UNIVERSITY OF HAWAII

JAMES K. K. LOOK LABORATORY
OF OCEANOGRAPHIC ENGINEERING

DEPARTMENT OF OCEAN ENGINEERING

MISCELLANEOUS REPORT NO. 9
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NEARSHORE ENVIRONMENTAL-OCEAN ENGINEERING; CURRICULUM DEVELOPMENT FOR GRADUATE STUDIES IN

BY
Karl H. Bathen

December 1973

PREPARED UNDER

Grant from Sea Grant Office
University of Hawaii
Their Report No. UNIHI-SEAGRANT-CR-74-06

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ABSTRACT

In response to strong public and student interest for ocean engineering graduate education in nearshore-environmental engineering a curriculum was developed and initiated at the University of Hawaii Department of Ocean Engineering during 1972 and 1973. The methodology of development and the results of the program in its initial year are discussed in the report. The objective of the effort was to define the discipline and verify the specific public need, design a graduate level curriculum, develop the academic program to include several new courses, outline the program areas of flexibility and emphasis, and prepare a student counselling document.

The public need was verified by a direct and mail poll of 147 professional groups in Hawaii and by a literature search, nation wide, of marine and engineering educational programs. The poll response showed "consulting engineering, marine studies, and environmental engineering" were the most frequently listed services, with "sanitary engineering studies, environmental impact analyses, water quality programs, pollution studies, coastal and harbor engineering studies" the dominant activities of those responding. Most groups had less than 100 employees, paid annual salaries averaging between $11,000 to $24,000, and estimated they require between 3 to 10 additional environmentally trained engineers in the next five years.

The graduate program developed emphasized three options: Marine Surveys and Environmental Studies with high-level mathematics and fluid mechanics prerequisite to graduate study of marine survey techniques, coastal engineering, estuary mechanics, and marine instrumentation; Water Quality Preservation

and Monitoring with moderate mathematical background plus fluid mechanics and chemistry prerequisites to graduate level study of marine survey techniques, physical and chemical oceanography for engineers, marine instrumentation, coastal engineering, marine economics; Coastal Pollution and Waste Disposal with moderate mathematical and engineering background as prerequisites to graduate study of oceanography for engineers, coastal engineering, marine economics, marine disposal of wastes, ocean engineering design. The new courses developed for the curriculum included Oceanography for Engineers covering required background in physical, chemical, geological and biological oceanography; Instrumentation Seminar with faculty lectures, student-to-peers presentations, and open discussion sessions on marine instruments--including theory of operation, construction, application, performance, limitations, costs and availability; Estuary Dynamics and Modelling including the descriptive and analyatical background to the significant physical processes occurring in estuaries, coastal embayments, and nearshore waters and background in numerical modelling techniques for circulation and water quality prediction.

The report notes that student response at University of Hawaii Manoa Campus since the fall 1973 has been excellent, e.g. 21 in Nearshore Environmental-Ocean Engineering of 40 students in the Department of Ocean Engineering. The report also provides a bibliography of 20 items, a list of those professional groups polled, a copy of the questionnaire used, and course outlines for each new course developed for the program.

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INTRODUCTION

BACKGROUND - The unprecidented economic and population growth in Hawaii during the past 30 years has, as in other states, brought with it increasing environmental problems. Though the health, aesthetics and recreational aspects of the Hawaiian marine environment have always been of importance to the tourist-agriculture economic orientation of the State, environmental degradation has been tolerated in the past as an inherent development cost. In recent years, however, it has become clear to many that some of the more serious coastal environmental degradation problems presently facing the State can have significant negative impact on the local economy if allowed to continue. Basically, the origin of these problems can be attributed to the lack of past environmental consideration in the design and/or operation of expanding municipal, residential and industrial facilities in the islands. Further, as nearshore and offshore areas receive new attention in the accelerated quest for food, mineral and energy resources the risks of environmental damage will multiply.

The scientific and engineering community in Hawaii is being called upon to help solve urgent, environmentally oriented, local and Pacific Basin problems. Many such efforts are underway. With the trend toward increased use of ocean resources, and toward rapidly developing national and local environmental policies supported by new legislation, many engineering firms, industries, and government agencies have begun to search for additional employees with ocean oriented environmental skills. Their intent seems to be to develop active in-house environmental abilities.

These groups often bear both the ability and the responsibility for future development and management of the island's marine resources. Further, other groups from throughout the Pacific Basin look to Hawaii and to the University for technical aid and personnel to help solve marine-oriented environmental problems. These needs have to be met if the State and the Pacific area is to reach their long-range goals while also maintaining or improving the health of their local marine environments.

In summary, strong interest has already been voiced for trained ocean engineers with marine-environmental background. Specifically, Hawaii and the Pacific Basin area needs graduate ocean engineers skilled in environmental studies to implement and conduct several types of efforts. These include: (1) efforts to engineer environmental safety into new products and services; (2) evaluate both new and existing equipment and operation methods in industry; (3) conduct field surveys and evaluate existing waste problems associated with industrial and municipal facilities; evaluate environmental studies contracted to special skill groups; (5) establish monitoring capabilities for aiding compliance with new laws for environmental standards; and (6) educate future engineers in ocean engineering environmental skills.

Paralleling the community and Pacific area need for trained personnel, strong interest in relevant environmental education presently exist among undergraduate and graduate engineers at the University of Hawaii. A graduate education program specifically aimed at providing the background and skills necessary for solving nearshore environmental coastal problems did not, however, exist at the University prior to this work.

OBJECTIVES - The Department of Ocean, University of Hawaii, undertook in the Fall of 1972 the development of a graduate education program to

provide training in the knowledge and skills directly applicable to solving nearshore environmental problems. The program development was funded by Sea Grant and completed during the Fall 1972, Spring 1973, and Fall 1973 semesters. The purpose of this report is to briefly describe the resultant new curriculum and to comment on several aspects of the development procedure and results.

Specifically, the objectives of the effort to develop the graduate option program were to:

1. define the pertinent areas of knowledge and skills,
2. design a curriculum of required and optional courses, which would be flexible enough to accommodate a variety of student interests and professional goals
3. develop new courses needed within the program, and outline them in sufficient detail for classroom instruction,
4. prepare a summary guideline document for counselling graduate students, interpret the curriculum, and comment on employment opportunities.

METHODOLOGY - The approach to the program's first objective began with and effort to determine the background ocean engineering graduates should possess to contribute effectively to the solution of nearshore environmental problems. Pertinent information on marine study programs, as reported in University Bulletins, periodicals and educational publications was assembled and reviewed. This effort was supplemented by conducting an information gathering survey. The survey was conducted of potential local and national employment sources, questioning their background, work, environmental involvement, and short and long range needs for personnel with ocean engineering-environmental background.

Next, an academic program was developed to fulfill these needs. The guidelines of the University of Hawaii regulations and the capabilities of the Department of Ocean Engineering were carefully considered. The

program development also considered the wide range of capabilities of the marine-oriented staff at the University and the marine-oriented courses presently being offered by the Departments of Oceanography, Civil Engineering, Mechanical Engineering, Microbiology, Zoology, Botany, Meteorology, Geoscience, and Economics. It was also considered that environmental research underway at several other organizations at the University, as the Environmental Center, Hawaii Institute of Marine Biology and Water Resources Research Center would provide additional general support as the program developed.

During the development of the option program, it became obvious that new courses were needed to fill voids in the present instruction. In particular, courses in: (1) oceanography for ocean engineers, (2) near-shore marine survey techniques, (3) evaluation of pollution applied marine instrumentation, and (4) estuary dynamics and numerical modelling techniques were required. The first of these four courses was necessary to provide students an engineering oriented background in the physical, chemical, geological, and biological processes occurring in the ocean. The second course was necessary because the subject of conducting field environmental surveys is fundamentally important to such a program for ocean engineers. The third course was felt necessary because nearshore work heavily depends upon instrumentation and the field of nearshore-environmental monitoring instrumentation is one of the most rapidly developing new areas in marine instrumentation. The fourth course, was felt a prerequisite for sufficient background knowledge in the explosive national growth in areas of environmental studies, pollution monitoring and numerical modelling/prediction efforts.

These three new courses were developed, being specifically designed to inter-relate background training and to challenge students with attempts to solve typical problem situations. In subsequent semesters, practical laboratory and field experience is to be provided through the use of the department's Look Laboratory of Oceanographic Engineering. The first two courses were initially taught during the 1972-73 academic year and have been repeated in the 1973-74 academic year. The third course was first taught during the Spring 1974 semester. Beginning with the 1972-73 academic year, and continuing in the four semesters since then, considerable interest in the new option program is evident in the high enrollment of ocean engineer graduate students in these new courses.

Last, all results of the survey, program development and course outlines were assembled and are reported here. The intent is that this brief report be used to counsel future students and existing students enrolled in the Department of Ocean Engineering who are interested in pursuing a career in nearshore environmental-ocean engineering studies.

SURVEY

PURPOSE - An early objective in the development of the educational option in nearshore environmental-ocean engineering was to define the pertinent areas of knowledge and skills graduates should possess to actively contribute to solving nearshore problems. This was accomplished principally in completing a literature review of pertinent educational publications, through interviews with marine-oriented members of the academic community at the University of Hawaii, and through interviews with local government agencies, industry and engineering firms. In addition, a written survey of these latter groups was conducted by mail. A sample of the letter of introduction and the accompanying questionnaire used for this survey, along with a list of the 147 sources contacted, is given in the appendix. The responding sources are marked accordingly The responses collected were assembled and carefully considered in defining the background that ocean engineers should have to meet the present and anticipated future needs of the community.

RESULTS - Table 1 summarizes the survey results for Part I, questions 1 and 2, respectively, of the survey questionnaire. Table 2 summarizes the responses to the remaining questions asked in the questionnaire.

In answer to "What is your service or product?" a total of 21 services were listed by the responding sources. Most listed involvement in up to three types of services. Most popular response was "consulting

engineering" (12). Other frequently listed services included "surveying", "marine studies", "environmental engineering", "engineering landscape architecture", "construction" and "transportation and urban consultation".

In response to question 2, "What is (are) the area(s) of activity in which you relate to the marine environment?" a total of 36 areas of activity were listed by the responding sources. The most frequently listed activity was environmental and sanitary engineering. Other activities often listed included water quality and pollution studies, coastal and harbor engineering, physical oceanography, shoreline waters, underwater pipelines, ocean recreation, marine biology, geology, impact statements, beach protection, and flood control design.

Reviewing the survey results summarized in Table 2 shows that most of the groups responding were small (less than 100 total employees) with civil engineering background most common in their engineering staff. The minimum salary for technical staff members in 1972 and 1973 ranged from $6,000 to $15,000 (averaging $9,980) and the maximum annual salary being paid ranged from $8,000 to $28,600 (averaging $20,850). The mode for the minimum was $10,000-$12,000 and maximum was $24,000-$25,000 annually.

Land and ocean-oriented environmental work were the most commonly listed environmental subjects. Primary interests were principally in projects associated with waste disposal, coastal preservation, land development, recreation, and harbor engineering, while secondary interests lie principally in the power generation and marine transportation areas.

TABLE 1

Response to Questions 1 and 2, Part I, of the Survey Questionnaire for Sea Grant Project, "Graduate Program in Nearshore Environmental Ocean Engineering Studies".

I. Relating to your Background:

Question: 1. What is your Service or Product?

Answer: (listed in the order of most to least frequent response)

Service or Product*	Number Responding
Consulting engineer	12
Surveying	4
Marine Studies	3
Environmental engineering	3
Engineering landscaping architecture	3
Construction	3
Transportation and urban consultation	3
Environmental sciences and toxic log services	2
Oceanographic instruments	2
Planning for the City and County of Honolulu	2
Municipal sewerage works	2
Marine science	2
Soils and geology	2
Recreational services and facilities	1
Administer, control, manage recreational harbors	1
Support services for construction	1
Communications	1
Project management	1
Photography	1
Petroleum	1
Petroleum products	1

*Note: Category labeling for each "service or product" or "area of activity" were chosen by those responding.

TABLE 1 (continued)

Response to Questions 1 and 2, Part I, of the Survey Questionnaire for Sea Grant Project, "Graduate Program in Nearshore Environmental Ocean Engineering Studies".

Question: 2. What is (are) the area(s) of activity in which you relate to the marine environment?

Answer: (Listed in the order of most to least frequent response)

Area of Activity*	Number Responding
Environmental and sanitary engineering	8
Water quality and pollution studies	5
Coastal and Harbor engineering	4
Physical oceanography	3
Shoreline waters	3
Underwater pipelines	3
Ocean recreation	3
Marine biology	2
Geology	2
Impact statements	2
Beach protection	2
Flood control	2
Pier and wharf design	2
Bathymetric surveys	2
Harbor design	2
Offshore engineering	1
Chemistry	1
Civil engineering	1
Offshore mooring	1
Marine transportation and commerce	1
Resort development	1
Petroleum tanker moorings	1
Military and civil programs	1
Monitoring	1
Foundation studies	1
Range operation and logistic base support	1
Cargo loading and discharge	1
Damage assessment	1
Power plants	1
Research and development	1
Supply equipment to engineers and scientists	1
Undersea cable installation and repair	1
Hydraulic design	1
River control	1
Navigable streams	1
Drainage control	1

*Note: Category labeling for each "service or product" or "area of activity" were chosen by those responding.

TABLE 2

Response to Survey Questionnaire for Sea Grant Project, "Graduate Program in the Nearshore Environmental Ocean Engineering Studies". (See Table 1 for Summary of Response to Questions 1 and 2, Part 1, of Questionnaire)

3. Total number of employees:

> 1000 - 2	> 1000 - 0
> 100 - 12	> 100 - 6
> 10 - 12	> 10 - 10
< 10 - 8	< 10 - 18

4. Background of engineering/techician staff (number of employees):

Civil	466	Marine	23
Electrical	176	Industrial	20
Mechanical	113	Other	151
Chemical	34		

5. Approximate salary range of technical staff: 28,600 to 6,000 annually; (averaging starting $9,980, overall average $15,415, mode $17,750)

II. RELATING TO EXISTING OR FUTURE REQUIREMENTS FOR ENVIRONMENTAL SKILLS:

1. Subjects of interest to

a) environmental in house studies:

land oriented	27
ocean oriented	22
atmosphere oriented	12

b) evaluation of subcontracted environmental studies - 0

c) environmental considerations applicable to:

product design	11
evaluation of environmental monitoring equipment	9
monitoring processing techniques	7
evaluation of new equipment	7
monitoring production	5

2. Areas of primary (p) or secondary (s) interest in which environmental skills would be most useful:

	(p)	(s)
a) waste disposal (thermal, domestic solid, agricultural industrial, other)	26	6
b) coastal preservation	19	2

TABLE 2 (continued)

Response to Survey Questionnaire for Sea Grant Project, "Graduate Program in the Nearshore Environmental Ocean Engineering Studies". (See Table 1 for Summary of Response to Questions 1 & 2, Part 1, of questionnaire.)

		(p)	(s)
c)	land development	17	7
d)	harbor engineering	11	7
e)	recreation	11	7
f)	marine transportation	7	9
g)	power generation	4	9
h)	agricultural	4	7
i)	marine chemicals	4	5
j)	mining	2	6
k)	commercial fishing	2	8
l)	pharmaceuticals	0	6
m)	other	4	0

III. REQUIRED (R) OR DESIRED (D) BACKGROUND FOR ENGINEERS:

1. The general area of application of environmental skills:

		(R)	(D)
a)	nearshore environmental studies	12	10
b)	marine structures	9	7
c)	harbor engineering	8	8
d)	coastal engineering	7	11
e)	floating platforms	2	8
f)	naval architecture	0	8
g)	other	2	4

2. Specific background desired:

a)	civil engineering	21	1
b)	mechanical engineering	8	8
c)	mathematical	8	5
d)	economic	6	9
e)	electrical engineering	5	8
f)	geological	5	9
g)	biological - marine	5	10
	other	0	5
h)	business	4	11
i)	other engineering	4	2
j)	physics	3	6
k)	industrial engineering	2	10
l)	chemical engineering	2	11
m)	legal	2	10
n)	chemical	2	9
o)	fisheries	1	8
p)	other	0	1

TABLE 2 (continued)

Response to Survey Questionnaire for Sea Grant Project, "Graduate Program in the Nearshore Environmental Ocean Engineering Studies". (See Table 1 for Summary of Response to Questions 1 & 2, Part 1, of questionnaire.)

3. Experience desired in new engineering employees with an environmental background:

		Field	Business	Industrial	Other
a)	0 - 1 years	11	2	4	4
	2 - 4 years	11	5	3	4
	5 or more years	6	3	0	1
b)	military background desired	4			
		BS	MS	PhD	No comments
c)	highest degree earned	3	6	2	23

IV. RELATING TO POTENTIAL EMPLOYMENT WITH YOUR GROUP:

1. What are your present needs (number):

0	1	2	3	5	8	12	26	35-40
15,	4,	3,	1,	1,	1,	1,	1,	1

2. What do you estimate your need may be during the next five years:

2/3 = 6, 10/12 = 3, 50/75 = 1

3. Your estimate for the next 10 years = 185, 20 years = 8.

Section III in the survey deals with the required or desired environmental background for employees or potential ocean engineering employees. The most frequent response for required background was "nearshore environmental studies" and for desired background was "coastal engineering". Specifically, civil engineering background is most commonly required, with desired supporting background training in business, chemistry or chemical engineering, and marine biology. Industrial engineering, and law supporting background also ranked highly desirable for new engineering employees. Most of the responding sources preferred new ocean engineering employees to possess some field experience (up to four years) with the addition of business experience felt to be of value. Employees with master's degree background was most desired to those responding.

In Section IV the potential opportunities for further employment was asked. The greatest need was shown to exist at the present, and to likely extend for at least the next two years (to 1975-76). Most responding sources felt two to three new engineering-ocean engineering employees with environmental background would be required by their group within the next five years. The anticipated needs of one potential employer was estimated by them to be as high as 185 over the 10 years.

GRADUATE OPTION PROGRAM

OPTION OUTLINES - Table 3 gives a general summary of the option program developed for the graduate program in nearshore environmental studies. All course designations pertain to the University of Hawaii, 1973-74 catalogue nomenclature. Appendix C lists the catalogue description of each course used in the program. Tables 4 through 6 give specific outlines of three specialized areas of emphasis that can be pursued in the program. These specialized areas are: (1) marine surveys and environmental studies, (2) water quality preservation and monitoring, and (3) coastal pollution and waste disposal.

In assembling a list of general program requirements, as given in Table 3, particular attention was paid to meeting University requirements for the master's degree, and in providing a balance course work in engineering science and engineering design. University of Hawaii master's degree requirements specify a minimum of 30 credit units of graduate work (courses at the 600 level or higher) must be completed. The Department of Ocean Engineering, as part of the College of Engineering, allows these units to be accumulated under Plan A (thesis option) or Plan B (non-thesis option). The department requires each graduate student, once initially prepared for graduate studies as specified in department general prerequisites, to successfully complete core studies in the fundamentals of ocean engineering and to meet all additional and pertinent university requirements for matriculation at the master's level.

Table 3, Part I lists the pertinent prerequisites felt necessary to successfully pursue the nearshore environmental engineering option. Basically an adequate background in fluid mechanics, mathematics (probability, statistics, partial differential equations, numerical analysis)

TABLE 3

NEARSHORE ENVIRONMENTAL ENGINEERING

GENERAL SUMMARY

I. Prerequisites (or equivalent)

MATH 402 or	Partial Diff Equations	(3)
MATH 471 or	Probability	(3)
ME 403	Advance Math for Engineers I	(3)
ME 404	Advance Math for Engineers II	(3)
CE 320 or	Fluid Mechanical Fundamentals	(3)
ME 322 or	Fluid Mech I	(3)
ME 323	Fluid Mech II	(3)
MATH 371 or	Elementary Problems Theory	(3)
CE 411 or	Applied Problem and Statistics	(3)
MATH 407	Intro to Numerical Analy	(3)
MATH 408	Numerical Solution of Diff Equat	(3)
OE 401	Intro to Ocean Engineering	(3)
OE 403	Ocean Engineering Environment	(3)

II. Core Program

Engineering Science

OE 603	Oceanography for Ocn Engins	(3)
OE 607	Wave Dynamics	(3)
OE 609	Prin of Ocn Engin	(3)
OE 651	Instr Seminar	(2)
OE 694	Econ of Marine Resources	(3)
OC 623	Chemical Oceanography	(3)
		17

Engineering Design

OE 652	Nearshore Marine Survey Techniques	(3)
OE 661	Cstl and Harbor Engin	(3)
OE 662	Cstl and Harbor Engineering	(3)
OE 683	Ocean Engin Design	(3)
OE 691	Special Topics in OE - Estuaries	(3)
		15
		32

III. List of Potential Electives

BOT 651	Dyn of Mar Produc	(3)	
CE 626	Surf-Water Hydro	(3)	
CE 631	Env & Sani Engin	(3)	
CE 641	Mar Dis of Wastes	(3)	
EE 422	Elec Instru	(3)	
GG 623	Marine Geology	(3)	
GEOG 405	Water Res Mgm	(3)	
PH 612	Ecol Concepts & Plan	(3)	
ISc 466	Comp Org & Plan	(3)	
ISc 650	Time Series Analy	(3)	
ISc 655	Applied Regr Analy	(3)	
MATH 407	Intro to Num Analy or	(3)	
MATH 408	Num Solu to Diff Equa	(3)	
MATH 442	Vector Analysis	(3)	
MATH 471	Probability	(3)	
ME 422	Heat Transfer	(3)	
ME 635	Corrosion Theory	(3)	
ME 636	Mat for Ocean Environ	(3)	
MIC 642	Marine Microbiology	(3)	
OC 641	Maj Ele Cyc in Environ	(3)	
OC 661	Tides	(3)	
OC 666	Nearshore Phys Oceano	(3)	
ZOO 620	Marine Ecology	(3)	

and fundamentals of ocean engineering is required. Further, it is assumed each student has an undergraduate background in general chemistry, physics and engineering. Additional background in economics, geology and biology would prove useful.

Part II of Table 3 lists the graduate courses comprising the core program for the nearshore environmental option program. Section III of Table 3 contains a summary of potential electives accepted in the program. Every core course need not be taken for each specialized area of emphasis (Reference Tables 4 through 6). Seventeen course units are defined as "engineering science" and 15 course units as "engineering design". The difference is principally that "engineering design" courses, though they may be composed principally or in part of lecture type instruction, require the student to actively participate in an independent design effort. The emphasis is in exercising design skills, i.e., each student directly applying his accumulating graduate training background to a specific design problem of either an assigned or independently selected nature. These course related efforts are independent of Plan A or B final seminar or thesis requirements.

Tables 4 through 6 outline characteristic programs emphasizing three areas of study within the option program. The tables also list the acceptable electives for each of the three areas of specialized interest. Substitutes for these electives can be arranged given any specific student area of interest relating to the option program or to the field of ocean engineering in general. In this manner individual educational goals can be easily accommodated.

The three areas of emphasis offered in the new option program as shown in Tables 4, 5 and 6, represent three ares of educational specialty in demand within the more general subject of nearshore environmental-ocean

engineering. These specialized areas would appear to best support the present and projected community and Pacific Basin needs. The areas of emphasis are:

1. Marine surveys and environmental studies - this area is strongly engineering science oriented, requiring a wide mathematics and fluid mechanics prerequisite background as part of or in addition to an engineering background. The graduate course work emphasizes techniques of marine surveys, coastal and harbor engineering methods, estuary studies, and marine instrumentation. The intent is to provide training allowing graduates to plan, conduct or critique field studies aimed at obtaining data to solve nearshore environmental problems associated with coastal projects and ocean engineering facilities.

2. Water quality preservation and monitoring - this area of study requires a mathematical, fluid mechanics and chemical background in addition to or as part of an engineering background. The graduate course work emphasizes principals of oceanography for ocean engineers, marine instrumentation, chemical oceanography, economics of marine resources, marine survey techniques, and coastal and harbor engineering methods. The intent is to provide training to enable graduates to help design, fabricate and implement water quality monitoring systems, obtain and evaluate water quality data and predict the impact in river, bay, coastal and harbor environments of engineering facilities.

3. Coastal pollution and waste disposal - this area of study requires principally a mathematical prerequisite background in addition to or as part of an engineering background. The graduate work deals principally with coastal engineering and oceanography for ocean engineers, ocean engineering design, economics of marine resources and marine disposal of wastes. The intent of this area of emphasis within the option program is to enable graduates to aid in the design or critique of municipal waste water and public utility facilities, industrial discharges, coastal projects, or in reclaimation and conservation programs.

Courses in the Department of Ocean Engineering provide essentially all of the graduate education in each of the above areas of emphasis within the option. The courses listed represent the suggested minimum effort. Each area does have elective flexibility, and a list of acceptable electives for each study area of emphasis is shown in the respective Tables 5, 6, and 7. The electives were selected in each case from courses available outside the department, most being at the graduate level. The electives

TABLE 4

NEARSHORE ENVIRONMENTAL ENGINEERING

I. EMPHASIS - MARINE SURVEYS AND ENVIRONMENTAL STUDIES

Prerequisites (desired)

Plan A and Plan B

As Given in the General Summary

Engineering Science

Plan A			Plan B		
OE 603	Oceanography for Ocn Engineer	(3)	OC 666	Nearshore Physic Oceano	(3)
OE 607	Wave Dynamics	(3)	OE 603	Oceanography for Ocn Engi	(3)
OE 651	Instr Seminar	(2)	OE 609	Prin of Ocn Engi	(3)
	Electives*	(3)		Electives*	(4)
		11			13

Engineering Design

OE 652	Nearshore Mar Sur Tech	(3)	OE 661	Cstl & Harb Engi	(3)
OE 662	Cstl & Harb Engin	(3)	OE 652	Nearshore Mar Sur Tech	(3)
OE 691	Spec Topics in OE-Estuaries	(3)	OE 662	Cstl & Harb Engi	(3)
	Electives*	(2)	OE 683	Ocn Engin Design	(3)
			OE 691	Spec Topics in OE-Estuar	(3)
				Electives*	(2)
		11			17

Thesis

OE 800	Thesis	(8)	
		30	30

*List of Recommended Electives

Engineering Science			Engineering Design		
GG 623	Marine Geology	(3)	CE 641	Marine Disposal of Wastes	(3)
OC 660	Ocean Waves	(3)	EE 422	Electronic Instrum	(3)
OC 661	Tides	(3)			
G 405	Water Resources Mngt	(3)			
MIC 642	Marine Microbiology	(3)			
Zoo 620	Marine Ecology	(3)			
OC 623	Chemical Oceanography	(3)			
		21			6

TABLE 5

NEARSHORE ENVIRONMENTAL ENGINEERING

II. EMPHASIS - WATER QUALITY PRESERVATION AND MONITORING

Prerequisites (desired)

Plan A and Plan B

As Given in the General Summary

Engineering Science

Plan A			Plan B		
OE 603	Oceanography for Ocn Engins	(3)	OE 603	Oceano for Ocn Engins	(3)
OE 623	Chemical Oceanography	(3)	OC 623	Chemical Oceanography	(3)
OE 651	Instr Seminar	(2)	OE 651	Instr Seminar	(2)
	Electives*	(3)	OC 666	Nearshore Phys Oceano	(3)
			OE 694	Econ of Marine Resources	(3)
				Electives*	(4)
		11			18

Engineering Design

OE 652	Nearshore Mar Sur Tech	(3)	OE 652	Nearshore Mar Sur Tech	(3)
OE 662	Cstl & Harb Engin	(3)	OE 662	Cstl & Harb Engin	(3)
OE 691	Spec Topics in OE-Estuaries	(3)	OE 683	Ocn Engin Design	(3)
	Electives*	(2)	OE 691	Spec Topics in OE-Estuar	(3)
				Electives	(3)
		11			12

Thesis

OE 800	Thesis	(8)			
		30			30

*List of Recommended Electives

Engineering Science			Engineering Design		
OC 642	Sedimentology II	(3)	CE 641	Mar Disposal of Wastes	(3)
PH 612	Ecol Concepts & Planning	(3)	EE 422	Electronic Instrumentation	(3)
BOT 651	Dyn of Mar Productivity	(3)	PH 612	Eco Concepts & Planning	(3)
		9			9

TABLE 6

NEARSHORE ENVIRONMENTAL ENGINEERING

III. EMPHASIS - COASTAL POLLUTION AND WASTE DISPOSAL

Prerequisites (desired)

Plan A and Plan B

As Given in the General Summary

Engineering Science

Plan A			Plan B		
OE 603	Oceanography for Ocn Engins	(3)	OC 666	Nearshore Phys Oceano	(3)
OE 651	Instru Seminar	(2)	OE 603	Oceano for Ocn Engins	(3)
OE 694	Econ of Marine Resources	(3)	OE 609	Prin of Ocn Engin	(3)
	Electives*	(3)	OE 651	Instr Seminar	(2)
			OE 694	Econ of Marine Resources	(3)
				Electives*	(2)
		11			16

Engineering Design

OE 652	Nearshore Mar Sur Tech	(3)	OE 652	Nearshore Mar Sur Tech	(3)
OE 662	Cstl & Harb Engin	(3)	OE 662	Cstl & Harb Engin	(3)
OE 683	Ocn Engin Design	(3)	OE 683	Ocn Engin Design	(3)
	Electives*	(2)	OE 691	Spec Topics in OE	(3)
				Electives*	(2)
		11			14

Thesis

OE 800	Thesis	(8)	
		30	30

*List of Recommended Electives

Engineering Science				Engineering Design			
GG	454	Engineering Geology	(3)	CE 641	Marine Disposal of Wastes	(3)
ME	422	Heat Transfer	(3)	CE 626	Surface-Water Hydrology	(3)
ME	635	Corrosion Theory	(3)	CE 631	Water Quality Management	(3)
ME	636	Materials for the Ocean Env	(3)	PH 612	Ecological Concepts & Planning	(3)
G	405	Water Resources Mngmt	(3)			
MIC	642	Marine Microbiology	(3)			
M	442	Vector Analysis	(3)			
M	471	Probability	(3)			
Zoo	620	Marine Ecology	(3)			
OC	623	Chemical Oceanography	(3)			
			30			15

listed were specifically selected to strongly complement each specialized area of study emphasis within the option program.

OUTLINES OF NEW COURSES DEVELOPED - The core program, as given in Table 3, Part II, contains four new courses that were developed as part of the option program. These courses are OE 603 (Oceanography for Ocean Engineers), OE 651 (Instrumentation Seminar), OE 652 (Nearshore Marine Survey Techniques) and OE 691 (Special Topics - Estuaries). The topics covered in each of these courses were felt to be an essential addition to the core program. The first three became a part of the department curriculum beginning in the 1972 fall semester. The estuary dynamics course is still under development and is to be added to the department's 1974 spring semester curricula.

Tables 7 through 10 contain outlines for each of the four new courses developed for the Option Program. Specifically the courses are:

> OE 603,"Oceanography for Ocean Engineers", is an introductory course covering the physical, chemical, geological and biological aspects of the world's oceans, emphasizing an approach to each topic as it is important to ocean engineering activities. The objective in OE 603 is for students to gain a background appreciation of the physical processes, chemistry and geological character, and biological abundance of the world's oceans as they affect: (1) coastal and nearshore construction, (2) nearshore environmental studies, (3) corrosion and marine fouling problems, (4) sea state conditions for floating platforms and other naval structures, and (5) deep ocean environment for submersibles and other deep structures. Descriptive background information is covered in the first one-third of the course, drawing upon engineering applications for examples of topic importance. The second one-third deals with the analytical approach to understand the physical processes in the ocean. The last one-third of the course, deals more explicitly with the tidal, wave, and circulation conditions of specific interest to coastal engineering activities.
>
> OE 651, "Instrumentation Seminar", was designed primarily to provide students an opportunity to develop and practice techniques of literature searches, instrument evaluation, oral presentations, and writing comprehensive and concise summary papers. Each student is required to complete a comprehensive literature research followed by both an oral and written presentation concerning a class of individually chosen marine instruments. The subjects in the presentation include the theory behind the sensor involved, construction, operation performance, field applications, limitations, pitfalls, costs and availability. Student presentations are supplemented by faculty and invited lecturer presentations.

OE 652, "Nearshore Marine Survey Techniques", is a new course that has brought together material from this rapidly expanding subject in the field of environmental studies. The course had no precedent; its origin represents an assembly of the wide range of existing field techniques used today to examine nearshore problems. The instructional objective is primarily to provide students with the skills to fully plan and conduct nearshore surveys aimed at helping solve problems related to nearshore processes, shoreline construction, and pollution research. Emphasis is on understanding the complexities and techniques of successfully planning and conducting these programs in detail, from the field surveys and data analyses, to the completed report. The developing knowledge and techniques in recent years on these subjects is rapidly increasing. This knowledge and the associated skills should be an integral part in the training of future researchers in the marine environment. This course is designed to provide this background. Further, the course is designed to provide this training through both a strong technical and practical orientation.

OE 691, "Special Topics - Estuaries", is presently under development. When first taught during the 1974 spring semester, the emphasis was on theoretical description of the physical processes effecting changes in estuarine and coastal embayment waters. The objectives are further to examine the techniques used to develop numerical models of estuary and coastal embayment dynamics and water quality changes.

TABLE 7

COURSE OUTLINE FOR OE 603

"OCEANOGRAPHY FOR OCEAN ENGINEERS"

PART 1. Description of the physical, chemical and geological and biological ocean environments - examples from engineering activities in the ocean.

- 1.1 references and historical background
- 1.2 land/sea distribution - coastal types
- 1.3 shoreline and deep water geological features
- 1.4 nearshore geological processes
- 1.5 surface processes - weather, winds
- 1.6 physical and chemical properties of sea water - relation to corrosion, marine fouling
- 1.7 surface currents - nearshore, open ocean
- 1.8 distribution of temperature and salinity - nearshore heat and water budgets; effects of shoreline contributions; stratification
- 1.9 water masses - formation, nearshore alteration
- 1.10 diffusion, mixing, turbulence - coastal pollutants
- 1.11 vertical distribution of properties - nearshore compared to offshore; relation to circulation
- 1.12 biological classifications, ecological concepts, marine organisms, fouling

PART 2. Analytical description and applications

- 2.1 mathematical approach to ocean problems for engineers
- 2.2 equations of continuity, hydrostatic motion - nearshore example applications
- 2.3 currents - component description in the nearshore and offshore environments
- 2.4 ocean tides - celestial background, example coastal tides, prediction, observation
- 2.5 ocean waves - importance in ocean engineering activities; formation, movement and decay, description
- 2.6 chemical and biological computations

PART 3. Coastal oceanography

- 3.1 coastal circulation - effect on property distribution
- 3.2 circulation in harbors and channels
- 3.3 coastal boundary currents - including upwelling
- 3.4 basin circulation - bays, lagoons, tidal flats
- 3.5 combined dynamics - ideal case
- 3.6 dynamics of tides in shallow seas - coastal examples
- 3.7 internal waves - importance in the nearshore environment
- 3.8 extreme wave and tidal conditions - storms, hurricanes, tsunamis, surges
- 3.9 ice-background; effect on structures

TABLE 8

COURSE OUTLINE FOR OE 651

"INSTRUMENTATION SEMINAR"

PART 1. Introduction

1.1 Course objectives
1.2 Selection of assignments

PART 2. Instructor Lectures

2.1 Desired presentation
2.2 Example using characteristic instrument
2.3 Survey of instruments
2.4 Measurement of theory and philosophy
2.5 Measurement terminology

PART 3. Student Participation

3.1 Students must research and present written paper and give oral presentation concerning any existing type of marine instrument or propose and substantiate a new instrument design.
3.2 Presentation to include comprehensive discussions on:
a) type of marine instrument - parameter measured (tides, currents, precipitation, humidity, waves, heat transfer, mixing, laboratory model, ship motion, underwater vehicles, habitats, fathometers, stress sensors, etc.)
b) sensor used - theory, applicable mathematics, precision, accuracy
c) design and construction - available equipment, costs, reliability, versatility, limitations, operation
d) type of data record - how reduced and evaluated
e) student's critical evaluation of the instrument - justify the advantages and disadvantages, make recommendations

PART 4. Instructor Lecture

4.1 Summary of presentations, needs for future instrumentation

TABLE 9

COURSE OUTLINE FOR OE 652

"NEARSHORE MARINE SURVEY TECHNIQUES"

PART 1. The Nearshore Environment, Descriptive and Analytical Background

- 1.1 Introduction
- 1.2 Environment Types - open coastline, open bays, isolated bays, coral reefs, estuarine, harbors, shorelines
- 1.3 Waves - observed range, analytical description
- 1.4 Tides - observed range, analytical description
- 1.5 Currents - observed ranged, bathymetric effects, tidal wind, baroclinic, barotrophic, transports, analytical description
- 1.6 Bottom Character - types, particle size, chemical and biological character, sand transports
- 1.7 Water Properties - observed range of 14 properties under varying conditions, turbidity and light transmittance
- 1.8 Biota - variations in the nearshore environment
- 1.9 Mixing - estuarine, isolated and open bays
- 1.10 Meteorology - observed range of wind, precipitation and runoff, heat budget, analytical descriptions
- 1.11 Typical Nearshore Problems - determining transports and rates of mixing, examining variations in water quality, specifying water resource use, determining path of pollutants, specifying pollutant stress on biota, defining thermal pollution

PART 2. Planning and Conducting a Field Program

- 2.1 Literature Reviews - methods, evaluation, usefulness
- 2.2 Establishing Field Program Objectives
- 2.3 Criteria in Planning Field Programs - costs, personnel required, time, available equipment, weather, location limitations
- 2.4 Planning Field Programs - type of data to be taken vs. intended use, spatial sampling, temporal scheduling, station selection
- 2.5 Selection of Equipment - intended use of data, insitu versus remote or occasional sampling, instrumentation per parameters examined, navigation, charts and graphics
- 2.6 Field Applications and Potential Problems - weather limitations, vessels, shipboard safety, navigation, field techniques, equipment maintenance

PART 3. Reduction and Analysis of Data, Presentation of Results

- 3.1 Data Reduction - format, multi-use concept, accessibility, computers.
- 3.2 Waves - method of analyses, usefulness of each method
- 3.3 Tides - method of analyses, usefulness of each method, time spent, presentation of results
- 3.4 Hypsographic Analyses
- 3.5 Currents - transport computations, frequent distribution, special analysis, cross correlation, regression techniques, fourier analysis

3.6 Water Quality - Effects of effluent discharges, nutrient distribution, property variation in space and time
3.7 Problems of Mixing and Dispersal
3.8 Runoff, Siltation, Turbidity and Light Transmittance Computations
3.9 Bathymetry and Character of the Bottom Data - reduction, accuracy and presentation
3.10 Biological Data - computations, presentation of data and results
3.11 Meteorology and Heat Budgets
3.12 Correlation between Data and Integration of Results
3.13 Developing Conclusions and Recommendations
3.14 Reporting Results

TABLE 10

COURSE OUTLINE FOR OE 691

ESTUARY AND COASTAL EMBAYMENT--DESCRIPTIVE,

ANALYTICAL AND MODELLING EVALUATION

Introduction

Descriptive Background

- Estuaries and coastal embayments--definition
- Classification by geology, salinity-evaporation balance, stratification, and by other characteristics
- Tides in estuaries
- Interacting physical components
- Biological characteristics
- Degradation

Analytical Background

- Physical processes--salt balance equation
- Types of estuaries--importance of terms
- Principals of circulation and mixing--analytics used, equations of motion, continuity and salt conservation
- Analysis of mixing--estimating flushing, two-layer model, tidal prism method, mixing length theory, effective horizontal diffusivity
- Quantitative treatment of circulation and mixing--estuary types (3)

Numerical Modelling of Estuaries

- Background--use, development, costs
- Theoretical considerations
  - Quantity-quality relationships
  - Advection-effective diffusion
  - Hydrodynamics of tidal motion
  - Quality considerations

- Model Representation
  - Conceptual
  - Functional
  - Analytics--equations of motion, continuity, conservation
  - Initialization
  - Solution sequence

- Simulation of Estuarial Ecosystems

- Applications

SUMMARY COMMENTS

In summary, the intent in developing an option program for nearshore environmental-ocean engineering studies within the Department of Ocean Engineering, University of Hawaii, was to help meet increasing local and national demands for ocean engineers with environmental background. These needs are apparent in both community and Pacific Basin needs and in graduate student interest. The information gathering questionnaire-survey of the former group, conducted as part of this option development, indicated that most of those responding were considerably involved with land and coastal resources use and development. Further, the survey results clearly showed an awareness in the local government, engineering, service, and science orientated communities of an increasing public environmental concern and ccrresponding increase in environmental legislation requiring compliance.

The option program developed considered primarily the capabilities of the Department of Ocean Engineering, the University requirements for matriculation at the master's level, and the community needs as indicated in the results of the survey. The secondary considerations were the availability of related marine educational support at the University and marine educational program information obtained in the literature review.

A core academic program in nearshore environmental-ocean engineering graduate studies was developed. Further, three specialized areas of emphasis were outlined. These areas were chosen to best support the present and immediate future need of the community and Pacific Basin, and because they appear to reflect the primary interest of graduate students interested in or enrolled in the program. The details given

in each specialized area of interest can be used for student counselling in combination with department and University scheduling criteria. In each case counselling must determine the individual students' background, interests, and objectives before advising a program that includes a list of suggested electives.

In general, department response to the new option program has been enthusiastic, since its initiation at the start of the fall 1974 semester. In particular, the student response is most apparent in the high enrollment (approximately 1/2 of the department students) in the four new courses. As of the spring 1974 semester, several students are enrolled in the option program. The initial graduates completing the program in nearshore-ocean engineering studies are anticipated at the completion of the 1974 spring semester.

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MacGinitie, G.E. and N. MacGinitie - Natural History of Marine Animals, McGraw-Hill Co., 1949.

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Shepard, F.P. and H.R. Wanless - Our Changing Coastlines, McGraw-Hill, 1971.

Sverdrup, H.U., M.W. Johnson and R.H. Gleming - The Oceans, Prentice-Hall Inc., 1946.

Tillett, B. - Marine Curricula at the University of Hawaii, Ocean Science Information Center, 10 pp., Jan. 1972.

APPENDICES

Appendix A

Survey Sample Questionnaire

UNIVERSITY OF HAWAII

Department of Ocean Engineering

October 25, 1972

Gentlemen:

The Department of Ocean Engineering at the University of Hawaii presently provides graduate level engineering education in a wide range of marine-oriented subjects that include: naval architecture, ocean acoustics, marine structures, and coastal and harbor engineering.

In recent years increased nationwide use of our nearshore resources has placed a new and important emphasis on examining and evaluating the environmental stress present or planned uses place on this resource. The Department of Ocean Engineering is presently developing, with the support of the marine educational resources at the University, a graduate level program that will enable ocean engineers to acquire the technical knowledge and skills applicable to solving nearshore environmental problems. The intent of this program is to provide engineers and ocean oriented technicians with the opportunity to develop a comprehensive practical background that would enable them to actively participate in responsible use of our marine resources and to help solve nearshore environmental problems.

You can considerably aid our program development by completing the enclosed questionnaire. The questionnaire was designed to help us define the areas of knowledge and skills you desire in graduate engineers. Your input will help us develop a program that is aware of and responsive to the present and future community needs.

If you wish a copy summarizing the questionnaire results and an outline of the program developed, it will be sent to you at the completion of this Sea Grant supported project. Thank you for your time and contribution.

Sincerely,

Karl H. Bathen
Associate Researcher

KHB:cs

2565 The Mall · Honolulu, Hawaii 96822 / Cable Address: UNIHAW

QUESTIONNAIRE

I. RELATING TO YOUR BACKGROUND:

1. What is your service or product -
2. What is (are) the area(s) of activity in which you relate to the marine environment -

3. What is your total number of:
   employees - engineers -
4. What is the background of your engineering/technician staff (number of employees):
   civil - industrial -
   mechanical - marine -
   electrical - other -
   chemical -
5. What is the approximate salary range of your technical staff - _____ to _____ annually.

II. RELATING TO YOUR EXISTING OR FUTURE REQUIREMENTS FOR ENVIRONMENTAL SKILLS:

1. What are the subjects of interest to your group -
   a) environmental in house studies:
      land orientated -
      ocean orientated -
      atmosphere orientated -
   b) evaluation of subcontracted environmental studies -
   c) environmental considerations applicable to:
      product design -
      monitoring production -
      monitoring processing techniques -
      evaluation of new equipment -
      evaluation of environmental monitoring equipment -

2. What are your areas of primary (p) or secondary (s) interest in which environmental skills would be most useful -

a) power generation
b) harbor engineering
c) land development
d) agricultural
e) marine transportation
f) mining
g) waste disposal (please specify: thermal, domestic, solid, agricultural, industrial, other)
h) coastal preservation
i) commercial fishing
j) marine chemicals
k) pharmaceuticals
l) recreation
m) other

III. RELATING TO YOUR REQUIRED (R) OR DESIRED (D) BACKGROUND FOR ENGINEERS:

1. The general area of application of environmental skills would be -

a) naval architecture	R	D	f) coastal engineering	R	D
b) floating platforms	R	D	g) nearshore environmental studies	R	D
c) ocean acoustics	R	D			
d) marine structures	R	D	h) other (please specify)-		
e) harbor engineering	R	D			

2. The specific background desired is -

a) mechanical engineering	R	D	i) physics	R	D
b) civil engineering	R	D	j) mathematical	R	D
c) electrical engineering	R	D	k) geological	R	D
d) industrial engineering	R	D	l) legal	R	D
e) chemical engineering	R	D	m) economic	R	D
f) other engineering (please specify) -					
g) biological - marine	R	D	n) business	R	D
other	R	D	o) fisheries	R	D
h) chemical	R	D	p) other		

3. The experience desired in new engineering employees with an environmental background is -

	Field	Business	Industrial	Other
a) 0-1 years-				
2-4 years-				
5 and greater years-				
b) military background				
c) highest degree earned				

IV. RELATING TO POTENTIAL EMPLOYMENT WITH YOUR GROUP:

1. What are your present needs (number) -
2. What do you estimate your need may be during the next 5 years -
3. Your estimate for the next _____ years would be -

V. 1. Would you like a summary of the data collected by this questionnaire?

2. Comments - (Particularly additional comments you may wish to offer pertinent to specifics of required or desired background for new employees):

APPENDIX B

Sources Contacted for Survey

Key: * Written Response (32)
** Oral Response (20)

*1. Chung Dho Ahn and Associates, Inc., 843 Fort St, Rm 404, Hono., 96813

2. Arthur Y. Akinaka, Ltd., 1339 N. School St, Rm 201, Hono., 96817

3. Y. Arakaki, 914 Ala Moana Blvd, Rm 202, Hono., 96814

*4. Austin Smith and Associates, Inc., 850 Richards St, Suite 502, Hono., 96813

**5. Belt Collins and Associates, Ltd., 745 Fort St, Hawaii Bldg, Hono., 96813

6. Community Planning, Inc., 700 Bishop St, Rm 608, Hono., 96813

**7. Dames and Moores, 2875 S. King St, Hono., 96814

8. Daniel Mann Johnson and Mendenhall of Hawaii, 210 Ward Ave, Suite 212, Hono., 96814

9. Dease Maitland C and Associates, Inc., 931 University Ave, Rm 201, Hono., 96814

10. Earth Sciences Associates, 1721 Colburn St, Hono., 96819

11. Fujinaka and Fujinaka, 1149 Bethel St, Rm 318, Hono., 96813

*12. Geolabs - Hawaii Inc., 1553 Colburn St, Suite 203, Hono., 96817

13. Harding Miller Lawson and Associates, 1259 S. Beretania St, Hono., 96814

14. Hawaii International Consultants, Inc., 843 Fort St, Rm 406, Hono., 96813

15. William Hee and Associates, Inc., 1020 Auahi St, Bldg No. 1, Hono., 96814

*16. Sam O. Hirota Inc., Amfac Bldg, Suite 707, Hono., 96813

17. William C. Hong, 1109 Bethel St, Rm 416, Hono., 96813

18. J. Brian Huges and Associates, Inc., 1670 Kalakaua Ave, Suite 605, Hono., 96814

**19. Koebig and Koebig, Inc., 700 Bishop St, Rm 902, Hono., 96813

20. George S. Kurio, 1300 Pali Hwy, Rm 208, Hono., 96813

21. Kutaka and Nishimura, Inc., 826 Kaheka St, Rm 302, Hono., 96814

22. Kutaka Portugal and Ibara, Inc., 4444 Rice St, Lihue, 96766

23. Frederick K. F. Lee, Pioneer Tower Bldg, Rm 622

24. Wa Joong Lum, 1214 Waimanu St, Hono., 96814

25. McIntire Quiros Hee and Associates, Financial Plaza of the Pacific, Suite 1801, Hono., 96813

26. A. E. Mivielle, Jr., 1651 Kapiolani Blvd, Hono., 96814

27. Munson-Nash-Futrelle and Associates, Gold Bond Building, 677 Ala Moana Blvd, Suite 510, Hono., 96813

28. Muroda and Itagaki, Inc., 1259 S. Beretania St, Hono., 96814

29. Tadaka Nakahata, 736 S. Beretania St, Rm 202, Hono., 96813

30. Park Engineering, Inc., Bethel-Puahi Bldg, 1149 Bethel St, Rm 710, Hono., 96813

31. Parsons Brinckerhoff Quade and Douglas, Inc., Amfac Bldg, Suite 712, Hono., 96813

32. Carl E. Reinhardt and Associates, Inc., 1507 Kapiolani Blvd, Rm 8, Hono., 96814

33. SIA Engineering, Inc., 70 Keaa, Hilo, Hawaii, 96720

*34. Norman M. Saito, Wailuku Townhouse Bldg, Wailuku, Maui

35. Shak Engineers, Inc., 559 Halekauwila St, Rm 206, Hono., 96813

36. Stanley S. Shimabukuro and Associates, Inc., 1126 12th Ave, Rm 309, Hono., 96816

37. Henry Sumida and Associates, Inc., 550 Halekauwila St, Hono., 96813

*38. Sunn, Low, Tom, and Hara, Inc., 1000 Bishop St, Hono., 96813

39. John B. K. Sur, 1451 S. King St, Rm 501, Hono., 96814

40. Paul T. Taniguchi, Ltd., Engineers, 1649 Kapiolani Blvd, Rm 21, Hono., 96814

41. Walter P. Thompson, Inc., 333 Queen St, Suite 400, Hono., 96813

*42. Towill Corp. - Engineers and Surveyors, 1600 Kapiolani Blvd, Hono., 96814

43. Trans-Asia Engineering Associates, Inc., 931 University Ave, Rm 209, Hono., 96814

44. Nyman Tryck and Hayes, 765 Amana St, Suite 204, Hono., 96814

*45. Tudor Engineering Co., 1136 Union Mall, Suite 702, Hono., 96813

46. Watson Lee, Inc., Bishop Insurance Bldg, 33 S. King St, Rm 512, Hono., 96813

*47. Wilson Okamoto and Associates, Inc., 1150 S. King St, Suite 800, Hono., 96814

48. Lionel L. Wong, 1019 University Ave, Rm 3, Hono., 96814

49. Harvey Wright and Wright, Bishop Insurance Bldg, Rm 415, Hono., 96813

50. Philip K. H. Yee and Associates, 243 Liliuokalani Ave, Hono., 96815

51. Charles Yoon and Associates, Inc., 1418 Kapiolani Blvd, Hono., 96814

*52. Hawaiian Telephone Company, 1177 Bishop St, Hono., 96813

53. Douglas V. MacMahon, Ltd., 931 University Ave, Rm 307, Hono., 96814

54. Robert W. Anderson and Associates, Inc., Honolulu Merchandise Mart Bldg, Rm 505, Hono., 96813

55. Henry Tuck Au, 926 Bethel St, Suite 201, Hono., 96813

56. Everett I. Brown Co., 1441 Kapiolani Blvd, Suite 907, Hono., 96814

57. Albert Chong Associates, Inc., 1040 S. King St, Suite 411, Hono., 96814

*58. Giovanni K. L. Chung, 770 Kapiolani Blvd, Rm 605, Hono., 96813

**59. Consulting Engineers Council of Hawaii, 1210 Ward Ave, Hono., 96814

60. Ferris and Hamig, Inc., 1110 University Ave, Rm 507, Hono., 96814

**61. Frederick H. Kohloss and Associates, Inc., 1259 S. Beretania St, Hono., 96814

62. Richard M. Libbey, Inc., 210 Ward Ave, Suite 222, Hono., 96814

63. T. Y. Lin Hawaii Inc., 1272 S. King St, Hono., 96814

64. Donald T. Lo, 1259 S. Beretania St, Hono., 96814

**65. Walter Lum Associates, 3030 Waialae Ave, Hono., 96816

66. John A. Martin and Associates, 320 Ward Ave, Suite 108, Hono., 96814

67. Maurseth Howe Lockwood and Associates, 94-901 Farrington Hwy, Waipahu, 96797

68. Harold T. Miyamoto, 1325 Nuuanu Ave, Rm 218, Hono., 96817

69. Nakamura, Kawabata and Associates, Inc., 1504 S. King St, Rm 407, Hono., 96814

70. Nakamura and Tyau, Inc., 1232 Waimanu St, Hono., 96814

71. Nakashima Associates Inc., 1210 Auahi St, Suite 103, Hono., 96814

72. George K. Nishimura Engineers, Inc., 826 Kaheka St, Rm 302, Hono., 96814

73. Shimazu, Shimabukuro and Fukuda, Inc., 1210 Ward Ave, Hono., 96814

*74. Donald Wolbrink and Associates, Inc., 1136 Union Mall, Hono., 96813

75. Alfred A. Yee and Associates, Inc., Ala Moana Bldg, Suite 810, Hono., 96814

76. Esco International, 1214 Waimanu St, Hono., 96814

77. Hamil and Co., 145-B Hakili St, Kailua, 96734

78. Robert Hamilton and Co., Ala Moana Bldg, Suite 819, Hono., 96814

**79. Hawaii Architects and Engineers, Inc., 195 S. King St, Rm 601, Hono., 96813

80. Hawaii International Consultants, Inc., 843 Fort St, Rm 406, Hono., 96813

**81. Holmes and Narver, Inc., 1240 Ala Moana Blvd, Suite 414, Hono., 96814

82. Peter Hsi Assoicates, Inc., 677 Ala Moana Blvd, Suite 333, Hono., 96813

83. Inaba Engineering, Inc., 273 Waianuenue Ave, Hilo, Hawaii, 96720

84. Kiyota and Associates, Inc., 770 Kapiolani Blvd, Suite 604, Hono., 96813

85. Lange and Thom, Inc., 826 Kaheka St, Rm 305, Hono., 96814

*86. Metcalf and Eddy, Inc., 1124 Fort St, Suite 201A, Hono., 96813

87. Oberhausen and Associates, Inc., 119 Merchant St, Suite 604, Hono., 96813

88. Pan Pacific Design Associates, Inc., 2849 Mokumoa St, Hono., 96819

89. Park Associates, Inc., 1507 S. King St, Hono., 96814

90. Park Wilsey and Ham, Kaiser Hawaii-Kai Shopping Center, Hono., 96825

*91. Parsons Brinckerhoff-Hirota Associates, 700 Bishop St, 7th Floor, Hono., 96813

92. Doerholm, Sorensen and Associates, Inc., 631-B Keeaumoku St, Hono., 96814

93. Harold M. Tanimura, 89 S. King St, Rm 401, Service Finance Bldg, Hono., 96813

94. Taniyama, Mitsunaga and Associates, 710 S. King St, Hono., 96813

95. William C. Vannatta, 1150 S. King St, Suite 304, Hono., 96814

*96. Alan M. Voorhees and Associates, Inc., 677 Ala Moana Blvd, Rm 603, Hono., 96813

*97. Ken R. White Co., 195 S. King St, Rm 604, Hono., 96813

98. Wilsey and Ham, 700 Bishop St, Suite 615, Hono., 96813

*99. Construction Consultants Corp., 837 Cooke St, Suite 200, Hono., 96813

100. Jack Mathews, 980 Iopono Loop, Kailua, 96734

101. Roe and McIndoe, 1650 Kanunu St, Apt 216, Hono., 96814

102. Bennett and Drane, 1507 Kapiolani Blvd, Rm 4, Hono., 96814

103. Stone L. Froberg, 1651 Mott-Smith Drive, Suite A, Hono., 96822

104. General Electric Co., I and S E Field Engineering, 440 Coral St, Hono., 96813

105. Ho and Okita Inc., 3604 Waialae Ave, Hono., 96816

106. Ward Wakefield, 827 S. Beretania St, Suite 201, Hono., 96813

*107. Kentron Hawaii Ltd., Main Office, 233 Keawe St, Hono., 96813

108. Carder Insulation Co., Inc., 2030 Homerule Rd, Hono., 96819

**109. Tetra Tech Inc., 1259 S. Beretania St, Rm 4, Hono., 96814

**110. Bechtel Corp., Financial Plaza of the Pacific, 12th Floor, Hono., 96813

111. Planning Research Corp., 677 Ala Moana Blvd, Rm 603, Hono., 96813

**112. B. P. Thibadeau Co., 311 Pacific St, Hono., 96817

113. H. D. H. Mechanical Designers Inc., 1724 Kalauokalani Way, Rm 201, Hono., 96814

114. Howard Hole and Associates, Inc., 1451 S. King St, Suite 404, Hono., 96814

115. Philip S. Wu, 436 Piikoi St, Hono., 96814

116. Air Photo Tech, Inc., 765 Amana St, Suite 204, Hono., 96814

117. Trans-Meridian Engineers and Surveyors, Inc., Amfac Bldg, Suite 404, Hono., 96813

118. Aloha Drafting Service, 44-116 Kauinohea Place, Kaneohe, 96744

119. Richard R. Bradshaw, Consulting Engineers of Hawaii, Inc., 307 Lewers St, Hono., 96815

120. Dimitrios Bratakos, 400 Bishop St, Suite 1014, Hono., 96813

121. International Consulting Company, Ltd., 850 Richard St, Suite 602, Hono., 96813

*122. Oceanic Foundation, Makapuu Point, Waimanalo, 96795

**123. Dillingham Corp., 1441 Kapiolani Blvd, Hono., 96814

*124. Ralph M. Parsons Co., 550 Paiea St, Hono., 96819

*125. Department of Public Works, Division of Sewers; City and County of Honolulu, Hono., 96813

*126. Department of Parks and Recreation; City and County of Honolulu, 1455 S. Beretania, Hono., 96814

*127. Department of Planning; City and County of Honolulu, 629 Pohukaina St, Hono., 96813

*128. Department of Transportation, Harbors Division; State of Hawaii, 400 Fort St, Hono., 96813

**129. Hawaiian Sugar Planters' Association, 1527 Keeamoku St, Hono., 96822

*130. Hawaiian Electric Company--Engineering, 820 Ward Ave, Hono., 96814

*131. GASCO, Inc., 1060 Bishop St, Hono., 96813

**132. Dole Company--Engineering, 650 Iwilei Rd, Hono., 96817

**133. Del Monte Company--Engineering, 94-100 Kunia Rd, Kunia, 96759

*134. U. S. Corps of Army Engineers, Fort Armstrong, Hono., 96813

**135. Matson Navigation Co., Marine Operations, 677 Ala Moana Blvd, Suite 1016, Hono., 96813

**136. Seatrain Lines California, Sand Island Access Road, Hono., 96819

*137. Standard Oil, 91-480 Malakole St, Ewa Beach, 96706

*138. Hydro Products, Box 2520, San Diego, California, 92112

**139. Tetra Tech, Inc., 630 N. Rosemead Blvd, Pasadena, California, 91107

**140. Continental Oil Co., 1130 17th St, NW, Suite 230, Washington, D. C., 20036

141. Ocean Science and Engineering Inc., 1601 Water St, Long Beach, California, 90802

**142. Metcalf and Eddy Inc., 1029 Corporation Way, Palo Alto, California 94303

*143. Engineering Science Inc., 150 E. Foothill Blvd, Arcadia, California, 91006

*144. Industrial Bio-Test Laboratories, Inc., 1810 Frontage Rd, Northbrook, Illinois, 60062

145. National Oceanic and Atmospheric Administration (NOAA), 1149 Bethel St, Hono., 96813

146. Department of Interior, United States Government, Bureau of Sport Fisheries and Wildlife, 337 Uluniu St, Kailua, 96734

*147. C. J. Mackenzie and Associates, P. O. Box 48, Hono., 96810

APPENDIX C

Course	Catalog Description
OE 401	Introduction to Ocean Engineering Review of man's past, present and future ocean-oriented activities with particular reference to ocean engineering. Ocean engineering environments, materials and systems. Introduction to ocean systems design process.
OE 461	Coastal and Harbor Engineering Solution of practical problems related to planning, design construction and maintenance of beaches, harbors and other coastal structures.
OE 603	Oceanography for Ocean Engineers Discussion of the physical, chemical and geological ocean environments for ocean engineers. Description of the world's oceans and dynamic processes, introduction to analytical description, circulation, waves, tides and measurements.
OE 607	Wave Dynamics Lawa governing motion of fluids; boundary conditions; free surfaces. Linear waves in basin and open water. Forced oscillations. Nonlinear waves, Stokes' theory. Waves in shallow water. Hydraulic jumps, shoaling. Effects of rotation. Analytical techniques necessary for analysis will be developed as course progresses.
OE 651	Instrumentation Seminar Student literature research followed by oral and written presentation concerning the theory of sensor, construction, operation, performance, applications, limitations, costs, and availability of individually chosen marine instruments. Student presentations supplemented by faculty and invited lecturer presentations.
OE 694	Economics of Marine Resources Application of techniques of economic analysis related to the unique problems of utilization and development of marine resources. Topics include: economics of fisheries and other uses of the seas; institutional and legal aspects of ocean use; resource management and public policies regarding rational use of marine environment; development and rate of diffusion of marine technology.
OE 652	Nearshore Marine Survey Techniques Introduction to the nearshore environment, planning and conducting field programs, reduction and analyses of data, presentation of results.

Course	Catalog Description
OE 662	Coastal and Harbor Engineering Solution of practical problems related to planning, design, construction, and maintenance of beaches, harbors and other coastal structures.
OE 683	Ocean Engineering Design Project Actual design of ocean or coastal structures or systems. Student will work as an individual or in a team. He will carry the project from the evaluation of boundary conditions through the conceptual design toward the actual engineering design of the selected structure or system.
OE 691	Special Topics in Ocean Engineering Course content will reflect special interests of visiting and permanent faculty.
Ocean 623	Chemical Oceanography Study of chemical processes occurring in marine waters with emphasis on why they occur and how they affect the oceanic environment.
Ocean 666	Nearshore Physical Oceanography Wave-driven water motions in and near the surf zone. Nonlinear and second order analysis techniques with emphasis on the "Radiation Stress" approach. Edge waves near the surf zone and on the continental shelf. Turbulent mixing and diffusion in the surf zone. Application to pollution in the nearshore environment.
Ocean 642	Sedimentology Analysis of sedimentary textures, chemical and physical properties, and sediment compositions; distribution of recent marine sediments; statistical applications to sedimentology; to be preceded by Geol-Geophysics 619 for an integrated survey of young marine sediments.
Ocean 660	Ocean Waves Ocean wave propagation; transforamtion of the wave spectrum on propagation and refraction; prediction of wind waves; application to swell, tsunamis, surf and other waves in the ocean.
Ocean 661	Tides Mechanics of particles and finite bodies; tide-generating forces; response of ocean and earth; harmonic and nonharmonic methods of analysis and prediction, geophysical implication of the tide.

Course	Catalog Description
CE 320	Fluid Mechanical Fundamentals Compressible and incompressible fluid properties; fluid statics; kinematics, energy and momentum considerations in steady flows; application of steady flow concepts to various fluid processes.
CE 411	Applied Probability and Statistics Description of sample data, probability and probability distributions; inferences from samples; testing hypotheses; experimental errors; correlation and regression; introduction to random time functions.
CE 626	Surface-Water Hydrology Quantitative studies of water cycle and relationships among principal hydrologic elements; precipitation, runoff, infiltration and evapotranspiration with emphasis on engineering and management of surface-waters.
CE 631	Water Quality Management Evaluation of major environmental factors affecting water quality including urban, industrial and agricultural activities. Engineering aspects of analysis are considered in relationship to control and management for water quality improvement.
CE 641	Marine Disposal of Wastes Types of wastes, their treatment and disposal; water quality standards; oceanographic variables and related data collection; diffusion and dispersion of effluent; ocean outfall design; ecological problems with pollutants; engineering problems outfalls.
ME 322	Fluid Mechanics I Fluid properties, statics and kinematics. Control volume approach to conservation of mass, momentum and energy. Relationship between systems and control volumes. Accelerating systems and angular momentum. Introduction to compressible flow, isentropic flow in ducts, choked flow. Dimensional analysis and similitude.
ME 323	Fluid Mechanics II Differential equations for conservation of mass and momentum. Solutions for nonviscous flow. Bernoulli flow, potential flow, stream function. Flow through nozzles and orifices, measurement techniques. Analysis by computer and analog techniques. Fluid machinery.
ME 422	Heat Transfer Steady and transient conduction. Fundamentals of radiation and convection. Heat exchangers.

Course	Catalog Description
ME 625	Numerical Methods in Fluid Mechanics and Heat Transfer Numerical integration of ordinary and partial differential equations. Methods of series truncation, integral relation, finite difference, finite element, characteristics, and Monte Carlo. Applications to incompressible and compressible flow, boundary layer theory, Navier-Stokes equations, conduction, convection, and radiation heat transfer.
ME 635	Corrosion Theory Quantitative application of electrochemical theory and materials science to corrosion and oxidation reactions. Effect of environment. Cathodic protection, coatings, inhibitors, treatment of water and stream systems.
ME 636	Materials for the Ocean Environment Application of materials science and corrosion theory to study of materials problems associated with ocean and to selection of materials of construction for this environment.
EE 422	Electronic Instrumentation Basic transducers and signal processing amplifiers for electronic control and measurements. Data acquisition and transmission circuits. Modulation and demodulation. Operational amplifiers and digital circuits in instrumentation. Interface and frequency selective circuits.
Math 371	Elementary Probability Theory Sets, discrete sample spaces, problems in combinatorial probability, conditional probability, random variables, mathematical expectations, moments, variance, study of the classical distributions (binomial, Poisson, normal, etc.), applications.
Math 402	Partial Differential Equations Integral surfaces and characteristics of first and second order partial differential equations. Applications to the equations of mathematical physics.
Math 407	Introduction to Numerical Analysis Solution to equations of one variable and systems of linear equations by iterative methods, interpolation, curve fitting, and convergence criteria for special iterations.
Math 408	Numerical Solution of Differential Equations Runge Kutta methods, finite difference methods for ordinary and partial differential equations, and convergence criteria.
Math 471	Probability Probability spaces, random variables, probability distributions, functions of random variables, mathematical expectations, moment-generating functions and characteristic functions, limit theorems.

Course	Catalog Description
Math 442	Vector Analysis Vector operatipns and their applications. Vector differential operators. Line and surface integrals. Theorems of Green and Stokes.
PH 612	Ecological Concepts and Planning Concepts of human ecology as bases for environmental management planning with emphasis on comprehensive health planning.
Bot 651	Dynamics of Marine Productivity Primary productivity, its variation and methods of assessment; conversion of energy in food chains ecosystems; factors affecting productivity.
GG 623	Marine Geology Marine geological processes and forms. For students with strong geological background; others see Ocean 622.
Micro 642	Marine Microbiology Microbial activities in sea; ecology and physiology of marine microorganisms.
ICS 466	Computer Organization and Programming Techniques Organization and machine language of typical computers. Machine language programming techniques. Introduction to operating systems. Introduction to data structures, sorting, retrieving data from files of information.
ICS 650	Time Series Analysis Filtering, prediction, spectrum estimation and transfer function estimation for stationary processes. Regression with stationary errors. Random fields and space-time processes.
ICS 655	Applied Regression Analysis Fitting a straight line by least squares, multiple regression, hypothesis testing, examination of residuals, dummy variables, step-wise regression, analysis of variance, nonlinear estimation. Computer assignments involving writing regression programs from scratch and using the regression package REGPAK.
Geog 405	Water Resources Management Hydrologic cycle including precipitation, evaporation, transpiration, infiltration, ground water and runoff, methods of collection and analysis of hydrologic data and their use in management and development of the resource system.
Geog 612	Ecological Concepts and Planning Concepts of human ecology as bases for environmental management planning with emphasis on comprehensive health planning.