The MIT/Marine Industry Collegium

OFFSHORE MINING OF SAND AND GRAVEL

Opportunity Brief No. 2

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Marine Industry Advisory Service
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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Sea Grant Program

ADMINISTRATIVE STATEMENT

In 1975 the MIT Sea Grant Program formed the MIT/Marine Industry Collegium, a working partnership between MIT Sea Grant and U.S. Industry to promote the commercial development and application of new marine technologies. In seeking to meet this objective, the Collegium acts as an information resource for industrial members, conducts meetings, workshops, and special programs, and publishes information on new ocean-related business opportunities.

The principal publications of the Collegium are Opportunity Briefs. These 15-25 page papers deal with specific business opportunities growing out of Sea Grant or other MIT sponsored marine research. Opportunity Briefs describe a new technology or process, outline economic and marketing implications, review technical requirements, and consider environmental, regulatory, and political factors. Briefs are a joint effort of subject experts, the MIT Sea Grant Marine Industry Advisory Service and Collegium members. The briefs remain anonymous to give greater freedom in the expression of opinions and in speculation about particular future opportunities.

The five Opportunity Briefs prepared during the Collegium's 1975-1976 year were:

Chitin and Chitin Derivatives

Offshore Mining of Sand and Gravel

Telemanipulators for Underwater Tasks

Advances in Underwater Welding

Untethered Robot Submersible Instrumentation Systems

Each of these Briefs was first issued to Collegium members in draft form. Following this, we held meetings to explore the topic in more depth and to discuss further directions with representatives of interested companies. The Brief in its edited form incorporates many of the comments and suggestions that we received from members through correspondence, phone conversations, and Collegium meetings.

If you would like to receive any of our other Opportunity Briefs, or wish to pursue further any of the topics covered, please contact the Marine Industry Advisory Service, MIT Sea Grant Program, Room 1-215, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139.

Dean A. Horn
Director

August 15, 1976

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1.0 A BUSINESS PERSPECTIVE

Sand and gravel are basic raw materials used in nearly all construction projects. Although available land-based reserves of sand and gravel are virtually inexhaustible on a global or national scale, regional shortages do exist and are rapidly becoming more severe and more widespread. Such regional shortages increase the delivered price of sand and gravel to the point that offshore recovery of these aggregates is becoming a financially attractive alternative to inland mining, particularly for coastal urban areas. Offshore mining of sand and gravel is already financially attractive and operational in the United Kingdom, Japan, and other countries.

The total market is very large--on the level of one to two billion dollars annually in the U.S. The fraction of the market that can profitably be obtained by sea-won resources is small today, but could grow rapidly within the next five to ten years.

Offshore recovery of sand and gravel will require large amounts of capital. The risks are also great and the uncertainties are abundant. In addition, environmental considerations presently raise severe regulatory and legal problems. However, comparable environmental problems are also associated with new landbased sources. There is evidence to suggest that offshore mining of sand and gravel may prove to be an attractive source of supply environmentally as well as economically.

No technological breakthroughs are needed to start an offshore sand and gravel mining industry, since requisite technology exists in dredging. However, detailed studies are required to ensure profitable operations at

specific, selected locations because costs and prices are site-dependent, varying strongly with local geological and market factors.

The initiation of offshore sand and gravel mining would present a broad range of new business opportunities for U.S. industries. Clearly, the greatest opportunities would exist for manufacturers of dredging equipment and mining systems, offshore mining companies, and vendors of construction aggregates. In addition, new opportunities could be expected to develop for companies providing related services and products. The rationale that suggests the advisability of offshore sand and gravel mining is summarized in Section 2 of this Opportunity Brief. The economic case is outlined in Section 3. Section 4 indicates some of the types of related products and services that will be required in order to initiate and maintain a viable offshore sand and gravel industry.

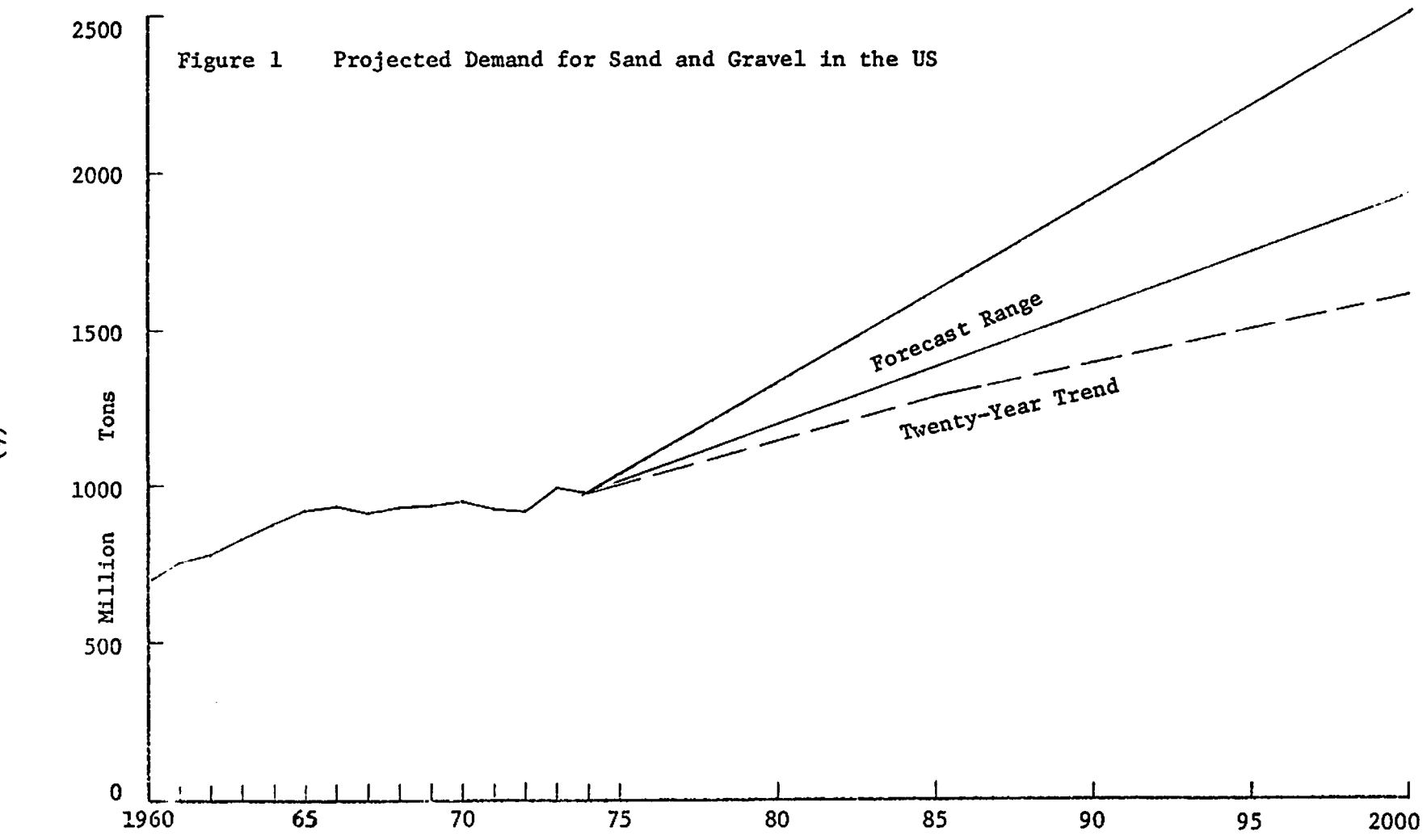
2.0 THE RATIONALE FOR OFFSHORE MINING OF SAND AND GRAVEL

2.1 The growing demand for construction aggregates. In almost any sizeable construction project, such as highways, buildings, or bridges, a principal material required is sand, gravel, or crushed stone. Supplying these construction mineral aggregates is a multibillion dollar industry. In 1972, construction projects in the U.S. consumed some 1.6 billion tons of aggregates at a value of $2.3 billion divided almost equally between sand and gravel and crushed stone (1). Although 1974 production was lower, amounting to about 900 million tons valued at $1.6 billion, forecasts by the U.S. Bureau of Mines (2,3) indicate that the demand for construction aggregates will continue to rise slowly at about 4% annually throughout this century. Although the historical data do not seem to justify such a high rate, it would nevertheless appear that the consumption of sand and gravel aggregates will at least double and may triple by the year 2000 (see Figure 1, page 4).

2.2 The restricted supply of land-based aggregates. As cities and suburbs expand, existing supplies of sand and gravel are depleted and potential supplies become inaccessible beneath highways, buildings, factories, and homes. Thus, mining operations are gradually being forced further from the market areas in which the demand is greatest, increasing the delivered cost of sand and gravel.

Because of the high bulk and low value of construction aggregates, transportation costs are a major element in determining the delivered price of sand and gravel. The industry is highly concentrated near urban centers. A study by Bronitsky (4) has shown that all of the construction aggregates

Figure 1 Projected Demand for Sand and Gravel in the US



Source: U.S. Bureau of Mines, Mineral Facts and Problems, 1975 Edition. [Advance Sheets]

used in the New York Metropolitan area come from within a 60-mile radius of the city. Thus, an extensive sand and gravel deposit in the Rocky Mountains is, for all practical purposes, inaccessible to New York City's construction industry.

Since new sources of land-based sand and gravel may not always meet the users' specifications, additional processing may be required, increasing the cost and creating environmental problems.

Increasingly strict environmental controls on land-based mining operations, coupled with increased prices, further suggest that the availability of reasonably priced construction aggregates near urban areas will continue to decrease.

Virtually all construction aggregates now used in the U.S. are mined from land-based sources, which will doubtless continue to supply the construction requirements of the interior areas of the U.S. However, for coastal urban areas, offshore sand and gravel could supplement, and perhaps eventually replace, land-based sources.

2.3 The rising price of construction aggregates. Based on the 1972 data, the production price of construction aggregates was about $1.46/ton. 1974 data show a price of about $1.70/ton. Delivered prices are higher than the average production price and show great regional variations, which arise primarily because the bulk value of the materials is low and the transportation costs are relatively high.

As local sources are depleted, new sources farther from urban centers

must be opened. Environmental factors, fuel costs, land costs and longer transportation will all tend to increase the delivered price of aggregates in urban centers.

2.4 The abundance of offshore sand and gravel. Marine deposits of sand and gravel are very large indeed. The upper ten feet of the ocean floor off the northeastern part of the U.S. has been estimated to contain about 450 billion tons of sand--a sufficient supply to meet construction needs for hundreds of years (5). Specific studies of local deposits of offshore aggregates have been done off the southeastern states (6,7,8); northeastern states (9); California (10); Hawaii (11); the New York Bight (12); and in Long Island Sound (13,14). All these studies revealed vast amounts of exploitable mineral aggregates that could be made available to coastal metropolitan centers where a very substantial amount of U.S. construction occurs.

These studies are far from complete from the viewpoint of commercial mining of sand and gravel, but they do suggest that we can look to the coastal offshore areas as a source of supply.

For the marine mining of sand and gravel, just as for land mining, the economics of distribution and transportation are of key importance. Sand and gravel, after being recovered on the open sea, must be transported to a marine terminal, unloaded, processed (washed in some cases), stored, and then reloaded on trucks for shipment to a construction site. Thus, marine based sand and gravel has a geographically limited market--one that can be defined as a few tens of miles from the seacoast.

2.5 The success of foreign sand and gravel industries. One reason for suggesting that a U.S. offshore sand and gravel industry may be viable is that in Europe, particularly England, a viable industry exists based on ocean-going hopper dredges. Figure 2 (page 8) traces the rising importance of sea-dredged aggregates in the United Kingdom. The fleet of suction hopper dredges ranges from very small vessels up to ships with hoppers of 8,800 ton capacity. The U.K. fleet is equipped with small compensators, advanced instrumentation for mining control, on-board processing facilities and self-discharging facilities. The industry is well described by Hess (15).

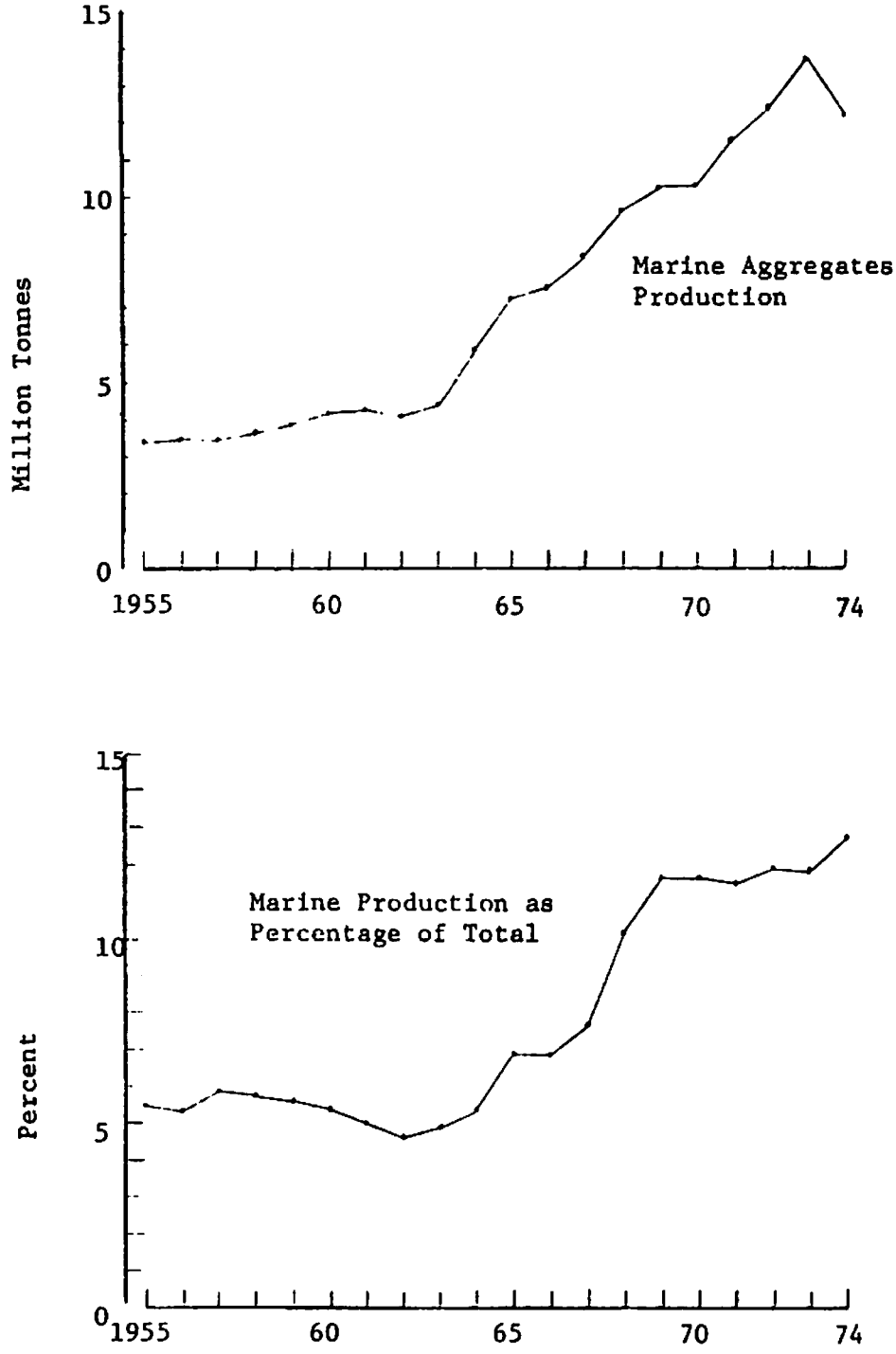


Figure 2 Marine Aggregates Production in the United Kingdom

Source: Institution of Geological Sciences. United Kingdom Mineral Statistics.

3.0 THE ECONOMIC CASE FOR OFFSHORE SAND AND GRAVEL MINING

For the U.S. to establish a viable offshore sand and gravel industry, the delivered price of the offshore product should be lower than or equal to the delivered price of the land-derived product. As a reference point, we take recent data from two coastal cities where the cost of sand and gravel is relatively high:

	Boston	Los Angeles
Sand	$4.25/ton	$4.70/ton
3/4" gravel	5.25/ton	5.65/ton

Source: Engineering News-Record, 195, No. 2 (July 10, 1975).

The variations in prices reflect differences in the costs of acquisition at the pit, processing, and transportation. The $1.00 difference in price between sand and gravel is probably attributable primarily to differences in processing costs. Thus, acquisition costs plus transportation for both sand and gravel would be about $4.25 to $4.70/ton. We take $4.50 as an average delivered price of land-based sand in high-cost areas of the U.S.

Costs and prices of offshore sand and gravel in the United States are not known precisely because the commercial activities do not yet exist. Dredged sand, gravel and fill in the U.S. are available primarily as a by-product of navigation dredging, which employs technology that is far from what would be optimum in open-sea dredging. Whereas the U.S. technology to date is primarily applicable in relatively calm, protected waters, English technology permits continuous mining in 10-12 foot seas. Because the capital equipment in the U.K. fleet can be fully utilized, sand and gravel

can be mined at a substantially lower cost.

A recent paper by Cruickshank and Hess (16) presents data (summarized in Table I, page 11) on costs, annual production and operation costs per ton for five marine sand and gravel operations in the North Sea. These data have been widely used to assess the economic viability of a U.S. industry.

While the data seem to argue that a U.S. industry should be immensely profitable, they are misleading if read without reference to the original source. First, the data are based on ships built in Europe* in the mid-1960s. The capital costs reflected in Table 1 are, therefore, extremely low.

Second, the operation costs cited in Table 1 are also clearly inapplicable to U.S. operations. For example, the crew costs used in calculating the annual operations costs are assumed to be $5,000 per year per man. Comparable average U.S. costs would be between $15-25,000 per year, depending upon the size of the ship, the operating schedule, etc.

Table 1 does indicate the relative impact of several important variables in forecasting the landed price of offshore sand and gravel. Other

*In the U.S., Federal Law (46 U.S.C. § 292) prohibits dredges of foreign ownership or manufacture from working in this country under penalty of forfeiture. While the applicability of this law to sand and gravel mining is yet to be tested, U.S.-built dredges are clearly required to establish a U.S. industry.

TABLE I

EXAMPLES OF CAPITAL INVESTMENT AND 1970 OPERATING COSTS FOR FIVE MARINE SAND AND GRAVEL MINING OPERATIONS IN THE NORTH SEA

EXAMPLE	CARGO (tons)	CAPITAL COST ($)	ROUND TRIP (miles)	ANNUAL PRODUCTION (tons)	ANNUAL OPERATING COST ($)	COST PER TON ($)
A	300	75,000	20	90,000	44,000	0.49[a]
B	500	200,000	8	191,800	78,500	0.41[b]
C	850	600,000	20	282,565	125,000	0.45[c]
D	1200	600,000	30	300,000	105,000	0.35[d]
E	2000	1,075,000	140	400,000	196,000	0.49[e]

(11)

SOURCE: Hess, 1971 (15)

[a]Converted (1948) [b]Conversion (1966) [c]New Build (1966) (Scraper Discharge)

[d]New build (1967) [e]New build (1967) (Scraper discharge)

factors that affect the cost of sand and gravel mined at an offshore location and delivered to a marine terminal include:

1. The distance from the offshore site to the marine terminal.
2. The site condition: that is, the depth at the site, the marine overburden, if any, which must be removed, and the composition required by the market. If, for example, gravel is to be extracted from a sand-gravel matrix that contains 75% sand, offshore screening of four tons of material will be required to obtain one ton of gravel.
3. The specifications of the dredging equipment: Important variables may be loading rate, unloading rate, processing capabilities on the dredge, the sailing speed, capacity of hoppers, etc.

The following representative data were provided through the courtesy of the U.S. Market Office of I.H.C. Holland, a company that has studied the economics of offshore sand and gravel mining in the U.S. in connection with their interest in the design and construction of hopper dredges.

Based on their experiences in building hopper dredges in Europe, I.H.C. estimates that it would cost (as of 1975) about $12 million to build a hopper dredge with a 3,400 ton capacity and about $22 million for an 8,500 ton capacity. The prices assume construction would be done in U.S. yards. based on these costs and on U.S. operating costs, I.H.C. provided the following summary of the impact of dredge hopper capacity and haul distance on production costs of offshore sand and gravel.

One Way Haul Distance (miles)	Dredge Hopper Capacity (short tons)	Delivered Cost of Sand and Gravel ($/short ton)
20	3400	$2.24
50	3400	2.90
20	8500	1.68
50	8500	2.10

These data are about five to ten times those indicated by Hess for the English case. The differences between Hess's data and those supplied by I.H.C. are probably attributable to:

1. Inflation in the past decade;
2. Differences between U.S. and European construction costs;
3. Differences between U.S. and British maritime wages and salaries;
4. The increased price of fuel;

Taking a representative landed price of $2.50/ton, and adding $0.50/ton for washing and processing, we calculate a total landed price of $3.00/ton, which is lower than the suggested $4.50/ton delivered price in metropolitan Boston and Los Angeles.

Assuming a delivery cost of about five cents per mile per ton, offshore derived sand and gravel might be competitive with land-based sources at a distance of about 20 to 30 miles from the marine terminal point.

4.0 RELATED BUSINESS OPPORTUNITIES

In this section, we identify several important business opportunities related to the initiation, support, and maintenance of an offshore sand and gravel industry. The nature of the related business opportunities together with the type of company that would likely provide the required services and products are listed below.

	Business Opportunities	Type of Company
A.	Market Analysis	Management Consultants, Aggregate Vendor, Shipbuilder
B.	Prospecting	Oceanographic Companies, Equipment Manufacturers, Survey Contractors
C.	Environmental Studies and Monitoring	Environmental Consultants
D.	Permits and Approvals	Management Consultants, Lawyers

4.1 Market analysis. The decision to extract aggregates from offshore is a multimillion dollar one. Careful and thorough market analysis is essential. Several such analyses (17, 18) have been performed as precursors to earlier marine mining ventures. These studies show that, based on the cost of reserves of competitive land-based materials, the northeast and southern California coastal regions offer the greatest opportunities for offshore mining ventures, at least for construction aggregates.

Each geographical market has its own characteristics. The demand for aggregates is determined largely by the extent and type of construction activities. Each market will have its own rate of consumption. For instance,

markets in California have traditionally shown higher demand than cities in the East.

For specific markets, one must identify the percentage of gravel in the sand/gravel mixture, the type of sand, the type of gravel, and the like. That is, the specifications of the sand and gravel needed must be clearly defined and related to the specifications of the sand/gravel mix available in local offshore deposits. For landfill and road base construction, such specifications may not be critical, but in aggregates for concrete mixes specifications are important. If the ratio of sand/gravel available and the sizes do not match the market specifications, the additional processing required may turn a potentially profitable operation into a losing one.

Since marine mining of aggregates would, in effect, make available a practically unlimited resource base to a geographically delimited market, a careful determination must be made as to how much the market can take without depressing prices to economically nonviable levels. Put another way, while there are real economies of scale in building hopper dredges, for example, it may not be possible or profitable to take advantage of those economies if a large dredge would supersaturate a market, thereby driving down the price. The annual capacity of a dredging system must be matched to the market size to guarantee efficient, profitable use of such a system.

4.2 Prospecting. Although earlier surveys (7,8,9,10,11,12,13,14) have already indicated the presence of offshore sand and gravel deposits, potential offshore miners will need additional detailed information before they can nominate tracts for lease sales and bid on mining rights to these tracts.

For example, the detailed composition of the sand/gravel/silt matrix must be known in advance in order to match the supply to the market need as closely as possible. Also, miners would want to avoid deposits of aggregates containing hollow shells or other refuse that could weaken concrete. There will be substantial opportunities for firms who can perform appropriate, detailed prospecting work for potential miners.

A combination of traditional and new techniques will have to be employed to determine specifically the composition of deep layers, a fact that indicates the need for new technology. For example, in "acoustical coring" (19) an "echo" from the seafloor is related to the bulk density of a geological layer and the speed of sound in that material. Thus, different layers of sand, mud, or gravel will have different echo characteristics. Computerized techniques have been developed to distinguish various materials on the basis of acoustic reflection properties (20). While these techniques are still in the experimental stage, they could prove powerful, especially in conjunction with a limited program of geological coring.

4.3 Environmental studies. Since marine mining will be carried out on government lands with government permits and approval, preparation of environmental impact statements and baseline environmental studies would be an important prelude to any marine mining operation. Because many unknowns are involved, a sound approach might be to investigate the actual environmental impact of a prototype marine mining operation. Such a program was proposed several years ago by NOAA. A New England Offshore Mining Environmental Study (NOMES) was planned but never carried out. Several current efforts are being carried out on the international scene--one in France by Centre

National Des Explorations Oceaniques (CNEXO) and one by the International Council for the Exploration of the Sea (ICES) (21). Conclusive data about the environmental impacts of these operations are still pending and a prototype operation will be needed before ongoing commercial marine mining operations can take place.

During a prototype lease operation, an entrepreneur would be required to cooperate with the government in studying and monitoring the environmental impacts of marine mining (22). After the prototype leasing stage, on-going monitoring requirements would probably be required. The key issues involved are:

1. Erosion--Hess (15) has shown that there is a lack of evidence connecting erosion with marine mining. Adequate techniques in coastal engineering now exist for analyzing and predicting whether coastal erosion will result from offshore mining.
2. Effects on bottom-dwelling organism--Marine mining can be seen as a seabed strip mining operation. Bottom-dwelling organisms are sucked up into the dredge along with sediments. This impact should be carefully examined, but since the disturbance is confined to the area mined--a relatively small portion of the total submerged land area--the overall impact may not be severe.
3. Relocation of fine sediments--Fine sediments are swept up and washed overboard during a dredging operation. Because of the buoyancy of these fine sediments and ocean currents,

a "rain of fines" occurs over a larger area than the mining site (23), creating changes in the seafloor which may cause organisms different than the original ones to repopulate the area (24). There could conceivably be severe effects on both deep ocean and bottom-dwelling organisms. Shellfish are particularly sensitive. The significance of these impacts is a controversial topic and research is needed to demonstrate their actual importance.

4. Release of Pollutants--As fine sediments descend, they may release attached pollutants, such as pesticides, sludges and heavy metals.

4.4 Permits and approvals. The authority to allow offshore mineral extraction is divided between the coastal states and the federal government. Many of the states have statutory powers to allow offshore sand and gravel extraction but have not really considered the question of how best to manage those resources. Thus, there is a lack of a coherent framework and procedure to assure potential miners that they could carry out their operations without costly shutdowns. In 1974, the Department of the Interior issued proposed regulations to govern hard minerals extraction on the Outer Continental Shelf (39, Federal Register, 4105), but these are still being revised and have not yet been finalized.

Before any mining of marine sand and gravel can take place, permits and approvals will have to be secured. Table II (page 19) provides a summary of the main permits that presently must be obtained. Within the territorial seas, the states control the submerged minerals. In some cases,

TABLE II

MAIN PERMITS AND APPROVALS REQUIRED FOR OFFSHORE SAND AND GRAVEL MINING

FUNCTIONS	STATE SUBMERGED LANDS				OUTER CONTINENTAL SHELF LANDS	
	New York		Connecticut		Federal	
	Authority	Agency	Authority	Agency	Authority	Agency
Prospecting	PLL § 3 (5)	OGS	NONE	-	43 USC §1440	USGS
Mining Lease	PLL § 3 (5)	OGS	CGSA §25-10	DEP	43 USC §1337	BLM
Mining Operations Supervision	PLL § 3 (5)	OGS	CGSA §25-10	DEP	43 USC §1334	USGS
Point Source Effluent Discharge	33 USC § 1342	DEC	33 USC § 1342	DEP	33 USC §1342	EPA
Dredged Materials Discharge	33 USC § 1344	CE	33 USC § 1344	CE	33 USC §1343	EPA
Water Quality Standards	33 USC § 1313	DEC	33 USC § 1313	DEP	None	-
Water Quality Certification	6 NYCRR § 608.16	DEC	no formal	DEP	Not Applicable	-
Navigability/Dredging Permit	33 USC § 403	CE	33 USC § 403	CE	None	-
Navigational Safety	14 USC § 2.81	CG	14 USC § 2.81	CG	None	-
Environmental Impact Statement	6 NYCRR § 615.1	Exec	CGSA §22a-1	CEPA	43 USC §4321	NEPA

OTHER REQUIREMENTS:

(1) Compatability with the States' Coastal Zone Management Program (16 USC §1456 (C) (3)).

(2) Compliance with the Occupational Health and Safety Act (29 USC §651

(19)

BLM - Bureau of Land Management, USDI
CE - U.S. Army Corps of Engineers
CEPA - Connecticut Environmental Policy Act (1973)
CG - United States Coast Guard
CGSA - Connecticut General Statutes Annotated
DEC - New York Department of Environmental Conservation
DEP - Connecticut Department of Environmental Protection
EPA - United States Environmental Protection Agency
Exec - Executive Requirement
NEPA - National Environmental Policy Act
NYCRR - New York Code of Rules and Regulations
PLL - New York Public Lands Law
USC - United States Code
USDI - United States Department of the Interior
USGS - United States Geological Survey, USDI

the jurisdiction of the states extends beyond the 3-mile limit, such as in Texas, Florida's Gulf Coast, and in Long Island Sound. As Table II shows, state controls in Long Island Sound are divided between Connecticut and New York. The complexity of the situation will require legal assistance in this process of securing appropriate permits. For a more detailed discussion of the maze of permits and approvals, see Lee and Baram (25).

5.0 SUMMARY AND CONCLUSIONS

1. Offshore mining of sand and gravel could become a viable business in the U.S. Current trends in delivered prices for land-based sources, growing environmental problems for land-based sources, adequacy and proximity of reserves offshore, and depletion of reserves on land--all point towards the future use of the offshore resource.
2. Impediments to the development and growth of an offshore sand and gravel industry are:
   a. The legal and environmental uncertainties associated with offshore mining, which will increase the financial risk of the offshore miner.
   b. A lack of offshore dredges in the U.S., which will require large capital outlays to develop an efficient fleet. The large capital requirement and the risks associated with (a) above prohibit rapid development of the new industry.
   c. Detailed geological studies are needed to locate the most desirable sources of offshore supply for each market area.
3. While the considerations in 2 a, b, and c above, may temporarily impede U.S. mining of offshore sand and gravel and make estimation of a developmental time frame difficult, they simultaneously represent a source of new business opportunities for companies with capabilities to assist in overcoming the impediments.

4. The foreign dredging technology seems adequate and appropriate for use in the U.S., but the legal requirements for U.S. construction of dredges will mean very much higher costs than in the U.K.

6.0 SEA GRANT SPONSORED RESEARCH

As noted several times, the economics of offshore mining of sand and gravel are specific to a particular geographic region. Many Sea Grant institutions have expertise in questions of sand and gravel. You may wish to contact the Sea Grant institution nearest you for further information. The following is an informal summary of the work of some of the leading institutions and their principal investigators. In some cases the schools were directly contacted; in others, their activity was revealed by normal literature search techniques.

University of California (Institute of Marine Resources, Box 1529, LaJolla, California 92037)

The Institute of Marine Resources has published the Marine Technician's Handbook on Rock Dredging in Deep Sea Areas, by F. L. Fisher and P. J. Liebertz. "An Oceanographic Inventory of the Southern California Shelf Sand and Gravel Deposits" has been prepared by Fisher and R. W. Berry.

University of Southern California (Sea Grant Program, University Park-SSW308, Los Angeles, California 90007)

T. C. Henyey and R. H. Osborn of the Department of Geological Sciences and F. K. Broward of Ocean Engineering have just completed a study of "Offshore Sand and Gravel Resources in California."

University of Georgia Sea Grant Program (110 Riverbend Rd., Athens, Georgia 30602)

R. Martin and R. G. Hicks have published "An Evaluation of Offshore Sand and Gravel Deposits as Construction or Specialty Materials" (Sea Grant Technical Report 75-3, January, 1975). R. Barksdale and J. L. Harding are currently continuing this research. John Noakes has been involved with undersea mineral sources of the Georgia Continental Shelf.

University of Hawaii Sea Grant Program (Honolulu, Hawaii 96822)

Hawaii has had an ongoing investigation covering an overall examination of, and problems associated with, practical uses and recovery of offshore sand as a general concept. Some representative works are:

Casciano, F. M. and Palmer, R. Q., Potential of Offshore Sand as an Exploitable Resource in Hawaii. Sea Grant publication 69-4.

Campbell, et. al., Reconnaissance Sand Inventory: Off Leeward Oahu, Hawaii. Sea Grant publication 70-2.

Moberly, R., et. al., Offshore and Other Sand Resources for Oahu, Hawaii. Sea Grant publication 75-03.

Massachusetts Institute of Technology Sea Grant Program (Cambridge, Massachusetts 02139)

Prof. M. S. Baram of the Department of Civil Engineering has conducted a study of the regulatory framework for mineral mining in the Coastal Zone. His assistant, W. W. Lee, completed his masters thesis on "A Technology Assessment and Environmental Analysis of Marine Minerals Extraction," and recently presented a paper at the 7th World Dredging Conference on decision-making techniques regarding submerged mineral resources. Some relevant publications include, The Evolution and Utilization of Marine Mineral Resources by H. S. Lahman and J. B. Lassiter, (MITSG 72-9); An Assay of Marine Mineral Resources in Massachusetts Bay, J. B. Lassiter, J. E. Soden, and R. Powers, (MITSG 74-26).

State University of New York - Stony Brook (New York State Sea Grant Program J-143, Marine Science Research Center, State University of New York, Stony Brook, New York 11790)

At SUNY, P. Sanko and John Schlee have written a technical monograph: "Sand and Gravel Marine Eco-systems Analysis (MESA) of the New York Bight Project." In addition, Sanko has written six volumes of geological and sediment studies of selected areas of the Atlantic and Pacific Ocean basins for the Office of Naval Research. J. Schubel has undertaken development of a management program for offshore mining of sand and gravel. The research objectives include: a determination of use and needs, and assessment of the quality and quantity of the resource and an evaluation of environmental impacts associated with a variety of mining strategies. The results are intended to assist the State of New York in the development of a management plan for the mining of sand and gravel from coastal waters.

University of Rhode Island, Marine Advisory Services (Narragansett, Rhode Island 02881)

URI has been active in the Narragansett Bay, R.I. Sound, and Georges Bank areas. S. B. Saila, a fisheries biologist, has published with S. D. Pratt and T. T. Polgar, "Dredge Spoil Disposal in Rhode Island Sound," (Sea Grant Marine Technical Report No. 2, 1972). Saila has been continuously involved with the environmental aspects of undersea mining and dredge disposal. M. J. Grant of the URI Coastal Resources Center published "Rhode Island's Ocean Sands: Management Guidelines

for Sand and Gravel Extraction in State Waters" in 1973, as Marine Technical Report No. 10. J. E. Eger of the Master of Marine Affairs Program has just completed a study entitled "The Future of Hard Mineral Mining on the New England Continental Margin." Others currently involved in related areas are Peter Cornillon of the Department of Ocean Engineering concerning sediment motion and R. L. McMaster of the School of Oceanography regarding estuarine deposits.

Texas A & M (Center for Marine Resources, College Station, Texas 77843)

Texas A & M sponsors the Center for Dredging Studies. Its director, John B. Herbich, has published a book, Coastal and Deep Ocean Dredging, designed as a text and general handbook. Dr. Herbich has also edited the various Proceedings of the Annual Dredging Seminar, and a Bibliography on Dredging. His present work centers on the design and operation of offshore sand and gravel mining. Wesley James and D. R. Basco of the Department of Civil Engineering are currently researching the environmental aspects of dredging operations. C. C. Matthewson of the Department of Geology is concerned with the location of dredge spoil islands and sedimentation budgets.

Virginia Institute of Marine Science (Gloucester Point, Virginia 23062)

VIMS has recently completed a three volume study, Shelf Sediment Off Chesapeake Bay. Volume one by M. M. Nichols is entitled "General Lithology and Composition" (VIMS Special Scientific Report 64). Volume two by G. S. Thompson and M. Nichols discusses "Grain Size and Composition" (VIMS Special Scientific Report 67). The final volume, "Heavy Minerals," is by B. K. Goodwin and J. B. Thomas (VIMS Special Scientific Report 68). The series endeavors to "expand knowledge of potential mineral resources. . .and provide a better knowledge of the economic potential of Virginia's continental shelf."

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R. P. Meyer of the Department of Geology and Geophysics has proposed an Assessment of Western Lake Michigan Sand and Gravel for 1976 Sea Grant support. Previous publications include an article by P. A. Smith, "Underwater Mining - Insight into Current U.S. Thinking," (WISSG - 72-330), and a report of the "Highlights of the Geo-Environmental and Mineral Session" (WISSG - 71-105).

7.0 ADDITIONAL READING

This section is not intended to be a comprehensive bibliography but rather a sampling of the useful literature for the reader with continuing interest in the subject.

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