Chapter XX

A Globally-Oriented Curriculum in Ocean Environmental Engineering

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Ocean Environmental Engineering is defined as the application of engineering and management principles to the conservation of the marine environment and the sustainability of its natural resources. This unique discipline is being developed within the ocean engineering major at the U.S. Naval Academy. Its essence is found in two fundamental courses: Ocean Environmental Engineering which focuses on marine environmental protection, and Ocean Resources Engineering which emphasizes marine resources stewardship. Other ocean environmental engineering opportunities include the introductory and capstone design course within the major and elective courses in environmental science and engineering in other majors. The purpose of this paper is to address the evolution of this environmental engineering option and to highlight some of the recent student research and design projects that have a global relevance.

INTRODUCTION

For the past ten years, the authors have been developing a unique environmental discipline within the ocean engineering major at the U.S. Naval Academy (USNA). We define ‘Ocean Environmental Engineering’ as the application of engineering and management principles to the conservation of the marine environment and the sustainability of its natural resources. The essence of this discipline is its two foundation courses: ‘Ocean Environmental Engineering’ that focuses on marine pollution, its principal causes, effects, and its remediation; and ‘Ocean Resources Engineering’ which emphasizes methods for ocean resource assessment, recovery and effective utilization. In both courses, midshipmen (i.e., our students) are required to research a problematic issue within the ocean environment and to seek mitigation alternatives. Recent globally-oriented examples include degradation of Pacific coral reefs; environmental and economic health of Manila Bay, Philippines; maintenance of world-wide fisheries; ocean energy conversion, oil-spill mitigation technologies, among others.

Ocean environmental issues are also addressed in the introductory and capstone design courses required of all ocean engineering majors. In the introductory design course, various phases of the design process are discussed and examples worked to enhance understanding. An extensive case study involving restoration of a coral reef is used to facilitate design instruction. In the capstone design course, students are expected to complete a feasibility-level design of an ocean engineering-related project. Typically, these projects are 'real world', i.e., proposed by public sector clients who not only detail the problem but often volunteer their time to mentor students during design development. Past projects include a design for harbor sediment mitigation in Puerto Rico, and an ocean energy plant for the U.S. Naval Support Facility (NSF) Diego Garcia, I.O. Environmental engineering opportunities are also available in the curriculum of other majors including elective courses in environmental economics, environmental policy and security, and marine environmental engineering.

The purpose of this paper is to share the experiences of our students as they research and seek to resolve the ever-more significant problems in the marine environment, with our goal of not only increasing their environmental awareness but their engineering acumen as well. We will review the course content of the two foundation courses and highlight selected ocean environmental research and design projects that have a global relevance.

THE FOUNDATION COURSES

The goal of 'Ocean Environmental Engineering' is to provide the student with a basic understanding of marine pollution – its principal causes, effects, and means of remediation. Students are introduced to engineering principles dealing with water quality, wastewater treatment, cultural eutrophication of water bodies, and other forms of water pollution. Issues in environmental laws, ethics and economics as they pertain to the marine environment are also discussed. Our sense is that the more favorable learning experiences come from the discussion of diversified case studies, usually drawn from current events, and the group research projects that allow students to investigate areas of particular interest. Examples of such case studies and research efforts include the investigation of tanker accidents and oil spills such as the Exxon Valdez and more recent Prestige sinking; the beneficial disposal of dredge materials for artificial island formations such as the Hart-Miller Island and Poplar Island preserves in the Chesapeake Bay, MD; and various world-wide coral reef and wetland degradation/mitigation projects. Class instruction is also enhanced by field trips to local water and wastewater treatment plants and environmental sites such as the Jug Bay Wetlands Sanctuary.

FIGURE 1. Midshipmen explore the Jug Bay wetlands by canoe.

'Ocean Resources Engineering' has an even broader range of topical coverage with technical discussions of alternate energy sources, coastal developments, deep-ocean oil and gas recovery, desalinization, dredging and dredge material disposal, ocean fisheries and mariculture, mineral exploitation, ocean depositories, and more. Here, too, the more effective learning experiences come from the independent research assignments but, also, from varied design projects accomplished by four-person teams. Brief summaries of three student research projects and a more intensive design project follow.

- Managing Fisheries ~ Fisheries world-wide are in decline due to excessive fleet capacity, ever-improving harvest technology, and accelerating competition. The midshipman interested in this issue investigated the development of fishing technologies and its consequences. He concluded that it would be beneficial for country governments to place fishery management under one central agency (e.g., NOAA in the U.S.) and that local governments establish and enforce catch limits consistent with conservation goals.

- Manila Bay Coastal Management ~ Fishing serves as the primary economic base for indigent populations surrounding Manila Bay, yet it is in serious decline due to illegal dumping and discharges, destructive fishing practices and overexploitation of the resource. The midshipman researching this problem learned that the Philippines government had implemented a Comprehensive Coastal Strategy Plan that included development of a waste management system and transfer facility, and instituted a seven-year ban on all forms of commercial fishing in the bay.

- Renewable Energy Source for the Philippines ~ The Republic of the Philippines is an island nation that relies heavily on imported fossil fuels. Two students investigated various renewable energy forms including solar and wind power, and concluded that harnessing tidal currents between many of the nation's 7000 islands would be the most practical alternative. Use of tidal fences or tidal turbines was suggested.

- Wind Energy Farm on Diego Garcia, I.O. ~ Wind energy is the fastest growing renewable energy source world-wide. For example, Denmark's 'Energy 21' Plan reflects a target for installed wind capacity of 5,500 MW by the year 2030, most of which will come from development of offshore wind farms. Teams of midshipmen were tasked to design a wind energy farm for NSF Diego Garcia. Students were required to assess the wind resource in terms of its statistical magnitude, direction, and seasonal variations. Operating characteristics of various wind turbines were investigated and integrated with the resource to determine the optimum number and size to meet facility requirements. Considerations of site location, construction method, and economic efficiency were also addressed.

INTRODUCTORY AND CAPSTONE DESIGN

In the introductory design course, 'Ocean Systems Engineering Design I', students are presented bathymetric data along with the following problem scenario:

"During pre-commissioning trials in June 2003, the U.S. minesweeper M/S Ravage ran aground on a coral reef off the northwest coast of Puerto Rico. Both the grounding and attempts to free the vessel resulted in significant damage to the reef substrate and associate marine organisms. The impact and weight of the vessel upon the reef fractured the underlying coral substrate and the ship's screws created an even deeper crater in the coralline seabed… "

FIGURE 2. Ship Grounding, Puerto Rico. http://www.darp.noaa.gov/.

Over the course of the semester, as the various steps of the design process are discussed in class, student teams are tasked to assess the extent of reef damage in terms of volume and depth; to develop and evaluate concepts for damage mitigation; and to develop a construction plan and cost estimate for the alternative deemed most effective. Not only do students gain appreciation of the step-by-step design process but, through their research efforts, they learn of technical concepts appropriate for ecological restoration - a discipline of ever-increasing importance in an environmentally conscious world. Further details of this semester-long coral reef restoration project are described in the paper by Mayer [1].

The goal of the follow-on capstone design course, 'Ocean Systems Engineering Design II', is to provide the student with a somewhat realistic design experience so as to enhance their understanding of the total design process. The design effort must encompass aspects of aesthetics, criteria satisfaction, economics, environmental quality, fabrication, maintainability, reliability, safety, and social impact [2]. Student teams of 4-5 midshipmen are given a choice of several design projects identified by the faculty. Such projects are often generated by inquires to local 'clients' such as naval installations, state and county agencies, and local non-profit associations. Quite often, the faculty learns of projects taking place world-wide that are adaptable to solution my midshipmen teams. Past projects with an environmental and global relevance include a harbor sedimentation study in Puerto Rico and development of an ocean energy system for NSF Diego Garcia, both of which are described below.

- Aguadilla Harbor, Puerto Rico ~ Since construction of its breakwater in 1995, the Aguadilla small boat harbor suffered from shoaling by littoral sediment moving around the toe of the structure. Midshipmen built a physical scale model of the harbor in the Naval Academy's Coastal Engineering Laboratory and conducted dye studies to study the flow of currents and sediments into the harbor. Modifications of the model suggested that a shore-attached breakwater perpendicular to but short of the tip of the existing breakwater would reduce the sedimentation without serious blockage of the harbor. A similar approach was later affected by the Corps of Engineers in the actual harbor.

FIGURE 3. Midshipmen build scale model for harbor sedimentation study

- NSF Diego Garcia, I.O. ~ In 1998, the U.S. Navy solicited proposals from private industry to construct, operate and maintain conventional power and fresh water utility systems for the NSF on the island of Diego Garcia. Coincident to private industry's efforts, three midshipman design teams were tasked to evaluate and propose a renewable energy scheme meeting similar utility goals. Each team investigated various ocean energy schemes including ocean winds, wave, current and ocean thermal energies and each concluded that a variant of an ocean thermal energy conversion (OTEC) plant would be most advantageous. By coincidence, one private consortium also proposed an OTEC system, but the Navy selected a conventional fuel-fired plant for reasons of reliability and construction uncertainties. In subsequent years, capstone design teams have proposed ocean energy systems for the naval facilities at Roosevelt Roads, PR, and Newport, RI.

Other recent capstone design projects with a marine environmental theme include the design of a tidal wetland to restore Hambrook's Bar, a barrier island in the Chesapeake Bay that provides natural shore protection; design of an artificial wetland habitat on James Island using dredged material that would otherwise have to be disposed elsewhere; and, the development of a reverse-osmosis fresh-water production system for NOAA's Aquarius Underwater Habitat. Such 'real-world' projects often serve a dual benefit – our students gain a valuable design experience, while their 'clients' benefit from a fresh look at projects often with long-term histories. In certain instances, the students' capstone design report has been a key factor in the solicitation (and granting) of funds for final design by professional engineers. Further details of the ocean engineering capstone experience can be found in the literature [3].

OTHER ENVIRONMENTAL OPPORTUNITIES AT USNA

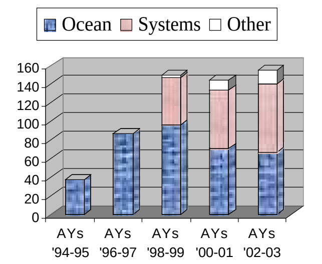
Besides the two foundation courses and two design courses, ocean engineering majors seeking further instruction in the environmental area may select elective courses in other majors. Environmental courses are available in energy conversion, green ships environmental systems, environmental systems engineering, environmental economics, environmental policy and security, and various courses within the oceanography curriculum. Highly-qualified students may also chose to pursue independent research project under the direct tutelage of a faculty member. Recently, two students worked independently to investigate the effectiveness of Reef Balls© and Fish Havens© for shoreline restitution. Both of these commercial products have been deployed internationally for habitat enhancement and have also been considered for use in shoreline protection and restoration.

RELATIVITY, RECEPTIVITY AND SUMMARY

Ocean environmental engineering is a relatively new discipline that is in stark contrast to environmental engineering programs at most universities. Most environmental engineering programs are focused on water and wastewater management issues with some consideration of wastewater discharge into lakes, streams and estuaries. Many schools offer a multidisciplinary program blending environmental science with engineering but, these programs generally have a stronger science than engineering focus and, again, emphasize land-based or inland water-body applications. Some schools also offer specialized courses in ocean engineering systems such as wave energy, ocean thermal energy, aquaculture, coastal engineering and offshore structures. The authors believe that the two fundamental courses offered within the ocean engineering major at USNA are sufficiently broad based in ocean environmental engineering topics that they are unique to all other ocean engineering programs. Given their breadth of coverage, the fine details of engineering practice are left to the individual student who has the opportunity to explore his/her specific interests through individual research projects, the capstone design, and subsequent study at the undergraduate or graduate level. What our courses do achieve from a pedagogical viewpoint is to expose the student to various marine environmental issues and the capabilities and limitations of the technologies being used in their resolution.

Besides ocean engineering majors, this new discipline has been successful in attracting students from other engineering and science majors. USNA's Weapons and Systems Engineering program subsequently initiated a track in environmental engineering and many of their students enroll in one or two of the fundamental courses to fulfill curricula requirements in their own major. As a result, enrollments in the two fundamental courses have essentially doubled from 1997 to 1998 and have held fairly steady ever since (see Chart 1.)

CHART 1. Enrollment by Major



Upon graduation, all midshipmen majoring in ocean and systems engineering will graduate with an accredited ABET degree and are commissioned as ensigns and 2nd lieutenants in the U.S. Navy and Marine Corps, respectively. Their service commitment will take them across many seas, and their exposure to environmental issues world-wide will be vast and varied. While opportunities to 'engineer' in the fleet may be limited early on, they will be faced with many environmental/economic tradeoffs decisions that will affect base operations, facility management, and most all aircraft, ship, and weapons acquisitions. It is our hope that exposure to this new environmental discipline on a global scale will arouse a consciousness for stewardship of the ocean environment and a facility to affect appropriate mitigation measures whenever necessary.

REFERENCES

1. Mayer, R.H., "An Integrated Approach to Teaching Engineering Design and Design Decision-making," *Proceedings of the 1999 ASEE Annual Conference and Exposition,* American Society of Engineering Education, Charlotte, NC, June 1999.
2. ABET, "Criteria for Accrediting Engineering Programs," Accreditation Board for Engineering and Technology, Inc., New York, 2000.
3. Kriebel, D.L. and Finlayson, W.S., "Ocean Engineering Design Experience at the U.S. Naval Academy," *MTS-IEEE Oceans 2001* , Marine Technology Society, Honolulu, HI, November 2001.

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