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Mineral Resource Assessment of Marine Sand Resources in Cape- and Ridge-Associated Marine Sand Deposits in Three Tracts, New York and New Jersey, United States Atlantic Continental Shelf

Chapter N of

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Abstract

Demand is growing in the United States and worldwide for information about the geology of offshore continental shelf regions, the character of the seafloor, and sediments comprising the seafloor and subbottom. Interest in locating sand bodies or high quality deposits that have potential as sources for beach nourishment and ecosystem restoration is especially great in some regions of the country. The Atlantic coast, particularly New York and New Jersey, has been the focus of these studies for the past 40 years with widely varying results. This study is the first attempt at applying probability statistics to modeling Holocene-age cape- and ridge-associated sand deposits and thus focuses on distinct sand body morphology. This modeling technique may have application for other continental shelf regions that have similar geologic character and late Quaternary sea-level transgression history.

An estimated volume of 3.9 billion m^3 of marine sand resources is predicted in the cape- and ridge-associated marine sand deposits in three representative regions or tracts on the continental shelf offshore of New York and New Jersey. These estimates are taken from probabilistic distributions of sand resources and are produced using deposit models and Monte Carlo Simulation (MCS) techniques. The estimated sand resources presented here are for only three tracts as described below and for Holocene age sand resources contained in cape- and ridge-associated marine sand deposit types within this area. Other areas may qualify as tracts for this deposit type and other deposit types and geologic ages (for example, paleo-stream channels, blanket and outwash deposits, ebb-tide shoals, and lower sea level-stand deltas), which are present on the New Jersey and New York continental shelf area but are not delineated and modeled in this initial evaluation.

Admittedly, only a portion of these probable sand resources will ultimately be available and suitable for production, dependent largely on geographic, economic, preemptive use, environmental, geologic and political factors. In addition, offshore sand resources should only be considered if the area is seaward of the active zone of significant nearshore sediment transport, about 10 to 12 m in depth, and in sufficiently shallow water so that sand can be extracted within U.S. dredging equipment limits, currently about 40 m in depth. If the material is to be used for beach nourishment, material must be of an appropriate sediment texture and character (grain size, sorting, shape, and color) to match the native beach and have mineralogical properties important to its use. Extraction of sand can disturb or alter the benthic habitat and seafloor ecology, so these factors and other site-specific effects will need to be evaluated for any intended use. These and other factors are not considered in this report but can be expected to reduce the total net volume of sand resources available for production. The purpose of this report is to describe and present results from a probabilistic mineral modeling technique previously applied to onshore mineral resources. This modeling and assessment procedure is being used for the first time to assess and estimate offshore aggregate resources; this study is part of the U.S. Geological Survey (USGS) Marine Aggregates Resources and Processes Project (http://woodshole.er.usgs.gov/project-pages/aggregates/).

Introduction

Federal, state, and local coastal managers and planners have been and continue to be concerned about the availability of high quality marine sand and gravel (primarily sand) suitable to mitigate erosion and protect coastal development and infrastructure, nourish beaches, and maintain recreation areas. Colony (1932) and Stetson (1938) were among the first marine scientists who expressed an interest in the character and distribution of sediments off the continental shelves of Long Island and New Jersey. Hall (1952) expanded upon this with an early awareness of the possibility that offshore sand may be used to nourish eroded beaches and possibly construct new beaches. A number of surveys to map seafloor geology to locate and quantify the volume of sand located offshore have been completed since the 1960s. One of the earliest studies using geophysical instruments and sediment cores was made along the northern New Jersey to the western Long Island coast in an area of about 400 km^2 in the inner New York Bight just seaward of Lower New York Harbor (Williams and Duane, 1974). This was followed by a study off the Long Island south shore inner continental shelf in an area of slightly less than 1,300 km^2 (Williams, 1976). Many other studies focusing on locating and quantifying marine sand deposits have been made by the U.S. Army Corps of Engineers (Meisburger and Williams, 1980; 1982) and USGS (Schlee, 1968; Foster and others, 1999; Schwab and others, 2000; Williams and others, 2006), as well as by states and universities (Uptegrove and others, 1999). State studies were funded, in part, by the U.S. Minerals Management Service to meet their sand leasing mission (Byrnes and others, 2001, 2004). Williams and others (2003) report details on publications about U.S. marine sand and gravel resources, and Williams and others (2006) most recently present maps and descriptions of surficial sediments for the New York Bight region based on the new usSEABED sediment database (see Reid and others, 2005 for the Atlantic shelf region).

Overall, federally sponsored beach nourishment operations in the U.S. have used about 920 million m^3 of sand in the past 80 years (http://psds.wcu.edu/1038.asp) Increased and often competing demands for marine sand raise concerns about long-term potential supply and emphasize the need for quantitative assessment of sand resources. Managers need to know the volume of sand resources likely present and what limitations may exist in both near term and longer term. With prospects for higher sea level and increased storm activity in the near future due to climate change, managers have a pressing need for credible and reliable information about the costs and sustainability of adaptation methods, such as beach nourishment, which is dependent on large quantities of high quality sand within economic transport distances to beaches being considered for nourishment.

The following mineral resource assessment of cape- and ridge-associated marine sand deposits is conducted using deposit models, quantitative assessment techniques, and a Monte Carlo Simulation (MCS) program described in Bliss and others (2009). Cape- and ridge-associated marine sand deposits, two classes of seafloor bedforms, develop on storm-dominated, relatively sand-rich continental shelves. These bedforms are particularly notable along a segment of the mid-Atlantic U.S. continental shelf that extends south from the eastern end of Long Island, New York and east from Cape May, at the southern end of New Jersey (fig. l). This type of marine sand deposit typically contains high quality sand suitable to meet the requirements for nourishment of eroded beaches along the Long Island and New Jersey coasts.

Acknowledgments

We thank Dave S. Foster for providing a helpful review and suggestions from a marine-geologic perspective, and Keith R. Long from a mineral-resource-assessment and modeling perspective. Mark R. Byrnes with Applied Coastal Research and Engineering, Mashpee, Massachusetts, and Jeffrey Waters with the U.S. Army Corps of Engineers also provided valuable suggestions on paper organization and content.

Monte Carlo Simulation

The use of Monte Carlo Simulation (MCS) techniques allows a representation of the uncertainty in a natural system based on a user-defined conditional distribution of undiscovered deposits, and models previously identified. The MCS program used in this assessment is written in SYSTAT Basic® that produces a distribution that allows a probabilistic estimate of how much marine sand is present in undiscovered cape- and sand-ridge associated marine sand deposits in three tracts (fig. 1) in the New York and New Jersey continental shelf area. The conditional distribution (number of deposits) estimated for the assessment are used in the simulation using a protocol outlined by Root and others (1992) and are given in this assessment for each tract following the subjective estimate. The estimates of undiscovered deposits are based on three criteria:

1) Expert judgment from a fundamental understanding of mid-Atlantic continental shelf geology,

2) Results of numerous other assessments, most based on analysis of geophysical data and sediment cores from field surveys, such as in Meisburger and Williams (1980, 1982), Williams (1976), and Byrnes and others (2004), and,

3) The character and distribution of sand bodies on other shelf regions having similar morphology and late Quaternary geologic history.

In addition, Singer and Menzie (2005) developed an algorithm that calculates the mean, standard deviation and coefficient of variation of the distribution of estimated numbers of undiscovered deposits in each tract given below.

For this assessment, MCS was executed for 4,999 iterations, using two distribution models for cape- and ridge-associated marine sand deposits: 1) a sand-volume model, and 2) a percent-of-sand content model. Both models are described in Bliss and others (2009). On the basis of the two distribution models, together with an estimate of the number of undiscovered deposits (table 1), we made probabilistic estimates of marine sand resources in cape- and ridge-associated marine sand deposits; the assessment results are presented and described below. However, the estimates provided and the actual amount of undiscovered marine sand suitable for extraction is likely considerably less because of the environmental and economic factors as discussed in the introduction and reported by Bliss and others (2009).

Mineral Resource Assessment

Introduction

The tract boundaries in this study are defined generally by seafloor features and landforms that are consistent with the presence of cape- and sand-ridge associated marine sand deposits. Some considerations for resource boundaries are made for minimum and maximum water depth criteria set forth for a generalized depth of closure, a time-dependent estimated depth of significant cross-shore sediment transport commonly used in coastal engineering modeling, and the current general U.S. offshore water depth dredging limits, respectively. The depth of closure for the Long Island region has been reported to range from 7.3 m to 12 m in depth (Hapke and others, in press). As such, resources being considered for dredging offshore Long Island and New Jersey should be seaward of a minimum of approximately 10 m water depth and landward of a maximum of 40 m water depth (the approximate current U.S. dredge equipment water depth limit). These inshore and offshore water depth limits have been broadly considered in setting the tract boundaries (fig. 1).

Tracts

Deposits in Tract A-1, B-1, and C-1 are not included in this assessment, but rather are described by Meisburger and Williams (1980), Meisburger and Williams (1982), and Williams (1976) using non-probabilistic assessment methods. Tract A-1 has an area of 1,200 km^2 on the Cape May platform and estimated sand resource volumes of slightly more than 1,000 million m^3. Tract B-1 has an area of 1,800 km^2 of the central New Jersey shelf and estimated sand resource volumes of 170 million m^3. Tract C-1 has an area of 2,100 km^2 of the Long Island Atlantic shelf and estimated sand resource volumes of 8 billion m^3. Noteworthy for all these studies, however, is that the sand volume estimates include a wide range of deposit types and geologic ages (i.e., Holocene and Pleistocene deposits).

Table 1 includes the estimated number of undiscovered marine cape- and ridge-associated marine sand deposits (column B) at three percentage levels of certainty (column A) for Tract A-2, B-2, and C-2 (fig. 1). The estimates of undiscovered deposits in all tracts were guided by the mineral deposit density (MDD) as described in Bliss and others (2008, table 3) and tract area. Table 1 also includes the actual number of deposits given in MCS (column C) and the probability that number of deposits was selected and defined as the allocated probability (column D) for all three tracts. Because the last two estimates in Tract A-2 are both 32 deposits (50 percent chance and 10 percent chance as given in table 1, column A) only one allocated probability value (column D) is given for 32 undiscovered deposits.

Using the algorithm developed by Singer and Menzie (2005), the mean of the number of undiscovered deposits in Tract A-2 is 28 deposits with a standard deviation of 3.4 and a coefficient of variation of 12 percent for the estimated numbers of undiscovered deposits (table 1). The mean of the number of undiscovered deposits in Tract B-2 is 12 deposits with a standard deviation of 2.1 and a coefficient of variation of 18 percent for the estimated numbers of undiscovered deposits (table 1.) The mean of the number

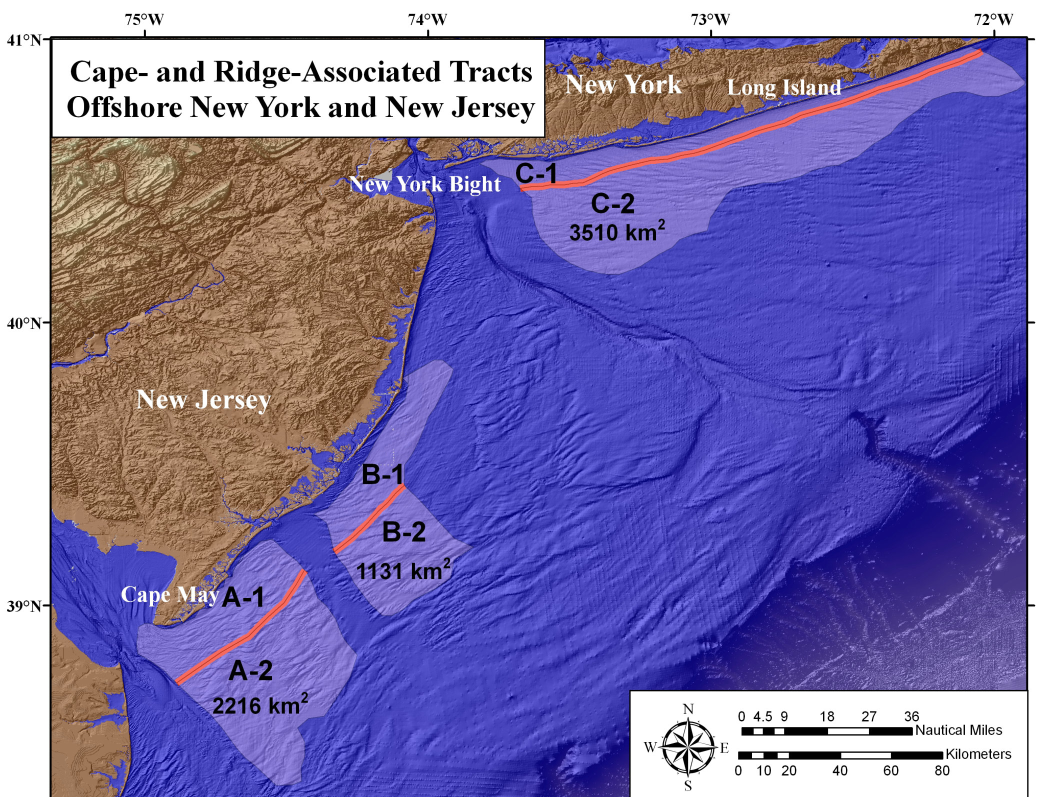

Figure 1. Location of three tracts assessed (A-2, B-2, and C-2) for cape- and ridge-associated marine sand deposits in the New York and New Jersey region, USA. Nearshore tracts (A-1, B-1, C-1), separated by the red lines from the offshore tracts assessed, are described in earlier publications (Meisburger and Williams, 1980; 1982; Williams, 1976), and are only briefly summarized in this assessment.

Table 1. Estimated numbers at three probability levels of undiscovered cape- and ridge-associated marine sand deposits in Tracts A-2, B-2, and C-2.

	A	B	C	D
Tract Number	**Level of Uncertainty**	**Estimated number of deposits**	**Number of deposits for Monte Carlo Simulation (MCS)**	**Allocated probability of deposit(s) for MCS**
A-2	Not an estimated interval	None made	0-24	0.00385 ea
	90% chance of at least	**25**	25	0.0324
	Not an estimated interval	None made	26-31	0.0571 ea
	50% chance of at least	**32**	32	0.528
	10% chance of at least	**32**	See Table footnote.	
B-2	Not an estimated **interval**	None made.	0-10	0.0087 ea
	90% chance of at least	**11**	11	0.204
	50% chance of at least	**12**	12	0.267
	Not an estimated interval	None made	13-14	0.133 ea
	10% chance of at least	**15**	15	0.167
C-2	Not an estimated interval	None made.	0-47	0.00206
	90% chance of at least	**48**	48	0.0296
	Not an estimated **interval**	None made.	49-54	0.0571 ea
	50% chance of at least	**55**	55	0.0571
	Not an estimated interval	None made.	56-61	0.0571 ea
	10% chance of at least	**62**	62	0.1286

No additional deposits are needed in MCS as the 50 percent and 10 percent chance of estimated number of deposits are the same (32) and the maximum number of undiscovered deposits is 32.

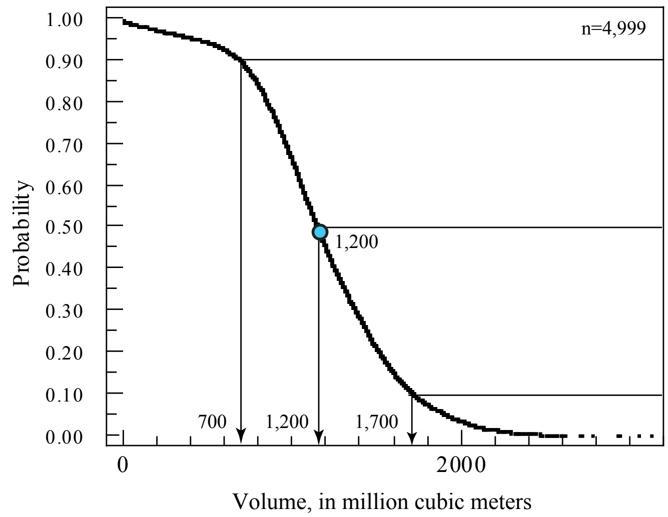

Figure 2. Cumulative distribution of marine sand predicted in undiscovered cape- and ridge-associated marine sand deposits in Tract A-2. Values of 700, 1,200 and 1,700 million m^3 for the generated distribution are given for the 90th, 50th, and 10th percentiles. The mean of the distribution (1,200 million m^3) is given at the blue point. N=4,999 is the number of MCS iterations used for figure preparation.

of undiscovered deposits in Tract C-2 is 52 deposits with a standard deviation of 7.1 and a coefficient of variation of 14 percent for the estimated numbers of undiscovered deposits (table 1). The low coefficient of variation suggests low uncertainty and no clustering of undiscovered deposits within assessment Tracts A-2, B-2, and C-2.

The MCS distribution of the sand predicted in undiscovered cape- and ridge-associated marine sand deposits in Tract A-2 are reported as a cumulative probability distribution (fig. 2). There is a 90 percent chance that Tract A-2 contains 700 million m^3 or more of marine sand, a 50 percent chance that the tract contains 1,200 million m^3 or more of marine sand, and a 10 percent chance of 1,700 million m^3 or more. The mean value of the distribution is 1,200 million m^3.

The MCS distribution of the sand predicted in undiscovered cape- and ridge-associated marine sand deposits in Tract B-2 are reported as a cumulative probability distribution (fig. 3). There is a 90 percent chance that Tract B-2 contains 230 million m^3 or more of marine sand, a 50 percent chance of 440 million m^3 or more, and 10 percent of 870 million m^3 or more. The mean value of the MCS distribution is 500 million m^3.

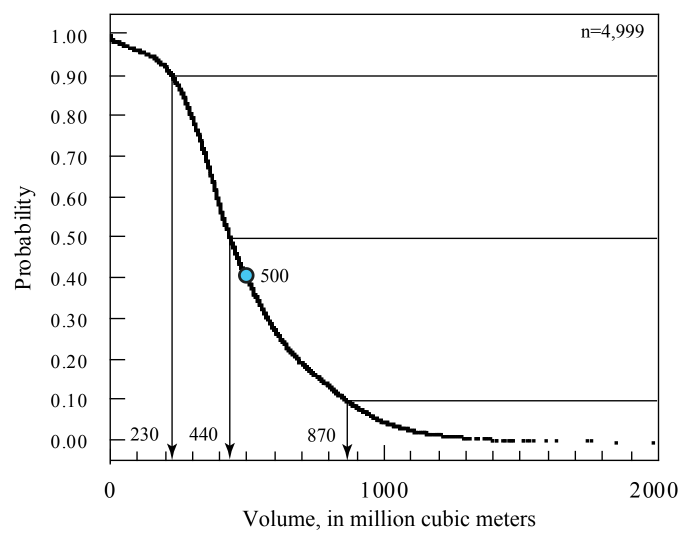

Figure 3. Cumulative distribution of marine sand predicted in undiscovered cape- and ridge-associated marine sand deposits in Tract B-2. Values of 230, 440 and 870 million m^3 for the generated distribution are given for the 90th, 50th, and 10th percentiles. The mean of the distribution (500 million m^3) is given at the blue point. N=4,999 is the number of MCS iterations used for figure preparation.

The MCS distribution of the sand predicted in undiscovered cape- and ridge-associated marine sand deposits in Tract C-2 are reported as a cumulative probability distribution (fig. 4). There is a 90 percent chance that Tract C-2 contains 1,400 million m^3 or more of marine sand, a 50 percent chance of 2,200

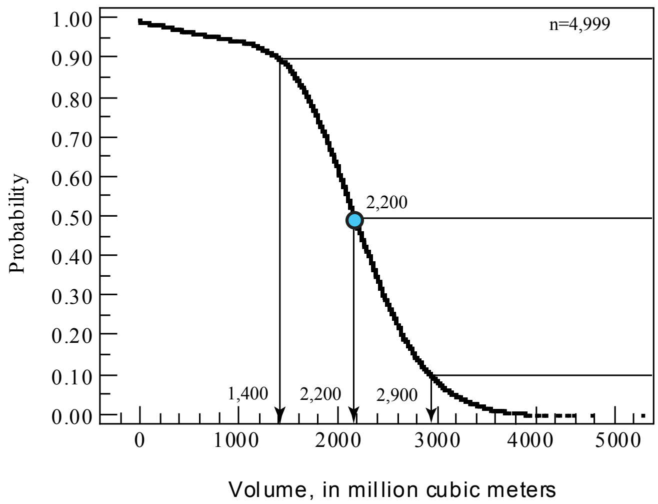

Figure 4. Cumulative distribution of marine sand predicted in undiscovered cape- and ridge-associated marine sand deposits in Tract C-2. Values of 1,400, 2,200 and 2,900 million m^3 for the generated distribution are given for the 90th, 50th, and 10th percentiles. The mean of the distribution (2,200 million m^3) is given at the blue point. N=4,999 is the number of MCS iterations used for figure preparation.

million m^3 or more, and 10 percent of 2,900 million m^3 or more. The mean value of the distribution is 2,200 million m^3.

Summary of Results

The results of the MCS modeling for cape- and ridge-associated marine sand deposits types in the three tracts are summarized in table 2. The mean value of the estimated volume for the distribution of undiscovered sand in Tracts A-2, B-2, and C-2 is 3,900 million m^3 or 3.9 billion m^3. The actual amount of undiscovered marine sand suitable for extraction is likely considerably less for reasons discussed in the introduction and discussed in Bliss and others (2009).

Mineral resource assessments are a time-dependent picture of expected mineral endowments. An assessment expresses the level of understanding about mineral deposit types and geological situations under evaluation, the quality and quantity of data available, and the accuracy and reliability of the deposit models. While this may be the first assessment of marine sand resources that gives probabilistic estimates of amounts of marine sand in cape- and ridge-associated marine sand deposits in three tracts in the New York and New Jersey continental shelf area, the assessment shows promise of yielding useful results and can be used in other regions. New and improved mineral resources assessments will be possible given additional new data, new and improved models and new and improved assessment methodologies combined with credible scientific evaluation. Assessment models for other sand body deposit types are being developed. Perhaps most importantly, modification of the assessment methodology will be required as our understanding of geologic controls and processes of marine sand deposition improves with continued data collection and research. There will be a continued demand for such marine mineral assessments to provide timely information to federal, state, and local policy makers and marine resources managers.

Table 2. Estimated sand (in million m^3) in undiscovered cape- and ridge-associated marine sand deposits in three tracts (Tract A-2, B-2, C-2) in the New York and New Jersey offshore region, USA.

	Marine Sand Resources, in million m^3			
Tract	**90th percentile**	**50th percentile**	**10th percentile**	**Mean**
A-2	700	1,200	1,700	1,200
B-2	230	440	870	500
C-2	1,400	2,200	2,900	2,200
Total	Not applicable	Not applicable	Not applicable	3,900

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