to centurial sea level rise inundation and storm surge. Locational data and descriptions of sites for many NGS monuments can be obtained online from the NOAA NGS, NOAA OPUS, the NPS DSC and online from state geospatial data clearinghouses.

Each relevant control point for which NGS, OPUS, NPS, or other data sheets describing the surveyed position have been obtained and are candidate for inclusion in the backbone database (i.e., inside park boundaries, not lost or destroyed) will be visited in the field. For each located control point we will photograph the site, ensure that the monument is intact and not damaged, and prepare both explicit descriptions of and instructions for navigating to the site. Any control point that cannot be found or which appears to have been damaged or disturbed will be so noted and indicated in the database. Damaged control monuments may be repaired and re-surveyed if they are in strategic locations and have adequate long-term stability. If we find there to be a prohibitively large number of potential control sites in some of the coastal parks, we will prioritize locations by initially targeting control points at elevations most likely to be impacted from sea level rise (<2 m elevation) or storm surge (< 10 m elevation).

<u>Phase 2: Compilation and Web Access.</u> All control points which have been field-verified – along with their associated data products (e.g., photographs, navigation directions to the site, data sheet notes, etc.) – will be consolidated in a web-accessible content management system. The master monument database will *initially* reside on a northeast region Field Technical Support Center (FTSC) server accessible via an application within the NPS NPMap website. *Ultimately*, the database will be migrated to and hosted by the NPS Lands Division. Directed by the NPS Resource Information Management Division, the NPMap framework housed at Colorado State University (CSU) provides an excellent foundation for data discovery and will allow users to search and view control points by park. Results will be overlain on the NPMap base imagery for visualization. Our database and web programmers will work closely with NPMap programmers at Colorado State University to provide them with an FGDC-documented spatial dataset and attributes that can be incorporated directly into a new NPMap application.

<u>Phase 3: Enhancement and Integration</u>. With guidance from professional surveyors, we will repair existing monuments that have been damaged or install permanent monuments for new backbone control sites in locations where the current network of suitable geodetic control is sparse. New or repaired monuments will meet NGS monumentation standards (Floyd 1978). We will do an initial measurement of location and elevation of newly monumented or repaired sites

using survey (geodetic) grade GPS technology and processed through the NGS OPUS system. This is the procedure being followed in other coastal parks to maximize the extent of control points for the lowest possible cost. NGS Blue-Book compliant surveying can be done at newly monumented or repaired sites at some future point when budgets allow.

While field-verifying geodetic control locations, we will also meet with park supervisors, resource managers, and NPS scientists to determine their priorities for locating sentinel sites within the park. This Park-driven assessment of critical sites will occur early in the project. Potential sentinel sites include areas with important infrastructure (e.g., interpretive centers, administrative facilities, road crossings, bridges, utilities, buildings, visitor facilities, waysides, parking lots), cultural resources (e.g., ASMIS sites and subsites database locations [point, line, and polygon]), and natural resources (e.g., critical habitats, important landscape features such as habitat corridors, rare and endangered species locations, threatened habitats). NPS will install monuments at sentinel sites and provide us locational information for each sites. This will be especially important for sites that have little visible reference on the ground, such as historical or archaeological resources. Measuring elevations for sentinel sites will be done by URI field scientists and Park Service personnel with expertise in using survey (geodetic) grade GPS equipment and carrier phase survey techniques. It is imperative that control locations at sentinel sites be fully documented and monumented so they can be revisited in the future. Depending on the sentinel site, nearby geodetic control might suffice for recording accurate XYZ measurements for the location. Where sites consist of hard infrastructure (buildings, roads) XYZ coordinates can be obtained from fixed features (building foundations, utility platforms). When sentinel sites do not have stable, permanent reference features to work from (e.g., shorebird nesting sites, salt marsh edges), the Parks will install stable monumentation that will allow revisiting the location in the future.

To summarize, we will have a variety of control sites to work from:

1) Existing NGS control
2) Existing NPS control
3) Newly monumented, repaired, or resurveyed control with at least 2-4 cm accuracy positions and elevations developed with carrier phase GPS survey techniques
4) Sentinel sites at critical park resources with 2-4 cm accuracy positions and elevations developed with carrier phase GPS survey techniques.

<u>Phase 4: Modeling and Inundation Risk Assessment</u>. We will work with Department of Interior climate change experts to identify appropriate scenarios for sea level rise and storm surge to evaluate inundation risk in coastal parks in the northeastern United States. Models will provide inundation threshold elevations (or range of elevations). From these models we will develop a process to determine which sentinel control sites are lower, which are approximately at the same elevation, and which are above the projected inundation levels. For example, a conservative range of sea level rise values from the models listed in Table 1 would be 25 cm to 1.45 m by 2100. Using the storm surge estimate of 9.0 m resulting from Hurricane Katrina as an upper limit to surge events, we would, therefore, evaluate inundation probability at sentinel sites from increases in sea level of 25 cm, 1.45 m, and 9 m. Sea level rise estimates for shorter time intervals (e.g., next 40-50 years) result in smaller ranges of sea level rise, usually less than

30-40 cm (Table 1). Evaluating inundation risk at these levels clearly illustrates the need to work from accurate elevation data such as that provided from the network of geodetic control.

We will develop a terrain model for the coastal sections of the Parks using best available LiDAR data which we will obtain from the Parks and the NPS Inventory and Monitoring program's Northeast Coastal and Barrier Network located at URI. The terrain model will permit us to make a first-cut assessment of inundation risk in the SLR and storm surge elevation ranges we are using. For mapping extreme SLR and surge scenarios (> 1-2 m), the LiDAR-based terrain model will provide a reasonable estimate of inundation zones. For assessment of SLR scenarios that are short-term or for areas with relatively low elevations (<25 cm) the LiDAR modeling may not be reliable and the use of geodetic control and sentinel sites will be most accurate. An added benefit of compiling the geodetic control data for the parks is these data can be used to independently assess the vertical accuracy of the LiDAR-based terrain models.

This process is complicated by tidal effects in coastal parks. Elevations are typically reported in the North American Vertical Datum of 1988 (NAVD88). However, NAVD88 does *not* represent the upper extent of high tide (Figure 2, from Thompson 2008). For example, on the Rhode Island shore (Newport), NAVD88 is 1.8 feet (0.54 m) below mean higher high water (the average extent of highest high tides). For inundation modeling, we are most interested in sea level (or storm surge) extents above the high water mark. Thus, an offset has to be applied to NAVD88 elevations to represent their position relative to mean higher high water (Kirshen et al. 2008). The amount of the offset is typically obtained from the NOAA network of tide gauges and is specific to each park. For example, the tidal range in Bar Harbor ME (ACAD) is 10.5 feet, whereas the average tidal range for Sandy Hook NJ (GATE) is 4.7 feet (NOAA Center for Oceanographic Products and Services; http://tidesandcurrents.noaa.gov). An important aspect of the procedures we develop will be to determine if there are adequate tidal data in coastal parks to effectively model increases in sea level rise. This will be especially acute in coastal lagoons with impeded tidal flow; the extent of tidal action will differ substantially from tide gauge data gathered from sites that do not have tidal restrictions. We will consult with surveyors and coastal geologists to determine if existing tide data are sufficient for more accurate sea level rise modeling in coastal parks.

Inundation risk is not uniform for all areas in coastal parks. Local variation in geomorphology, wave exposure, and susceptibility to shoreline change can combine to create different levels of vulnerability to sea-level rise over relatively short distances (Thieler and Hammar-Klose 1999, Pendleton et al. 2004). We will incorporate coastal vulnerability index (CVI) assessments into our analysis of inundation risk at sentinel sites.

Our method will also take into account factors such as the accuracy of the elevation at the sentinel site, the landscape setting of the site, distance from shore, and other site-specific factors. Landscape setting, for example, will have to be sensitive to large scale landscape morphology, such as the presence of high elevation features between the sentinel site and the shoreline (Opdam et al. 2009). An 0.5 m high location that is exposed to the shore has a high probability of flooding under many SLR scenarios, whereas an 0.5 m site that is behind a 10 m berm or dune may be sheltered and may or may not become inundated. This aspect of the project will require building a terrain model for coastal parks using best available LiDAR data to establish landscape setting parameters for sentinel sites that would then be used in the final assessment.

An important element of our assessment of inundation risk is the development of a simple web-based visualization system that makes it possible to determine sentinel sites at risk under various sea level rise or storm surge scenarios. The system will need to be sufficiently interactive to accommodate emerging scenarios resulting from future modeling activities and predictions of sea level rise extents. The system will also need to be transferrable to multiple parks and multiple regions.

We acknowledge that predicting sea level rise and inundation probabilities for time periods in the distant future are problematical. Sea-level rise modeling is an active area of research and better models will be developed in the future. Revised estimates of global sea level rise are published on a regular basis as new data are collected and models evaluated. For example, a recent reassessment of west Antarctic ice sheet melting rates has added "10's of centimeters" to year 2100 sea level rise estimates (Turner et al. 2009). Furthermore, shoreline change is a dynamic process that is routinely documented in short time scales. Future coastlines will be the result of current accretion and erosion processes. Superimposed on this are stochastic events, such as large storm events that can cause sudden and profound changes to shorelines, and human activities such as beach replenishment, dredging, and shoreline hardening (Ashton et al. 2007). Thus, our ability to predict shoreline condition far in the future is tenuous. This, however, reinforces the value of establishing a network of reliable, permanent geodetic control networks in coastal parks that can serve as reference locations to evaluate inundation risk as new models are developed and as coastlines change in response to the multitude of complex factors that influence them.

Phase 5: Institutionalizing the Process and Information

The results of this project will serve the resource management interests of the National Park Service long after our work is completed. The network of field-verified NGS and NPS control points and park sentinel sites will be an invaluable resource for future climate change studies as well as any project requiring ready-access to accurate horizontal and vertical geodetic control. We are committed to following existing and emerging NPS information systems, like NPMap, as vehicles for disseminating geodetic control and sentinel site data. Additionally, all of our GPS data will be collected to insure publication to the nation-wide OPUS website. We look forward to working with NPMap staff to develop a process to efficiently integrate our information into their architecture. It is premature, however, to predict how our data will interface with park-wide information systems 2-3 years from now. Geospatial mapping and database systems are a rapidly evolving technology and the NPMap of today will probably bear little resemblance to the same system years from now. Nevertheless, we are committed to ensuring that our geodetic control database and risk assessment research integrates into the larger NPS-wide information-serving architecture that serve a broad base of Park Service users.

We will work closely with the NPS Inventory and Monitoring (I&M) program and other NPS divisions to document our procedures so they may be replicated in other parks and in other regions of the country. Our methods to consolidate geodetic control for parks, disseminate control point locations via a web-based interactive mapping system (compliant with NPMap), establishing sentinel sites, and evaluating inundation risk from seal level rise and storm surge models will be clearly documented so these operating procedures are transferable to other coastal parks.

b. Tasks, Organization, and Schedule:

The task list below outlines the different stages of the project and the elements of work within each stage. Inasmuch as some of the mission-critical steps in the project require collaborative assistance by individual parks (establishing sentinel sites, permitting) our estimates of the time it will take to complete an activity are only approximate. Moreover, the time it will take to complete many of the tasks here can only be estimated at this early stage. Once we know the number and condition of potential control sites in coastal parks, and how many new monuments need to be installed, we can better estimate time to completion.

Activity	Description of Activities
A. ***Establish Backbone Network of Monuments***	1. Locate and consolidate records for NGS, NPS and state monuments for each park. 2. Establish minimum criteria for backbone sites. If control points have not been found or have been destroyed, are on private property, are of questionable long-term stability, or have difficult access (e.g., Church steeple, in a swamp) they are not viable candidates for use as backbone monuments. 3. Review existing monument records for candidacy as backbone sites. A simple database of sites reviewed and the reason for their exclusion or retention will be established. 4. Provide map and shapefile of candidate control sites to park, Nigel, Shaw and Tim Smith for their examination. Existing OPUS records will always be part of the backbone. Ask the park to identify regions of highest priority for backbone sites (based on sentinel sites and other project requirements) to focus field assessment of sites. Once the park priority regions are established, we can identify where the rest of the backbone control needs to be (at least one monument every 15 km) to provide park-wide coverage. 5. Field verify candidate control points. Stop search when a high quality monument is found in an area where we need a monument. If a monument cannot be found in a 30-45 minutes search by two people, deem it a non-candidate site. 6. Prepare a proposed network of backbone monuments that makes use of high quality, stable, accessible, and secure existing sites. Propose new monuments where required to provide backbone coverage. Send proposed backbone network to the park, Nigel Shaw, and Tim Smith for review. 7. Complete permitting for proposed new backbone monument sites as required. This will be done by Park personnel. 8. Once backbone sites have been identified, install new monuments where needed, survey all sites and enter into OPUS DB.

	9. Develop and enter supporting locational attribute documentation such as maps, photos, shapefiles, and descriptions to aid in relocating BB monuments. 10. Enter each backbone site into emerging/draft monuments database and deliver to the park (with maps, photos, etc.). Deliverables: Backbone monument network, monument database, establishment of criteria for using existing monuments as backbone sites, protocols for establishing new BB monuments (how to place marker, how to conduct survey).
B. ***Monument Database***	1. Create DRAFT monument database standard using OPUS and WASO Survey Monumentation data templates. The template will consist of a combination of the NPS core data standards, the obsolete DSC monument database, OPUS DB data fields, as appropriate, and attribute fields for field-finding aids such as maps, shapefiles, photos, descriptions, and notes. Will do this in MS Excel and convey to Tim Smith (cc: to Nigel Shaw) for review, approval, and adoption by NPS. We will strive to keep this as lean as possible recognizing that fields not relevant to us might have to be added as it moves through the review process. 2. URI Team will be available to answer questions on the draft DB if they come up. 3. Start entering records for existing and new monuments for the backbone network into this template with the understanding that we might need to backfill fields once a final standard has been approved by NPS. Include in this database existing monuments that have been found to be useful for future surveying efforts but are not part of the backbone network. 4. Add records for newly established sentinel sites. Deliverables: draft monument DB standard; enter backbone and sentinel site records into database.
C. ***Sentinel Sites***	1. Schedule meeting with Parks when we visit to search out candidate monuments for the backbone network. Invite the Superintendent, GIS staff, chief of facilities and resource management personnel. Brief them on the project and review process to establish sentinel sites. Develop a web site to inform the process. 2. URI will provide guidance on selecting sentinel sites and instructions on installing new sentinel site monuments. Parks will make final sentinel site selection and install monuments. 3. URI to survey sites when network of sentinel sites is established (includes both existing and new SS monuments). 4. URI will document sentinel sites and enter into monument DB, including supporting locational attribute documentation such as maps, photos, shapefiles, and descriptions to aid in relocating SS

	monuments. Deliverables: kick-off meeting with each park; guidance on selecting sentinel sites; instructions on installing sentinel site monuments; survey of sentinel sites and entry of these records into NPS monument DB.
D. Develop NP Map Application	1. In consultation with NPS programmers, assist in the development of a new NP Map application to display the monument database. Application will provide for display of monumentation data overlaid on NPS Bing imagery in NP Map, including accommodating attribute-heavy features. A simple application for display only – no editing or other functionality. Deliverables: NP Map application to display monument data.
E. *Sea Level Rise Modeling*	1. Recruit MS student to develop system to assess risk at sentinel sites from best available SLR and storm surge models. Seek Rob Thieler's guidance on this as much as his time and patience permit.
Sequence of Parks to Visit	CACO, ASIS, ACAD, FIIS, GATE, COLO, BOHA, GEWA, ELIS, STLI At minimum, we envision three visits to each park to accomplish: 1) BB search and survey (& SS kick-off meeting); 2) establish & survey new BB monuments; 3) survey SS monuments established by Park.

6. Deliverables and Other Reporting Requirements

This project will provide a number of information products that will allow the National Park Service to assess risk from sea level rise and storm surge resulting from global climate change. The primary reports and deliverable are:

a. Annual Accomplishment Report:

b. Final Accomplishment Report:

c. Final Completion Report:

d. Deliverables by Entities other than the Park:

- Develop backbone monument network
- Develop monument database
- Develop criteria for using existing monuments as backbone sites
- Formalize protocols for establishing new BB monuments (how to place marker, how to conduct survey)
- Develop monument DB standard

- Enter backbone and sentinel site records into database
- Organize kick-off meeting with each park
- Develop guidance on selecting sentinel sites
- Provide instructions on installing sentinel site monuments
- Survey of sentinel sites and enter these records into NPS monument DB
- Develop NP Map application to display monument data

7. Quality Assurance, Quality Control, and Data Quality Objectives:

Quality assurance of backbone monuments will be based on the NOAA OPUS solution report. Quality assurance of sentinel site elevations will be based upon the NOAA OPUS solution obtained when surveying the backbone position being used for the RTK base station location and the RMS error recorded during the RTK survey.

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