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TOWARDS THE DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR THE COLUMBIA RIVER LITTORAL CELL

Brian Voigt, Washington Department of Ecology, Coastal Monitoring & Analysis Program
Peter Ruggiero, Washington Department of Ecology, Coastal Monitoring & Analysis Program
George Kaminsky, Washington Department of Ecology, Coastal Monitoring & Analysis Program

Abstract

Historically, the accreting beaches of the Columbia River littoral cell received little management focus, and the relatively benign conditions of the past several decades led to an influx of coastal development. In more recent times, a trend reversal from accretion to erosion in many areas of the littoral cell coupled with increased development pressure along the coast warrants the creation of a knowledge bank to support coastal planning and decision-making. The Southwest Washington Coastal Erosion Study is actively engaged in research and analysis of the Columbia River littoral cell evolution and is developing multi-disciplinary data through regional research and monitoring. A process for integrating this multi-disciplinary data set to examine regional physical susceptibility to coastal change will utilize a suite of modelling applications and geographic information system (GIS) software to develop an interactive, query-based decision support tool for the coastal management community. Employing knowledge of the physical system to develop a susceptibility profile for coastal communities will facilitate the development of coastal policies and management decisions that pursue desired outcomes (economic, social, environmental) with respect to scientifically-based scenarios of future physical coastal conditions.

Introduction

The Southwest Washington Coastal Erosion Study (Study) is a five-year cooperative research program initiated in 1996 to examine the evolution of the Columbia River littoral cell (CRLC) over a variety of time scales. The littoral cell spans 165 km of coast between Tillamook Head, OR and Point Grenville, WA (Figure 1). Co-directed by the Washington Department of Ecology and the US Geological Survey, Coastal and Marine Geology Program, the Study is currently in a position to begin developing management support tools for use by coastal communities, counties and state and federal agencies with jurisdiction in the coastal zone. Washington's coastal management program began with federal approval of the state's Shoreline Management Act in 1976. Coastal zone management is administered at the city or county level under the direction of local Shoreline Master Programs.

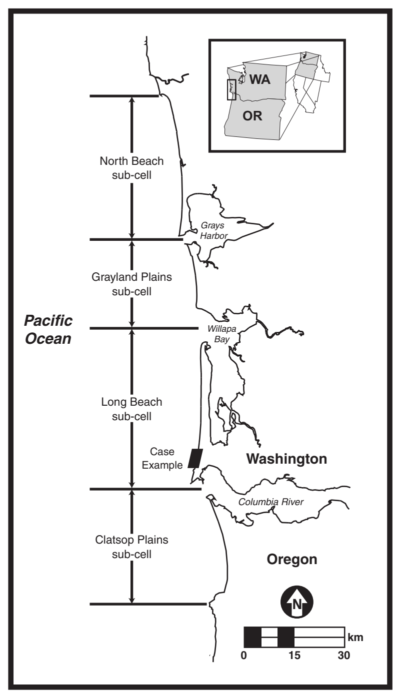

Figure 1. The Columbia River littoral cell spans 165 km of coast between Tillamook Head, OR and Point Grenville, WA.

In the past, the primary economic resources in the region were timber and fishing. Declining productivity of the natural system along with increased environmental legislation has resulted in a reliance on significant economic contributions from tourism and related development. The recent upsurge in economic development activities throughout the littoral cell marks the beginning of a transition from self-reliant coastal communities to tourist destinations, complete with hotels, casinos, condominiums and the commercial capacity to support a rapidly developing part-time population (Voigt, 1999). In light of these recent development trends, previously undeveloped areas are experiencing growth at unprecedented rates. Without question the short-term increases in local tax base resulting from new development will benefit the local economy. However, over the long-term, this same development may require economic outlays for coastal protection works by both public and private sectors that could exceed the economic and social benefits derived from current development. Beach nourishment, property acquisition, shoreline armoring and other management alternatives targeted at protecting existing infrastructure and safeguarding public welfare are becoming increasingly expensive. As more communities vie for funding from the same stable or declining funding sources, the likelihood of arranging a federal or state supported project may decrease.

One of the primary goals of the Study is to understand and predict coastal change at time and space scales relevant to coastal management (decades & tens of kilometers) (Kaminsky *et al.*, 1999). To further this goal, an effort to develop decision support tools (e.g. GIS database, maps and reports) for use by the coastal management community has been initiated. Spatial data is archived and maintained in a centralized geographic information system (GIS) database. Study results are being integrated to identify areas at risk from the evolving coastal environment. The outcomes of this process will lead to a formalization of Study results, presented as a susceptibility rating (Figure 2). Specifically, this formalized knowledge is represented by defining realistic scenarios of future coastal conditions and their associated encounter probabilities to serve as the basis for long-range coastal planning and management. Results can be used to develop a susceptibility profile that evaluates impacts on the natural, social and economic systems and prioritizes management activities based on the perceived value of each system within the community.

A susceptibility profile can facilitate coastal policy development that attempts to resolve preferred versus predicted change. One goal of this effort is to identify areas susceptible to physical coastal changes so that adaptive risk management measures can be identified and implemented in the most cost-effective, socially responsible way. The analysis will result in a coastal classification scheme that assigns relative values of susceptibility to regions within the littoral cell. When overlaid upon data layers such as land use, beach access/recreation or future development potential, communities can develop a management approach that balances development and conservation in order to meet specified socio-economic values and result in better long-term infrastructure investments and fiscal management. Decision-makers can refer to local Shoreline Master Programs, environmental legislation mandating minimum standards of environmental quality and land use plans that prescribe desired future conditions to encourage coastal development commensurate with publicly acceptable levels of risk.

Developing a susceptibility framework

A region's susceptibility to coastal change is defined by the physical, social, economic and ecological conditions that comprise the area of interest. The Study is actively engaged in quantifying the physical processes and long-term evolution of the CRLC with the intent that the scientific data will be integrated with social and economic data of collaborating local communities and counties. Ecological data should also be considered due to the ramifications of loss of critical habitats, wetlands and endangered species. However, an examination of the physical, social and economic realms can provide the basis for cost/benefit analyses that quantify impacts of shoreline change on current and future coastal development. While it can be argued that physical processes influence short-term coastal change and long-term coastal evolution, the management response to these forcings is most certainly driven by social and economic priorities established at the community level through a coordinated planning process.

The Study is integrating multi-disciplinary data with results from a suite of modelling applications (e.g., coastal processes, shoreline change, etc.) using a GIS to develop physical susceptibility parameters as input variables for a Decision Support System. This tool addresses coastal management issues by presenting coastal research as formalized knowledge that can readily be incorporated into the decision-making process. Formalizing coastal research into management applications progresses through a four-stage framework (Figure 2). Beginning with the *data phase*, the process continues through the *information phase*, followed by a characterization of the area of interest in the *knowledge phase* and finally formalization of that knowledge as part of the *experience phase* (Capobianco *et al.*, 1999). The result of this process is a set of physical susceptibility parameters that can be integrated with social, economic and ecological data to evaluate susceptibility to coastal change.

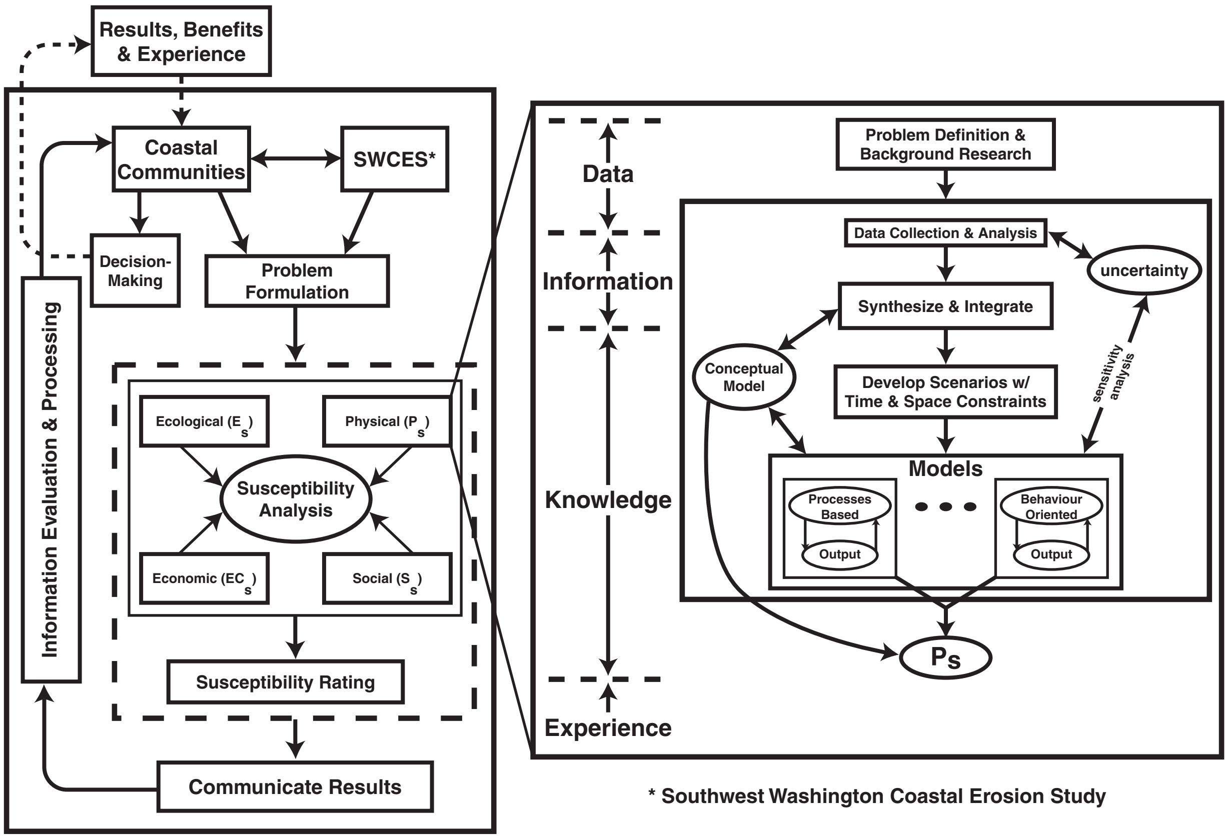

Figure 2. Flow diagram for information transfer between the scientific and management communities and a physical susceptibility framework. The left panel depicts the information flow from coordinated problem formulation to local decision-making. The right panel illustrates a framework for deriving physical susceptibility to coastal change. The physical susceptibility (P_s) is integrated with ecological, social and economic susceptibilities to derive a susceptibility rating. As decisions are made and evaluated over time, communities benefit from past experience.

The framework's *data phase* includes problem formulation, identification of available resources, background research and initiation of data collection efforts. The Study began in 1996 at the request of the coastal communities and the Department of Ecology. A coordination of efforts, with the local communities as the primary beneficiaries, helped define the problem, scope and desired outputs needed for long-range planning and decision-making.

The *information phase* involves the organization and analysis of the *data phase* efforts. As information is developed, uncertainties should be quantified and noted in consideration of prioritizing future research. While some uncertainty can be accounted for simply by collecting additional data or performing additional analysis, it is not always possible or cost-effective to do so. The Study conducts quarterly beach monitoring surveys to refine uncertainties in morphological seasonal variability estimates, and error analysis has been performed to quantify the accuracy of converting paper maps to digital shorelines. Predictive uncertainties, on the other hand, may best be dealt with via sensitivity analyses that evaluate changes in model outputs based on varying input parameters (Cowell *et al.*, 1994). One of the greatest challenges to this process lies in understanding and managing the uncertainties that will ultimately affect decision-making outcomes. As a result, the development and implementation of a susceptibility rating as a decision support tool relies heavily on the expert knowledge resulting from the research.

The *knowledge phase* expands on the data synthesis and integration component of the *information phase*. A conceptual model of the littoral system is currently under development as a means of representing the littoral cell sediment budget over multiple time scales (Gelfenbaum *et al.*, 1999). Shoreline change and probabilistic total water level models are being used to develop likely ranges of decadal scale coastal change and delineate areas susceptible to flooding. Additional efforts in this phase include working with coastal communities and other user groups to develop input forcing scenarios with appropriate temporal and spatial constraints to serve as the basis for long-term planning. Monitoring coastal processes and associated morphological variability enables refinement of processes-based models (Ruggiero *et al.*, 1999) that result in the prediction of short-term, small-scale events. These results can be integrated with those of longer-term coastal evolution research to develop management scale predictions based on integrated modelling of the long-term behaviour (evolution) of the coastal environment (Kaminsky *et al.,* 1999).

The *knowledge phase* results in output variables (e.g. predicted shoreline change, flooding potential) that quantify the susceptibility of the littoral system to physical coastal changes. The output variables lead to a formalization of knowledge in the *experience phase*. This formalized knowledge will be developed into management products that facilitate the incorporation of available scientific knowledge into the decision-making process. Successful science and management integration will be dependent on presenting management scale research results in appropriate formats and utilizing expert knowledge developed through the course of the research. Continued assessments of the coastal system functioning will refine the understanding of the relationship among littoral cell evolution, regional coastal susceptibility and relative success of selected management alternatives in relation to predefined objectives.

Case example: The southern Long Beach Peninsula

An initial attempt at applying this susceptibility framework and developing management products has begun for an 8-km stretch of the southern Long Beach Peninsula (see Figure 1). The case scenario examines shoreline change over a 25-year period (1995 - 2020) coupled with the seasonal variability of beach state parameters and the impacts associated with predicted wave runup (dune toe impact and dune crest overwash). Future shoreline position is presented as a range of values incorporating uncertainty in data sets and model formulation as well as short-term seasonal variability. Integrated data and model results are plotted on an orthophoto base map to illustrate potential conflicts between the predicted future shoreline positions and existing coastal development.

Figure 3a displays the alongshore variability of dune toe and dune crest elevations. The mean dune toe and dune crest elevations for this 8-km stretch of coast measure 4.7-m (NAVD 88) and 7.8-m (NAVD 88), respectively. Beach slope, as calculated between the 1.0 and 3.0-m contours averages 0.025 (1:40). An assessment of the frequency of dune toe impact and wave overwash has been performed utilizing a probabilistic total water level model (Ruggiero *et al.*, 1996), and the results are displayed in Figure 3b. Although dune overwash is an infrequent occurrence, wave impact at the dune toe is problematic along the southern end of the study area, with 7 locations (denoted by asterisks) experiencing more than 75 hours of wave impact per year. Figure 3c displays predicted shoreline change for the time period 1995 - 2020 derived from the processes-based shoreline change model UNIBEST (Delft Hydraulics, 1994). Results indicate larger shoreline retreat at the southern end of the case study tapering off to the north. Figure 3d maps a scenario of potential future impact that reveals several kilometers of shoreline susceptible to coastal change with increased potential for dune erosion and coastal flooding along the southern extent of the case example.

While mapped output may be useful over the short-term, the static nature of a printed map may limit its utility into the future. Ideally, decision support is provided as a GIS tool that enables a range of scenarios to be tested, allowing local communities to determine specific boundary conditions and objective evaluation measures, combined with their associated probabilities, uncertainties and levels of risk to facilitate the adoption of scientifically-based, publicly-acceptable coastal management plans.

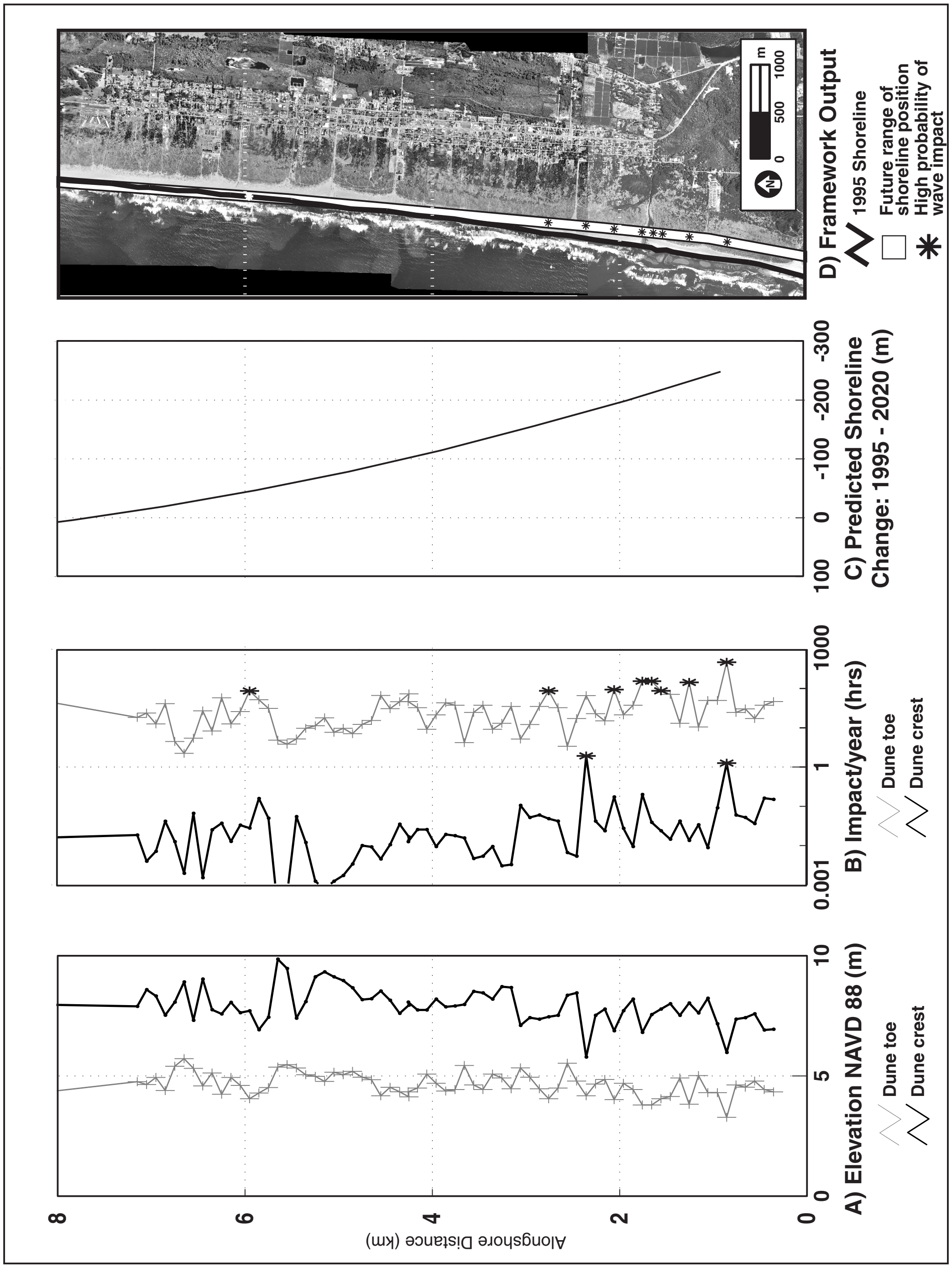

Figure 3. A) dune toe and crest elevations, B) annual hours of dune toe impact and dune crest overwash, C) shoreline change prediction, D) susceptibility analysis output mapped on southern Long Beach peninsula orthophoto; asterisks denote significant dune erosion and coastal flooding potential.

Conclusions

The Southwest Washington Coastal Erosion Study is developing a knowledge bank capable of providing decision support tools for the coastal management community of the CRLC. This paper presents a framework for integrating multi-disciplinary data to quantify implications of coastal evolution to the human environment. In effect, management direction will be defined by the estimated level of risk, public perception of acceptable levels of risk and the desired future direction for individual communities as defined by local Comprehensive Plans and Shoreline Master Programs. A case example of integrated data types and modelling results were used to identify areas along an 8-km stretch of the southern Long Beach Peninsula susceptible to shoreline change and coastal flooding, and presented a potential management tool. A complete susceptibility assessment should include an investigation of the social, economic and ecological characteristics of the system. However, an investigation of the impacts of physical change on the social and economic systems can establish the need for increased research and management focus in susceptible areas to mitigate current hazards and avoid future management crises.

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Brian Voigt
Washington Department of Ecology, Coastal Monitoring & Analysis Program
PO Box 47600
Olympia, WA 98504-7600
Phone: (360) 407-6568
Fax: (360) 407-6902
Email: bvoi461@ecy.wa.gov