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Humboldt Bay Region Sea Level Rise Data Synthesis: Executive Summary

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Sea Level Rise Data Synthesis
Humboldt County, California:
Executive Summary

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1 OVERVIEW

In May 2011, The Humboldt Bay Initiative (HBI) contracted Pacific Watershed Associates (PWA) to conduct a data synthesis project with the goal of identifying and characterizing existing geospatial information and modeling tools relevant to sea level rise planning and adaptation for the Humboldt Bay region. This project was coordinated by University of California Sea Grant Extension Program and funded through U.S. Fish and Wildlife Service's (USFWS) Coastal Program. The Coastal Program is a voluntary cooperative conservation program within the USFWS with a mission to protect and conserve Federal Trust Species and coastal resources by supporting restoration and enhancement of priority coastal habitats.

The HBI, an ecosystem-based management program, is an inclusive and broad effort with over 30 participating organizations (http://ca-sgep.ucsd.edu/focus-areas/healthy-coastal-marine-ecosystems/humboldt-bay-ebm). The HBI promotes coordination, communication and collaboration among diverse local and regional partners through public meetings, workshops, training, and field tours. Recently, HBI completed a formal strategic planning process which identified a number of strategies needed to address critical threats to the Humboldt Bay ecosystem (Schlosser et al. 2009). This data synthesis project represents an important preliminary step towards addressing Strategy B: Coordinate Response to Coastal and Climate Change by identifying and describing existing data sets that can be integrated with geospatial decision support tools to plan for sea level rise in the Humboldt Bay region.

HBI conducted a series of public outreach meetings during Spring 2011 to identify potential sources of geographically relevant social, cultural, economic, infrastructure, coastal-dependent industrial/commercial, recreational, geophysical, biological, and weather related data or information that could support efforts to plan for the effects of sea level rise in the Humboldt Bay area. Pacific Watershed Associates evaluated and characterized the data identified during these meetings as well as available geospatial modeling tools that could be useful for sea level rise planning. The following summary describes the results of this synthesis project.

2 DATA CHARACTERIZATION

A total of 294 individual sources of geospatial information were identified and evaluated. GIS shapefiles, raster datasets, reports with tabular data, spreadsheets, and published maps were identified, organized by theme, and described. Table 1 illustrates the number of data sources that were included in the synthesis project, organized by category. Data were ranked on a scale of 1 to 3 as a way of describing data quality with respect to integration into a GIS analytical software environment. Table 2 describes the criteria used to characterize data quality. An excel spreadsheet characterizing these data sources as well as other online resources relevant to sea level rise planning and adaptation are included in the appendix. The appendix represents the bulk of the effort involved in this synthesis project.

Table 1. Number of data sources by category included in the data synthesis.

Data Category	Number of data sources
Cultural-social-economic	32
Infrastructure	36
Administrative boundaries	15
Coastal dependent	5
Recreation	7
Geophysical	121
Biological-ecological	76
Weather-climate	2
Total	**294**

Table 2. Criteria used to characterize data quality with respect to geospatial analysis.

Data Quality Level	Description
1	Published GIS data, publicly available, archived, and containing descriptive metadata
2	Published reports with detailed methods and geographically relevant information requiring some level of processing prior to use with GIS
3	Un-published reports and/or data with a geographic component requiring some level of processing and/or interpretation prior to use with GIS

3 DATA GAPS

Active hazard sites, underground storage tanks, and Brownfield sites

Active hazard sites and underground storage tank locations are not currently available in a digital format for Humboldt County; however, the data will be entered into a statewide database called the California Electronic Reporting System (CERS) by January 1, 2013. The data will include the location and number of underground storage tanks and will be geo-referenced by address/and or geographic coordinates. Currently, Humboldt County lacks a comprehensive inventory of Brownfield sites. Andrew Whitney, a recent graduate of Humboldt State University, developed a GIS-based inventory of Brownfield sites by compiling information from local, state, and federal sources, conducting site visits, and conducting interviews with key informants. The methodology described in Andrew's thesis could be expanded to provide a more comprehensive inventory for Humboldt County (Andrew Whitney, personal communication, August 15, 2011).

Tribal cultural resources- (data gap/modeling challenge)

The following is a response from Janet Eidsness, THPO for the Blue Lake Rancheria.

"-*The Blue Lake Rancheria Tribal Historic Preservation Officer (THPO) maintains* *confidential records of recorded Wiyot cultural resources as part of its THPO Agreement with the National Park Service. Site locations are confidential and exempted from FOIA disclosure under various State & Federal laws. We maintain the records and mapped locations in a digitized database that we will be converting to another GIS system in coordination with the Tribe's Environmental Dept. database. The Tribe's geographical area of concern for cultural resources is depicted on the attached map.*

Blue Lake's area of concern overlaps in some places with the areas of concern identified by the Wiyot Tribe and the Bear River Band of the Rohnerville Rancheria. All three Tribes are independent, sovereign, federally recognized nations, and the THPOs for each tribe frequently coordinate on protection of cultural resources of mutual concern to the tribes. Each of these three tribes has citizens of Wiyot ancestry.

For your information, the State of CA Office of Historic Preservation (OHP) maintains the statewide record of cultural resources records and reports through its CHRIS system (California Historical Resources Information system), which you may learn about by going to www.ohp.ca.parks.gov – CHRIS. The North Coastal Info Center (NCIC) operated by the Yurok Tribe under an Agreement with the OHP, holds most of the records for Humboldt and Del Norte counties.

Please keep me informed about your progress and upcoming meetings. The locations of known Wiyot cultural resources cannot be disclosed or shared in any manner that would not protect their confidentiality. Modeling of low elevation coastal site locations may be a solution; a grad student at HSU recently worked on such a project in collaboration with the Wiyot Tribe (Dmitra Jarvis-Chase)."

Levees and dikes – Shoreline conditions around Humboldt Bay

Currently, there is a lack of information regarding the condition of artificial structures such as dikes and levees which constitute over 90% of the shoreline of Humboldt Bay (Hoover, 2011). Management of these structures in a comprehensive way is complicated by fragmented ownership and jurisdictional authority (Walters, 2011).

The following is an excerpt from the U.S. Army Corp of Engineers National Levee Database web page:

"The National Levee Database currently includes only levee systems in the USACE Levee Safety Program, approximately 14,000 miles of the estimated 100,000 total miles or more of levees in the United States. Data in the NLD has been populated through a detailed inventory and the inspection of all the levees in the USACE Levee Safety Program. The integration of levee data collected by FEMA's National Flood Insurance Program (NFIP) into the NLD, currently underway, will increase the total number of miles of levee systems in the NLD and add important data points about those levees. In addition, USACE is developing guidance and providing assistance to states to better enable submission of voluntary information in support of USACE's efforts to inventory non-federal levees."

The National Levee database initiated in 2006, will provide a framework for incorporating non-federally regulated levee information in the future. The National Levee Database is currently under construction.

Rare/sensitive species habitats-

Resolution of data describing distributions of individual species and alliances associated with rare coastal plant communities is lacking. More detailed geospatial information is needed to support management of rare plant and animal species potentially at risk from rising sea level (Andrea Pickart, personal communication, August 10, 2011.)

Vertical land movement-

Interseismic tectonic strain accumulation leads to ongoing vertical land-level changes in the Humboldt Bay area which is located near the southern end of the Cascadia Subduction Zone. Vertical land level changes in conjunction with eustatic sea level rise (ESLR) influence the rate of relative or local sea level rise. Currently little is known about how the rate of uplift or subsidence varies with respect to location around Humboldt Bay. Information from the NOAA tide gage located on the North Spit suggests that current relative sea level rise is occurring at a rate of approximately 4.7 mm/yr. Recent estimates suggest that the regional ESLR is approximately 2.3 mm/yr (Burgette and Weldon, 2009), therefore; the North Spit in the vicinity of the tide gage appears to be subsiding at a rate of approximately 2.4 mm/yr. In contrast, relative sea level is falling in Crescent City at a rate of approximately 0.65 mm/yr which suggests an uplift rate of approximately 3mm/yr. Conducting leveling surveys in conjunction with strategic deployment of additional tide gages around Humboldt Bay would help fill an important knowledge gap regarding the variation and gradient in ongoing interseismic vertical land level changes in the region. This in turn would provide important information about how the rate of sea level rise varies with respect to location around Humboldt Bay.

Elevation/bathymetry-

Recently published LiDAR-derived topographic data provided by the California Coastal Conservancy's Coastal LiDAR Project provides the Humboldt Bay region with high-resolution topographic data spanning the mid-intertidal zone up to and in some cases, beyond the 10 m elevation contour. This dataset appears to be of a sufficient resolution and accuracy to support detailed analyses of land level, vulnerability to inundation from rising sea level, and shoreline elevation. Development of this dataset helps to address what has been a significant data gap in terms of providing seamless, high-resolution topographic data for coastal areas of Humboldt County. The only remaining significant data gap with respect to terrain information is modern bathymetry for low-intertidal and shallow subtidal areas within estuarine and nearshore areas of Humboldt Bay and the outer coast. Acquisition of shallow water bathymetry data for coastal California is planned to occur within the next two years, which will hopefully address this remaining topographic/bathymetric data gap for Humboldt Bay and the outer coast.

Sediment accretion-

Little is known about sediment accretion rates in Humboldt Bay. Accretion, tectonic land level changes, and eustatic sea level rise together are the principal factors that determine the rate of relative sea level change. Sediment accretion is influenced by a multitude of factors including sediment quantity and quality relating to organic and mineral composition, tidal elevation, tidal asymmetry, shallow subsidence and presence or absence and type of estuarine vegetation (Thom, 1992; Callaway et al., 1996; Cahoon, 1997; Peralta et al., 2008; Moore et al., 2009; Kairis and Rybczyk, 2009). Understanding how sediment accretion rates vary both spatially and temporally in Humboldt Bay is required to forecast the response of saltmarsh and existing/potential eelgrass habitat to relative sea level change, as well as to forecast erosion and deposition rates around Humboldt Bay.

4 MODELING TOOLS

The following modeling and decision support tools were evaluated and determined to be of potential interest/utility in regards to future planning and modeling efforts dealing with issues associated with sea level rise. Italicized descriptive text is excerpted from the sources that offer the tools and the associated web links are presented.

BathyFusion Toolbox

Online source: http://ebmtoolsdatabase.org/tool/bathyfusion-toolbox.

Description:

> *The BathyFusion Toolbox is a modeling tool as well as a commercially available ArcGIS extension that enables fusion of disparate topographic or bathymetric data sources into a unified high resolution data set. The BathyFusion Toolbox can merge disparate bathymetry data sets to produce a single bathymetry surface in a given area. It is also able to remove bias from input datasets during the merge process, track metadata of input datasets and provide high quality output metadata. It can also create variable bathymetry surfaces for implementation of ensemble modeling and merge topographic datasets for flood modeling and coastal risk analysis application.*

The BathyFusion tool could be a useful tool for integrating disparate topographic and bathymetric datasets that cover portions of the Humboldt Bay region in order to develop a more unified topographic model of subtidal, intertidal, and terrestrial areas. The skills required to implement this tool include extensive training in GIS and related programming applications.

Required dataset(s): Digital Elevation Models (DEMs), point location depth sounding or elevation data.

Brainstorm Anywhere

Online source: http://ebmtoolsdatabase.org/tool/brainstorm-anywhere

Description:

> *Keypad polling is a decision support tool commonly used in public meetings to obtain anonymous feedback from participants at key decision points. This feedback is important in public processes as it allows the group to confirm whether consensus is reached or it may inform the process facilitator that additional information or discussion is required. Such technology consists of hand held keypads (similar to TV remote controls) that communicate via with a base station. Responses are recorded anonymously when each participant selects a number on his or her keypad corresponding to a multiple choice answer or preference along a scale (for example, "Enter 1 if you strongly disagree and 5 if you strongly agree"). Polling results are displayed on the projection screen seconds after each question is asked.*
>
> *One advantage of Brainstorm Anywhere over other polling applications is that it runs on a web platform instead of as a plug-in on top of PowerPoint. This makes it possible to synchronize keypad polling with online polling using computers or handheld devices like smartphones and PDAs and thus enables participants to take part in the decision-making process at a face-to-face meeting or remotely from home or work.*

Brainstorm Anywhere may be of some utility to the HBI during future planning efforts in which participants may be more likely to submit feedback on sensitive topics if they were able to remain anonymous during the decision-making process. This technology would also facilitate rapid feedback from participants who may be attending forums remotely via conference call or webinar.

Coastal Resilience-(Future Scenarios Mapper)

Online source: http://coastalresilience.org/

Coastal Resilience is a framework for decision support and represents a process rather than an actual modeling tool. Applying the coastal resilience framework involves among other things, the integration of geospatial data and modeling tools to support informed management decisions.

Description:

> *The purpose of the Coastal Resilience project is to provide communities, planners, businesses, and officials with easy access to information on projected changes in sea level and coastal storm impacts in order to assist in coastal planning and management decisions.*
>
> *For ease of use, critical coastal information is accessible through interactive decision support tools. These tools are designed to help stakeholders explore ranges of flooding scenarios from sea level rise and storm surge, analyze the potential ecological, social, and economic impacts of each scenario at local to regional scales, and provide progressive solutions to address current issues. Because this information is web-based, it can be used by anyone, including those who live, work, or invest near the coast. Stakeholders should routinely consult Coastal Resilience whenever faced with making tough choices about people*

and nature in the face of reasonable future flood scenarios along our coastlines. By comparing the social, economic, and ecological conditions under future coastal hazard scenarios, stakeholders and decision-makers can utilize this information in their local planning processes.

Coastal Resilience is a ***framework*** *that supports decisions to reduce the ecological and socio-economic risks of coastal hazards. The framework includes 4 critical elements:*
(1) community engagement to identify the local risks and values, and understand the vulnerability to coastal hazards
(2) development of a database and mapping application to visualize current and future coastal hazards as well as natural, social and economic resources at risk
(3) decision support to examine options in practice and policy for reducing risk - including ecosystem-based options
(4) collaborative evaluation with community leaders and other stakeholders.

Community Viz

Online source: http://ebmtoolsdatabase.org/tool/communityviz

Description:

CommunityViz is advanced yet easy-to-use GIS software designed to help people visualize, analyze and communicate about important land-use decisions. Operating as an extension to ESRI's ArcGIS platform, CommunityViz offers:

- *Easy-to-use tools for creating realistic 3D visual models of your world as it is, and as it could be.*
- *Interactive features for analyzing choices about development, growth and change over the years to come.*
- *Myriad ways to make and share decisions about geography and the future of your community, your land and your world.*

Strengths

- *3-D visualization and modeling can be incredibly powerful in showing people how a potential planning decision would look and feel*
- *Assumptions and values can be changed on the fly and immediately used to update the analysis, which is helpful for group discussions and presentations*
- *CommunityViz integrates seamlessly with ArcGIS and works with other tools like Google Earth and SketchUp*
- *CommunityViz is one of the more affordable 3-D visualization and modeling platforms available*

Limitations

- *CommunityViz relies on GIS, so communities without robust GIS programs and skilled practitioners may be unable to use it*
- *Models and analyses are only as good as the data that goes into them*
- *Some training and time is required even for advanced GIS users to learn CommunityViz*

Equipment Needs: Dependent on knowledge of ArcView and project.

Technical Expertise: Given intermediate GIS skills, most people can get started in two days, and continue to learn more over time.

Scientific Expertise: None unless required by the needs of a particular project.

CommunityViz could be a useful tool for the purposes of visualizing and communicating possible future land-use change scenarios driven by sea level rise. This tool could be integrated with other analytical tools such as N-Spect and NatureServe Vista as a way to help the community visualize the results of potential adaptive management responses to sea level rise in the Humboldt Bay region. CommunityViz is priced at $850 for a package including 12 months of full-service technical support and free upgrades, or $500 for a basic package with web-based self-service technical support.

Required dataset(s): Dependent upon specific goals of the project. Examples of relevant data include GIS land-use/land cover shapefiles and raster datasets, as well as tabular or numeric data.

DSAS (Digital Shoreline Analysis System)

Online source: http://woodshole.er.usgs.gov/project-pages/dsas/

Description:

The Digital Shoreline Analysis System (DSAS) is computer software that computes rate-of-change statistics from multiple historic shoreline positions residing in a GIS. It is also useful for computing rates of change for just about any other boundary change problem that incorporates a clearly-identified feature position at discrete times.

DSAS is an extension to ArcGIS that could be very useful for analyzing rates of change though time for a number of boundary features within the land/seascape. Although the primary focus of the tool involves looking at historic boundary positions relative to recent or current conditions, this kind of analysis could be quite useful for estimating future positional changes or trajectories of a particular feature. Possible applications include analyzing rates of advance or retreat of shoreline features, saltmarsh-mudflat interface, saltmarsh- freshwater marsh-upland transition, and so on. This tool could be extremely useful in conjunction with many of the historic datasets available in the Humboldt Bay Historical Atlas to develop a more quantitative understanding of geomorphic and ecological change through time in the Humboldt Bay region.

Required dataset(s): GIS shapefiles representing linear boundary features such as shorelines or ecological boundaries.

Habitat Priority Planner

Online source: www.csc.noaa.gov/digitalcoast/tools/hpp/

Description:

> *The Habitat Priority Planner provides a format for analyzing critical coastal habitat that is consistent, repeatable, and transparent. Teams of people working on habitat decisions use this tool to share information and find answers to these questions, and others:*
> - *Where are we most likely to find this plant/ animal/demographic?*
> - *Where is the best place to locate this dock/ marina/school?*
> - *How will our proposed boundary impact a nearby resource/school/road?*
> - *How do we prioritize areas vulnerable to climate change impacts?*

The Habitat Priority Planner (HPP) is an extension to ArcGIS that is intended to help coastal resource managers and planners make informed and prioritized decisions regarding habitat restoration and conservation. HPP works with both vector and raster land cover data, which would allow the integration of the 2009 Benthic Habitat dataset, NOAA C-CAP land cover data, and updated NWI data once it is available. The HPP is available for free from the NOAA Coastal Services Center and represents a tool that could be integrated with other geospatial modeling tools such as SLAMM to integrate sea level rise predictions with land-use changes. The HPP also produces output files in .KML format that are compatible with Google Earth to improve visualization and communication of model results.

Required dataset(s): The HPP is compatible with a wide variety of datasets including land cover, soils, benthic coverage, parcels, or topography.

HAZUS MH

Online source: http://www.fema.gov/plan/prevent/hazus/index.shtm

Description: The Federal Emergency Management Agency's (FEMA) HAZUS- Multi-Hazard (MH) ArcGIS Extension is a risk assessment tool designed to project potential losses from flooding, hurricanes, and earthquakes. Losses and damages associated with these types of disasters are estimated through the integration of geospatial modeling tools with socio-economic datasets provided with the software. HAZUS MH can been adapted to project the impacts associated with sea level rise by incorporating sea level inundation projections with the socio-economic community datasets provided with the software. This software is available free of charge from FEMA and could be a useful tool for projecting socio-economic impacts or developing mitigation strategies associated with rising sea level.

Potential loss estimates analyzed in Hazus include:

- ***Physical damage*** *to residential and commercial buildings, schools, critical facilities, and infrastructure;*
- ***Economic loss****, including lost jobs, business interruptions, repair and reconstruction costs; and*
- ***Social impacts****, including estimates of shelter requirements, displaced households, and population exposed to scenario floods, earthquakes, and hurricanes.*

Required dataset(s): None. Socio-economic datasets are included with the software.

Impervious Surface Analysis Tool

Online source: http://www.csc.noaa.gov/digitalcoast/tools/isat/

Description:

The Impervious Surface Analysis Tool (ISAT), which is available as a geographic information system extension, is used to calculate the percentage of impervious surface area within user-selected geographic areas (e.g, watersheds, municipalities, subdivisions). In small watersheds, the correlation between an increase in impervious surfaces and a decrease in water quality has been well established. People use the information derived from ISAT to predict how different management scenarios might impact local water quality.

ISAT might be useful for modeling future development or land-use change scenarios with respect to imperviousness and predicting how those changes might affect water quality. The tool is fairly simple and only requires land cover data such as C-CAP as an input. The output of this tool is categorical such that areas (polygons) generated by the tool represent good, fair, or poor water quality. The tool is freely available from the NOAA Coastal Services Center.

Required dataset(s): land cover

Marxan

Online source: http://www.uq.edu.au/marxan/

Description:

Marxan provides decision support to a range of conservation planning problems, including:

- *the design of new reserve systems*
- *reporting on the performance of existing reserve systems*
- *developing multiple-use zoning plans for natural resource management*

Marxan is freely available for download and can be used in conjunction with ArcGIS or as a stand alone application. As a stand alone software application, Marxan is not directly applicable to sea level rise studies, however; in combination with a tool such as SLAMM, Marxan could be used to model the effect of sea level rise on the optimal location of conservation or future potential wetland migration easements.

Required dataset(s): Marxan is flexible and is capable of working with a wide variety of biological, physical, and socioeconomic data. Marxan documentation suggests that data quality with respect to the goals or objectives of a project is more important than the type of data used. More specific examples of input datasets that could be used with Marxan would include presence/absence, abundance, modeled distributions, spatially relevant expert opinion information, and culturally significant areas.

N-SPECT (Nonpoint-Source Pollution and Erosion Comparison Tool)

Online source: http://www.csc.noaa.gov/digitalcoast/tools/nspect/download.html

Description:

> *N-SPECT can be used to investigate potential water quality impacts from development, other land uses, and climate change. N-SPECT was designed to be broadly applicable, but the tool operates most accurately in medium-to-large watersheds having moderate topographic relief. Features include projections and maps of surface water runoff volumes, pollutant loads, pollutant concentrations, and total sediment loads. N-SPECT helps users analyze land-use change scenarios and identify areas that might benefit from changes to proposed development strategies.*

N-SPECT could be a useful tool for predicting changes in pollutant loading and erosion associated with changes in land-use or climatic conditions. It might be possible to integrate N-SPECT with SLAMM to explore how potential changes in the distribution of coastal wetlands (i.e. land cover) would influence future pollutant loads and erosion in coastal watersheds.

Required dataset(s): Land use or land cover, elevation, soil, rainfall factor (R factor), precipitation, coefficients.

NatureServe Vista

Online source: http://www.natureserve.org/prodServices/vista/overview.jsp

Description:

> *NatureServe Vista is a decision-support system that helps users integrate conservation with land use and resource planning of all types.*
>
> *Planners, resource managers, scientists, and conservationists can use NatureServe Vista to:*

- *conduct conservation planning and assessments*
- *integrate conservation values with other planning and assessment activities, such as land use, transportation, energy, natural resource, and ecosystem-based management.*
- *evaluate, create, implement, and monitor land use and resource management scenarios designed to achieve conservation goals within existing economic, social, and political contexts.*

Natureserve Vista is a promising planning tool that could be paired with other modeling tools such as N-SPECT and SLAMM to develop an integrated modeling approach for factoring the impacts of sea level rise into the overlapping interests of conservation, land-use and natural resource planning at the community level. Natureserve Vista is also interoperable with Community Viz, which could be used to communicate the outcome of various model scenarios with stakeholders.

Required dataset(s): Boundaries, streams, roads, place names, topography, digital orthophotos, fish and game species habitat maps, vegetation cover maps, modeled distribution maps, scenic views, historic sites, existing land use, current management policy, and element occurrence attributes including non-spatial information such as goals and weights indicative of social values.

SLAMM (Sea Level Affecting Marshes Model)

Online source: http://warrenpinnacle.com/SLAMMFORUM

Description:

SLAMM simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise. A complex decision tree incorporating geometric and qualitative relationships is used to represent transfers among coastal classes. Each site is divided into cells of equal area; each cell has an elevation, slope, and aspect.

Relative sea level change is computed for each site for each time step; it is the sum of the historic eustatic trend, the site-specific rate of change of elevation due to subsidence and isostatic adjustment, and the accelerated rise depending on the scenario chosen (Titus et al. 1991; IPCC, 2001).

Within SLAMM, there are five primary processes that affect wetland fate under different scenarios of sea-level rise:

- *Inundation: The rise of water levels and the salt boundary are tracked by reducing elevations of each cell as sea levels rise, thus keeping mean tide level (MTL) constant at zero. Spatially variable effects of land subsidence or isostatic* *rebound are included in these elevation calculations. The effects on each cell are calculated based on the minimum elevation and slope of that cell.*

- *Erosion: Erosion is triggered based on a threshold of maximum fetch and the proximity of the marsh to estuarine water or open ocean. When these conditions are met, horizontal erosion occurs at a rate based on site- specific data.*

- *Overwash: Barrier islands of under 500 meters width are assumed to undergo overwash at a user-specified interval. Beach migration and transport of sediments are calculated.*
- *Saturation: Coastal swamps and fresh marshes can migrate onto adjacent uplands as a response of the fresh water table to rising sea level close to the coast.*

- *Saturation: Coastal swamps and fresh marshes can migrate onto adjacent uplands as a response of the fresh water table to rising sea level close to the coast.*

- *Accretion: Sea level rise is offset by sedimentation and vertical accretion using average or site-specific values for each wetland category. Accretion rates may be spatially variable within a given model domain.*

SLAMM is the premier geospatial modeling tool for projecting the effects of sea level rise on the distribution of coastal wetlands and the geomorphic configuration of coastal areas. SLAMM has been widely applied as a modeling and decision support tool to help coastal resource managers plan for the effects of sea level rise. Although SLAMM can be run using as few as three publicly available input data sources, the model is flexible and allows for the incorporation of a number of regionally specific data sources where available. SLAMM can be used to generate plausible future conditions of coastal and wetland configurations under various assumptions of future sea level. These predictive outputs could then be integrated with other modeling tools such as the Habitat Priority Planner or N-Spect to develop a more robust decision support framework to plan for future management needs. Once the Humboldt Bay region develops more accurate and comprehensive topographic data, as well as a refined understanding of interseismic vertical land level changes, SLAMM may become one of the most potentially useful modeling tools to address the effects of sea level rise in the Humboldt Bay region.

WEM (Wave Exposure Model)

Online source: http://www.ccfhr.noaa.gov/stressors/wemo/

Description:
The wave exposure model (WEMo) uses linear wave theory to calculate actual wave height and derived wave energy while taking into consideration wind generation and local water depth

characteristics such as shoaling and dissipation from breaking waves. WEMo also provides predictions of seafloor sediment movement.

The model works in a simple Geographic Information System (GIS) format in association with ArcGIS:

- *Forecasts (and hindcasts) quantitative and geographically accurate wave energy and seafloor sediment movement for enclosed or semi-enclosed water bodies (e.g., estuaries and lakes)*
- *Foundation for studying or modeling restoration success, seafloor and shoreline erosion, and limits to habitat tolerances.*
- *Integrates easily with standard data formats for association with dependent factors such as shoreline erosion, landscape patterns and faunal associations.*
- *Guides sample stratification by wave energy regime.*
- *Adaptable for use by non-specialists in hydrodynamics; designed for those with basic knowledge of Geographic Information Systems (advanced college class, introductory graduate level classes)*
- *Tunable to either chronic or extreme wind events as well as in synchrony with storm surge.*
- *seagrass exclusion areas (i.e., areas where wave energy is too high for persistent seagrass habitat);*

Example Applications:

- *the potential for restoration of seagrass;*
- *submersed and shoreline habitat landscape pattern;*
- *shoreline susceptibility to hurricanes and other extreme wind events;*
- *effects of shoreline structures on habitat*

WEMo could be a very useful tool for developing a more refined understanding of the effects of bathymetry, shoreline characteristics, and local winds on the susceptibility of coastal wetland and eelgrass habitats to wave-induced erosion. WEMo could be used in conjunction with DSAS to hindcast the possible influence of hydrodynamics on shoreline and wetland habitat change. This kind of effort could then provide insight into the possible future trajectory of shoreline change within Humboldt Bay and the Eel River estuary. WEMo could also potentially be used in conjunction with model DEMs representing future sea level rise scenarios as a means of providing more refined model inputs to the erosion component of the SLAMM model, thereby improving the overall model outputs from SLAMM.

Required dataset(s): Shoreline, bathymetry, and local wind data.

5 SEA LEVEL RISE PLANNING EFFORTS IN OTHER AREAS

Many community organizations, academic institutions, as well as state and local governments are actively involved in climate change adaptation planning efforts. This field of study is rapidly expanding as scientists and policy makers advance multi-disciplinary efforts to better understand and prepare for the effects of climate change on society and the natural environment. In coastal areas the effects of sea level rise may be the most immediate and tangible consequences of climate change on coastal communities and ecosystems. The NOAA Coastal Services Center, U. S. Fish and Wildlife Service, and Georgetown Climate Center provide a wealth of coastal climate change resources and information. These and a number of other online resources relevant to climate change and sea level rise planning are provided in the appendix of this document.

6 LIMITATIONS

This project represents a preliminary assessment and characterization of available geospatial data potentially useful for regional sea level rise planning efforts. Due to limited scope of the project, this synthesis is not exhaustive but rather, represents a prioritized collaborative approach to identifying and evaluating existing geospatial information. Due to the large number of geospatial data sources identified, our efforts were focused on the characterization of geospatial data and evaluation of geospatial decision support tools, both of which took priority over descriptions of sea level rise planning efforts in other areas.

7 RECOMMENDATIONS

Although there are currently a number of data gaps with respect to fundamental geospatial information needed to support sea level rise adaptation and planning efforts in the Humboldt Bay region, there are also a number of opportunities to advance sea level rise planning interests while these data gaps are addressed. Several modeling tools could be used to provide preliminary feedback and information and then later refined on the basis of improved model inputs. Developing appropriate management questions that will guide the selection and use of available modeling tools is already underway.

Currently there are a number of developments with respect to new sources of data and information that are expected to address several of these data gaps during the course of the next two years. A new LiDAR-derived digital elevation model covering coastal areas up to the 10 meter elevation contour is now available for the entire state of California, and a recently completed shoreline characterization study is expected to be published by summer 2012. Updated NWI data for the Humboldt Bay region is also anticipated for 2012. A refined understanding of vertical land level changes and active hazard sites are expected by 2013.

Now that new LiDAR topographic data is available, there is a need to develop a more refined, fused topographic and bathymetric model of the Humboldt Bay region. This may be the highest priority modeling exercise to undertake because the majority of available modeling tools useful for sea level rise planning hinge on accurate topographic and bathymetric information. Methodology for developing integrated topography and bathymetry for the Humboldt Bay region has recently been published and could serve as a template for guiding the fusion of various input data sources into a unified dataset (Carignan et al., 2010). A number of datasets available in the Humboldt Bay Historical Atlas could also be used in conjunction with available modeling tools to refine our understanding of the changes that have occurred to coastal areas in the Humboldt Bay region during the past 150 years. Developing a refined understanding of the changes to the historical configuration of coastal areas and habitats could provide a great deal of insight regarding the current trajectory of physical and ecological changes occurring in the Humboldt Bay and Eel River estuary.

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9 APPENDIX

(See attached Excel spreadsheet on CD)