MODELING COASTAL SEA-LEVEL RISE IN DELAWARE

This is a research proposal designed to explore and focus on using ArcGIS to model the management of a natural resource and understand an increasing problem. The grant I would want to receive is the “Evian Foundation Grant” with a budget of up to $700,000 for the “Delaware Land and Sea Project”.

*NOTE: grant name, budget, timeframe were all mock developed for the project.

Background:

There is new and stronger scientific evidence that climate change and its potential influence have become a serious problem. Earth’s climate is becoming warmer because of an increase in “greenhouse gases (GHG’s),” especially carbon dioxide (CO2). This warming is resulting in a melting of ice masses, such as glaciers, sea ice, and polar ice caps. Due to global warming, the sea level rises will keep increasing over the coming century and there will be a boost in storm severity. According to research done by Weifeng Mao at the University of Delaware, in the state sea level has risen about 13 inches in the last 100 years based on tide gauge data, and is estimated to continue to rise about 3mm per year (Mao, p.4). Delaware is a coastal state; its economy and quality of life have historically been linked to its shoreline, vast expanses of tidal wetlands and its fertile farm fields. Due to its location and link to the coast it is particular vulnerable to SLR, and Geographic Information Systems software may help understand as well as predict the past, present, and future.

Delaware’s biggest problems with sea level rise are management, regulation, and outreach. It’s public policy contexts fall within the local and state legislator, programs, and committees who are trying to find varying solutions to the problem. But policy in the state does lack community involvement and policy maker understanding because some do not easily see the
consequences. Because the state has such a dynamic ecosystem, in particular the coastal zones and wetlands, it is a critical player in providing habitats, recreational areas, port access and tourism, and water resources. It’s vast amount of natural resources and ability to provide for a number of ecosystems in relation to the population’s distance from the sea make water level rise an extremely significant topic to research using GIS. With a width of about 35 miles, a general coastline of 28 miles, and a tidal shoreline of 381 miles, large portions of the state are threatened by rise and the implications that come with it, making its spatial context extremely suitable for analysis.

As of now, the status of the issue is increasing in importance and currently effecting a large number of population, as well as vast areas of land, and may affect human lifestyles. The agricultural and poultry industry and industrial sector land use combined with the southern part of the state’s beach tourism create a unique spatial context that effects livelihoods, ability to adapt, and natural resource exposure to threats. The current situation is mainly focusing on the southern portions of the state, with considerations to low lying water areas and ports in the northern reaches. In addition to its size, areas affected by the issue at hand involve: beaches, wetlands, low-lying lands, coastal flat plains, estuaries, and aquifers. What GIS can do is paint a much better picture of where the problems lie, who will be affected, and what must be evaluated before regulations are put in place. Not only is sea-level rise a growing problem, but also land area shrinkage has progressively increased with rising levels. What the state is currently facing as a whole are these two major environmental-water related issues, as well as the array of geographical obstacles.

**Literature Review:**

GIS has been used all over the world for many different reasons, but even though Delaware is the oldest state, its precautions and previous research on sea level rise are fairly new.
In C.H.J Hull and James Titus’ book, *Greenhouse Effect, Sea Level Rise, and Salinity in the Delaware Estuary*, research done in 1986, along the Sussex to Kent county Delaware coast, found that, “a sea level rise of even thirty centimeters (one foot) would have major impacts on coastal erosion, flooding, and saltwater intrusion” (p.15, Hull). Evidence discussed in these findings provides support and acts as strength for the basis of understanding consequences of SLR. And since the sea level in Delaware has already risen by a foot, using previous data incorporated with GIS can aid in understanding how certain natural resources, like birding habitats or wetland sanctuaries, have already been affected. Another investigation called the, “Summary of Coastal Program Initiatives that address Sea Level Rise as a result of Global Climate Change”, by Rubinoff, Vinhatero, and Piecuch, goes into detail about the five major climate change initiatives done in the past on SLR in the state. What is unique about two of the programs, Delaware Coastal Program and the Delaware Sea Grant Marine Advisory Service, is that they consist of advisory boards that investigate the potential future environmental stress from erosion of the ocean shoreline, which is a key economic resource. The other three are strictly associated with Delaware’s Department of Natural Resources and Environmental Control (DNREC) on mitigation plans, outreach methods, and coastal resilience.

In addition to those studies, Figure 2, in the appendix, was featured in DNREC’s Federal Coastal Zone Management Act, in which they worked with National Oceanic and Atmospheric Administration to create enhancement assessment and strategies. What this table summarizes are the key hazards and areas affected by sea-level rise and land shrinkage, showing the problems and opportunities that exist when trying to solve the problem. Not only does this information express the impact on coastal regions, but also indicates where important management is needed. Even though these ideas are intricate and comprehensive, the overall management and policy on SLR in Delaware is weak in using spatial representation and analysis capabilities of GIS. Main
applications of GIS in the state fall more along the lines of railroad or I-95 management, such as research done in Chance Malkin’s potential impact on railroad corridors in New Castle county, rather than natural resource control. The advance climatic problems along the coasts combined with the impending threats of technology and human impact have resulted in forcing policy makers, scientists, and communities to prepare for a whole new set of environmental effects. What previous research has shown is that before preparations can be executed, these potential impacts must first be understood.

**Hypotheses:**

The first area of questions stems from a more scientific field of strategy and understanding, and may result in specific answers after GIS analysis. After defining the study area, which is the entire state, the grant wants to identify infrastructure affect by the sea level rise at different areas within each state. To answer this question this grant would require at least 5 monitoring stations at a variety of infrastructure elements with different threat levels within each of the three counties. Because so much of the state is near, at, or below sea level knowing which technologies or man-made structures will be affected is crucial in their design implementation for the future. Next the grant hopes to uncover the extent of incursion of sea level rise and storm surge on land, knowing how much saltwater intrusion is occurring and where can benefit the management of aquifers, water quality, and wells. This hypothesis will require several types of data in order to get a comprehensive scope of the extent, as well as comprehensive hydrology and geomorphology information monitors and data collectors, especially in low-lying areas of Sussex County. A third question to be answered is what types of land cover are in the state, which could indicate the land-use, including how much of each type. Furthering the indications of what specific natural resources are in what particular areas across the state. Once this knowledge is known than one could possibly know the potentially inundated or degraded land.
After determining the more technical questions, this grant will take a social and economical approach.

According to the book, *Impact of Sea Level Rise on Society*, by H.G. Wind, increasing water levels, “affect society through economic or political conditions, social circumstances, and management” (p.7, Wind). From an economic standpoint, data will hopefully expose evidence to support this grant’s simple estimate that the risk of sea-level rise, in terms of monetary damage, is extremely important. But what Wind points out is that most coastal states cannot support or entirely cover the amount of money estimated or needed (p.8, Wind). Posing the political question of who is in charge of paying, and where will that money come from. This furthers the issue of politics by putting stress on society, making it difficult to distinguish who or what within the area are in charge (p. 184, Wind). In such a small state as Delaware, is it the local governments job to address issues, or a politician who has ties with DNREC? Strenuous questions such as that are what Delaware faces when it comes to SLR, and GIS can help in guiding policy makers and governments in the right regulatory or monetary direction.

In regards to social conditions, problems affecting the region have to do with migration of population, or in extreme cases abandonment of coastal homes. The way a society reacts to rising sea level depends on social structure, so the issue that needs to be addressed is how Delawareans respond to threats. This grant proposal hypothesizes that social conditions stem from a society’s knowledge about problems they’re facing, and that’s what needs to be solved. Another batch of questions to be answered are in regards to management, in particular water organization and coastal defense. H.G. Wind describes it as a “matter of policy to decide whether to defer action, set up retreat, or strengthen coastal defense systems” (p.9, Wind). Proper management is needed in low-lying shore regions of Delaware, as well as areas further from water, like the city of Middletown, to aid in the fight against sea level rise now and in the future.
What GIS data and spatial analysis can do is distinctively point out what resources are important and vulnerable, as well as how government and communities can work together in understanding results of data.

Data:

Due to its small size, the region this grant is proposing to do work in is within the whole state, with special attention to the coastal areas, shorelines, and places within a certain distance of the ocean. In order to better understand the layout of where the projects, planning, solutions etc. will take place, a general overview of Delaware is needed. Figure 1, in the appendix, shows a map of Delaware’s lakes, rivers, and water resources and identifies the widest East-West extension of about 35miles wide. This project requires information on a diverse collection of materials and samplings, ranging from environmental habitats to economic monetary matters. The first data luckily in digital form needed is the base map from the United States Geographical Survey Delaware Data website or World Bank Data, using possibly the most recent year. From a variety of websites I would be able to gather data that includes ocean depths, tidal heights, or typographical changes in the land. Then even be able to collect information on different income levels based on location and number of coastal homes within a certain distance to the shore. An example of extremely specific information that would be gathered would be to look at tax assessments of landowners and then compare them to the assessments of landowners who agree to preserve or protect their property from SLR. These are materials published by a number of local, state, and federal government agencies or commercial businesses, and are used quite widely.

This grant requires access to databases like FedWorld, Bureau of the Census, and GeoData.gov. Some of the most essential data needed would show the possible picture of who and what would be affected by the change in sea level. There are some basic types of geospatial
data to be used in this research including base surface elevation, water surface elevation, and shoreline data. In addition to the primary, NOAA’s research conducted in the, “Technical Considerations for Use of Geospatial Data in Sea Level Change Mapping and Assessment”, they lay out a more specific parameter of information that are required in our grant proposal:

- Water level data and datum elevations, water level extremes, and derived sea level trends
- Geodetic data, geoid, topography
- Vertical land motion, subsidence, uplift
- Geophysical data- hydrology and river flow/stage
- Coastal water temperature and density
- Coastal meteorological data Bathymetry

Now comes the more difficult question: where to find and incorporate data that isn’t in digital form. So what this grant plans to do if any data isn’t available in that form, for information from local business, go door-to-door asking about taxes, conservation easements, and preparedness. With monitoring programs any data that is collect in non-digital form can be put into an excel spreadsheet and then transferred into digital form, such as water level in canals around the area. In addition to that, any image or audio recordings can be used for analysis and then turned into digital formats through transcription. Particularly for ocean data, non-digital methods such as Microfilms could be used for tides or marine geophysics, but still can be used and transferred with proper understanding of microfiches on smooth sheets and withdrawn charts. In this day and age, information of the smallest state can be in the biggest forms, in order to accurately map out data required for this grant, information in digital form may be easier to bypass any difficulties. The final aspect of data use is how it will be structured- vector versus raster. Because raster images generally are used to store image information, such as scanned paper maps or aerial photographs, they can be used for data captured by satellite and other
airborne imaging systems. This GIS application will be based on raster technology, where each cell contains a value representing information, such as temperature. With raster files data formats can come in many means, such as thematic data, which can represent land use or soils data needed for the project, or continuous data, like temperature. In order to conduct a critique on Delaware’s sea level rise issues, raster structure is more suited for intricate spatial analysis.

Methods:

The main methodology used in this research uses the spatial representation and analysis capabilities of the computer based geographical information system. The base map will be from the United States Geographical Survey Delaware Data website, and will include the most recent year of data. Then using the Delaware dataMIL Website, the map requires some key pieces to confirm modeling predictions including: state and county outlines, current typography and sea level information. Once this data is gathered, the shapefiles are imported into GIS to develop a general map of the state in which current conditions are shown. This will be strength for the entire project because the USGS develops specific data to create an exact and informative image of Delaware. The next step is to add and import different layers of data onto the already created map, also in digital form, such as streams, tidal gauge data, and any of the geospatial information. Using the information suggested in NOAA’s research in 2010, additional significant layers and rasters will then be displayed and calculated for spatial analysis.

In order to show exactly how sea level rise will effect the state initially, following the input of all the essential geospatial layers, series of maps starting with a 0.5 meter increase moving to a 1 meter, 1.5 meter, 2 meter, and 5 meter one will be displayed. By doing this procedure, government agencies, policy makers, and citizens can see the average increase over the next century, to the worst case scenario in the years after. At each level, inundation on census tract, land use, infrastructure, beach erosion, salt-water intrusion etc. maps will be
created. Permanent inundation means that SLR caused by thermal expansion of the ocean’s waters, the melting of glaciers and ice caps, melting of northern Ice Sheet, and subsidence. A storm surge is an offshore rise of water associated with a low-pressure weather system, typically tropical cyclones and strong extra tropical cyclone. These scenarios displayed by the images on GIS will take into account both inundation and flooding caused by extreme weather like storm surges. By this finding, people could know which areas and natural resources may be impacted the most, as well as develop alternative methods of policy implementation. Another strength of this type of methodology is that all of the data is concrete and some even scientific backed by governments, agencies, and societies. This will work as an advantage on the public and policy front because people are simply more likely to believe.

Even though these methods are generally successful, there are some challenges and weaknesses on the local level analyses. The utility and accuracy of a sea-level rise assessment depends on the resolution of the underlying elevation data. Different sources of available supply varieties of standards, which may be thought of as coarse where coastlines are highly developed or not substantial at all. So one problem with local assessment is that some maps, such as ones generated from USGS National Elevation Dataset, may not provide accurate predictions of exposure of specific assets. Another area that has some weaknesses is when it comes to inundation mapping that can be misleading because of elevation is not the only determinant of coastal vulnerability. A way this grant is hoping to deter from that flaw is by mapping uplift and subsidence of the land surface. The strengths as well as the weaknesses of the proposed data needed ultimately make the projects spatial analysis an intricate discovery.

**Anticipated results:**

An initial key result I expect to find is that some areas of the state that are particularly low-lying have highly erosive beaches, or if they are ports are in high threat zones of sea level
rise. This is a major issue within Delaware’s water problem because of their tourism industry and large company manufacturing and shipping, especially in the north. Due to the vulnerability of the state, more extensive methods through the grant program will be put into place when facing flooding, erosion, land loss, construction or infrastructure implementation, and salt intrusion. Results from the GIS data should demonstrate variability in land cover, and even lead investigations on what type of agriculture is beneficial where and what water being used is being infiltrated by salt. From monitoring the various infrastructures in all three of the counties, based on the spatial review of the locations, I expect to find that monetary will occur when it comes to placing or altering those elements for SLR. Because of those factors this grant proposes that coastal areas receive access to loans, taking the important measure of increasing the loan fund for Port of Wilmington (a large money maker for the state). Then establish access to an “Adaption Loan Fund” where citizens can acquire loans from local banks for adapting their homes land to the results of sea-level rise. Finding what types of energies work the best and where will give Delawareans access to energies that can facilitate management of the states diverse environments.

Based on the GIS and integrated analytic results, this grant suggests a 3-step approach to SLR in: production services, natural resource components, and man-created facilities or institutions. In regards to the first step, it will confront problems facing agriculture, fisheries, industry and tourism within the state of Delaware, ranging from overuse or pollution of beaches to subsidies of agricultural land because of area decreases. Our second measure will manage natural resource components, such as groundwater, soils, pollution, or flooding, then enact polices configured with local governments that help in prevention and aid. The last aspect of management we will cover relates to man-created facilities and institutions, like energy use, infrastructure/zoning ordinances, and coastal protection. Here is where DNREC, the DGS, and
the DCP will enforce zoning regulations, specific coastal permits, and implement creative money programs (tax incentives, easements, etc.). Through a comprehensive visual illustration of the impact areas in which areas in Delaware are in danger of being either affected by sea level rise, flooding, or perhaps even destroyed, the state can prepare for the future.

**Policy Applications:**

This research could potentially improve public policy by first taking a more qualitative approach to investigating which policies work the best. Referring back to the work done in H.G. Wind’s piece, in an interview with 350 people living in the low-lying coastal region of Bangladesh, 279 of them confirmed that if they had information available to them about sea level rising, they as a community could take further action in precautionary measures (p.139, Wind). This research provides an accurate view of how this grant would approach Delawareans on the problems they face: more information available supplies protection, prevention, and conservation. The basis for solutions in public policy begins with comprehensive planning, where the provision of long-range design is used to guide future development in a community or shoreline area. This includes local governments, organizations, and societies in deciding on land use, conservation efforts, emergency plans etc. that can be used currently in the future. Another way result could better policy involves regulatory tools, which include: zoning rules, building regulations, environmental restrictions, and permit orders. These types of solutions will specifically aid in combating human influence and increase citizen awareness about the water issues.

A third solution to the problems approaches the economic or political conditions, also addressed in the hypotheses. What this grant research could do is promote spending programs and money management tools essential in sustaining improvements in preparation for rising sea level and changes in land immensity. Hull’s research also supports this idea by providing
example framework and growth structure involving conservation easements, tax incentives, and buyout programs. These types of implementations allow for conservation of vulnerable property while allowing for the government and other organizations invest in sustainable development patterns, particularly on the coast. Policy is developed and derived from how the status and reaction to sea level rise directly correlates to the shape of government. Local governments, who bear the largest responsibility for coastal planning, long have struggled with balancing strong demand for increasing development with protection of fragile environmental and cultural resources. This type of research, especially in Delaware’s vast coastline, could identify where the money could be spent and possible relieve the government of stress.

A final aspect of public policy involves making sea level rise and land area shrinkage a citizen involved issue, where this grant can work with the community on sustainable development or water management skills. This area focuses on education and outreach about Delaware’s diverse resources and components, a variety of educational programs with a goal of enhancing public awareness, understanding, and wise use of estuarine resources in the region will encourage environmental ethics among users. This grant will require K-12 schools within the state to have an education program where kids have at least 2 classes on coastal zone importance and resources (to be implemented in the next 5 years). Then start a “Community Workshop” with $20,000 of the grant money to broaden the understanding of preservation, preparedness, and reduction (see Budget for details). This sector of public policy could perhaps better the public understanding of policy maker’s decisions, as well as gain support for their decisions.

**Budgets:**

The final aspect of the DSLP is the budget, or anticipated costs, of what the grant plans to use the grant money for. Figure 3 in the appendix is the detailed budget/plan of where the
$700,000 will go from the Evian Foundation. This budget includes what each of these items is, and more importantly, why they are necessary. Justifications for these needs are based upon current issues the state has and ones they will be facing as sea level rises and land area decreases. Developing a clear comprehensive plan is necessary to ensure the states safety and understanding of the issues, thus the purpose of the grant money. The “Delaware Land and Sea Project” will provide the guidance and tools to make well-informed and consistent decisions regarding sea level rise and land area shrinkage. (SRL/LS=sea level rise/land shrinkage)

<table>
<thead>
<tr>
<th>Program within Project</th>
<th>Cost ($)</th>
<th>What It Does</th>
<th>Why It’s Necessary</th>
</tr>
</thead>
<tbody>
<tr>
<td>GIS Software</td>
<td>$15,000</td>
<td>Data Analysis Program</td>
<td>To conduct research based on information from the field and databases</td>
</tr>
<tr>
<td>GIS Analyst</td>
<td>$23 per hour full time every 3 months for 1 year= $24,000</td>
<td>Input, investigate, conduct, and collect data into GIS Program</td>
<td>Essential skill that is required for grant/certain skills required</td>
</tr>
<tr>
<td>Community Workshop</td>
<td>$20,000</td>
<td>Heightens public awareness</td>
<td>Families, communities, and society value their relationship to water. Understand the importance of conservation, usage, and future consequences.</td>
</tr>
<tr>
<td>Monitoring Program and salaries</td>
<td>$100,000</td>
<td>Examines climatic parameters, hydrology, geomorphology, ecology of species/ecosystems, social perception and economic change</td>
<td>Allows for the public to interact with local governments and organizations on what is going on within there ecosystems. Also allows for understanding of SLR/LS.</td>
</tr>
<tr>
<td>Port of Wilmington Loan</td>
<td>$20,000</td>
<td>Port for goods, services, and area for sustainable sea infrastructure.</td>
<td>Better infrastructure in the future to aid against SLR. Allows decrease in depletion of LS.</td>
</tr>
<tr>
<td>Activity</td>
<td>Timeframe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>--------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitoring- Measurement Data- 2 personnel</td>
<td>Summer to Summer~ 10-12 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GIS work, creation of maps- 1 person</td>
<td>Fall to Spring~ 4-6 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analyst work- 1 person</td>
<td>Summer to Winter~ 4-6 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy Implementation and Regulation Work</td>
<td>Winter to Winter~ 10-12 months</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 1.

Map of Delaware’s rivers, lakes, and water resources.

(http://geology.com/lakes-rivers-water/15delaware.shtml)
FIGURE 2. Table identifying risk levels and geographic scope of impact for coastal regions.

(Federal Coastal Zone Management Act, DCP, DNREC)

<table>
<thead>
<tr>
<th>Type of Hazard</th>
<th>General Level of Risk (H,M,L)</th>
<th>Geographic Scope of Risk (Coast-wide, etc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding</td>
<td>High</td>
<td>Coast-wide</td>
</tr>
<tr>
<td>Coastal storms, including associated storm surge</td>
<td>High</td>
<td>Coast-wide</td>
</tr>
<tr>
<td>Geological Hazards (e.g., tsunamis, earthquakes, etc.)</td>
<td>Low</td>
<td>Coast-wide</td>
</tr>
<tr>
<td>Shoreline erosion (including bluff and dune erosion)</td>
<td>High</td>
<td>Coast-wide</td>
</tr>
<tr>
<td>Sea level rise and other climate change impacts</td>
<td>High</td>
<td>Coast-wide</td>
</tr>
<tr>
<td>Land subsidence</td>
<td>Medium (when coupled with SLR and coastal storms/flooding)</td>
<td>Coast-wide</td>
</tr>
</tbody>
</table>
CITATIONS


