OCS Study
MMS 2001-081

Proceedings: Nineteenth Annual Gulf of Mexico Information Transfer Meeting

November 30 - December 2, 1999

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

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Prepared under MMS Contract
1435-0001-30665
by
University of New Orleans
Office of Conference Services
New Orleans, Louisiana 70814

Published by

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

New Orleans
October 2001

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CITATION

This study should be cited as:

McKay, M. and J. Nides, D. Vigil, eds. 2001. Proceedings: Nineteenth annual Gulf of Mexico information transfer meeting, December 1999. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, La. OCS Study MMS 2001-081. 530 pp.

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

LIST OF FIGURES

LIST OF FIGURES
(continued)

LIST OF FIGURES
(continued)

LIST OF FIGURES
(continued)

LIST OF FIGURES
(continued)

LIST OF TABLES

LIST OF TABLES
(continued)

ACKNOWLEDGMENTS

The Minerals Management Service thanks all ITM participants. Recognition goes to the speakers whose timely individual and panel presentations stimulated discussions and exchange of information. Authors are listed by name with their articles and again in an index at the back of this publication.

We are grateful to the chairs and co-chairs for the many hours spent in organizing and chairing the sessions and for spending time gathering presentation summaries. They are listed by name in the table of contents as well as at the beginning of each session.

The University of New Orleans, Office of Conference Services, was the contractor responsible for the meeting. The dedicated staff and subcontractors play an integral role in the execution of this meeting and the completion of the proceedings. Their tireless efforts are greatly appreciated.

The staff of the Airport Hilton were personable and accommodating to our countless requests.

INTRODUCTION

Ms. Debra L. Vigil
Environmental Sciences Section
Minerals Management Service

The primary purposes of the ITM are (1) to provide a forum for interchange on topics of current interest relative to environmental assessments in support of offshore oil and gas activities in the Gulf of Mexico OCS Region; (2) to present the accomplishments of the MMS Environmental Studies Program for the Gulf of Mexico and of other research programs or study projects; and (3) to foster an exchange of information of regional interest among scientists, staff members, and decision-makers from MMS, other Federal or State governmental agencies, regionally important industries, and academia and to encourage opportunities for these attendees to meet and nurture professional acquaintances and peer contacts.

The ITM agenda is planned and coordinated by the MMS staff of the Gulf of Mexico OCS Regional Office around the three themes mentioned above—issues of current interest to the Region or MMS oil and gas program; accomplishments of the agency; and regional information exchange. Presentations are by invitation through personal contacts between session chairpersons and speakers who have demonstrated knowledge or expertise on the subject.

The ITM is considered a meeting of regional importance and is one of the Region's primary outreach efforts. Attendance in recent years has been 250-300 people, including scientists, managers, and laypersons from government, academia, industry, environmental groups, and the general public.

Support funding is provided through the MMS Environmental Studies Program. Logistical support for the ITM is provided by a contractor and subcontractors selected through the Federal procurement process. A proceedings volume is prepared for each ITM based on summaries of brief technical papers submitted by each speaker and on each session chair's added comments.

SESSION 1A

GEOCHEMICAL ISSUES IN THE GULF OF MEXICO

Chair: Dr. Mary Boatman, Minerals Management Service
Co-Chair: Ms. Sarah Lindsey, Minerals Management Service

Date: November 30, 1999

Presentation	Author/Affiliation
A Remote Station to Monitor Gas Hydrate Outcrops in the Gulf of Mexico	Dr. Thomas M. McGee Dr. J. Robert Woolsey Center for Marine Resources and Environmental Technology University of Mississippi
Deepwater Program: Literature Review, Environmental Risks of Chemical Used in Deepwater Oil & Gas Operations	Mr. David Turton Arthur D. Little, Inc. Dr. Dan Caudle Sound Environmental Solutions
A Literature Review of Environmental Impacts of Synthetic Based Drilling Fluids: A Progress Report	Dr. J. M. Neff Battelle Ocean Sciences Mr. S. McKelvie Rudall Blanchard Associates Dr. R. C. Ayers, Jr. Robert Ayers & Associates
Gulf of Mexico Comprehensive Synthetic Based Muds Monitoring Program	Dr. James P. Ray Equilon Technology Westhollow Technology Center
Field Results of a New High-Resolution Seismic System Tested in Shallow and Deep Waters of the Gulf of Mexico	Dr. Thomas M. McGee Center for Marine Resources and Environmental Technology University of Mississippi

A REMOTE STATION TO MONITOR GAS HYDRATE OUTCROPS IN THE GULF OF MEXICO

Dr. Thomas M. McGee
Dr. J. Robert Woolsey
Center for Marine Resources and Environmental Technology
University of Mississippi

INTRODUCTION

The possibility of installing a multisensor station to monitor a gas hydrate mound on the sea floor of the northern Gulf of Mexico has been discussed for some years. During 22-26 March 1999, a workshop entitled “New Concepts in Ocean, Atmosphere and Seafloor Sensor Technologies for Gas Hydrate Investigations and Research” was held in Biloxi, Mississippi. It was sponsored by the Center for Marine Resources and Environmental Technology (CMRET) of the University of Mississippi, Oxford, and the Institute for Marine Sciences (IMS) of the University of Southern Mississippi, Ocean Springs. Participation was international and included a delegation from the Russian Academy of Sciences.

One day of the workshop was devoted to discussion sessions that addressed practical aspects of assembling and deploying a remote station to monitor the formation/dissociation of gas hydrates and slope stability in the vicinity of a known hydrate mound.

From those and subsequent discussions, a concept of a project to realize such a station was developed and a board of scientific supervisors was assembled (Appendix A). A meeting of that board with other interested parties was held on the Oxford campus of the University of Mississippi during 21-22 October 1999. Design aspects of monitoring station component systems were discussed and plans were made for field activities during the year 2000 to test component systems and begin the process of selecting a site.

BACKGROUND INFORMATION

In the Gulf of Mexico, gas hydrate mounds form along the intersections of faults with the sea floor. They are edifices constructed largely of water from the sea and hydrocarbon gases that have migrated up the faults from buried reservoirs. In addition to gas hydrates, they also contain various minerals deposited by bacteria feeding on the hydrocarbons. The mounds are ephemeral, capable of changing greatly within a matter of days. Many geoscientists familiar with recent geologic processes in the Gulf of Mexico think that events which produce changes in the hydrate mounds also trigger episodes of sea-floor instability.

Hydrates in direct contact with a relatively large volume of sea water are stable only marginally. Variations in the pressure, the distribution of temperature in the water column, the chemical composition of the gas and the rate of gas flow combine to determine whether hydrates within the mounds accumulate or dissociate. Major influences are the warm eddies of water that separate from the Loop Current and raise bottom temperatures in the northern Gulf of Mexico by as much as 2-3˚C. The result is a quasi-cyclicity of sea floor hydrate formation that is driven largely by these current-induced temperature variations of bottom waters. Changes in pressure, gas composition and flow rate that can also contribute are not well understood but probably are due partially to tectonic activity associated with salt movement.

Hydrates contained in sediments are stable when the sediments are within the hydrate stability zone (HSZ) as defined by pressure, temperature and chemical composition. If hydrocarbon gases migrating up faults encounter sediments of sufficient permeability lying within the HSZ, hydrates can form within the pore spaces and act to cement the sediment grains. This increases the sediment's shear modulus and thereby its bearing capacity. The location of the lower boundary of the HSZ is determined by the geothermal gradient. As continuing sedimentation increases their depth of burial, hydrated sediments within the HSZ are subjected to successively higher temperatures and pressures until they eventually lie below the HSZ. Then the hydrates cementing them dissociate, their bearing capacity decreases and a potential for sea floor instability is created. The same result can be produced by distortions of the geothermal gradient such as those caused by proximity to salt bodies or drilling activities. Common indicators of such instability are the speeds at which compressional (P) and shear (S) waves propagate below the sea floor and the efficiency of P-to-S conversion (PS) at reflecting horizons.

MONITORING STATION COMPONENT SYSTEMS

Vertical Line Arrays

The primary sensory system of the station will be a net of vertical line arrays (VLAs) moored to the sea floor. Each VLA will consist of a number of hydrophones spaced at selected intervals. The signal from each hydrophone will be digitized and recorded individually. The set of signals will be processed by correlation and matched field processing (MFP) techniques that make use of time and amplitude information to provide estimates of:

- the distribution of temperature in the water column (by travel-time tomography),
- speeds of P-wave propagation in sea floor sediment/hydrate (by MFP), and
- 3-D images of geological structure beneath the sea floor (by MFP).

These estimates will be used to detect changes in the sea floor due to a triggering event and to provide an image of the subbottom geological structure after an event is detected.

Acoustic transducers will be placed at fixed locations on the sea floor so that the positions of individual hydrophones can be determined by triangulation. This will allow corrections to be made during data analysis for variations in the geometry of the VLA net.

After the station has been deployed, the site will be calibrated via an acoustic model of the station's environment that uses shipboard sources fired at known locations and times. The noise of passing ships, i.e. sources of opportunity, will then be tracked and employed to monitor changes to that model on a more-or-less continuous basis. The site will be recalibrated as necessary using controlled sources.

Horizontal Seismic Array

A horizontal seismic array (HSA) of four-component (4-C) sensors will be installed on the sea floor. Each 4-C sensor will consist of a hydrophone and a three-component seismometer or accelerometer. The hydrophone components of the HSA will augment the VLAs by improving the azimuthal resolution of the VLA tracking capability. The other three components will allow the identification of S waves and measurement of their amplitudes, thereby providing subbottom information not available from P waves alone. During site calibration, S-wave speeds immediately below the sea floor will be measured by recording signals from an S-wave generator towed on the sea floor, and PS waves converted at deeper reflecting horizons will be generated by sources deployed on the sea surface. Between calibrations, the three-component instruments will monitor seismic activity and the noise of passing ships.

The complete set of HSA data will be useful for studying the evolution in time of the gas hydrate stability zone, the underlying free gas zone associated with the hydrate mound, and the configuration of pathways through which gases and liquids migrate.

Current Measurements

An acoustic doppler current profiler will be installed to monitor water flow. Data from it will also be processed to estimate suspended particulate mass. In addition, a number of three-axis acoustic current meters will be installed near the VLA net to assist in determining the VLA receiver geometry.

Gas Bubble Observations

The sound of gas bubbles seeping from the sea floor will be recorded and analyzed. Since each bubble resonates at a characteristic frequency depending on its size and shape, it may be possible to infer the rate of seepage from their sounds. The sounds will be recorded by a broadband ambient noise measuring system placed near an area of known gas emissions. The size and distribution of gas bubbles will also be monitored using transmission and reflection of sound waves from an acoustic source.

Geoelectric Systems

The electrical resistivity of sediments in the vicinity of a gas hydrate mound is expected to be elevated due to the effects of free gas, hydrates and particularly fresh pore waters and authigenic carbonates. During site calibration, a bottom-towed electromagnetic profiler will be used to determine the electrical resistivity in the upper 10-20m of sediment. After calibration, the station will incorporate a number of remote probes to monitor the resistivity profile within the upper meter of sediment. These data will indicate changes in the sea floor resistivity with time and, when combined with acoustic and geochemical data, be particularly useful for characterizing sediments near the sea floor.

Thermal Studies

Transects of heat flow measurements in the vicinity of the monitoring station will provide information about the background level of heat flow and its local variability. The interaction of temperature transients and hydrate formation/dissociation will be addressed by deploying an array of thermistors that spans a near-bottom interval from the water column into the subbottom sediments. Based on thermal conductivity/diffusivity determined by the heat probe measurements, the rate of propagation of oceanographic warming transients will provide valuable information about the dynamics of hydrate destabilization.

The subbottom thermal measurements will be accompanied by pore-fluid pressure measurements to provide information about the effects of hydrate dissociation on the physical/mechanical properties of the sediments. The effects will be described in terms of both absolute pressure (and how it changes due to a small amount of gas release) and load partitioning between sediment matrix and pore fluid during tidal cycles and meteorological events.

Optical Spectroscopy

This spectrometer uses a technique similar to that employed by the Mars Rover. An optical spectrometer will be used to identify and quantify hydrocarbon gases present in the sea water. Samples will be illuminated by laser light shining through an optic fiber and the back-scattered light collected by other optic fibers. Spectral analysis of the back-scattered light will provide information concerning the chemical composition of the gas in each sample.

Pore Water Chemistry

Pore water and sea water sampling will elucidate parameters affecting gas hydrate stability. Pore water analyses will address gases, broad based chemistry of major ions, and selective isotopic studies of pore water and solid phase substrates, including delta-13 carbon, radium and radon. These will provide ground truth for acoustic data collection and the optical spectrometer observations. They will also validate and calibrate observations pertaining to sea floor stability and ecosystem health.

Underwater Vehicles

A variety of underwater vehicles will be used at various stages of the project: deep-tow and bottom-tow devices, tethered remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs). They will carry sensors that are more effective when moved about, thus will improve spacial resolution. The locations of underwater vehicle activities will be determined in relation to the long baseline navigation system.

Towed vehicles and ROVs will be deployed from surface ships during site selection and calibration. Towed vehicles will reconnoiter areas with survey profilers. ROVs will be used to investigate specific sites and to deploy and service instruments at fixed locations. Together, they will provide close-up images of the sea floor and measurements to identify hydrate outcrops, hydrocarbon seeps and chemosynthetic communities.

The AUV will be used primarily during periods when the station is not attended by surface ships. It will be guided by genetic algorithms and other software to search designated sectors for new targets. Given appropriate development, it will operate from a docking facility near the monitoring station where data can be downloaded, instructions received, and batteries recharged. The dock will be connected by optic fiber to a site, probably an oil platform, where the images and spectral data can be transmitted ashore and instructions received. Electric power for recharging batteries will be obtained from that site.

Real-Time Interactive Video

Several video systems with pan and tilt capability will be installed for scientific, educational and public outreach purposes. Not only will the live images be useful to scientists for visual evaluation of sea floor conditions as they change in response to either experimental or natural stimuli, they will be made available to K-12 educators for use in classrooms. Students at any facility with access to the Internet will be able, on a predetermined schedule, to pan, tilt and zoom the cameras, engage different lights, and compare the images with other data and with images from other, similar systems.

Data Recovery

The station will produce many channels of data on a more-or-less continuous basis. The total data volume will be large, and its recovery is not a trivial problem. Present plans are to digitize each channel on site and transmit the digital signals via optic-fiber cable to a structure, such as an oil platform, where they can be telemetered to an onshore processing facility.

It is possible that electrical power on the sea floor and satellite data transmission facilities will be available from the Conoco Marquette platform in Green Canyon Block 52 starting in the summer of 2001. This possibility is made especially attractive by the fact that large hydrocarbon seeps and prominent hydrate outcrops exist a few miles west of the platform.

CONCLUSIONS

A project to installing a station to monitor an area of the sea floor near hydrate mounds on the continental slope of the northern Gulf of Mexico has been initiated. Design aspects have been discussed in detail by some of the world’s foremost experts in appropriate fields. There is unanimous agreement that not only is the project feasible but that most necessary components exist and already have been used in deep ocean applications. A few components still require some development, however. Tests of component systems and site selection will commence in the spring of 2000.

The monitoring station is expected to become operational by the end of 2004 and will provide, on a more-or-less continuous basis, physical and chemical information concerning sea-floor stability and the accumulation/dissociation of gas hydrates. If that information reveals factors which elicit responses from chemosynthetic communities residing nearby, the station's capabilities will be expanded to include biologic monitoring. That would allow exploration of the interactions between life forms and physical/chemical stimuli and of the ways biologic agents produce or modify geologic materials and processes.

An effort will be made to make activities and results of the monitoring station available for use in classrooms. The access will be in near-to-real time and, as much as possible, interactive.

Dr. Thomas McGee has been active in geophysics, both applied and theoretical, for forty years. He has worked at the University of Mississippi Oxford Campus for two years and serves as Associate Research Professor of Geophysics in the Center for Marine Resources and Environmental Technology. His current areas of research interest are high-resolution seismic profiling and its applications for estimating engineering properties of water-covered sediments. Dr. McGee received his B.Sc. degree in geophysical engineering from St. Louis University and his Ph.D. in geophysics from the University of Utrecht, The Netherlands. He is a registered professional engineer in British Columbia, Canada.

APPENDIX A

Board of Scientific Supervisors

Bob Woolsey (general manager and underwater vehicles)
CMRET, University of Mississippi, Oxford

Harry Roberts (geologic framework)
Coastal Studies Institute, Louisiana State University, Baton Rouge

Paul Higley (data recovery and technical advice)
Specialty Devices Inc., Plano, Texas

Ross Chapman (vertical line arrays)
School of Earth and Ocean Sciences, University of Victoria, B. C.

Ingo Pecher (horizontal seismic array)
Institute for Geophysics, University of Texas, Austin

Rob Evans (geoelectric systems)
Woods Hole Oceanographic Institute, Woods Hole

Earl Davis (thermal studies)
Geological Survey of Canada, Pacific Geoscience Centre, Sidney, B. C.

Ralph Goodman (gas bubble observations)
Applied Research Laboratory, Pennsylvania State University, University Park

Vernon Asper (current measurements and video monitoring)
IMS, University of Southern Mississippi, Ocean Springs

Jeff Chanton (pore water chemistry)
Department of Oceanography, Florida State University, Tallahassee

John Noakes (optical spectroscopy)
Center for Applied Isotope Studies, University of Georgia, Athens

Tom McGee (geophysical site surveys)
CMRET, University of Mississippi, Oxford

DEEPWATER PROGRAM: LITERATURE REVIEW, ENVIRONMENTAL RISKS OF CHEMICAL USED IN DEEPWATER OIL & GAS OPERATIONS

Mr. David Turton
Arthur D. Little, Inc.

Dr. Dan Candle
Sound Environmental Solutions

INTRODUCTION

This project includes the following tasks concerning chemical usage during petroleum exploration and production (E&P) activities within the United States waters of the Gulf of Mexico (GOM):

- A baseline chemical usage (excluding premixed drilling fluids) inventory for the Gulf of Mexico petroleum exploration and production activities
- Projection chemical usage models for the chemical classes and generic chemicals
- Chemical characteristics for the top twenty potentially significant-impact chemicals
- 16 chemical spill scenario model runs
- A hazardous substance inventory for the Gulf of Mexico petroleum exploration and production activities

INVENTORY

A literature search was conducted to identify chemical usage for offshore exploration and production in the Gulf of Mexico. The surveys prepared by Charles M. Hudgins of Petrotech Consultants, Inc. provided core information, which was updated and augmented with Gulf of Mexico specific data added from chemical inventories obtained from the MMS, literature, chemical suppliers and inventories provided by Shell, Chevron and BP-Amoco.

The inventory of chemicals is divided into 10 tables based on chemical usage:

- Non-Water Based Drilling Fluid Components (Synthetic, Mineral, Diesel)
- Water-based Drilling Fluid Components
- Well Cementing Materials
- Production Treatment Chemicals
- Waterflood Chemicals
- Gas Treating Chemicals
- Acid Stimulation Chemicals
- Gravel Packing Chemicals
- Sand Washing Chemicals
- Well Completion Chemicals

Data on chemical usage has been added to the tables for the following categories (as appropriate and available).

- Chemical Function
- Generic Chemical
- Trigger, Handling, and Storage
- Usage Rate (Volume)
- Hazardous Substance - designated as hazardous substances by Table 116.4A found in the Code of Federal Regulations 40 - Protection of Environment, part 116 - Designation of Hazardous Substances
- Aquatic Toxicity (LC50, ppm)
- Animal Toxicity (Oral LC50, ppm)
- Chemical and Physical Properties
- Subjective Environmental, Health, & Safety (EHS) Impact (1 low–5 high)
- Further Investigate (Yes / No)

The chemicals selected for further characterization were chosen using the assembled inventory and three basic criteria:

1) Volume of chemical (objective)
2) Environmental, Health and Safety Impact (subjective)
3) Experience (subjective)

Based on this criteria, we have identified 23 chemicals for further characterization and possible modeling studies (see Table 1A.1).

PROJECTION MODELS

The use of chemicals offshore is mandated by the need to solve or prevent specific problems. The amount of chemicals used is bound by the level required to do the job on the lower end and the limitations of economics on the upper end. The technology on which chemical use is based is well developed and the amount of chemicals used in any given period can be estimated from technological limits and the production data on which chemical use is based.

A baseline chemical usage inventory was run for the year 1998 using the developed projection models and data requested from Mineral Management Service (MMS). Projections based on technology proved to be the most viable based on cost and the information and insight it provided on chemical use. Chemicals used offshore fall naturally into categories based on the type of applications for which they are used. Most applications are in one of two basic categories: treating production streams and treating wells. Ultimately four models were used: one for production treating chemicals and three for well treatments.

Production treating is a well characterized business operating on a well-known set of general principles. Production rates for oil, gas and water set upper limits on chemical usage. The type of production and site specific factors further modify the amount of production treating chemicals used.

Table 1A.1. Proposed selected chemicals for further investigation.

Selected Chemicals			Deepwater	Shallow-water
Acids	1.	Hydrochloric acid	Yes	Yes
	2.	Hydrofluoric acid		
	3.	Phosphoric/Phosphorus acids		
Antifoam/Defoaming Agents	4.	Silicones	Yes	Yes
Biocides	5.	Glutaraldehyde	Yes	Yes
	6.	Quaternary compounds		
	7.	Tetrakishhydroxymethyl phosphonium sulfate (THPS)		
Cement	8.	Portland cement	Yes	Yes
Chemical Stabilizer	9.	Sodium hydroxide	Yes	Yes
	10.	Potassium chloride		
Corrosion Inhibitor	11.	Amides/Imidazolines	No	Yes
	12.	Amines & amine salts		
Fluid Loss Agents	13.	Lignite	Yes	Yes
	14.	Hydroxyethyl cellulose (HEC)		
Gas Hydrate Prevention	15.	Methanol	Yes	Yes
	16.	Ethylene glycol		
	17.	Triethylene glycol		
Oxygen Scavenger	18.	Ammonium bisulfite	Yes	Yes
Spotting Fluids	19.	Sulphonated asphalt	Yes	Yes
Thinners & Dispersants	20.	Lignosulphonates	Yes	Yes
	21.	Modified tannin (DESCO)		
Solvents/Carriers	22.	Heavy aromatic hydrocarbon	Yes	Yes
	23.	Mixed xylenes		

Finally, the jobs that the chemicals are employed to do affect the amount used. After consultation with industry members and suppliers it was decided to divide production treating chemicals up into seven subcategories based on type of production (oil or gas), water depth (<1,200' or > 1,200'), platform or subsea wells. Total production was taken from MMS data. Allocation to specific subcategories was made using industry data and MMS data. Amounts of chemical used per unit production were determined from operator data and checked against supplier experience. Amounts were calculated from this information for each specific type of chemical used to treat production streams (emulsion breakers, corrosion inhibitors, etc.)

Chemicals used on wells can be divided based on the specialized uses, each of which is provided by a set of specialized suppliers. These include drilling chemicals, cementing chemicals, stimulation, workover and completion chemicals. Projections of chemical use are naturally based on the number of wells involved, the design of the well, the activity being carried on them, and the impact of problems encountered. For example, for drilling chemicals, the number of new wells drilled in the target year, the well depths, and the problems encountered that might have caused sidetracking or stuck pipe, etc would determine the amount of chemical used. Amounts of cementing chemicals used are also determined by the number of new wells. The other subcategory is based on a mix of new wells, old wells, and site-specific problems. A further factor in projecting amounts of drilling fluid chemical used is that non-water based drilling fluid chemicals are specifically excluded from this study because they are being studied under programs.

There are representative designs for wells that reach various depths. Therefore, subcategories for projecting drilling chemicals used were based on well depth. Data on wells drilled and water depths were obtained from MMS records. Data on chemical use were obtained from operator data and confirmed in interviews with suppliers. Operators and suppliers amounts were calculated, based on MMS data, for each type on chemical used in the well chemical categories.

SPILL SCENARIO SELECTION AND MODELING

Chemicals accidentally discharged to the environment can be characterized in at least two ways:

- Where they end in the environment (fate)
- What are their potential effects (effects)

Possible fates include:

Fate A: Falling to the bottom and resting on or in the sediment layer. This includes materials that are solid, water insoluble, heavier than seawater, and non-reactive with seawater.

Fate B: Floating up to the water surface. This includes materials that are lighter than seawater, insoluble in seawater, non-reactive with seawater, and usually liquid.

Fate C: Dissolving or dispersing into the water column. This includes materials that are non-reactive with seawater, either liquid or fine solids, or those having high surface activity.

Fate D: Chemically reacting with seawater. This includes materials that rapidly react with seawater or some component of it.

Fate is further influenced by how the accidental discharge occurs. For example:

- When a container of liquid is dropped overboard does it stay intact, at least for a while?

- Does a pallet of plastic-wrapped bags drop straight to the bottom as a unit and then leak over a period of time?
- When a container splits, are the pure contents discharged immediately into the sea or is secondary containment a factor?

Potential effects include:

> *Modifications to the physical environment:* This includes changing the physical composition (grain size, hardness, density, chemical composition, etc,) of sediments or the composition of the water column (turbidity, light scattering).
>
> *Oxygen demand:* This includes materials that are biodegradable and use up oxygen as bacteria and other organisms degrade them in either the sediment or the water column.
>
> *Toxic effects:* This includes materials that interfere with the life process of living organisms.

Separation and reaction in the environment further complicate effects.

SPILL MODELING

The physical-chemical properties for the chemical or product determine the fate of the spilled material. Thus, the chemicals were categorized according to their properties to delineate modeling scenarios representative of the class of chemicals. Properties considered were physical state, solubility or miscibility, reactivity, and potential impact. Products with similar properties will behave similarly when spilled. All acids will dissociate, and the lowered pH will react with seawater after adequate dilution. Meanwhile the low pH may cause some toxicity. Thus, modeling results for one acid may be used to evaluate other acids. More complex mixtures can be separated according to miscibility with water and further on the potential effects of both the solvent and the active components of the mixture. If two organic compounds have similar physical-chemical properties, their fates and resulting concentrations (given the same size spill) will be similar. Their respective toxicities will determine the significance of the resulting concentrations.

Table 1A.2 summarizes the chemical spill scenarios proposed for modeling. A model scenario is a particular chemical product and location (i.e., at the water surface or subsurface) combination. For surface spills of soluble chemicals or those lighter than water, whether the spill site is on the shelf or over the slope is not likely to significantly affect the dispersive pattern around the spill site. Thus, these spill scenarios will be modeled at the shelf location. For releases at bottom locations the potential for use of the chemical at specific locations is accounted for. For example, the high umbilical release of alcohol and/or glycol (i.e., methanol) will be modeled as a deep-water release near the sea bottom.

Given the large number of chemical products to be addressed, as well as the large number of potential spill sites, the objective is to maximize the information that may be gleaned from the results. The number of chemicals and potential release depths that could be modeled is extensive, even with considerable categorization (Table1A.2). The discussion here focuses on the selected

Table 1A.2. Proposed chemical spill scenarios. The priority ranking was used to select the 16 scenarios to be run (H = Habitat, O = Oxygen Demand, T = Toxicity).

Scenario Chemical Product	Priority Rank	Model Scenario #	Modeling Parameter	Representative Chemical Product	Other Chemicals in Category	Model Class
Acids	4	1	H^+	13.5% HCl + 1.5% HF	Hydrochloric acid	101
Bases	4	2	OH^-	NaOH	KOH	102
Non-reactive salts	2	3	K^+	KCl	NaCl, NaBr	103
Reactive salts – solid product	1	4	Zn^{+2}	$ZnCl_2$	$CaCl_2$, $CaBr_2$	106
Reactive salts – gas product	1	5	NH_4^+	NH_4Cl		106
Insoluble solids	2	6	Solid	Barite	cement, silica, bentonite,	190
Soluble solids - toxic	2	7	Solid	DESCO	Lignosulfonate, Soltex	230, 241, 242
Soluble solids – non toxic	2	8	Solid	Lignite		230, 241, 242
Soluble pure organic liquids	3	9	Liquid	Methanol	ethylene glycol, triethylene glycol	201
Soluble pure organic liquids	3	10	Liquid	Methanol	ethylene glycol, Triethylene glycol	201
Miscible organic mixtures	4	11	Active ingredient (glutaraldehyde)	Biocides XC-102	Water clarifiers	201, 202, 252, 206
Miscible organic mixtures	4	12	Active ingredient (glutaraldehyde)	Biocides XC-102	Water clarifiers	202, 252, 206
Miscible organic mixtures - reactive	4	13	Active ingredient (THPS)	Tetrakish-hydroxymethyl-phosphonium sulfate (THPS)		201, 202, 252
Immiscible organic liquids	3-5	14	Naphtha Solvent Mix #1, Active ingredient	Corrosion inhibitors (amines, amides, etc.)	emulsion breakers, defoamers	(may include 202,206,207,220, 230,231)
Immiscible organic liquids	3-5	15	Naphtha Solvent Mix #2, Active ingredient	Corrosion inhibitors (amines, amides, etc.)	emulsion breakers, defoamers	(may include 202,206,207,220, 230,231)
Immiscible organic liquids	3-5	16	Naphtha Solvent Mix #3, Active ingredient	Corrosion inhibitors (amines, amides, etc.)	emulsion breakers, defoamers	(may include 202,206,207,220, 230,231)

Notes:

1. The naphtha solvent of scenarios 14-16 may contain alcohols and/or ketones. Representative solvent mixtures will be used. The active ingredient will be that with the highest volume usage, combined with toxicity.
2. Bottom discharges for solids are assumed to be in sacks on pallets. Bottom discharges of liquids are assumed to be in plastic or metal containers. Bottom discharge assumes that the containers reach the bottom and then break up immediately and release the material.

Table 1A.2 (continued). Proposed chemical spill scenarios. The priority ranking was used to select the 16 scenarios to be Run (H = Habitat, O = Oxygen Demand, T = Toxicity).

Scenario Chemical Product	**Solubility Behavior**	**Relevant specific gravity**	**Volatile Component**	**Biodegradable**	**Chemically Reactive**	**Particle Size (diameter)**	**Potential Impact (H/O/T)**	**Release Depth (m)**
Acids	soluble	-	no	no	yes	-	T	surface
Bases	soluble	-	no	no	yes	-	T	surface
Non-reactive salts	soluble	-	no	no	no	-	T or none	surface
Reactive salts – solid product	soluble	-	no	no	yes ($ZnCO_3$ ppt)	-	T	surface
Reactive salts – gas product	soluble	-	yes	yes (uptake)	yes (to NH_4OH)	-	T	surface
Insoluble solids	insoluble	4.3	no	no	no	~ 6 um	H	surface
Soluble solids - toxic	dissolves slowly (min.-hours)	1.5-1.7	no	yes	no	< 10 um	T,O	surface
Soluble solids – non toxic	dissolves slowly (min.-hours)	1.5-1.7	no	yes	no	< 10 um	O	bottom
Soluble pure organic liquids	soluble	-	yes	yes	no	-	O, (T)	surface
Soluble pure organic liquids	soluble	-	yes	yes	no	-	O, (T)	high umbilical
Miscible organic mixtures	soluble	-	no	yes	no	-	T	surface
Miscible organic mixtures	soluble	-	no	yes	no	-	T	bottom
Miscible organic mixtures - reactive	soluble	-	no	yes	yes, deactivates with oxygen (use decay rate)	-	T	surface
Immiscible organic liquids	insoluble	< water	yes	yes	no	-	T	surface
Immiscible organic liquids	insoluble	< water	yes	yes	no	-	T	surface
Immiscible organic liquids	insoluble	< water	yes	yes	no	-	T	bottom

Notes:

1. The naphtha solvent of scenarios 14-16 may contain alcohols and/or ketones. Representative solvent mixtures will be used. The active ingredient will be that with the highest volume usage, combined with toxicity.
2. Bottom discharges for solids are assumed to be in sacks on pallets. Bottom discharges of liquids are assumed to be in plastic or metal containers. Bottom discharge assumes that the containers reach the bottom and then break up immediately and release the material.

locations for the spill modeling and the environmental data used to characterize the potential spill sites.

The model can simulate a spill anywhere in the Gulf of Mexico, given the appropriate environmental data for the area. Oil and gas operations are along most of the shelf and slope, with the focus of the present program being the deepwater sites. However, chemical products involved with deepwater sites are transported to and from shore support facilities. Thus, the entire Gulf region could potentially be affected.

NEXT STEPS

The results of spill modeling will be used to assess impacts. We will identify potentially impacted species and assess the nature and extent of such impacts. This work is just getting underway and will need the results of spill modeling before it can be completed. In addition to the spill modeling, work that is currently in progress includes:

- Conducting the needed research to identify, compile and write chemical profiles, including eco-toxicological thresholds and chemical properties
- Identifying Gulf of Mexico biological communities that may be potentially at risk from chemical products used in drilling operations include, soft-bottom benthic, pelagic, marine mammals, chemosynthetic, biogenically-structured, hard-bottom biologically-structured, National Marine Sanctuaries, National Estuarine Research Reserves.
- Identifying for each the biological resources and chemical pairing that will be evaluated in the Risk Assessment, the appropriate eco-toxicological threshold values

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A LITERATURE REVIEW OF ENVIRONMENTAL IMPACTS OF SYNTHETIC BASED DRILLING FLUIDS: A PROGRESS REPORT

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INTRODUCTION

Synthetic Based Drilling Fluids (SBFs) are a relatively new class of drilling fluids that are particularly useful for deepwater drilling. While the technical and economic benefits of using these fluids in the deepwater Gulf of Mexico are clear, the environmental impacts of drilling wastes associated with these fluids are less well understood.

The US Minerals Management Service has the responsibility of seeing that the deepwater reserves are developed with a minimum of environmental impact and therefore has a special interest in these fluids. As a result, MMS has commissioned this review of existing data on the environmental effects associated with discharges of SBF cuttings to the ocean. This review will include information published in the scientific literature as well as reports done for individual companies, industry associations, and government agencies. The available information will be incorporated into a risk assessment framework for use by the MMS. An annotated bibliography will also be provided.

BACKGROUND

Drilling fluids or drilling “muds” are an essential part of the drilling operation. Drilling muds provide a means for removing cuttings from the wellbore, maintain a positive pressure in the wellbore to prevent formation fluids from entering the annulus, and cool and lubricate the drill bit.

There are two basic types of drilling fluids, water based fluids (WBFs) and non-aqueous based fluids (NABFs). WBFs, used in most drilling situations, consist of water, barite, clay, caustic soda, lignite, lignosulfonates and/or water-soluble polymers. A detailed discussion of the drilling process and WBF composition is given in National Research Council, 1983.

NABFs are water internal emulsions. They are more expensive than WBFs and are used only in difficult drilling situations. High formation temperatures, highly unstable hydratable shale formations, and extended reach, high angle wells may require the use of NABFs. NABFs contain a non-aqueous base fluid that forms the continuous external phase of the emulsion and barite, clays, emulsifiers, water, calcium chloride, lignite and lime.

NABFs fall into three categories as defined by the base fluid that is used in the emulsion (U. S. EPA 1996). These are oil based fluids (OBFs), enhanced mineral oil based fluids (EMOBFs) and synthetic based fluids (SBFs).

OBFs have diesel or conventional mineral oil as the continuous phase. They are the least expensive NAF and were the only NAF in use until the last few years.

EMOBFs use an enhanced mineral oil as the continuous phase. Enhanced mineral oils are distinguished from conventional mineral oils by their low polycyclic aromatic hydrocarbon content.

SBFs use a synthetic material as the continuous phase. A "synthetic material" or "synthetic," means a material produced by the reaction of specific purified chemical feedstock, as opposed to materials derived from crude oil solely through physical separation processes such as diesel and mineral oils. Synthetics are typically free of polycyclic aromatic hydrocarbons.

U.S. regulations permit WBFs and the associated cuttings to be discharged in federal offshore waters, provided certain limitations are met. On the other hand, discharge of OBFs and the associated cuttings are prohibited in U.S. offshore waters. The used OBFs are taken ashore for treatment and eventual reuse while the cuttings are taken ashore to a disposal site. In some situations when drilling occurs from a fixed platform, the cuttings may be disposed of on site through injection down the annulus of an existing well or into a disposal well. While this procedure may be less expensive than onshore disposal, injection is much more expensive than discharge to the ocean. Furthermore, on-site disposal of cuttings by injection is not practical from a floating rig in deep water.

Constraints on the discharge of OBF cuttings directly to the sea greatly increases well costs. The need to drill increasingly difficult wells coupled with the desire to discharge cuttings spawned the development of SBFs. Synthetics are designed to (1) be less toxic and degrade faster than conventional mineral oils and diesels, and (2) yield mud systems similar to OBFs in drilling performance (Friedheim and Conn 1996).

SBFs can greatly enhance drilling performance over WBFs in difficult wells. Burke and Veil (1995) present case studies showing costs of wells drilled with SBFs to comparable wells drilled with WBFs. Drilling times were reduced by 50 – 60%, and well costs were generally cut in half. In addition, the total quantity of waste discharged was considerably less, primarily because when SBFs are used only cuttings are discharged. In the case of WBFs, both fluid and cuttings are discharged.

Relative to WBFs, SBFs reduce the total quantity of waste discharged to the sea. However, this environmental advantage is counterbalanced by the greater impact synthetics cause at the seafloor. The technical literature clearly documents that WBMs and the associated cuttings cause little or no adverse biological impact in the water column or at the seafloor (National Research Council 1983). Other studies, primarily conducted in the North Sea, show that in many cases, cuttings from OBMs can cause measurable adverse biological effects at the seafloor that may persist for years (Davies 1989). North Sea study results to date indicate that SBFs may cause seafloor impacts similar to those caused by OBFs. However, for some of the SBFs, impacts may be less severe and of shorter duration than those from OBFs. Also, differences between the North Sea and Gulf of Mexico (e.g. SBF usage rates per well are less in the Gulf, different bottom sediment types in the Gulf) may cause seafloor impacts to be less severe in the Gulf than in the North Sea.

NATURE OF SYNTHETICS

Synthetics may be classified into four general categories:

- Synthetic hydrocarbons
- Esters
- Acetals
- Ethers

SYNTHETIC HYDROCARBONS

The most common synthetic hydrocarbons used in SBMs are olefins. These consist of Linear Alpha Olefins (LAOs), Poly Alpha Olefins (PAOs), and Internal Olefins (IOs). LAOs are produced by the polymerization of ethylene. LAOs range from C_8H_{16} to $C_{20}H_{40}$ and have a double bond in the alpha position. PAOs are formed by the polymerization of appropriate LAOs to yield a mixture of larger branched olefins with a double bond between two internal carbon atoms. IOs are formed by isomerization of LAOs to shift the double bond from the alpha position to a position between two internal carbon atoms. In today's market, LAOs and IOs are generally preferred over PAOs. LAOs and IOs are normally used in blends, designed to achieve a balance between physical properties important to the drilling operation (e.g. viscosity, pour point, flash point, etc.).

ESTERS

Esters are formed by the reaction of an organic acid with an alcohol. An example of such a synthetic material used in SBMs might be a mixture of C_8-C_{14} fatty acid esters of 2-ethylhexanol. In addition, esters may be used in combination with a synthetic hydrocarbon in an SBM to attain some particular drilling performance characteristic. Esters are relatively stable under neutral conditions but may undergo hydrolysis and revert back to the acid and alcohol under basic or acidic conditions.

Acetals

Acetals are formed by the acid catalyzed reaction of an aldehyde with an alcohol (one mole of aldehyde and two moles of alcohol). Acetals are relatively stable under neutral and basic conditions but may revert back to the aldehyde and alcohol under acidic conditions.

Ethers

Ethers are formed by the condensation reaction of an alcohol to yield a saturated hydrocarbon with an oxygen atom in the center. Ethers are more stable both chemically and biologically than esters or acetals

COMPARISON OF SYNTHETIC TYPES

Olefins and esters have been used the most in recent years. The olefins are more stable at high downhole temperatures, are less viscous at low temperature, and are more adaptable to deep water drilling environments. Olefins usually are preferred if only drilling properties are considered. However, esters tend to biodegrade more rapidly than olefins in marine sediments. Esters are still being used in SBFs, either alone or as olefin-ester blends

FATES OF SBFS IN THE OCEAN

Several field studies, most of them in the North Sea, have been performed concerning the environmental fate of SBFs associated with SBF cuttings discharges to the ocean. SBF cuttings tend to form clumps when discharged and sink rapidly to the sea floor. Large cuttings piles have been observed near discharges to the North Sea but not in the Gulf of Mexico. SBFs have unique GC-FID signatures that can be used to quantify their concentrations in sediments. Usually, there is a gradient of decreasing SBF with distance from a discharge. Highest concentrations, usually observed within about 75 m of the discharge, may reach 175,000 mg/kg (ppm) initially. Background concentrations usually are reached in 300 to 1,000 m of the discharge.

In most monitoring surveys, SBF concentrations in sediments decline with time after cessation of discharge. The rate of decline of esters is most rapid. Olefin concentrations decline more slowly, with LAOs and IOs degrading faster than PAOs. Usually, a substantial decline in the concentrations of SBFs in sediments near the discharge can be documented within one to two years of cessation of cuttings discharges. In some cases in the North Sea and Gulf of Mexico, SBF concentrations in sediments near the discharge actually seemed to increase with time after cessation of discharge. This probably reflects the extremely heterogeneous distribution of SBF deposits on the sea floor and the difficulty of exactly reoccupying the same sampling locations on different surveys.

BIODEGRADATION OF SBFS

Declines with time in the concentrations of SBFs in sediments are caused by a combination of resuspension/dispersion/dilution and biodegradation. SBFs may be dispersed and diluted by storm- or current-induced sediment resuspension and bed transport. They also are subject to biodegradation by indigenous sediment microbiota. Biodegradation probably is the main mechanism of SBF decline in deep-water sediments. In sediments 25 m from an ester-SBF cuttings discharge to the North Sea, ester concentrations in sediments declined from 1,000-8,400 mg/kg to 0-1,900 mg/kg one year later (Daan *et al.* 1996).

Several tests have been developed to measure the rate of SBF degradation under aerobic and anaerobic conditions. Results of different tests vary widely. However, in general, esters are degraded most rapidly, followed by LAOs and then IOs. Ethers and PAOs are degraded more slowly, at a rate roughly similar to the degradation rate of low toxicity mineral oils used in some OBFs. Degradation rate decreases with increasing SBF concentration. Degradation rate of all SBFs is slower under anaerobic than under aerobic conditions.

TOXICITY OF SBFS

SBFs are practically non-toxic to standard water-column toxicity test organisms, such as mysids and copepods. Median lethal concentrations nearly always are greater than 150,000 mg/L. Sediment-dwelling marine animals may be more sensitive, possibly reflecting a sensitivity to sediment hypoxia caused by SBF degradation. The relative toxicity of olefin SBFs to bivalve mollusk embryos and amphipods is, from most to least toxic, LAOs, IOs, and PAOs. Esters generally are less toxic than olefins. However, laboratory and field studies indicate that most (if not all) of the adverse effects of SBF in sediments are caused by sediment anoxia resulting from SBF biodegradation.

BIOLOGICAL EFFECTS OF SBFS

There have been several field studies of the effects of SBF discharges to the ocean on benthic communities. The benthic environment around a discharge of 441 bbl of cuttings and 354 bbl of PAO drilling fluid to the western Gulf of Mexico was monitored for three years after completion of the discharge (Candler *et al.* 1995). Elevated concentrations of PAO and barite were detected in sediments near the platform on all three surveys. Two years after cessation of the discharge (survey 3), benthic communities within 50 m of the discharge point were still adversely affected by the accumulation of SBF in sediments. The effects were greater than those usually observed after discharge of a similar volume of WBF. However, the benthic biological effects were much less severe than those usually observed in the North Sea after discharge of OBF cuttings.

The benthos was sampled before and at 1, 4, and 11 months after discharge of ester SBF cuttings to shallow waters of the Dutch sector of the North Sea (Daan *et al.* 1996). On each survey, ester concentrations and macrofaunal densities were estimated in sediments at 75 m to 3,000 m from the discharge. At one and four months after discharge, ester concentrations in surficial sediments were as high as 4,700 mg/kg; after 11 months, concentrations as high as 250 mg/kg were detected within 200 m of the discharge. Adverse effects on the benthic marcofaunal community were observed out to 1,000 m from the discharge at 1 and 4 months after completion of the discharge. After 11 months, effects could still be detected at 75 m and 200 m but not further from the discharge. Substantial recovery of the benthic community was observed within a year of completion of the discharge.

Following discharge of SBF cuttings (mostly mixed olefins) in 565 m of water off the Mississippi Delta, surface sediments near the template had a thin veneer of cuttings (Gallaway *et al.* 1997). Deepest cuttings accumulations were 20-25 cm deep. ROV observations indicated evidence of biological activity, possibly including SBF biodegradation, near the template. Sediments collected within 50-75 m of the discharge contained up to 165,000 mg/kg SBF shortly after the discharge. However, the distribution of SBF in sediments was very patchy. There were high densities of benthic macrofauna in sediments near the platform site, possibly related to organic enrichment from the SBF. There was no strong evidence of adverse effects on the benthic macrofauna due to SBF accumulation on the bottom.

Ester SBFs were used to drill wells in the Bass Strait off southeastern Australia (Terrens *et al.* 1998). Ester concentration increased rapidly in sediments during drilling, and then declined rapidly after completion of drilling. Eleven months after completion of drilling, ester could not be detected in sediments. Effects on benthic communities were restricted to within 100 m of the discharge and recovery was evident within four months after completion of drilling. The minimal effects of SBF cuttings on the benthos of the Bass Strait was attributed to rapid biodegradation of esters and the high-energy, dispersive environment of the Bass Strait.

These and other similar studies show that impacts of SBF cuttings discharges to the ocean are restricted to the benthos. The effects are intermediate between those of WBF and OBF. Impacts of SBFs on benthic communities probably are due primarily or exclusively to the development of anoxia in surficial sediments due to microbial degradation of the synthetic fluid. Ecosystem recovery appears to be rapid and seems to begin before the synthetic is degraded or dispersed completely.

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Dr. Robert Ayers became an environmental consultant in 1992 after retiring from Exxon Production Research Company with 30 years of service. His research interests are fate and effects of drilling and production discharges in the marine environment. He is a past member of the Department of the Interior's OCS Advisory Board Scientific Committee and served as a panel member on the National Research Council study of Drilling Discharges in the Marine Environment. He has also served on several industry committees concerned with environmental and regulatory issues. He holds a Ph.D. in physical chemistry and a B.S. in chemical engineering, both from the University of Texas at Austin.

GULF OF MEXICO COMPREHENSIVE SYNTHETIC BASED MUDS MONITORING PROGRAM

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The Environmental Protection Agency (EPA) is moving ahead with proposed effluent guidelines that will allow the discharge of cuttings containing Synthetic-Based (SBM) and other Non-Aqueous Drilling Fluids with the publication of the proposed rule in the Federal Register on 3 February 1999. EPA intends to have the final guidelines published by December, 2000, using the presumptive rulemaking process to expedite the promulgation. EPA Region 6 published in the Federal Register on 19 April 1999 proposed changes to the National Pollutant Discharge Elimination System (NPDES) general permit for oil and gas activities on the western portion of the OCS. The proposed modification will allow the discharge of cuttings containing SBF.

Information about the effects of SBMs on the seafloor communities is limited. As part of the NEPA process, MMS will need to include in Environmental Assessments, and perhaps Environmental Impact Statements, an evaluation of the degree and extent of effects from the discharge of the cuttings. In particular, the MMS GOMR region has mitigations requiring that drilling does not occur close to sensitive communities such as chemosynthetic communities. The zone of impact specified for discharge of cuttings containing SBMs will depend on evaluations of the extent of impact.

Over the past few years, the industries synthetic based mud (SBM) activities have been a combined effort of the National Ocean Industries Association (NOIA), American Petroleum Institute (API), Petroleum Equipment Suppliers Association (PESA), and Offshore Operators Committee (OOC). This past year, when it was identified that there were numerous technical issues that required research efforts, it was decided to do a separate, external subscription to raise the funds. To support the subscription program, API was retained to provide contracting and administrative services.

The Minerals Mangement Service and the Department of Energy (DOE) are joining with 36 companies, including oil companies, mud companies, and SBM chemical manufacturers, to share in the cost of the Seafloor Monitoring Program. This group of “subscribers” is known as the SBM Research Group (SBMRP). It has an Oversight committee of eight people (same as an executive committee) which represents the subscribers. Within the SBMRP are six work groups: the Seafloor Monitoring Program; Toxicity Workgroup; Bioremediation; Modeling; Technology Assessment; and Analytical. Also, there is a separate, but parallel organization known as the SBM Committee comprised of NOIA/API/PESA/OOC. They represent all of the interested parties, regardless of whether or not the parties are subscribers to the research program. This group is responsible for handling the policy related issues, such as effluent guidelines, permits, etc.

This paper describes the SBM Monitoring Program that will be conducted over the next three years in the Gulf of Mexico.

BACKGROUND

Drilling fluids play an essential role in providing for the safety and effectiveness of the drilling process. They provide the means for maintaining pressure on the formations being drilled, removing cuttings from the borehole, protecting and supporting the borehole wall, protecting permeable zones from formation damage, and cooling and lubricating the drill bit and drill string.

Drillers currently use two basic types of drilling fluids: water-based fluids and non-aqueous based fluids. Water-based drilling fluids or muds (WBM) have water or a water-miscible fluid as the continuous phase. Non-aqueous based drilling fluids have an organic, water-immiscible fluid as the continuous phase. Non-aqueous based fluids are subdivided into oil-based fluids, enhanced mineral oil-based fluids, and synthetic-based fluids or muds (SBM) according to the nature of the organic fluid phase (EPA 1999). Non-aqueous based fluids are used when drilling conditions require more stabilization of the borehole, lubricity, and resistance to thermal degradation than can be provided by WBM. The conditions encountered during drilling of the initial portions of a well usually are appropriate for the use of WBM. As conditions requiring a non-aqueous fluid are encountered during drilling of later portions of wells, the WBM is typically discharged and a non-aqueous fluid is used to complete the drilling process.

Non-aqueous based fluids are frequently used in development drilling operations because the well paths are deviated, rather than vertical, to reach distant parts of the reservoir from a fixed drilling location. Deviated wells typically have more stringent requirements for drilling fluid lubricity and well bore stability than do vertical wells. Synthetic based drilling fluids, based on organic fluids such as esters, olefins, acetals, and ethers were developed to provide drilling performance equivalent to that of oil-based muds and improvements in environmental performance compared to that of oil-based muds.

The U.S. offshore oil and gas drilling industry has developed and made increasing use of SBM over the past six years. The bulk discharge of these fluids is prohibited. However, the discharge of cuttings drilled with SBM has been allowed in the western Gulf of Mexico subject to the same restrictions as the discharge of cuttings drilled with water-based mud.

EPA is pursuing a presumptive rulemaking process for revision of the offshore effluent guidelines for the use of SBM. This process involves the EPA, industry, MMS, and other stakeholders in collecting information needed for the rulemaking process. EPA recognized that use of SBM in place of water-based muds may reduce the amount of solids and other drilling fluid components discharged to the marine environment. EPA also recognized that the properly controlled discharge of SBM cuttings could provide non-water quality benefits compared with the use of oil-based muds followed by disposal of the cuttings in shore-based landfills or by injection under the seabed (EPA, 1999).

EPA (1996) indicated that additional methods development and additional environmental performance information would be needed to develop effluent limitations for SBM cuttings discharges. EPA expressed concern about both the short-term and the long-term seafloor effects of

SBM cuttings discharges. The overall objective of this research program is to obtain information about these effects.

OBJECTIVES

The objective of this program is to assess the fate and effects of discharged cuttings drilled with SBM at continental shelf (40-300 m) and deepwater (>300 m) Gulf of Mexico sites. The purposes of this assessment are to (1) provide the Environmental Protection Agency (EPA) with scientific data upon which to base effluent limitations for the discharge of SBM cuttings; (2) provide industry with scientifically valid data for the environmental assessment of the discharge of SBM cuttings; and (3) provide MMS and DOE with environmental data useful in leasing assessments and offshore management.

Specific sub-objectives include:

- Determination of the thickness and areal extent of SBM cuttings accumulations on the seafloor and the magnitude and temporal behavior of SBM base fluid concentrations in sediments near discharge sties representative of Gulf of Mexico conditions at both continental shelf (40-300 m depth) and deepwater (> 300 m depth) discharge sites.

- Determination of the temporal behavior of SBM base fluid concentrations in sediments near discharge sites representative of Gulf of Mexico conditions at both continental shelf (40-300 m depth) and deepwater (>300 m depth) discharge sites.

- Documentation of physical-chemical conditions in sediments in areas where SBM base fluids are present and to compare these conditions with conditions in reference sediments distant from SBM discharges. Sediment conditions include SBM base fluid concentrations, effects on sediment oxygen levels due to SBM accumulation, shifts in the depth of the redox potential discontinuity (RPD) layer, and changes in sediment mineralogy due to the addition of drill cuttings solids.

- Determination of whether a zone of biological effect has developed related to the discharge of SBM cuttings. Chemical toxicity, hypoxia, and physical habitat disruption may all contribute to biological effects. Biological changes due to physical effects should be distinguished from those due to the presence of SBM base fluids on cuttings through evaluation of both physical and chemical characteristics of sediments.

SCOPE OF WORK

The scope of work is divided into nine tasks as follows:

Task 1.Sampling Site Selection

The Seabed Survey Work Group (SSWG) will approach the issue of site selection through a process of collection and analysis of data on the water depth, location, and discharge history of sites where

SBM cuttings have been discharged in the Gulf of Mexico. Sites will be selected for sampling based on the likelihood that information about sediment conditions at those sites would best facilitate achieving the overall technical objectives of this program.

The SSWG will coordinate with operators to obtain historical discharge data and permission to conduct sampling operations near their discharge site. The SSWG will obtain seafloor pipeline maps for each discharge site in the study. Detailed data on the materials discharged from a subset of the discharge sites visited during the Screening Cruise will be collected by the SSWG and used to select platforms for the final sampling program. This data will be used to identify sites whose sampling will best support the overall objectives of this program.

Task 2. Plans and Procedures for Field Operations and Laboratory Analyses

For the purpose of this program, the Contractor will prepare Sampling and Analysis Plans, a Quality Assurance Project Plan, Standard Operating Procedures for field and laboratory procedures, and a Statistical Analysis Plan.

Task 3. Scouting Survey of Cuttings Accumulations

An initial scouting survey will include the collection of physical survey data to assess the extent of SBM cuttings accumulations at 13 continental shelf platforms during the Spring of 2000. The platforms will be evenly divided between the 40-100 m depth range (8 platforms) and the 100 – 300 depth range. The information derived from these surveys will be used to (1) refine the choice of platforms for Task 4 and (2) test the cost effectiveness of using a small, dedicated vessel for physical surveys to guide sediment sampling on later cruises.

Task 4. Screening Cruise

The Screening Cruise will visit 8 discharge sites: 5 shelf locations (from the 13 visited in the Scouting Survey) and 3 locations in the > 300 m depth range. The deepwater locations will include the Mississippi Canyon 28 template sampled as described by Fechhelm *et al.* (1999). The results of the Screening Cruise will be used to (1) test and refine field procedures and analytical techniques for use on later cruises and (2) develop biological and sediment-toxicity sampling programs for later comprehensive studies at shelf sites.

Analyses to be conducted during the Screening Cruise include water column profiles of salinity and temperature, SBM base fluid concentration, sediment grain size analysis, mineralogical characterization of sediments, total organic carbon, total petroleum hydrocarbons, sediment barium concentration, and sediment redox measurements. Initial samples will also be collected to support the design of the biological and sediment toxicity sampling program (five stations).

Task 5. Sampling Cruise 1

Sampling Cruise 1 will visit 8 discharge sites: 5 shelf locations (from among the 12 visited in the Scouting Survey) in the 40 – 300 m depth ranges and 3 locations in the > 300 m depth range. During

Sampling Cruise 1, samples will be collected for physical and chemical measurements of sediment conditions at all shelf and deepwater sites, for definitive biological and sediment-toxicity analyses at 3 shelf sites, and for physical survey and video observations of sediment conditions at deepwater sites. The results of the Sampling Cruise 1 will be used to (1) contribute to definitive assessment of accumulation of SBM based fluids in sediments at shelf and deepwater sites and (2) initial assessment of the zone of biological and sediment-toxicity effects at selected shelf sites.

Task 6. Sampling Cruise 2

Sampling Cruise 2 will be a repeat of Sampling Cruise 1 approximately one year later to examine temporal variations.

Task 7. Final Report – Interpretation and Synthesis of Results

The final report will consist of an interpretation and synthesis of the results of the program in three volumes, an executive summary, a technical report, and an appendix volume containing the data.

Task 8. Presentations

Presentations of the results will be made to various groups (industry, sponsors, and regulatory agencies) during and at the conclusion of this project.

Task 9. Administrative Reporting

Monthly progress reports and a program schedule document will be prepared as a part of this program.

SUMMARY

The Gulf of Mexico Comprehensive SBM Monitoring Program represents a joint effort between the Federal Government and industry to evaluate the effects of the discharge of cuttings containing synthetic based drilling fluid on the seabed.

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FIELD RESULTS OF A NEW HIGH-RESOLUTION SEISMIC SYSTEM TESTED IN SHALLOW AND DEEP WATERS OF THE GULF OF MEXICO

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INTRODUCTION

During the past several years, the Center for Marine Resources and Environmental Technology (CMRET), formerly the Marine Minerals Technology Center (MMTC), Continental Shelf Division, of the University of Mississippi has been active in developing and testing geophysical systems to remotely determine physical properties of underwater sediments. Toward this end, a digital seismic capability was acquired and field programs were carried out to test the use of broadband marine seismic sources with the multi-channel profiling technique known as “common mid-point (CMP) stacking.” The results were less than satisfactory.

In 1997, in an effort to determine why satisfactory results were not being achieved, the CMRET engaged in discussions on an international level with other practitioners of water-borne reflection profiling. It was discovered that there is a widespread and growing realization that certain time-honored assumptions of deep exploration seismology are not necessarily valid in high-resolution contexts. The assumptions upon which the seismic profiling portion of the CMRET Geophysical Systems Development Program relied were examined thoroughly. This examination led to a change of focus for the seismic portion of the program. The use of CMP stacking was suspended and the principal effort was redirected toward improving resolution. First results after the change are reported herein.

THE ASSUMPTION OF LIMITED BANDWIDTH

The most basic assumption influencing seismic resolution is that seismic signals are band limited, i.e. that they contain no power above some maximum “cutoff frequency.” The existence of a cutoff frequency would have far-reaching consequences because the *minimum* rate at which the analogue signal should be sampled is twice the cutoff frequency (Shannon 1949). The frequency equal to one-half of the sampling rate actually employed for a particular data set is called the “Nyquist” frequency of that set and is the highest frequency that can be described uniquely by discrete Fourier transformation.

From a theoretical point of view, only signals of limited bandwidth may be digitized without loss of information (Shannon 1949, Slepian 1976). A consequence of the Uncertainty Principle is that signals of limited bandwidth, i.e. sinusoids, have infinite duration and signals of limited duration, i.e. pulses, have infinite bandwidth. The duration of seismic wavelets is limited because they are “causal,” i.e. they don’t exist prior to their onset time. By the Uncertainty Principle, therefore, they cannot be bandlimited (McGee 1998). Of course, this presents a conundrum when digitizing seismic signals. The implication is that seismic signals require an infinite sampling rate to avoid information loss. A corollary is that some information, or resolution, is always lost when seismic signals are digitized (because the rate is finite).

In 1991, an experiment to determine how often signals generated by common seismic sources should be sampled was carried out on Lake Windermere in Cumbria, U.K. (McGee *et al.* 1992). Under quiet conditions, the signatures of several commercial seismic sources were digitized at 204,000 samples per second. It was learned that the spectra of two commonly used sources, the watergun and the boomer, generate signatures with exceptionally broad power spectra. This is illustrated in Figure 1A.1 where a boomer pulse and its power spectrum are shown. Although the spectrum (Figure 1A.2) extends as high as 102kHz, the Nyquist frequency, no cutoff frequency is observed. In fact, the power decays so slowly that it does not drop below -40db (1% of maximum amplitude) until well above 30kHz.

It is often argued that fast sampling rates are unnecessary because high frequencies are absorbed during propagation. This argument ignores the way geologic information is encoded into a seismogram and the fact that a sampling rate is adequate only insofar that it allows geologic information to be retrieved. For reasons of computational efficiency, the retrieval is usually accomplished in the frequency domain. Thus, it is important to understand how geologic information is represented in the frequency domain.

That representation is illustrated in Figures 1A.3 and 1A.4 by a simple “seismogram” and its power spectrum. In the time domain (Figure 1A.3), the “seismogram” consists of two identical boomer wavelets separated by an interval of time. The “geologic” information is the amplitude and polarity of the wavelets and the length of time between them. In the frequency domain (Figure 1A.4), the “geologic” information is coded into a pattern of destructive interference (solid line) that is modulated by the power spectrum of the individual wavelets (dashed line). The pattern appears as a set of spectral notches whose spacing is associated with the interval between wavelets. Since the wavelets are of the same polarity, the notches occur at odd-integer multiples of a "base" frequency whose period is twice the separation interval. (If the wavelets were of opposite polarity, notches would occur at all integer multiples of a base frequency with period equaling the interval.) Relative wavelet amplitude is coded into the depths of the notches. The deepening of every fifth notch is due to a serendipitous coincidence of notches and odd harmonics of the dominant wavelet period.

The spectrum of a real seismogram would display a number of such interference patterns, one for every pair of wavelets. Processing algorithms retrieve the geologic information in a real seismogram by identifying each base frequency, determining whether its pattern consists of only odd or all harmonics, and considering the depth of the notches. The accuracy with which this can be done increases as more harmonics of the base frequency are described. That requires a sampling rate greater than one merely capable of describing the source signature.

OVERSAMPLING

Decades ago, when data storage was relatively limited and analogue-to-digital (A-D) converters were much slower than they are now, the volume of digital data was limited by assuming a rather

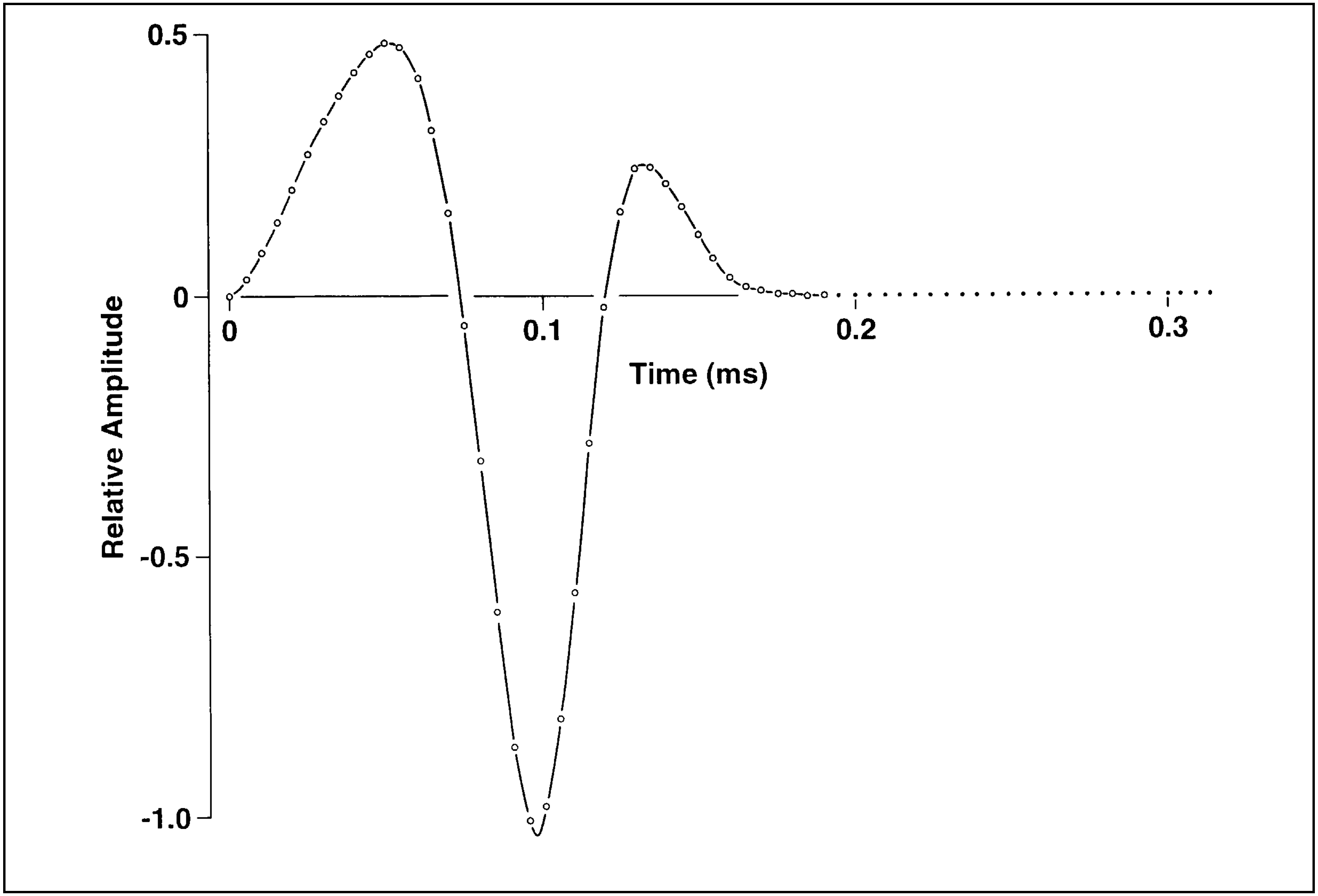

Figure 1A.1. Axial far-field signature of a "boomer" marine seismic source. The continuous-time wavelet is approximated by the solid curve. Digital samples are indicated by circles. The sampling rate is 204,000 samples per second. Note that the maximum excursion falls between samples.

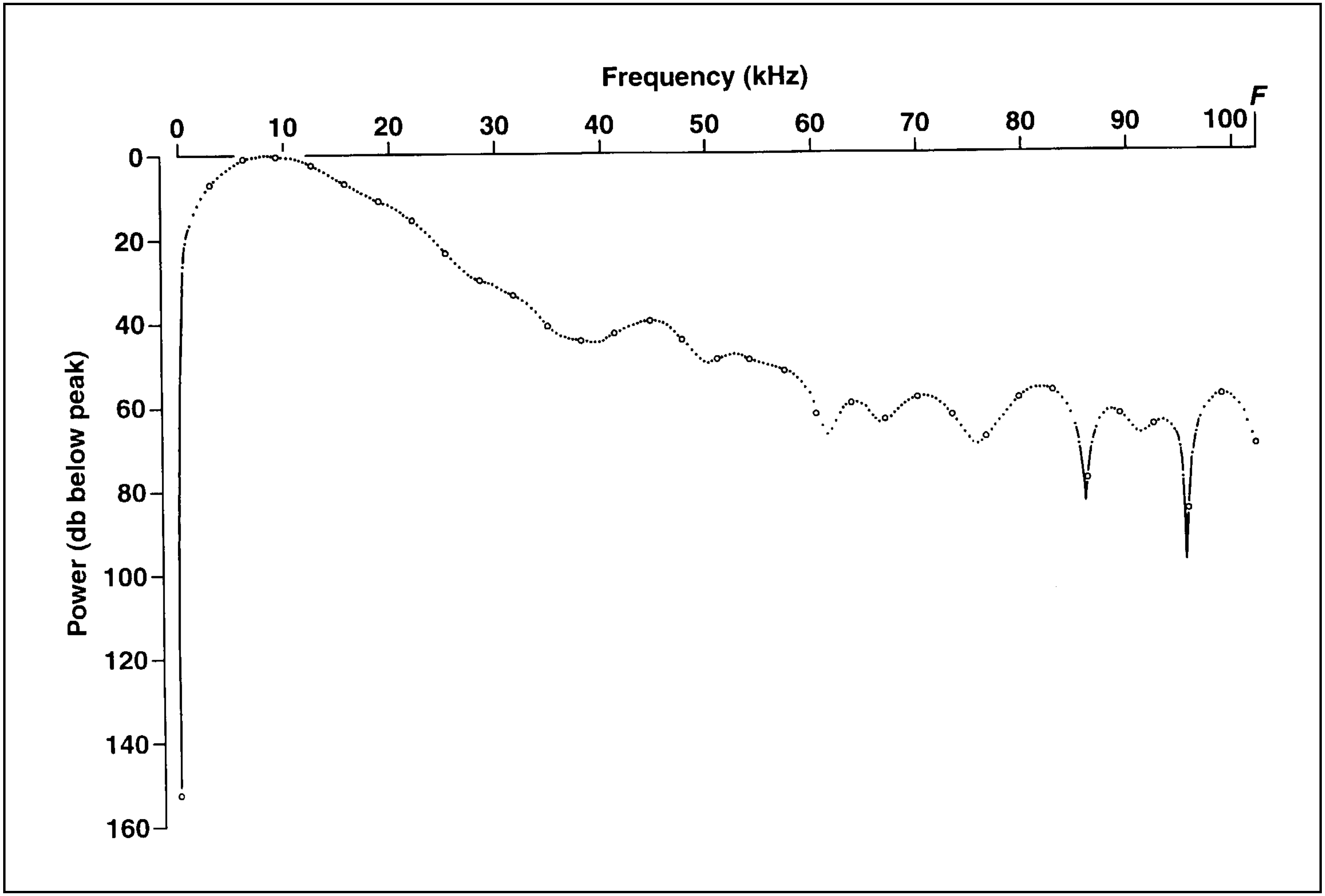

Figure 1A.2. Power spectrum obtained by applying a radix-2 Fast Fourier Transform (FFT) to the signature in Figure 1A.1. Zeros were appended to the signature to produce a 64-point FFT (circles) and a 512-point FFT (dots). The Nyquist frequency (*F*) is 102 kHz.

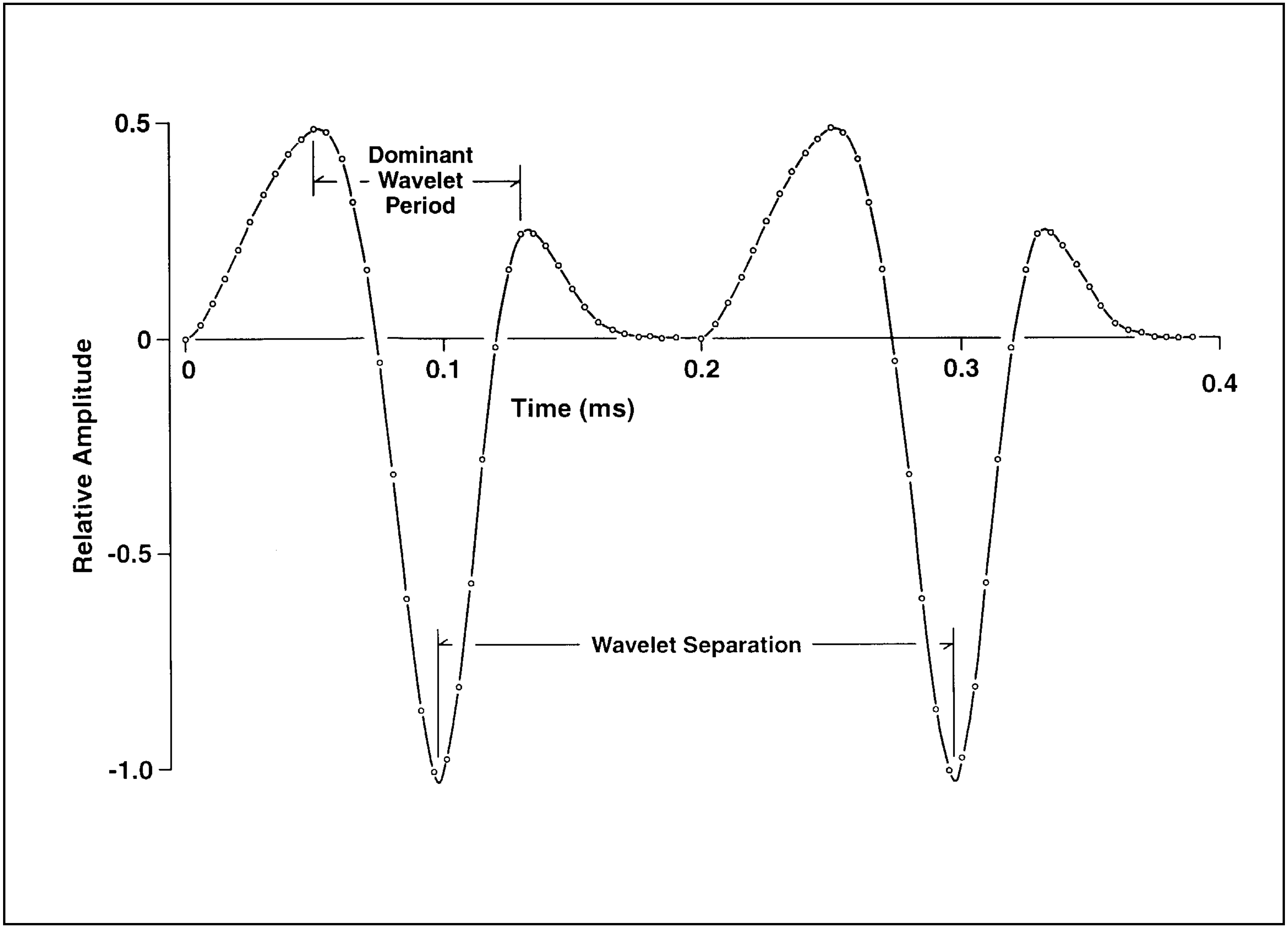

Figure 1A.3. Simple "seismogram" constructed by adding a time-shifted version of the signature in Figure 1A.1 to itself.

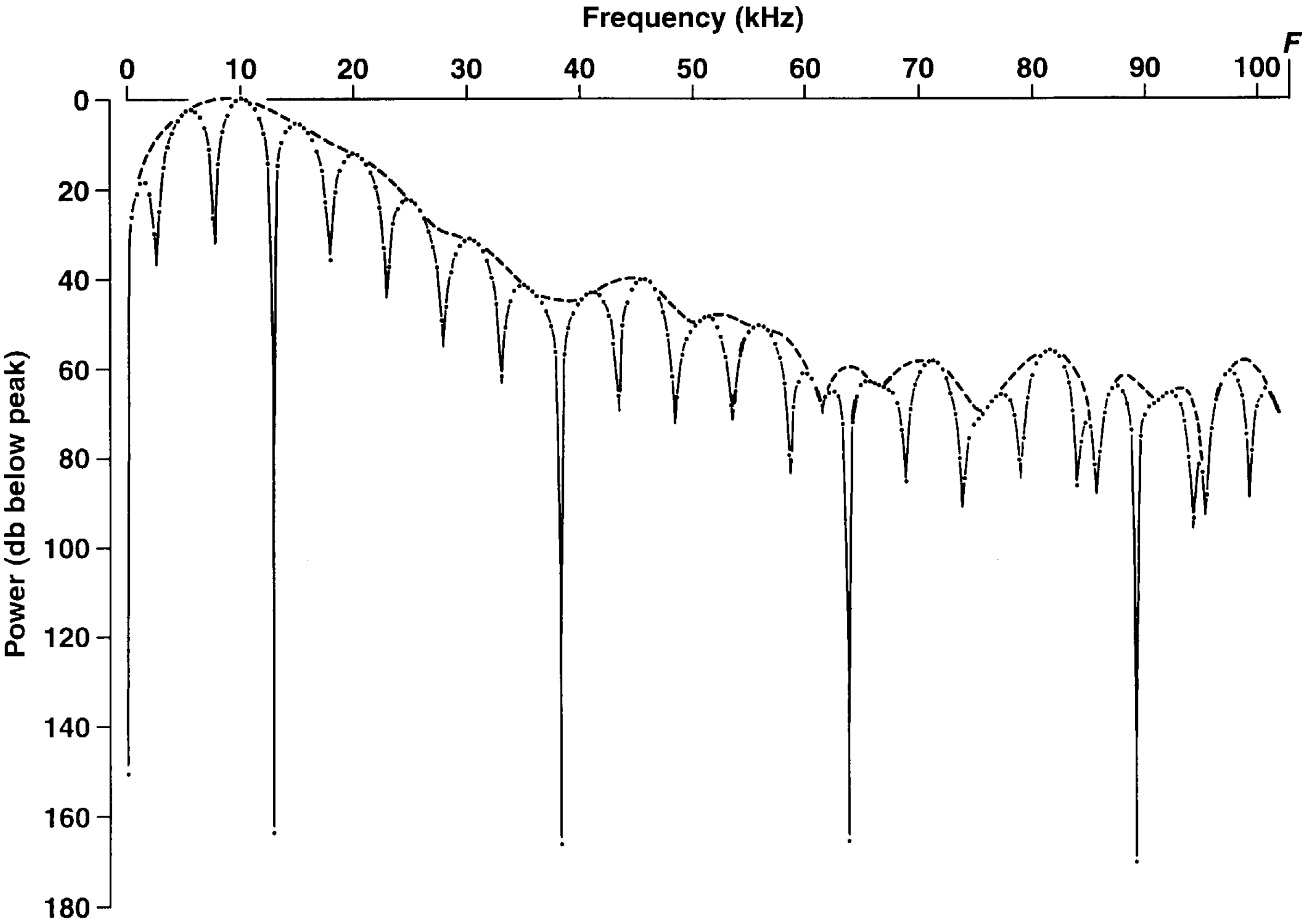

Figure 1A.4. Power spectrum obtained by padding the signal in Figure 1A.3 with zeros and applying a 512-point FFT (solid curves and dots). The spectrum of the signature in Figure 1A.1 (dashed) is shown for comparison. The Nyquist frequency (*F*) is 102kHz.

low cutoff frequency and attenuating power at higher frequencies by filtering the analogue signal, even though information (or resolution) was lost by doing so.

Digital technology has now advanced to a point where the size of available storage and the speed of A-D converters can accommodate Nyquist frequencies so high that little signal power can possibly exist at higher frequencies. In fact, such exploitation of the vastness of modern digital capacity is the rationale behind the concept of "oversampling" (Alesis Corporation 1996). Oversampling is well suited to seismic application because, since the spectra of seismic wavelets decay naturally as frequency increases, it is not difficult to avoid analogue filtering entirely by selecting a Nyquist frequency that is several octaves above the highest frequency of interest. When applied to seismic profiling, oversampling allows exceptionally high resolution to be attained.

BROADENING THE CMRET GEOPHYSICAL SYSTEMS DEVELOPMENT PROGRAM

Having recognized that there is no intrinsically "correct" sampling rate associated with a particular seismic source and that some information/resolution is always lost when seismic data are digitized, the CMRET addressed two questions in its broadened program:

1) What is a reasonable sampling rate for seismic data?
2) How much seismic resolution can be realized?

The answer to the first is simple; seismic data should be sampled as rapidly as is allowed by the equipment available. If the available equipment is not fast enough, better equipment should be obtained.

The answer to the second relies on carrying out experiments in both shallow and deep water situations because the appropriateness of acquisition and processing techniques depends to a large extent on field environment. For purposes herein, the measure of seismic resolution is taken to be the width of the dominant peak, or trough, of a seismic reflection. That would be about one-half of the dominant signal period and correspond closely to the minimum layer thickness (in two-way time) that can be discerned on a seismic profile. Also for purposes herein, conversion of time to distance is accomplished using a speed of 1500m/s, which is within a few percent of the propagation speed in sea water and most unconsolidated sediments.

RESULTS IN SHALLOW WATER – SOURCE SIGNATURES NOT RECORDED

Several tests of shallow water profiling were done between December 1997 and March 1999 near Cat Island in Mississippi Sound using a boomer source. Water depths were about 4m (12ft). In each test, a 105-Joule boomer and a short hydrophone array were towed separately, but close to each other. They were towed on the stern quarter rather than directly astern in order to avoid entrained air bubbles that deteriorate broadband signals. Digital recording was in 16-bit SEGY integer format at 200,000 samples per second. Signal gain was constant. No filters were applied to the analogue signal prior to digitization (except the anti-alias filter intrinsic to the A-D converter).

Figure 1A.5 shows an example of field data acquired under good sea conditions. The most obvious feature is that each trace is offset from its null position by a slowly varying trend. These offsets were corrected during processing by use of a procedure known as "detrending" (Brussaard and McGee 1992). The detrended data are shown in Figure 1A.6 after having been corrected for spherical divergence of the wavefront. It should be noted that water-bottom multiples are not obvious on the processed profile except in its right-hand portion.

It may be observed in Figure 1A.6 that the reflections consist of two wavelets. The first is the primary reflection and the second, opposite in polarity, is a "ghost" reflection from the water surface. Figure 1A.7 shows enlargements of three such reflections; (a) from the sea floor, (b) from 3ms below the sea floor and (c) from 17ms below the sea floor. Each shows the ghost following the primary by about 0.5ms. Since the boomer backing prevents the generation of a ghost above the source, the delay indicates that the hydrophone array was being towed about 38cm (15in) below the water surface.

The wavelets of Figure 1A.7(a) and Figure 1A.7(c) are of the same polarity while that of Figure 1A.7(b)is of opposite polarity. Thus, if (a) represents an increase of acoustic impedance, perhaps due to the sea floor being more dense than sea water, (c) also represents an increase but (b) represents a decrease.

The wavelet in Figure 1A.7(b) is part of the apparently negative reflection in the central portion of Figure 1A.6. It appears to be faulted with a throw of about 40cm (16in). The wavelet in Figure 1A.7(c) is taken from the deep horizon in the left-hand portion of Figure 1A.6 that appears to be eroded.

The dominant period in Figure 1A.7(a) and Figure 1A.7(b) is 0.20ms while that in Figure 1A.7(c) is 0.28ms. These values indicate that a resolution of 0.10ms (about 7.5cm or 3in) can be attained within the upper 3ms (about 2.3m or 7ft) of sediment. Resolution is reduced to 0.14ms (about 11cm or 4in) at a depth of 17ms (about 14m or 45ft) below the sea floor, apparently due to the effect of absorption.

The almost total absence of multiples indicates a weakly reflective, very soft sea floor. Cores showed the soft bottom to be dark grey, soupy silt. The more strongly reflective sea floor in the right-hand portion of the profile is due to the presence of oyster reefs. The reflection of apparently negative polarity 3ms below the sea floor was found to correspond to a grey sandy silt-clay. An odor of H_2S was emitted when the cores were split, so perhaps the presence of free gas accounts for the reflection being apparently negative. A comparison of cores was consistent with the apparent faulting. The cores were too short, however, to penetrate the deep horizon thought to be the top of the Pleistocene, exposed and eroded during a low stand of sea level.

RESULTS IN DEEP WATER – SOURCE SIGNATURES RECORDED

Deep-water tests were conducted over the continental slope of the northern Gulf of Mexico during June 1998 and September 1999. The 1998 cruise went into parts of the Mississippi Canyon area where gas hydrates outcrop at the sea floor. The 1999 cruise was in portions of the Garden Banks

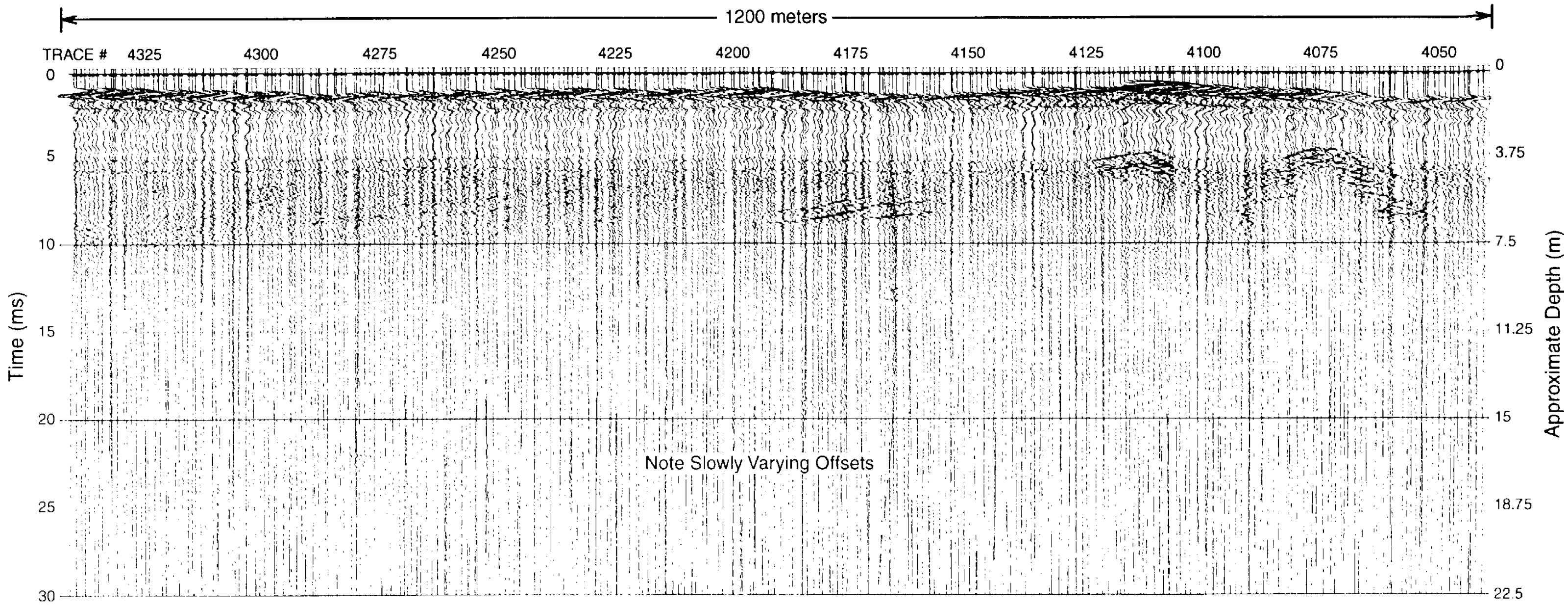

Figure 1A.5. Field data at constant gain, 105 Joule Boomer Profile, sampling rate 200,000 samples per second.

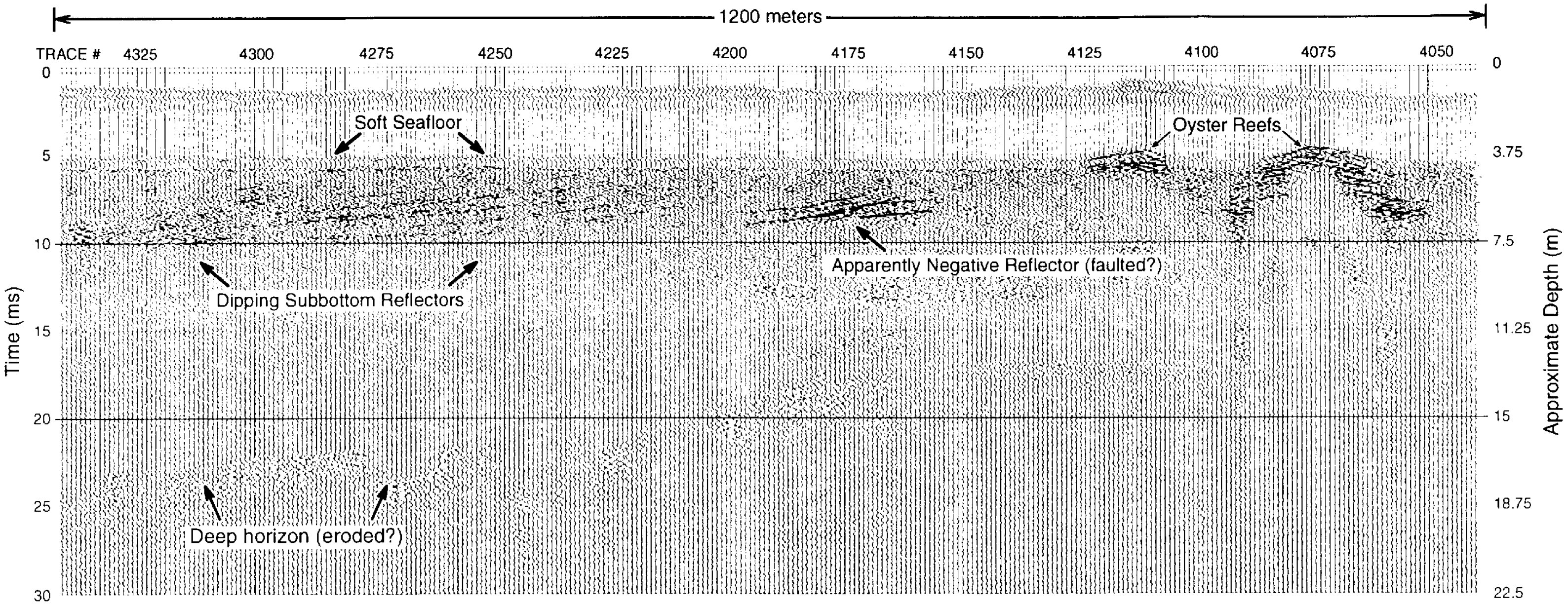

Figure 1A.6. Processed data corrected for spherical divergence, 105 Joule Boomer Profile, sampling rate 200,000 samples per second.

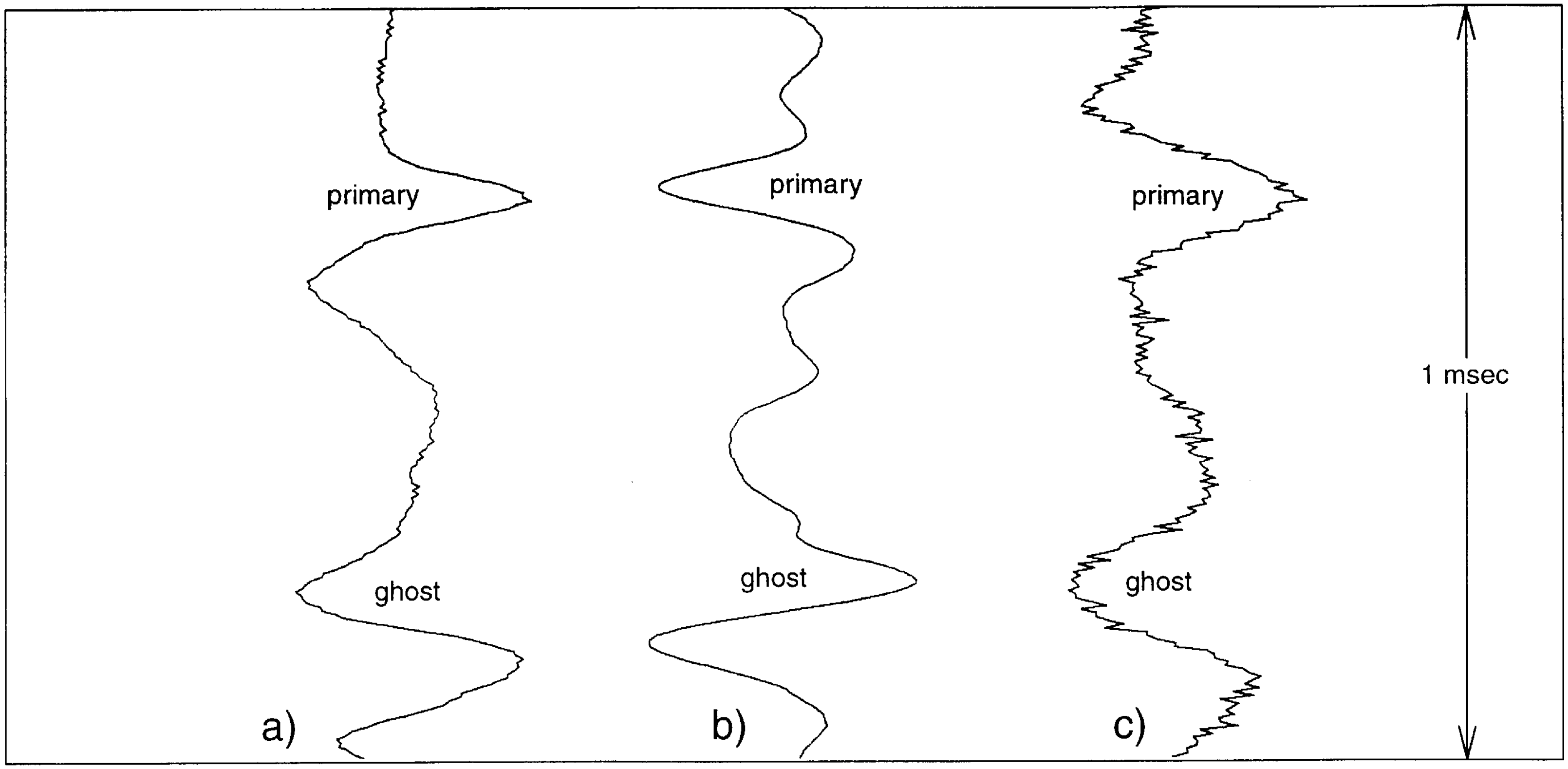

Figure 1A.7. Reflected pulses (a) from sea floor, (b) from 3 ms below sea floor, and (c) from 17 ms below sea floor.

area and duplicated conventional seismic profiles through wells where shallow flowing sands had been encountered.

During the 1998 cruise, a broadband seismic source was deployed on the surface and a hydrophone array towed at depth. The intention was to record the outgoing source pulse isolated in time from the returning reflections so that it could be used as a source signature during subsequent data processing. Results were promising, and that geometry was used exclusively during the 1999 cruise.

In 1999, a 15 in^3 watergun source was towed on the surface and a short single-channel hydrophone array was towed about 250m (800ft) below the surface, both about 300m (1,000ft) behind the vessel. There was a 300ms interval between the sea-floor reflection and the surface ghost so that about 450m (1,460ft) of bottom sediment could be imaged before interference by ghost reflections. Twenty profiles were acquired in 16-bit SEGY integer format, two profiles in opposite directions on each of ten tracks. On the first profile, the source was fired at 5-second intervals and recording was done for 3 seconds, 2 seconds being allowed for data storage and resetting. The firing interval was too short, however, because water-layer multiple energy from the preceding shot did not have time to dissipate. This was corrected on the other profiles by increasing the firing interval to 6 seconds, which allowed the record length to be increased to 4 seconds. The digitization rate was 80,000 samples per second on all profiles. Traces in the first profile contain 240,000 samples and the others contain 320,000 samples.

A format restriction is encountered when recording so many samples per trace because the number of samples per trace is written into the SEGY header as a two-byte integer, which cannot exceed about 32,000 samples. The restriction was circumvented by dividing each trace into segments and writing it as a multi-channel record. Thus the 240,000-sample traces were written as 8-channel records of 30,000 samples each channel (Figure 1A.8(a)) and the 320,000-sample traces as 16-channel records of 20,000 samples each channel (Figure 1A.8(b)). The segments were reassembled into a single trace for processing and the output separated into channels again.

A linear gain was applied prior to digitizing as a means of compensating for signal decay due to wavefront divergence. The first profile was recorded with no electronic filtering prior to the analogue-to-digital (A-D) convertor. Strumming of the deep-tow cable produced the strong 40Hz signal visible in Figure 1A.8(a). To avoid clipping the strum signal, it was necessary to reduce the gain with the result that the seismic signal occupied only the low portion of the 16-bit dynamic range. In order that the gain to the seismic signal could be increased, the strum signal was attenuated on the other profiles by applying a 160Hz (12 db per octave) low-cut filter. Typical filtered field traces are illustrated in Figure 1A.8(b).

After detrending, the source signature was used both to deconvolve and to matched filter the data before correction for spherical divergence. Figure 1A.9 shows (a) a typical watergun signature, (b) the signature deconvolved to itself and (c) the signature matched filtered by itself. The wavelets are normalized to unit energy across the interval shown and plotted in relative, not true, time. The outgoing source signature begins with a small precursor at 40ms and develops into a complicated, high-amplitude pulse near 60ms before decaying to insignificance beyond 80ms. The deconvolved and matched filtered signatures are symmetrical about a time near the onset of the precursor. The

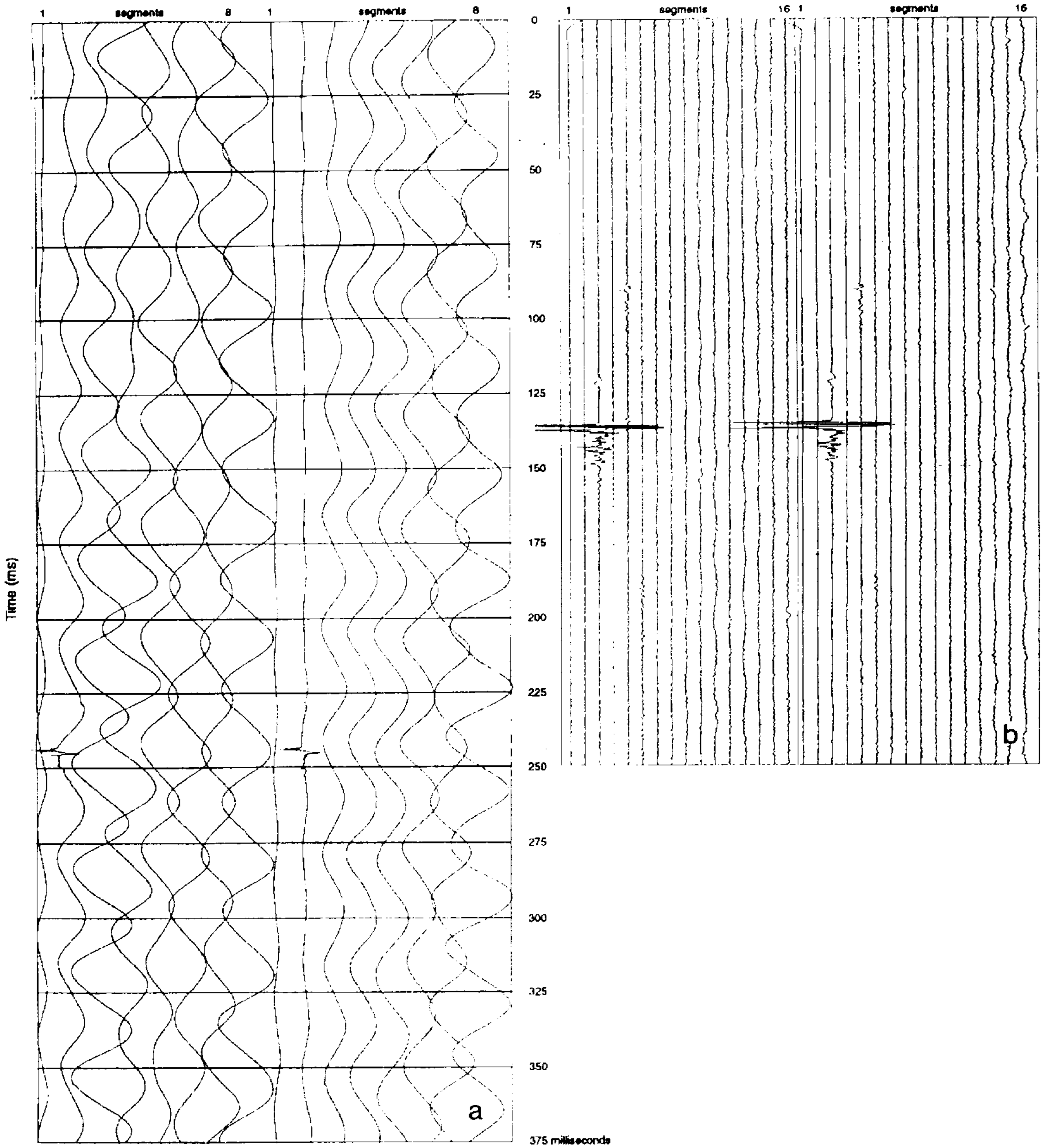

Figure 1A.8. Field data: surface source, deep towed received, 80,000 samples per second (a) 3 second traces in 8 segments (note strumming), (b) 4 second traces in 16 segments (low-cut filter to remove strumming).

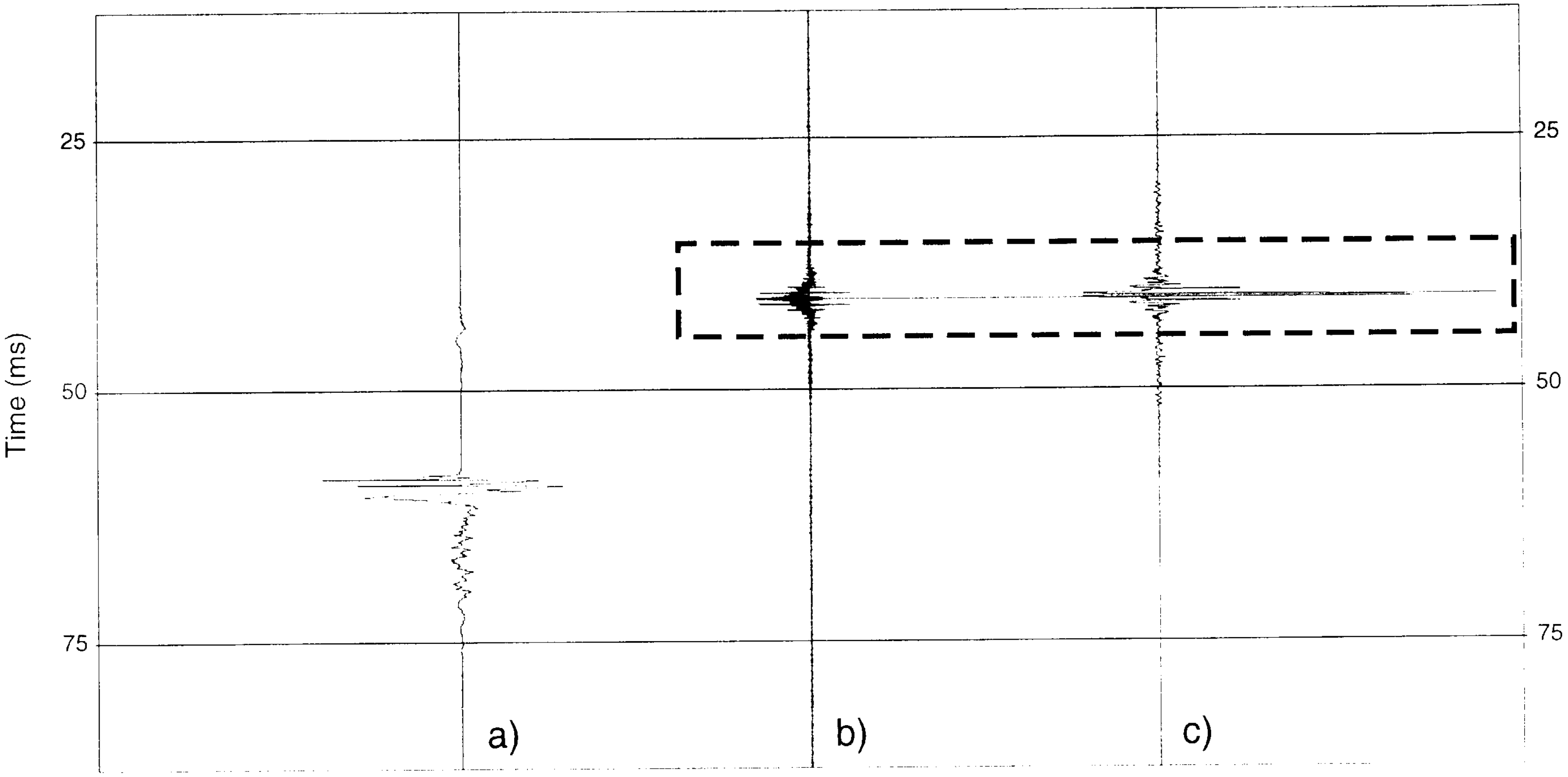

Figure 1A.9. Outgoing pulses at deep-towed receiver sampling rate 80,000 samples per second (a) raw signal, (b) deconvolved, and (c) matched filtered.

symmetry is more obvious in Figure 1A.10 where the plots of the processed wavelets are enlarged; (a) deconvolved and (b) matched filtered. In can be seen that secondary peaks are located about 0.5ms on each side of the dominant peak.

Most of the energy in the source signature is distributed over about 20ms. For the processed signatures, the same energy is compressed into their central peaks. The width of the peak of the deconvolved wavelet is 0.060ms, a compression ratio of more than 300. The width of the matched filtered peak is 0.156ms, a compression ratio of about 130. It is oversampling that allows the compression to be so great. If the sampling rate were smaller, the amount of compression would be less.

The widths of the central peaks are an indication of the best resolution that can be accomplished without increasing the sampling rate. At the speed of sound in sea water (1,500m/s), the deconvolved peak is about 4.5cm (1.8in) wide, and the matched filtered peak is about 11.7cm (4.6in) wide. Thus signature deconvolution provided resolution about 2.5 times better than the matched filter process. Deconvolution is notoriously susceptible to noise, however, so matched filtering is often preferred in practice even though it provides somewhat lower resolution.

Figure 1A.11 shows segments of two profiles after matched filtering. Figure 1A.11 is a portion of a profile with no analogue filtering prior to A-D conversion and Figure 1A.12 is a portion of a similar, nearby profile that was analogue filtered to reduce strum noise. Both show the same reflecting units, but the reflections are not compressed as much in (b) as in (a). The decrease in compression probably is due to the low-cut filter restricting the spectral shape.

Figure 1A.13 shows details within the two boxes outlined in Figures 1A.11 and 1A.12. The dominant peaks and troughs are about 0.12ms wide which implies a resolution of about 9cm (3.5in).

In Figure 1A.13(a), the uppermost event is the reflection from the sea floor. Rather than simply a single reflection, it appears to be a weak peak followed closely by a stronger peak. The reflection complex near 6ms below the sea floor (BSF) marks the upper boundary of a layer whose lower boundary is near 11ms (8m or 27ft) BSF. The upper boundary appears to be a weak negative followed by doublet consisting of a strong positive and a strong negative whose separation is near the limit of resolution. The lower portion of the layer exhibits a region of numerous reflections that may indicated a series of layers too thin to be resolved.

Figure 1A.13(b) shows a 1m-thick layer at 31ms (23m or 76ft) BSF. Its upper boundary is marked by a positive reflection and its lower boundary by a negative reflection. It could well be a sand unit overlain and underlain by soft silt or clay.

SUMMARY

Previous results led the CMRET to forego the use of CMP stacking and to begin investigating ways to maximize seismic resolution. It was realized that seismic wavelets are causal and therefore cannot be band limited. In theory, an infinite digitizing rate would be required to avoid loss of resolution. In practice, this implies that sampling should be as rapid as possible.

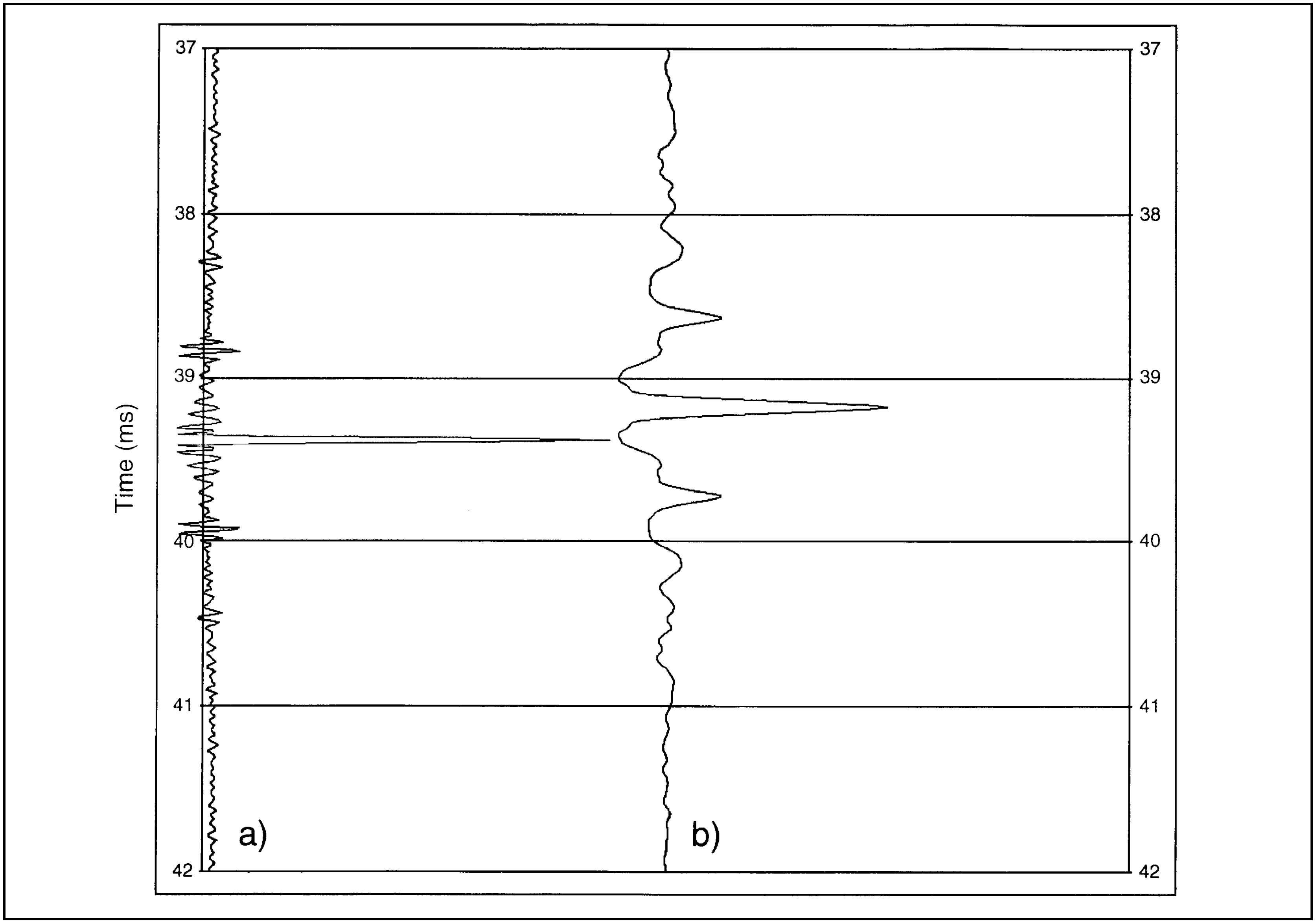

Figure 1A.10. Enlargement of processed outgoing pulses in Figure 1A.8 (dashed rectangle) (a) deconvolved, (b) matched filtered.

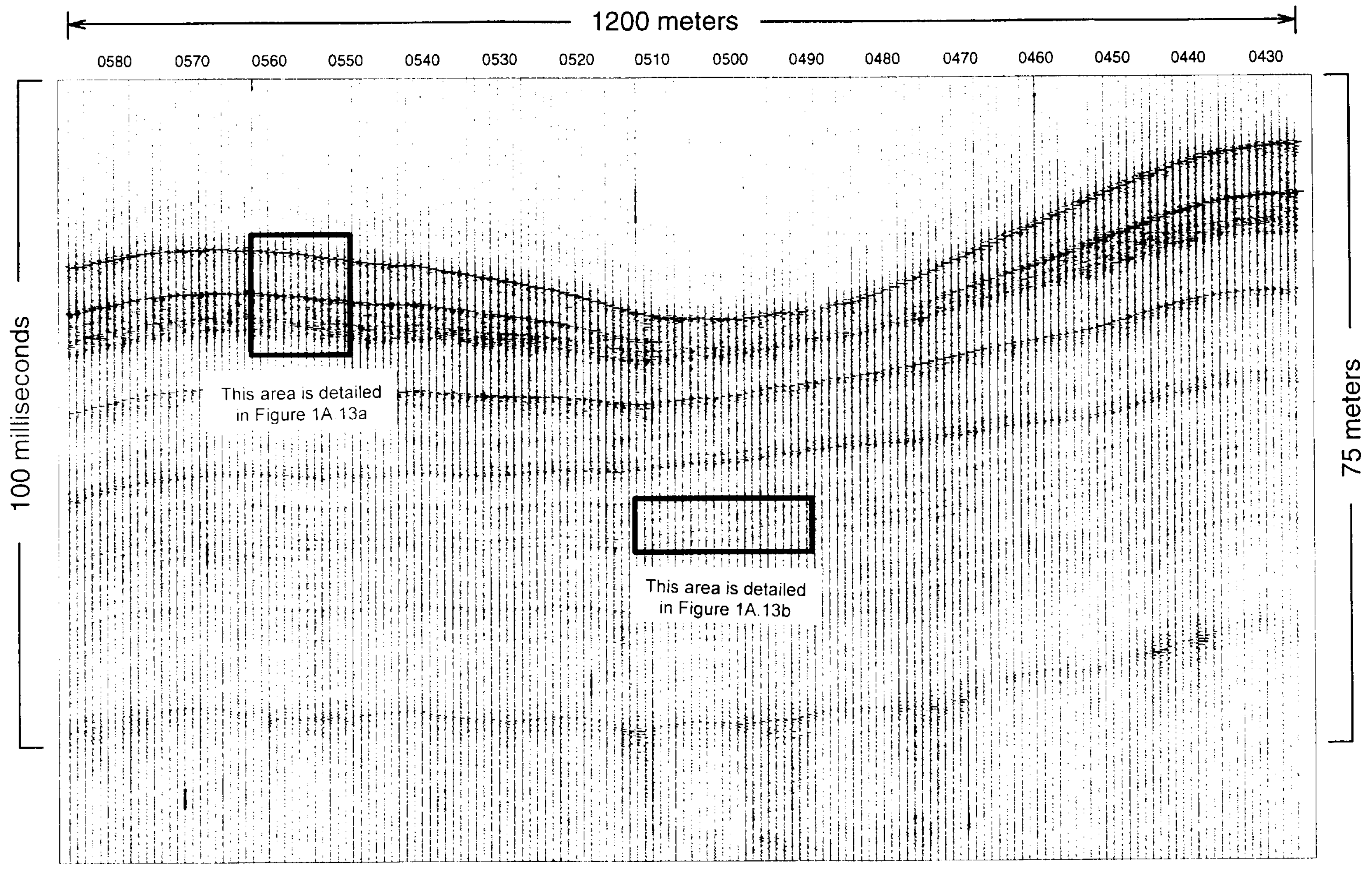

Figure 1A.11. Processed section, no filtering prior to A-D converter.

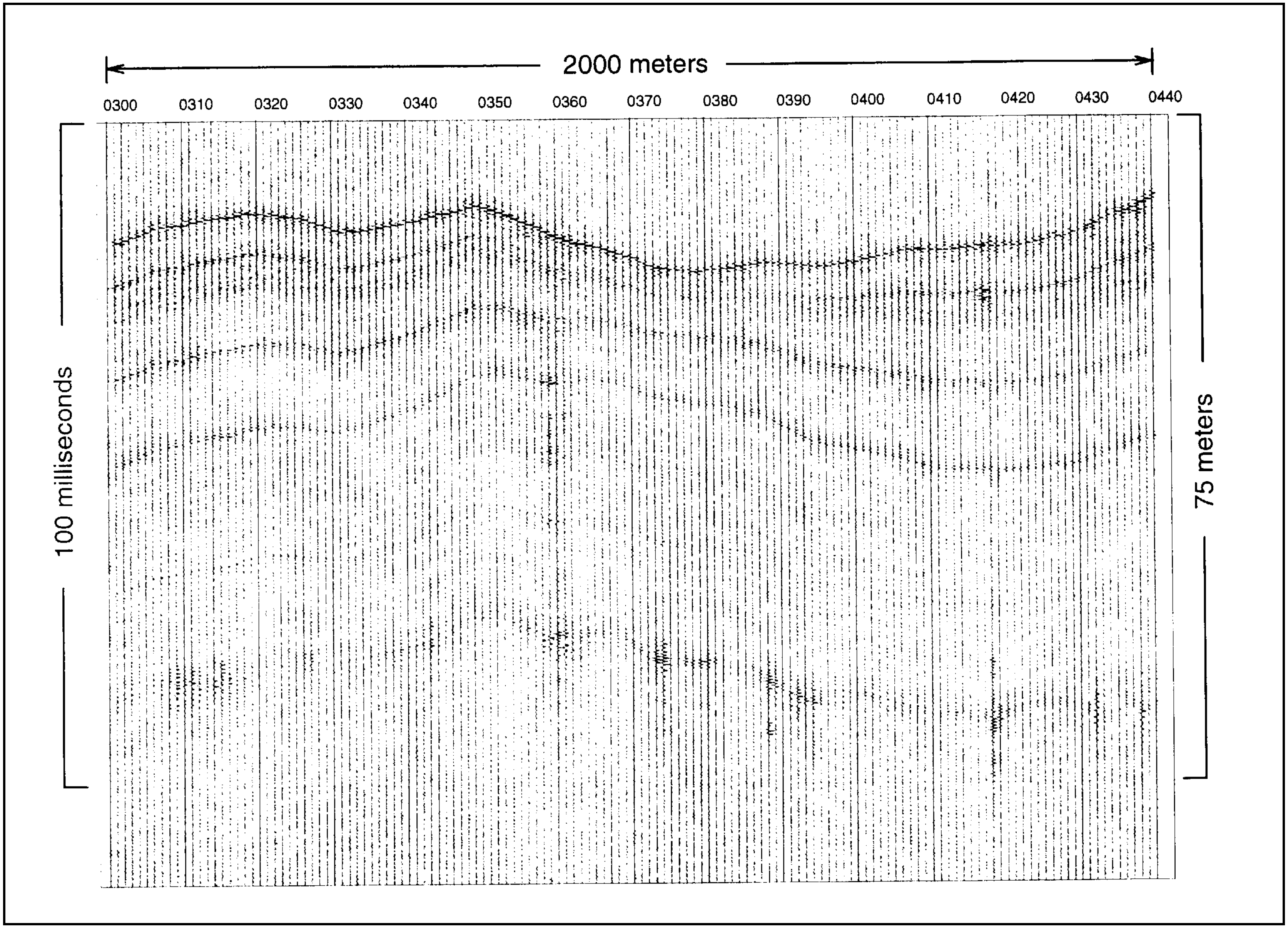

Figure 1A.12. Processed section, 160 Hz low-cut filter prior to A-D converter.

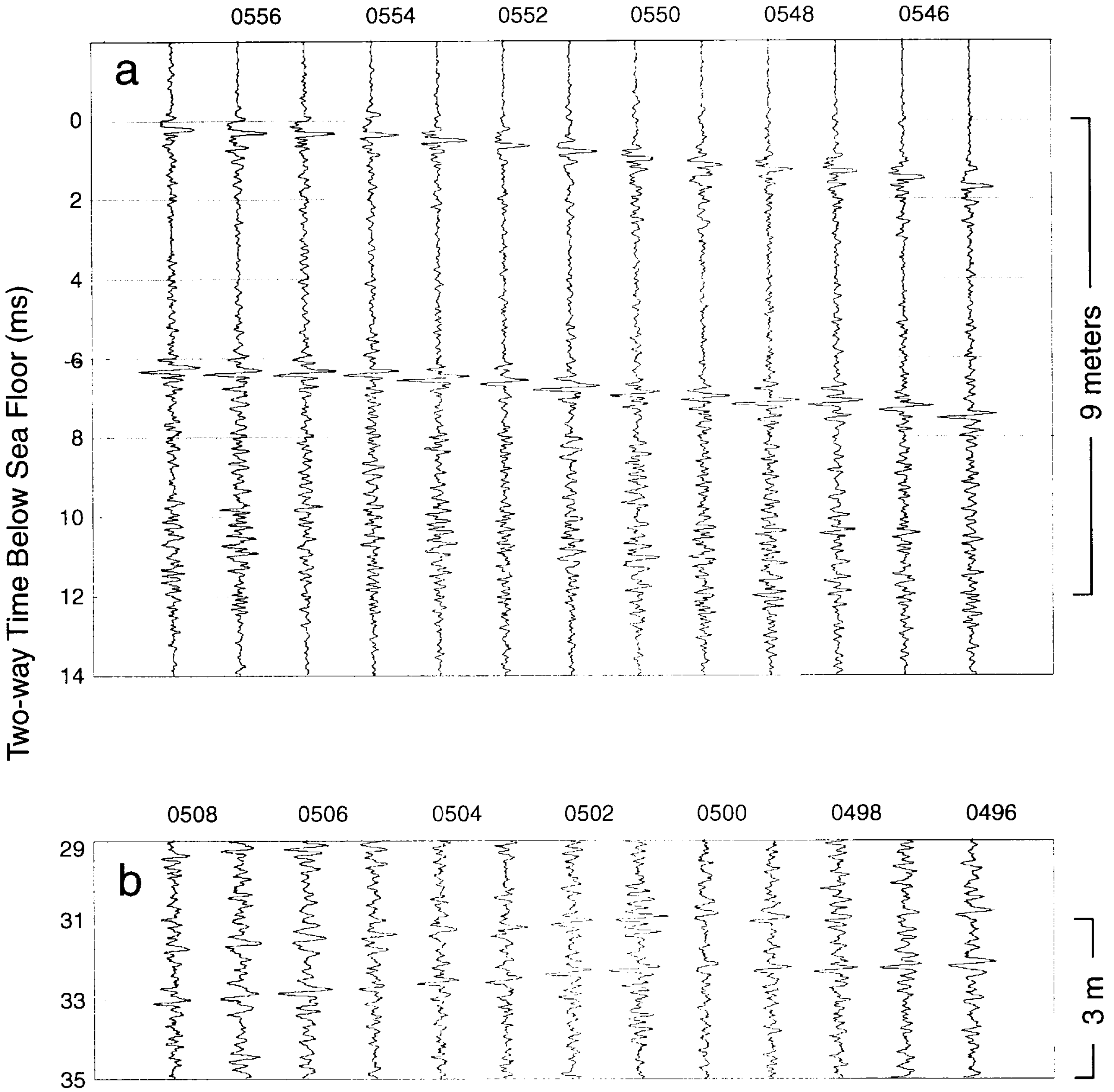

Figure 1A.13. Detail of areas indicated on Figure 1A.11.

It was also realized that, if the seismic method is to be useful, the sampling rate should be fast enough to recover the geologic information that is coded into seismograms. This usually requires a much faster rate than that necessary to describe the source wavelet. The practice of very rapid sampling to improve resolution is called "oversampling."

These ideas have been substantiated by acquiring and processing single-channel data in both shallow and deep water. Oversampling was practiced, i.e. digitizing at 200,000 samples per second in shallow (4m or 12ft) water and at 80,000 samples per second in deep (1,300m or 4,430ft) water. In both cases resolution is on the order of 10cm (4in). In deep water, recording the source signature for use during processing was crucial to achieving that resolution.

ACKNOWLEDGMENTS

The shallow-water tests were carried out from CMRET's research vessel the R.V. "Kit Jones." The deep-water tests were done from the M.V. "David McCall II" of Gulf Ocean Services Inc. in Cameron, Louisiana. The sites of the deep-water tests were selected by Marathon Oil Company and Conoco. Marathon's Deepwater Drilling and Production Technology Group in Lafayette, Louisiana, supplied proprietary seismic exploration data and Conoco's Project Engineering and Management Group in Houston, Texas, funded half of the ship time.

The digital system acquisition system was from Lookout Geophysical Company (LGC) of Dillon, Colorado. The processing software includes algorithms by Thalassic Data Limited (TDL) of Vancouver, British Columbia. The Department of Mathematics at Tulane University in New Orleans, Louisiana, increased processing speed by implementing some TDL algorithms under the Linux operating system.

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Dr. Thomas McGee has been active in geophysics, both applied and theoretical, for forty years. He has worked at the University of Mississippi Oxford Campus for two years and serves as Associate Research Professor of Geophysics in the Center for Marine Resources and Environmental Technology. His current areas of research interest are high-resolution seismic profiling and its applications for estimating engineering properties of water-covered sediments. Dr. McGee received his B.Sc. degree in geophysical engineering from St. Louis University and his Ph.D. in geophysics from the University of Utrecht, The Netherlands. He is a registered professional engineer in British Columbia, Canada.

SESSION 1B

MORGAN CITY, NEW IBERIA AND OFFSHORE OIL BENEFIT AND BURDEN

Co-Chairs: Dr. Claudia Rogers, Minerals Management Service
Dr. Diane Austin, University of Arizona

Date: November 30, 1999

Presentation	Author/Affiliation
Effects of Offshore Oil on Individuals and Families: Case Studies Of Morgan City and New Iberia	Dr. Diane Austin Dr. Thomas McGuire Ms. Marcia Brenden University of Arizona Ms. Teresa Bagwell Ms. Sonya Cloutier St. Mary Parish Schools Ms. Leslie Chambers Ms. Norma Cormier Ms. Margaret Kleinpeter Ms. Susan Lissard Iberia Parish Schools

EFFECTS OF OFFSHORE OIL ON INDIVIDUALS AND FAMILIES: CASE STUDIES OF MORGAN CITY AND NEW IBERIA

Dr. Diane Austin
Dr. Thomas McGuire
Ms. Marcia Brenden
University of Arizona

Ms. Teresa Bagwell
Ms. Sonya Cloutier
St. Mary Parish Schools

Ms. Leslie Chambers
Ms. Norma Cormier
Ms. Margaret Kleinpeter
Ms. Susan Lissard
Iberia Parish Schools

INTRODUCTION

In this decade, the MMS Gulf of Mexico region has dedicated resources to a comprehensive social science research program that seeks to examine the effects of OCS development. This is the second MMS project for our University of Arizona team and is an attempt to understand the effects of that development on individuals and families. We have benefited from prior social science studies and the tremendous support we have received from the communities of New Iberia and Morgan City, Louisiana.

Because of extensive recent industry changes, we designed our study to investigate the many facets of OCS development as we explored its individual impacts. We quickly learned that any information about either the industry or impacts depended on who you asked and when you asked them. This is a simple way of saying what you all already know: the oil and gas industry in the Gulf of Mexico is extraordinarily complex and dynamic. To study impacts to individuals and families, we developed a participatory research methodology that allowed us to capitalize on local knowledge and expertise and track change as it occurred. An advantage of our ethnographic approach is that questions about the nature of the industry did not have to be answered in full before the study but could become a product of the research. So, we identified two communities within which we found people interested in the study and in becoming local research partners.

Table 1B.1 displays the methodology of this study. As you can see, we are in the second of the three years of the study, and community ethnography forms its backbone of the study. Table 1B.2 shows the composition of the ethnographic research team. The residential ethnographers are research specialists who lived in the communities for nine months from September 1998 to June 1999. The teacher-researchers are local teachers who participated in the project during that entire period; many of them have continued the project into this second year. The university researchers who conduct the concentrated site visits stay for two to four week periods at several intervals throughout the project. The roving ethnographers visit communities outside Morgan City and New Iberia to gather additional information about families and workplaces.

Table 1B.1 Study methodology.

<table>
<tr><th colspan="2">July 1998 - June 1999</th><th colspan="2">July 1999- June 2000</th><th colspan="2">June 2000- July 2001</th></tr>
<tr><td colspan="6">Literature Review and Electronic Bibliography</td></tr>
<tr><td colspan="4">Community Ethnography</td><td colspan="2"></td></tr>
<tr><td colspan="2"></td><td colspan="4">Analysis and Presentation of Results</td></tr>
</table>

The thirteen teacher-researchers who joined the study participated in a day-long workshop at which they were introduced to the "funds of knowledge" methodology and philosophy that are central to their involvement. The term "funds of knowledge" as applied to educational anthropology was first coined by Carlos Vélez-Ibáñez and James Greenberg (1992) from the Bureau of Applied Research in Anthropology at the University of Arizona. In a funds of knowledge study, teachers enter the homes of their students as learners seeking to better understand the contexts within which those children live (see Gonzalez 1995). In addition to the workshop, the university and teacher researchers met monthly throughout the first year for training, sharing results, and adapting the study to fit changing circumstances. This presentation highlights the participation and findings of the teacher-researchers in the community ethnography and the local applications of what we have learned.

Table 1B.2. The ethnographic research team.

<table>
<tr><th colspan="8">July 1998- June 1999</th><th colspan="6">July 1999- March 2000</th></tr>
<tr><td rowspan="3"></td><td colspan="7">Residential Ethnographers</td><td colspan="4"></td><td>Site Visit</td><td>Site Visit</td></tr>
<tr><td colspan="13">Teacher-Researchers</td></tr>
<tr><td>Site Visit</td><td></td><td>Site Visit</td><td></td><td>Site Visit</td><td></td><td>Site Visit</td><td></td><td>Site Visit</td><td></td><td>Site Visit</td><td></td><td>Site Visit</td></tr>
<tr><td colspan="5">Rovers</td><td colspan="3">Rovers</td><td colspan="6">Rovers</td></tr>
</table>

THE OIL/GAS INDUSTRY: COMPLEX AND PERVASIVE

As noted, the oil and gas industry is both complex and pervasive in the study communities. OCS activities draw workers to platforms, rigs, boats, helicopters, trucks, fabrication yards, and machine shops. Work happens in the air, on land, and over and beneath the waters of the Gulf. Schedules vary from regular shifts of seven days out and seven days home to on-call routines in which workers do not know from day to day when and how long they will be gone. Some work requires extensive formal education and training while other tasks are learned on the job.

One certainty of the oil and gas industry is change, so the most perplexing question in identifying impacts is “when?” With the ups and downs in the industry, the new technologies that are brought on line, and corporate restructuring, the industry is continually evolving. Jobs that once required nothing more than a strong back and willingness to work hard now require specialized training and even academic degrees. Employment that once brought steady salaries is now offered on a contract-by-contract basis. Where work schedules once required workers to be away from home for seven or even 14 days at a stretch they now demand that they be gone for 28 days at a time. All of these factors must be recognized and considered in the effort to understand how industry activities impact individuals and families.

The overall outlook of the industry is equally dynamic. Our university-based researchers first entered the communities in August 1998. Locals were guardedly optimistic that the industry was stable. By the new year, many of the workers first contacted were out of work. Then, oil rose to over $20 a barrel and has stayed there; yet rigs are still stacked and companies, with an eye to their stockholders, are waiting to reach their “comfort level” with the price trend. One industry analyst with whom we talked looked back fondly on the “10-year cycles” in the industry. Lately, he commented, “things have been real choppy.” Several of the research approaches we are using—ethnographers resident in the communities, the repeat visits by our teacher-researchers to family homes, return visits by university-based investigators to the communities—are efforts to map this “choppiness.”

OCS ACTIVITY WITHIN MORGAN CITY AND NEW IBERIA

We selected Morgan City and New Iberia as study communities primarily for their density of involvement, both historically and now, in offshore oil and gas activity. Moreover, both communities are involved in a range of functions related to the OCS: drilling, fabrication, service, support, and production. Thus, they differ from locales such as staging areas that serve a single function; at the same time, they are not dominated by downstream segments of the industry, such as is the case in refining regions. We thus anticipated that, in both communities, we would find “individuals and families” with historic involvement in the offshore industry.

But we anticipated, and are in the process of comprehending, differences between the two communities. New Iberia has a large sugar industry; Morgan City has a seafood industry. Morgan City’s port has a competitive advantage over New Iberia in water access to the Gulf; the Port of Iberia has the advantage in land. Morgan City, with a smaller population, is characterized by many as more vulnerable to ups and downs in the oil and gas industry; New Iberia, with its plantation homes and other tourist attractions, is viewed as more resilient to industry fluctuations. In an effort to understand these similarities and differences, we have been collecting archival material, newspaper accounts and observations by community officials and the business sector.

Shrimping declined as the oil and gas industry was taking off, and many of Morgan City’s residents shifted from the one occupation to the other. Because of their maritime skills and experience in the waters of the Gulf of Mexico, after the first platform was established offshore in 1947, many moved from shrimp boats to crew and supply boats servicing the offshore rigs. As its 1954 decision to rename the annual Shrimp Festival the Shrimp and Petroleum Festival indicates, the transformation of the community was quick and extensive. Morgan City is an island with a limited land base, but it was not long before a significant portion of its landscape was converted to industrial use in service of the offshore oil and gas activity.

In contrast, New Iberia came to oil from an agricultural economy based largely on sugar and continues to this day to associate itself more strongly with sugar than with oil, despite the greater impact of oil and gas on the community's economy. As the annual Sugarcane Festival attests, sugar is still the primary marker of local identity. Contrary to Morgan City's rapid acquiescence to the overwhelming influence of the oil industry, New Iberia's sugar elites strove to maintain their economic and political advantage and resisted change. Their control of the land surrounding the city and refusal to sell it for industrial development limited the scope of change. Only recently has new acreage passed from agricultural to industrial use at the Port of Iberia.

LOCAL TEACHERS AS EXPERTS AND ETHNOGRAPHERS

In communities with rich and complex histories from which present day involvement in oil and gas emerged, the knowledge and interpretations of local residents familiar with the past and active in the present are crucial to teasing apart the various factors that affect individuals and families involved in OCS-related work. Consequently, university researchers paired up with local teacher-researchers to develop and conduct this study. The university researchers bring research experience and information about a wide range of communities. The teachers, as insiders with multiple roles within the communities, bring in-depth knowledge of those places. Local views of the communities and the project findings are distinct from those of the "outside" researchers. These differences have significant implications for the quality of knowledge that will be gained from the research. The teachers, as co-researchers, live and teach in the community and therefore contribute to the research process and final products in unique ways.

The resident ethnographers and the teachers were responsible for talking with workers and their families. The teachers used several approaches to contact families for the study. One teacher sent home a letter explaining the research project and asked for any interested families to contact her. Some teachers interviewed former students' families and others chose to interview people they knew. Once they had joined the project, many people, in the custom of South Louisiana, offered their brothers, sisters, cousins, and various other relatives and said that, of course, they would love to be interviewed. The names of these contacts were passed along to the resident ethnographers when the teachers had identified all the families with whom they would work.

After each teacher established contact with at least three separate families, she gathered information through family trees, occupational timelines, and guided discussions. The original study design called for two meetings with each family, but, because of the decline in OCS activity that occurred between the summers of 1998 and of 1999, the team decided to conduct follow up discussions at least three months after the initial contacts to get information about how the downturn was affecting workers in various sectors of the oil and gas industry. The first discussions centered around the family background, jobs, work schedules, hobbies, and plans for the future. Then, the discussions focused on how the OCS worker's job affects his or her family.

BENEFITS OF COLLABORATIVE AND PARTICIPATORY RESEARCH

The information gathered by the teacher-researchers was enhanced by the regular interactions that take place between teachers and their students, friends, and family throughout the year. That information was shared at monthly study group meetings during which all researchers discussed the progress of the study, shared names of families who might join the study, and related the findings to work from previous studies.

The project, the researchers, and the community have benefited from the active involvement of local researchers. The teachers gained access to individuals and families that may have been reluctant to share information with strangers. Being familiar with the area, the industry, and the culture, locals are able to understand both the dialects and the special oilfield jargon that may be strange to outsiders. Those whose families that are and have been involved in OCS-related work established special bonds with the study participants. In the process, the teachers came to view the communities differently, We learned more about ourselves, our students, and the problems and resilience of members of our communities. Even those who had lived in the communities all our lives gained new insights of the impacts of the oil and gas industry.

The teachers who have the experience of being the wife or daughter of an offshore worker offered first-hand insights into the family accommodations and negotiations they experienced in relation to their father's or husband's frequent absences. These insights were invaluable as we evaluated the questions we would ask and discussed the responses of offshore workers and their families. Teachers' first-hand experience and intricate connections with a network of other oil families in the community provided the project with many contacts and fruitful leads.

The insights of the teachers who were relative newcomers to the community also contributed to the team's discussions and interpretations and complemented the insights of those whose families had been in the area for generations. These teachers often compared their own family history rooted in a different culture and place to those of offshore oil workers they were interviewing. They also offered insights concerning their experiences of moving into and working as teachers in the communities of study and the many ways in which they were made to feel both welcome and "on the outside." Thus the array of interpretive lenses and experience histories of the local researchers helped us as we continually reflected on and re-valued the research process.

SIGNIFICANT PRELIMINARY FINDINGS AND COMMUNITY OUTREACH

Community researchers are a tremendous asset for the dissemination of results and identification of strategies to mitigate negative impacts of OCS-related activity. Rather than waiting three years for the conclusion of the study, the teacher-researchers have begun to get information back into the communities and find ways to use what we have learned to improve our teaching and increase our community involvement.

The data from the field are still being analyzed, so here we only offer a few of the issues that have emerged from the study. Industry cycles up and down faster than in the past. The most recent downturn has had and continues to have significant and notable effects on companies and workers. Many people have been laid off due to downsizing and restructuring. Where jobs still exist, many of the companies now look different than they did only recently. Hourly workers are being kept at forty hours per week, which for many who are paid just above minimum wage is not enough money to support a family. Still, in the midst of the downsizing, many salaried employees are finding themselves working longer hours for the same pay. There is less opportunity for growth at the levels of both the individual and small company, and survival is still uncertain for many companies. Families have had to adjust to layoffs, longer work hours, and schedule changes.

Scheduling impacts are among the most significant for families. In many cases, lifestyles and child rearing are determined by how long the oilfield worker will be gone. When a worker is on a 7 and 7 shift, then household responsibilities may move from one parent to the other at each shift change. If the worker is gone 14 days at a time, the parent at home is frequently the major disciplinarian. With a 28 day rotation, spouses report that young children lose contact with their absent parents and many are fearful of the returning parent. For on-call workers, the unpredictability surrounding when and how long jobs take place generally means that families organize their lives to go on without the worker, and financial uncertainty prevails.

Despite the widespread involvement in the oil and gas industry, many in our communities do not readily recognize the impact of the oil industry in the lives of their families. Recording the work history of individuals similar to husbands and fathers has helped even the teacher-researchers understand the great impact OCS-related work has had on our families. Too often, we found families of workers do not share their common hardships with one another or understand the reasons they are struggling with the tasks of daily living.

As the bust of the eighties gradually became the boom of the nineties, lifestyles changed. In the downturn, older workers remembered the lean years and told us how they would survive if another major bust came about. New workers who had not experienced previous downturns did not heed the warnings of others. Many were left without jobs but with houses with large notes. Many left town. Budgets for schools were slashed when sales tax revenues went down drastically. With the study communities' heavy dependence on OCS-related work and revenues, we expect that oil will continue to drive our local economies. Therefore, for community researchers, a key question became, “How do we prepare the next generation for work in the oil industry?”

As Thomas Jefferson once said, “No child's education is complete unless he has a knowledge of the industry that supports the economy of the area in which he lives.” The classrooms became the first place to tell the story of the oilfield workers. The students needed to know about the industry that supports the economy of south Louisiana. First, we wanted to give students a realistic view of the industry and its cyclical pattern of prosperity and decline. We believe that students will be better prepared to make occupational choices and to become oilfield workers if they understand what the jobs entailed. Several teachers and their students participated in a summer workshop that drew upon the expertise of a computer specialist and researchers from the University of Arizona and of the students from St. Mary and Iberia Parishes to design a web site about the oil industry. This site is designed to help teachers and potential oilfield workers share the stories and locate information about working in the industry.

Other classroom activities include career awareness projects and a social studies fair project that is attempting to determine the number of students whose parents work in the oilfield. Through the study, teachers have made contact with workers we can invite to our classrooms to share knowledge and experience.

The teachers have reported back to the school boards about the impact of the oilfield in local classrooms. The school boards are supportive of the study and are eager to hear the final outcome. It has been pointed out that money is often the only voiced concern when the oilfield slows down. The next major milestone in the study will occur in March 2000 when the study team sponsors a series of meetings and workshops to share preliminary findings with various groups throughout Morgan City and New Iberia and gain feedback to incorporate in the project report.

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Leslie Chambers is a New Iberia native and a middle school teacher with the Iberia Parish Schools. She holds a B.A. degree in elementary education from University of Southwestern Louisiana, recently renamed the University of Louisiana at Lafayette. She has taught school for five years, and both her grandfathers, her father and her husband have worked in the offshore oil and gas industry.

Norma Cormier is a New Iberia native. She has taught middle school for the Iberia Parish Schools for three years. She received her B.A. degree from the University of Louisiana at Lafayette. Her husband is a principal at Iberia Parish Career Center.

Margaret Kleinpeter is a long-time New Iberia resident and a librarian with the Iberia Parish Schools. She has worked for the special education department for thirteen years. She received her B.A. degree in psychology from University of Louisiana at Monroe, an M.S. in library science from Louisiana State University, and an Ed.S. in reading and instructional technology from the University of Louisiana at Lafayette. Many of her relatives have worked in the oil industry, including her father-in-law who owns an oilfield service company.

Susan Lissard is a native of New Iberia and a middle school teacher for the Iberia Parish Schools. She holds a B.A. degree in elementary education from University of Louisiana at Lafayette and has taught school for 25 years. Her father and husband both worked in the offshore oil and gas industry.

SESSION 1C

CHEMOSYNTHETIC COMMUNITIES, PART I

Co-Chairs: Dr. Robert Avent, Minerals Management Service
Dr. Ian MacDonald, Texas A&M University

Date: November 30, 1999

Presentation	Author/Affiliation
Evidence for Stability and Change in Gulf of Mexico Chemosynthetic Communities from GIS, Remote Sensing Imagery, and Instrumentation	Dr. Ian R. MacDonald Dr. Gary Wolff Dr. Norman L. Guinasso, Jr. Geochemical and Environmental Research Group Texas A&M University Dr. Paul Montagna Marine Science Institute University of Texas
Geophysical Detection of Chemosynthetic Sites	Dr. William W. Sager Texas A&M University
Inorganic Biogeochemistry of Cold Seep Sediments	Dr. John Morse Dr. Rolf Arvidson Ms. Samantha Joye Ms. Susie Escoricia Mr. Craig Cooper Mr. Jeffrey Morin Mr. Luis Cifuentes Mr. Ethan Grossman Mr. Steve Macko Texas A&M University
Hydrocarbon Geochemistry of Gulf of Mexico Chemosynthetic Communities	Dr. Roger Sassen Texas A&M University
Beggiatoa Mats	Dr. Douglas C. Nelson University of California, Davis

EVIDENCE FOR STABILITY AND CHANGE IN GULF OF MEXICO CHEMOSYNTHETIC COMMUNITIES FROM GIS, REMOTE SENSING IMAGERY, AND INSTRUMENTATION

Dr. Ian R. MacDonald
Dr. Gary Wolff
Dr. Norman L. Guinasso, Jr.
Geochemical and Environmental Research Group
Texas A&M University

Dr. Paul Montagna
Marine Science Institute
University of Texas

INTRODUCTION

The CHEMO II Program (Stability and Change in Gulf of Mexico Chemosynthetic Communities) combines at least twelve independent investigations that address the geology, geochemistry, ecology, microbiology, and molecular biology of hydrocarbon seeps. The investigations are spread over a wide area of the continental slope and are examining processes that have long time constants. With this range of disciplines, producing a meaningful synthesis of results presents a significant challenge. At the within-site and between-site level, CHEMO II has been planned and executed with a statistically robust sampling design, which integrates analytical results from individual habitats within representative community sites. Data QA/QC depends in large part on a common system of sample identification to facilitate comparison of results obtained at common locations by different disciplines. Analysis for final data synthesis makes use of principal component analysis and other multivariate techniques.

A limited time-series of physical oceanographic parameters was completed during the program. In addition to data collected during the 1997 and 1998 field seasons, CHEMO II has integrated available time-series, geophysical, and remote sensing data from industry sources. Other aspects of data synthesis in CHEMO II are linkage between regional data and establishment of community status benchmarks that will make it possible for future investigators to detect changes in the ecological health of these communities. To satisfy this need, CHEMO II developed a Geographic Information System (GIS) database that encompasses all program sample collections. All of these materials are compiled in the GIS. This GIS will be delivered to MMS at the completion of CHEMO II and will be released to the public in CD-ROM and web-access modes. In addition to the CHEMO II program, MMS has supported other ongoing investigations of hydrocarbon seeps. It is hoped that these data will also be integrated into present GIS at the appropriate time.

This presentation briefly describes the organization of the GIS database. Selected results from the combined information contained in the GIS will demonstrate spatial and temporal processes characteristic of seeps. These include physical limits on the stability of gas hydrate at mid-slope seeps, characteristic dimensions of seep communities determined by faults that intersect the seafloor, and variability in fluid expulsion at dormant and active mud volcanoes.

RESULTS

A GIS combines multiple data sets within a common set of geographic coordinates. Each data set generates a layer which can be plotted individually or in combination with other layers, with the result that numerous unique maps can be produced to explore the relationship between different analytical results (Figure 1C.1). There are two fundamental types of GIS datasets: vector and raster. Vector data consist of points or lines such that each point or line is associated with sets of observations. In the CHEMO II data, for example, sampling stations are points within one of the program study sites. All collections can be accessed through the individual sampling stations, either by selecting points within the graphic display or by addressing station descriptors through Boolean queries. Additionally, graphs or photographs can be associated with the station locations and accessed through the GIS interface. Raster data consist of images or gridded data such as

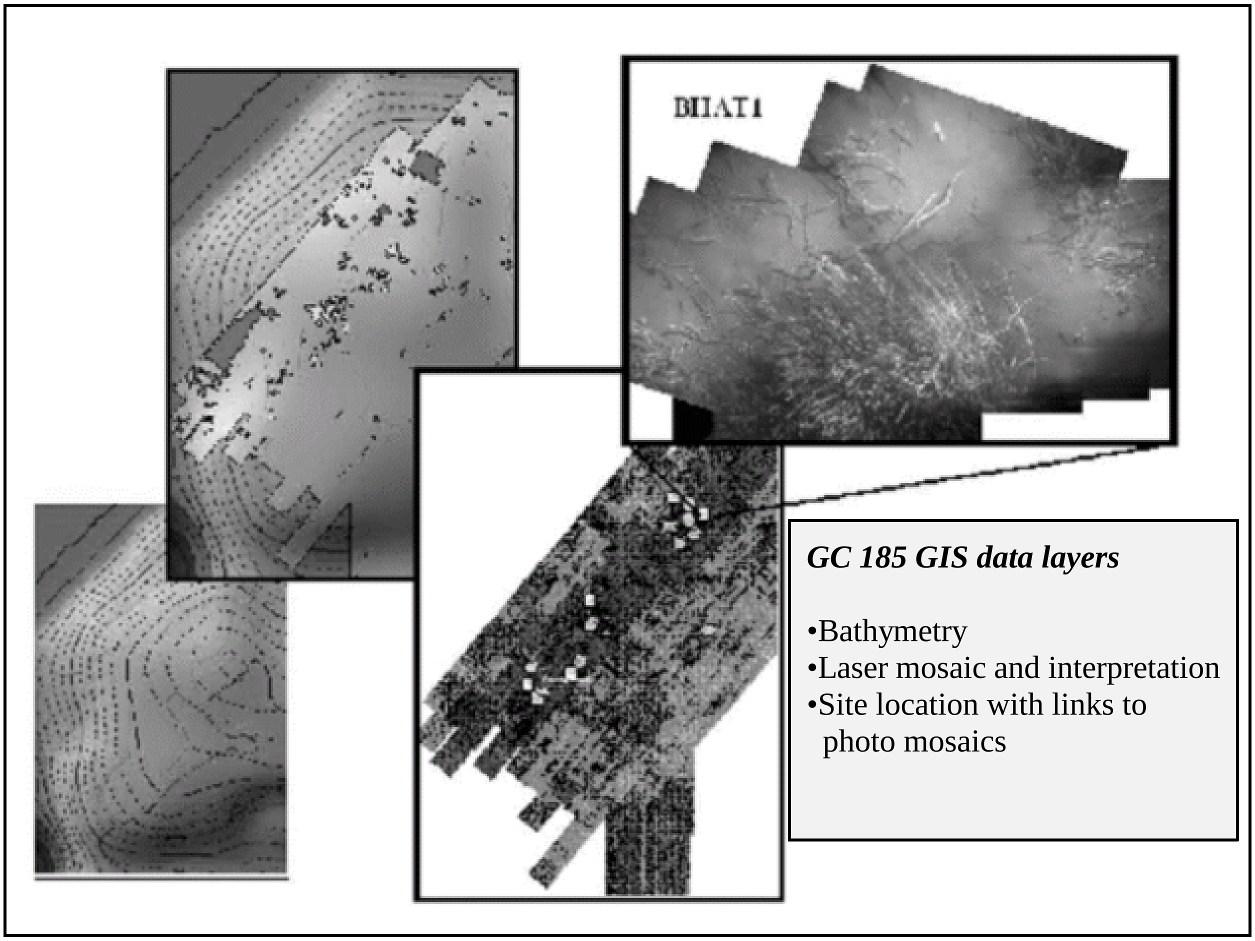

Figure 1C.1. Examples of GIS layers from the GC185 sampling site. Clockwise from lower left, the layers depicted are a high-resolution bathymetric model, bathymetry overlaid with community attributes, a photo-mosaic that documents a sampling station, and a laser line scan mosaic with station locations.

bathymetric depth models. In raster data, information is contained in the color or intensity of individual grid cells. In the CHEMO II GIS, raster data include bathymetry, laser line scan mosaics (optical images covering 100s of square meters), and side-scan sonar mosaics. Gas hydrate is an ice-like solid that forms under extreme pressure when hydrocarbon gases and water combine at low but above-zero temperatures. There are two principal forms of gas hydrate: structure I, composed of methane gas, and structure II, composed chiefly of propane. The two structures have different stability horizons of temperature and pressure. Understanding of the role that shallow gas hydrate plays in mid-slope seep communities has increased significantly during the course of CHEMO II. Gas hydrates are common in the upper 1m of the sediment column at all study sites except GB425. As results presented by Sassen *et al.* (1998) demonstrate, the molecular and isotopic composition of gas hydrate in CHEMO II sampling sites is variable and may indicate dynamic interaction with the microbial community. The discovery of the so-called "ice worm" by Fisher *et al.* (*In Press*), proves that metazoan organisms are both dependent on gas hydrate and can affect its stability in shallow sediments. The combined physical time-series data compiles at the constrains the type of gas hydrate that can persist in the shallow sediment of mid-slope seeps. The temperature and depth (pressure) range found at the study sites encompasses 6° to 12° C and 540 to 640m. This is only marginally favorable for formation of structure I gas hydrate (Sloan 1990). From this result, it is shown that structure I, if it occurs, will be a transient deposit, persisting only until temperatures exceed the stability envelope. Ambient conditions at mid-slope seep communities which do not appear to exceed the stability horizon for structure II gas hydrate. Structure II gas hydrate, as was proposed by Carney (1994), is a stable deposit that stores quantities of gas (and oil) in shallow strata, releasing them slowly and re-channeling or trapping fresh material that seeps in from below.

Influence of shallow-angle or antithetic fault zones in determining migration of hydrocarbons to shallow sediments of the Gulf of Mexico was proposed on the basis of sesimic data collected at the GC234 site (Behrens 1988), and the GC185 site (Cook and D'Onfro 1991). Subsequently, information on the distribution of tube worms and other chemosynthetic fauna was combined with seismic profiles and it was proposed that "fault-dominated" communities were most likely to support "complex communities" comprising tube worms and associated species (Reilly *et al.* 1996). Results from the CHEMO II program confirm aspects of this theory. Exhaustive mapping of tube worm clusters at GC185, based on a laser line scan mosaic, describes a single band adhering to the upthrown side of a north-south fault (Figure 1C.1). Prolonged activity along this fault is confirmed by accumulation of authigenic carbonate westward of the tube worm zone. At GC234, a similar process has a more complex realization due to the intersection of at least three, roughly parallel faults. No laser line scan data are available for this site, but transect estimates of tube worm density can be fitted to a robust trend surface by use of spatial kriging (Cressi). This surface, when compared to geologic interpretations, confirms the alignment of bands of tube worm clusters with the faults. These results refine the previous work and suggest tube worm colonization is mostly restricted to a ~50m wide zone along fault axes. This means that, in sites similar to GC234 and GC185, the width of communities can be estimated from geophysical survey data.

Fluid expulsion features on the Gulf of Mexico continental slope, sometimes called mud volcanoes, have been shown to be an important component of seep geology (Neurauter and Roberts 1994; Roberts and Carney 1997) and to support dense communities of the seep mussel, *Bathymodiolus childressi* (MacDonald *et al.* 1990). By design, the study sites included two fluid expulsion features which were believed to be at different stages of activity. GC233 is comparatively inactive and has been dormant for the at least the past ten years. Over longer time frames, however, subbottom profiles indicate that the feature formed as a series of indurate layers, each marking a separate eruption. GB425 is more active and is believed to have erupted during the course of the program. Thermistor records from a mud-filled crater and satellite synthetic aperture radar (SAR) images of the region over the site (supplied by UNOCAL and RADARSAT) document a series of events during the period from July 1997 to July 1998. Shortly after the thermistor was deployed, pool temperature increased to 48˚ C and remain high, but variable throughout the deployment. (min 6.1˚C, max 48.3˚C, mean 26.1˚C, stdev 9.07). The largest oil slicks detected by SAR coincided with the most rapid and extreme increase in fluid temperature. These results demonstrate dynamic fluctuations in the rate of hydrocarbon seepage and fluid expulsion in a continental slope setting.

CONCLUSION

The findings presented here document several time-scales for stability in chemosynthetic communities in the mid-slope region of the Gulf of Mexico. Fault-dominated systems appear to have the longest time-scale of change. Shallow gas hydrate and authigenic carbonate contribute to stability in these systems by plugging migration channels and, in the case of gas hydrate, buffering large quantities of hydrocarbons. Mud volcanoes have active and dormant stages, the latter lasting for years and the former changing markedly over periods of weeks. GIS is found to be an effective means for integrating diverse data in multi-disciplinary studies. It is hoped that MMS will distribute GIS layers generated by this program in CD-ROM and web-access formats.

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GEOPHYSICAL DETECTION OF CHEMOSYNTHETIC SITES

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INTRODUCTION

Chemosynthetic organisms have found a good place to hide. They live at oil seeps hundreds of meters below the ocean surface in an environment that is difficult for humans to reconnoiter. As a result, much of our knowledge of chemosynthetic ecosystems in the Gulf of Mexico comes from a small number of sites, most found by chance. Gulf of Mexico chemosynthetic sites are found in water depths from several hundred meters to more than two thousand meters (MacDonald *et al.* 1990). They seem to exist wherever there are hydrocarbons seeps on the continental slope. Despite the apparent large range, the distribution of such organisms is poorly known owing to sparse data. A fundamental unanswered question is whether lush chemosynthetic sites are rare and fragile or ubiquitous and robust.

Because chemosynthetic organisms are small, they are difficult to detect using geophysical methods. It would be useful if there were a geophysical technique that could detect them from the sea surface, but systems that can probe through several hundred to thousands of meters of water have insufficient resolution for this task. Even near-bottom geophysical records do not readily show chemosynthetic organisms. This means that confirmation of chemosynthetic organisms at a given site depends on near-bottom optical imaging of some sort: submersible observations, photography, laser-scanning, etc. Nevertheless, geophysical techniques can detect hydrocarbon seeps (Roberts *et al.* 1990); thus, the task of locating chemosynthetic sites becomes one of defining the small percentage of the seafloor affected by seepage and checking that area for chemosynthetic habitation.

STUDY RATIONALE AND METHODS

In this study we collected a geophysical data set that allowed complete coverage of the seafloor in several areas of known seeps. A modest amount of ground truth data, consisting of cores and submarine observations, were collected to help interpret the geophyiscal data. Since large tracts of the slope have been surveyed by the oil industry using 3D multichannel seismic data (MCS), it might have been more appropriate to use such data for our surveys. However, budget limitations did not allow us to collect or purchase 3D MCS data. Instead, we used a digital, long-range side-scan sonar, named *TAMU*^{2} (Hilde *et al.* 1991). This sonar was capable of imaging the seafloor at depths to several kilometers with pixel sizes of a few meters. Its records respond to variations in the physical properties of seafloor sediments and can quickly survey large areas.

During 1997, the *TAMU*^{2} side-scan sonar and a 3.5 kHz echosounder were used to survey three areas, totalling ~2,400 km^2, of the Louisiana continental slope known to contain numerous seeps. Two of these areas are on the upper slope in 300-1,100 m water depths. One is a 12 x 13 km rectangle centered on an active mud volcano at the border between Garden Banks (GB) leaseblocks 424 and 425. The other is a 26 x 44 km rectangle in the northern Green Canyon (GC) leaseblocks containing several well-known chemosynthetic and seep sites (GC-139/140; Bush Hill; Bush Lite; GC-272; Brine Pool NR-1; Mussel Beach; GC-234). The third survey was a 29 x 44 km rectangle located due south of the shallower GC survey. This area contains water depths from 1,000-2,250 m and is typical of the salt high and salt-withdrawal basin topography common on the lower slope. Sea surface slicks indicate that each of the GC survey areas contain 10 or more seeps (MacDonald *et al.* 1993).

A total of 31 gravity and piston cores were acquired from features in the side-scan sonar records to help interpret the sonar images. All but two of these were taken in the GC shallow survey area. The cores were split, photographed, described, and bulk density measurements were made. Chromatograms were made from samples containing oil.

Additional ground truth data come from submarine and submersible observations. Over the past dozen years, numerous dives have been made on the aforementioned chemosynthetic sites using the *Johnson Sea-Link* submersible and the U.S. Navy research submarine *NR-1*. As a part of this study, 19 features in the GC shallow survey area were investigated using the U.S. Navy research submarine *NR-1* with visual observations and a 2-12 kHz chirp sonar during a short cruise in 1998.

Although much of the focus of this study has been interpretation of side-scan sonar images, we also compared the responses of different geophysical data types in the areas of known seeps. From industry sources, we obtained several MCS lines from GB424/425 (the mud volcano) and GB184/185 (Bush Hill). In addition, 3D MCS surface amplitude anomaly maps were obtained over GC-184/185 and GC-272/273. An industry “geohazard” map (derived from high-frquency echosounder data) was acquired for GC-233/234/235 and an academic equivalent was obtained for a slightly larger area centered on these blocks (Behrens 1988).

RESULTS

The side-scan sonar mosaics show variations in “backscatter,” the sound scattered off the seafloor and returned to the sonar fish. Backscatter is affected by topography, surface texture, and sound scattering within the sediments just beneath the seafloor (Johnson and Helferty 1990). In the two shallow surveys, areas of low backscatter represent undisturbed hemipelagic clay and mud blanketing the upper slope. This is interrupted by high-backscatter (“sonar bright”) zones, principally along faults, that probably represent sediments disturbed by seepage. Cores from such zones typically show some combination of gas, oil, authigenic carbonate nodules, shells, or mechanical disturbance by slumping or flowage. Sonar bright zones are sometimes linear (often following faults), sometimes patchy, and have dimensions of tens to hundreds of meters. The sonar data show numerous subcircular sonar bright areas, many of which correspond to mud volcanoes. Preliminary results suggest that the brightest mud volcanoes are currently active, whereas those with lesser backscatter are dormant. The sonar mosaics also show numerous features that look like sediment flows. Some appear to emanate from subcircular mounds whereas others appear to have occurred either from leakage along faults or sediment instability.

Side-scan sonar mosaics from the deep GC survey area appear much different than its shallow counterparts. Although a few subcircular or patchy features can be seen, similar to the shallow survey areas, the images are dominated by the effects of sediment mass movement caused by salt tectonics. Large flows are seen to emanate from salt high flanks and pond on basin floors. Headwall scarps and faults ring the salt basins as a testament to ongoing tectonic motions. Gullies on the flanks of the salt highs suggest active downslope transport of sediments and accompanying erosion.

Because our comparison data sets are few, our observations are tentative and require confirmation elsewhere with additional data. The high-frequency, sea surface echo sounder data typically show acoustic “wipeout” (i.e., subbottom signal loss) or “turbidity” (i.e., acoustic scattering) in areas affected by gas and seepage. The wipeout/turbidity zones correspond to sonar bright zones imaged with the side-scan sonar. Presumably, the same seep disturbances cause anomalies seen in both data types. It appears that in most cases the wipeout and turbidity zones are wider than the corresponding sonar bright zones. What is more, the sonar images typically show details within the sonar bright zones that can be interpreted as geologic features. The 3D MCS surface amplitude anomalies show Bush Hill and a probable seep in GC272 as small, subcircular bright features. In these two cases, this type of image is superior to the sonar or high-frequency echosounder data because it shows the seeps as small, clearly defined anomalies. However, examination of other 3D MCS surface amplitude datasets indicates that such anomalies can often cover large areas, presumably a result of seep related alteration to seafloor sediments..

CONCLUSIONS

Chemosynthetic sites cannot be found directly using geophysical data, but such data can find seeps at which such organisms may be found. Geophysical survey methods can reduce the area of the seafloor to be examined to a few percent or less by delineating the small part of the seafloor affected by seepage. Definition of areas affected by seepage are based on defining areas of near-seafloor sediments with anomalous characteristics owing to the effects of seep related alteration. The side-scan sonar data collected in this study showed areas of anomalous sediment as sonar bright zones, typically located along fault systems. These data showed faults, mud volcanoes, sediment flows, and carbonate mounds. Other data types show seeps by different anomalies. Because different seeps appear more clearly in different data sets, probably no one data type is always best for defining seeps. Moreover, a geologic model is probably necessary to understand geophysical anomalies sufficiently to make a reliable determination of a seep location. The preferred method is to combine a geologic model with interpretation of several geophysical data types. The final confirmation of whether a site is inhabited by chemosynthetic organisms or not is likely to require near-bottom visual or optical observations.

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INORGANIC BIOGEOCHEMISTRY OF COLD SEEP SEDIMENTS

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OVERVIEW

The first phase of this project called for a detailed examination of the inorganic biogeochemistry occurring in cold seep sediments so that the processes responsible for cold seep benthic communities and their unique characteristics could be better understood. Therefore, a team of specialists in this field was assembled and an integrated research program was added to the second phase of this research.

The primary focus of the new research was on understanding the processes influencing the carbon dioxide and sulfide systems. This research is presented in sections that have been divided according to major activity. Later these results are included a general synthesis of overall findings. The major sections are

1) *Pore water and solid phase chemistry*: This section uses a “classical” approach in which cores were sectioned to establish depth profiles of dissolved and solid phase chemical components of interest.

2) *Sulfate reduction rates*: It is possible to measure the rates at which bacteria convert dissolved sulfate into hydrogen sulfide by using a radiotracer technique. Both depth profiles and “integrated” rates were determined at most sites.

3) *Stable isotope chemistry*: Fractionation of the stable isotopes of carbon, oxygen and sulfur occurs by both biotic and aboitic processes. Stable isotope ratios of these elements were determined at selected sites for both dissolved and mineral phases to aid in the interpretation of the processes occurring in cold seep sediments.

4) *Microelectrode profiling*: An “emerging” new technology was utilized to obtain very detailed depth profiles of dissolved sulfide near the sediment-water interface. This was done in order to obtain better estimates of fluxes across the sediment-water interface and behavior of sulfide in the highly dynamic region.

PORE WATER AND SOLID PHASE CHEMISTRY

Approximately 120 push cores were collected at four primary chemosynthetic sites (GC233, GC234, GB425, and GC185) comprising 28 distinct stations (BHAT1, BHAT2, BHB3, BHBC2, BHBXC1, BHM3, BHM4, BHST1, BHST2, BHUN1, BHUN2, BPAT1, BPB2, GBM1, GBM2, GBB1@GBM2, GBUN1, GCAT1, GCB1@GCAT1, GCAT2, GCB3 (Orange, White, and Offmat), GCBX2, GCBXC1, GCJT1, GCJT2, GCST1). Cores were sampled at 2 cm intervals, and over thirty different analyses were performed on extracted porewater and solid phases yielding a large data set (~10,000 analyses).

An important geochemical process that serves to discriminate stations is the extent of sulfate reduction. The reduction and depletion of seawater sulfate in these porewaters yields dissolved H_2S, which is absent in the overlying oxic water column, and an increase in dissolved inorganic carbon(DIC). Elevated DIC concentrations in turn promote production of solid phase calcium carbonate at the expense of dissolved calcium. The basic stoichiometry of these coupled reactions is easily identified within the data set and supports a basic scheme of grouping stations according to the overall extent of reduction (see discussion in following subsection).

Observed porewater nutrient and DOC variations with depth are generally complex and do not form a clearly recognizable pattern. Relationships within solid-phase properties and between solid and porewater parameters are also generally more complex than those existing within the porewater data set.

All sediment recovered is distinctly fine-grained. Generally positive relationships are observed between the abundance of solid phase sedimentary carbon (both total organic and inorganic) and porewater DIC. Good correlation is also seen within solid phase metal extractions (iron and manganese). Acid volatile sulfide concentrations are everywhere less than 40 µmols/g (4 µmols/g average). Total reduced sulfur (TRS) concentrations average 108 µmols/g. The low abundance of extractable iron indicates that it probably limits the extent of solid phase sulfide formation and is in part responsible for the very high levels of dissolved sulfide observed at certain stations.

SULFATE REDUCTION RATES

Sulfate reduction rate measurements were made at selected sites. When these data are combined with those from the porewater and solid phase geochemisty, they suggest the following organization:

- *Inactive* station porewaters show little significant departure from ordinary seawater in composition, with only slight increases in DIC (up to ~ 4mM, a twofold increase), small (<10%) to negligible depletions of sulfate and calcium, and sulfide concentrations less than ~250 µM (often below our detection limit of 3 µM). These stations also show integrated sulfate reduction rates of <10 to 55 mmoles m^{-2} day^{-1}. Chloride and other major ion concentrations are within 10% of standard seawater compositions. This group comprises the largest number of stations, and with the possible exception of bacterial mats, does not distinguish itself biologically in any obvious way. These stations are variously dominated by adult, juvenile, and senescent tubeworms and mussels.

- *Active* stations show clear evidence of intense sulfate reduction, either in terms of a high integrated sulfate reduction rate (>55 mmoles m^{-2} day^{-1}), or in terms of depleted sulfate and calcium. These stations include BHUN2 (1998 core), BHM4 (dive 4046), BHB3, GCAT1 (dive 2,880), GCAT2, GCB3, and GCJT2. In addition, integrated rates at certain active sites are so high as to merit further division of this category to *high* (50—1,000 mmoles m^{-2} day^{-1}) and *extreme* (>1,000 mmoles $^{—2}$ day^{-1}). Active-high stations thus include BHUN2 (1998 core), GCAT2-dive 4048 and GCB3 (orange *Beggiatoa* mat); active-extreme stations are limited to GCAT2 (dives 2,872; 2,886; 4,029). The depth at which sulfate is depleted is variable, and ranges from 5-10 cms below the sediment-water interface. Stations dominated exclusively by Beggiotoa (GCB3) exhibit sulfate depletion curves that are markedly less in slope compared with those found at GCAT2. In addition, the stoichiometry of sulfate-DIC relationships in samples for which the extent of sulfate reduction is greater than 90% is consistent with the organic matter undergoing oxidation being methane.

- Brine stations show clear evidence of mixing between seawater and Na-Ca-Cl brine compositions, and these stations (GBM2 and BPB2) form a separate category. Although sulfate reduction in these stations may also be very high, it is limited to the shallow interval just below the sediment-water interface. Variations in sulfate and sulfide can be understood in terms of a simple mixing model, in which the brine end member contains zero sulfate and 3x normal seawater sodium chloride.

STABLE ISOTOPE MEASUREMENTS

Based on the above observations, stable isotope measurements were made on selected samples. Carbon isotope ratios were determined on DIC and calcium carbonate, where oxygen isotopes were also measured. Sulfur isotope ratios were measured on total dissolved hydrogen sulfide and total reduced sulfide (dominated strongly by pyrite). This is a difficult and laborious task. These results comprise, to the best of our knowledge, the only existing data set for marine sediments where both major dissolved and solid phase isotope data coexist for the sulfide and carbonate systems.

A strong correlation (R^2 =0.85) was observed between solid phase carbon and oxygen isotopes. This correlation is interpreted as a mixing line between biogenic carbonates formed in near surface waters and authigenic carbonates formed in sediments, which have more positive oxygen and more negative carbon isotopes. The relative abundance of the authigenic component increases with increasing sediment calcium carbonate and organic carbon concentrations. There was no obvious relationship between the carbon isotope ratio in DIC to that of the calcium carbonate. This probably reflects both a variable fraction of authigenic carbonates in the solid fraction and perhaps also indicates that these carbonates did not entirely form from the current DIC pool.

As is often the case because of the complexities of biogeochemical processes in the sedimentary sulfur system, there are generally no clear patterns or relationships among the sulfur isotope ratios in different phases or with other probably important sediment parameters. However, in some cases there is a tendency for most data to closely clump together in a narrow range with other data radiating in a loosely preferred orientation (e.g., Figure 1C.2). The explanations for these observations are still under consideration.

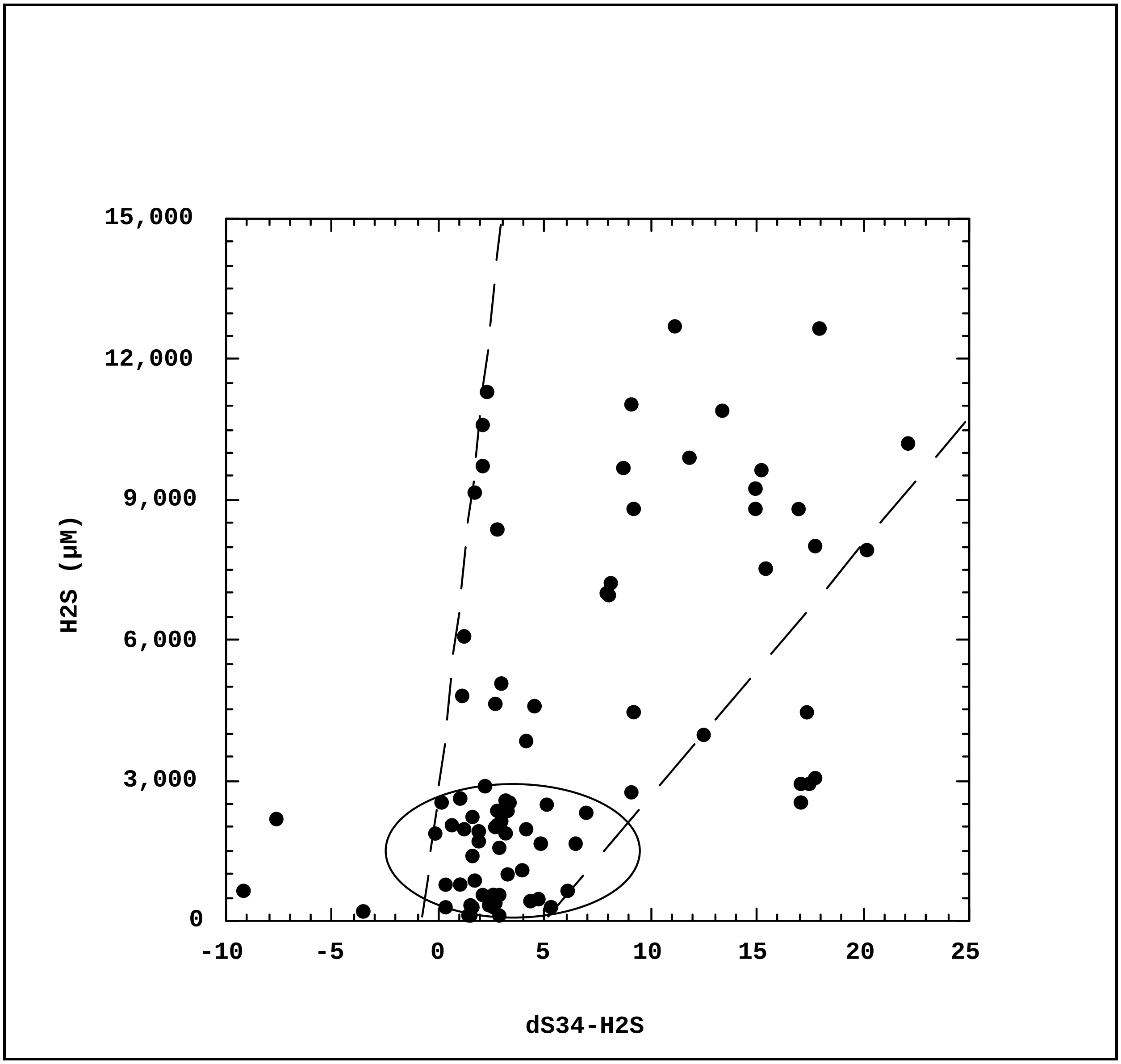

Figure 1C.2. The relationship between dissolved sulfide and its stable sulfur isotope ratio.

MICROELECTRODE PROFILES

As part of the geochemistry program, a new solid state microelectrode technology was employed to obtain millimeter scale profiles of dissolved oxygen, O_2, and reduced metabolites, primarily H_2S, in sediment pore waters. The microelectrode system made possible the simultaneous determination of O_2, H_2S, reduced iron (Fe^{2+}) and reduced manganese (Mn^{2+}) concentration. However, Mn^{2+} and Fe^{2+} concentrations were typically below the analytical detection limit of the system, and the O_2 concentration was difficult to quantify because of sampling problems associated with the time between collection and analyses. The primary focus thus became documenting the distribution of H_2S in sediments in order to obtain improved estimates of sediment-water fluxes.

Table 1C.1. Calculated approximate H_2S fluxes for sampling events in 1997 and 1998. An asterisk (*) indicates an apparent small influx of sulfide due to storage problems. Fluxes at these sites can generally be expected to be small.

1997 H_2S FLUX (UMOL CM^-2 DAY^1) Tube Worm Bush		**1998 H_2S FLUX (UMOL CM^-2 DAY^1) Tube Worm Bush – Drip Line**	
GCST1-5	0.0	BHAT1-3	0.0
BHST2-7	-760	BHST1-5	0.0
BHAT2-2	*	GCAT2-1	-0.1
GCAT1-8	*	BPAT1-4	0.0
BHAT1-4	*	BHAT2-2	0.0
		GCJT2-4	0.0
		BHM3-8	-350
		Tube Worm Bush – Peripheral	
		BHAT1-6A	0.0
		GCAT2A-3	-3600
		GCST1-5	0.0
		GCAT1-9A	0.0
		BHAT2-7A	0.0
Orange Mat		**Orange Mat**	
GBM2-6	-810	GCB1-4	-110
GCAT2-6	-260	BPB2-5	-1400
GCAT2-3	-1100	GCB3-4	-660
White Mat		**White Mat**	
GCB-6	-480	BHB1-3	-540
GCB-1	-1900	BHB3-2	-300
BHST1-5	-62	GCB1-3	-2100
		GBM2-5	-3200
Controls		**Controls**	
BHBC2-4	*	GCBX2-5	*
BHUN1	0.0	BHBXC1-4	0.0
		GCBXC1-3	-3.3
		GBUN1-5	-60

Thirteen cores from tube worm bushes, bacterial mats, or control sites (no chemosynthetic fauna) were microprofiled in 1997. Three cores were from along the drip line of adult tube worm bushes (BHAT2-2; BHAT1-4; GCAT1-8) and one core was from the drip line of a senescent tube worm bush (GCST1-5). Twenty-five cores were profiled during the 1998 cruise. Seven drip line cores and five peripheral cores were sampled from tube worm bushes. Three orange bacterial mats and four white bacterial mat cores were collected. Two of those cores were collected along a transition zone from an orange to white bacterial mat. One core was collected from an uninhabited site and three cores were sub-cored from box cores.

Results of sulfide flux calculations are presented in Table 1C.1. Although there are certainly a few exceptions that bear close scrutiny e.g., GCAT2A-3) from both the chemical and biological perspectives, there are certainly strong tendencies for:

1) Controls to have small to negligible sulfide fluxes; as they should in this area.

2) Algal mats to have moderate to very high sulfide fluxes.

3) Tube worm sites to have negligible to very low sulfide fluxes.

SUMMARY

The studies of the inorganic benthic biogeochemistry went well and largely very close to the initial plans. The results constitute a truly unique and large data set documenting the complexity and heterogeneity of these chemosynthetic communities. These results will be synthesized with the other components of this project.

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HYDROCARBON GEOCHEMISTRY OF GULF OF MEXICO CHEMOSYNTHETIC COMMUNITIES

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In ecological terms, stability connotes the ability of a community to return to a prior condition following perturbation (May 1973). Unique complex chemosynthetic communities were first discovered in the Gulf of Mexico during trawling in areas characterized by sediments containing free hydrocarbon gases, gas hydrates (Figure 1C.3), and bacterially oxidized crude oil rich in toxic aromatic hydrocarbons at water depths in the 600-700 meter range (Kennicutt *et al.* 1985). These low-temperature complex chemosynthetic communities derive energy from reduced carbon, mainly hydrocarbon gases, and bacterial H_2S. Later research confirmed that a number of complex chemosynthetic communities are spatially associated with hydrocarbon production (Sassen *et al.* 1993). Hence, an important issue is whether or not hydrocarbon production in the Gulf of Mexico slope will affect the stability of complex chemosynthetic communities.

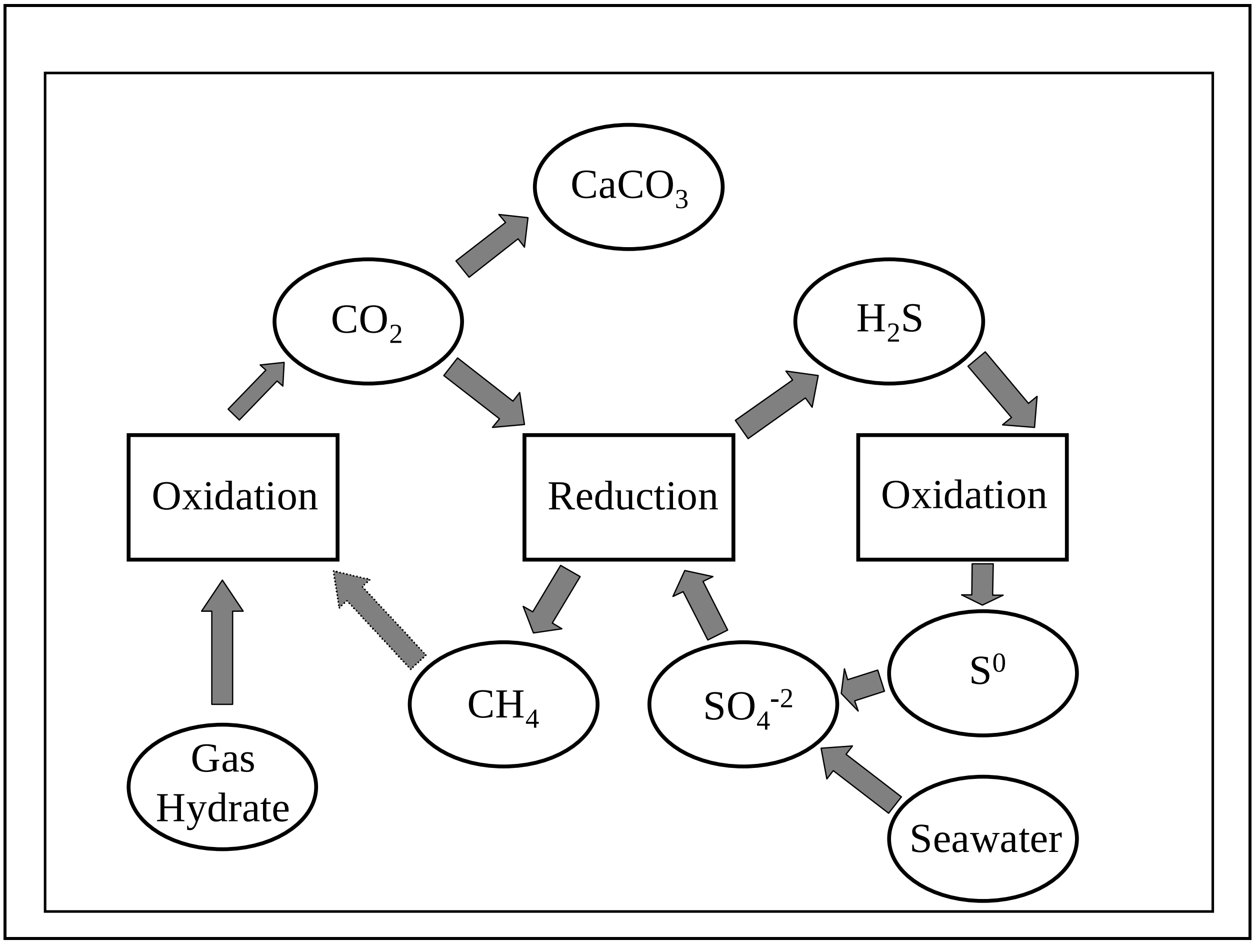

Figure 1C.3. Geochemical overview of the gas hydrate environment.

Understanding of the Gulf slope subsurface hydrocarbon system is necessary to address community stability. A large structural complex formed during the Tertiary across much of the Gulf slope by syndepositional loading of an unstable salt substrate, creating temperature conditions within salt withdrawal basins to generate enormous volumes of oil and gas from deeply buried petroleum source rocks (Sassen *et al.* 1999a). Biomarker analysis of an oil sample from the Green Canyon (GC) 185 area, plus numerous unpublished biomarker analyses performed at GERG, are consistent with a single petroleum source rock of varying lithology and maturity. Upper Jurassic source rocks are thought to be the main source of hydrocarbons across the much of upper Gulf slope from Garden Banks (GB) east to southern Mississippi Canyon (Gross *et al.* 1995). Actively moving salt bodies and concomitant faults are the migration conduits from depth where oil and gas reservoirs occur, and to the sea floor upon which chemosynthetic communities are often found (Sassen *et al.* 1993). The main conclusion is that the occurrence of chemosynthetic communities of the Gulf slope is largely related to a single Upper Jurassic hydrocarbon system in which hydrocarbon generation is ongoing or geologically recent.

Upper Jurassic-sourced oil is found in anomalous amounts in sediments at or near four of our chemosynthetic community sites (GC 185, GC 234, GC 233, GB 425). The mean of 108 measurements of oil concentration performed on the four study sites is about 11,778 ppm by sediment weight. The range between individual measurements is large, however, from 6 ppm to 46,834 ppm. This wide range is expected in sediments of hydrocarbon seeps, and even within single piston cores of seep sediments. Although oil is present in low abundance in most Gulf slope sediments (<10 ppm), three of our sites are clearly anomalous in terms of oil concentration. Differences in concentration of oil between three sites (GC 185, GC 234, GB 425) are not thought to be meaningful. In contrast, new data and previous studies (Sassen *et al.* 1994) do not demonstrate that crude oil is as widely distributed in sediments adjacent to the GC 233 brine pool site. This, however, could be an artifact of sampling.

C_{15+} chromatography of crude oil from chemosynthetic communities as part of the present and previous studies shows a common pattern of alteration. If in significant concentration, all oils are heavily affected by bacterial oxidation that did not necessarily occur within surficial sediments of chemosynthetic communities. Bacteria selectively oxidize the *n*-alkanes and isoprenoid hydrocarbons originally present in the oil, eventually leaving only an elevated baseline on chromatograms called the unresolved complex mixture (UCM) (Sassen *et al.* 1994). The work of Sassen (1980) implies that the lack of a continuous alteration series from altered to unaltered oil shows that the process of bacterial oxidation of oil is either inactive or only active at a low rate. Thus, slow bacterial oxidation of increasingly toxic crude oil could have a minor effect on driving geomicrobiologic processes but cannot be assumed as a major driving force driving bacterial activity at present in shallow sediments (<20 cm) of our study areas. This uniformly advanced bacterial oxidation of oil was also observed in studies of three of the same localities in previous years (Sassen *et al.* 1993a, 1993b, 1994). In other areas not part of the present study (i.e., the GC 142 mud volcano) show the continuous alteration series in oil samples, but such areas are generally not occupied by chemosynthetic communities (Sassen *et al.* 1994). This bias is inherent to our study based on our choice of sampling sites.

Hydrocarbon gas, however, appears to be more effective at driving bacterial processes at all of our study sites (GC 185, GC 234, GC 233, GB 425). Molecular and isotopic properties provide abundant evidence of the classic bacterial alteration series of hydrocarbon gases commonly observed in geologic environments (Winters and Williams 1969; Sassen 1980) and in laboratory simulations (Stahl 1980). Unaltered thermogenic hydrocarbon gases from the subsurface hydrocarbon system were sampled at GC 185 and GC 234 (Sassen *et al.* 1998, Table 1; Sassen *et al.* 1999b, Table 1), sites with complex chemosynthetic communities including various species of tube worms, mussels, clams, and other organisms. The bulk of thermogenic gases and CO_2 from the subsurface hydrocarbon system bypass shallow sediments and exit by venting to the water column (Sassen *et al.* 1999b). Vent gas undergoes a rapid phase change under ambient temperature and pressure and crystallizes as abundant solid gas hydrate at these localities.

An extensive treatment of the molecular and isotopic properties of vent gases and gas hydrates at the GC 185 and GC 234 two localities is given by Sassen *et al.* (1998, 1999b). Conclusions cannot be extended to all chemosynthetic communities but, where present in abundance, gas hydrates can have a profound localized effect on diverse bacterially mediated geochemical processes in complex chemosynthetic communities dependent on hydrocarbon gases and H_2S (Sassen *et al.* 1999b). Gas hydrates occur physically as vein-fillings in hemipelagic muds near gas vents, and are surrounded by chemosynthetic organisms such as tube worms at GC 185. Molecular and isotopic properties of the gas hydrate forming C_1-C_5 hydrocarbons and CO_2 provide key insight to bacterially mediated processes. Hydrate-bound methane is altered by bacterial oxidation at GC 185, as indicated by enrichment of ^{13}C and deuterium (D), and by hydrate-bound CO_2 depleted in ^{13}C (Sassen *et al.* 1998, Table 1). Results suggest that the degree of gas hydrate alteration is related to duration of exposure of gas hydrate at the sea floor (Sassen *et al.* 1999b). It is speculated, on this basis, that gas hydrates could play a role in initiation and development of complex chemosynthetic communities.

The rate of hydrocarbon gas oxidation is orders of magnitude higher in the sediments associated with gas hydrates at GC 185 and GC 234. In sediments associated with gas hydrates, bacterial oxidation of a mixed pool of C_1-C_5 hydrocarbon gases yields a net production of CO_2 highly depleted in ^{13}C (Sassen *et al.* 1999b, Table 2). The bacterial oxidation rate is assumed to be rapid based on molecular and isotopic evidence, suggesting that concomitant bacterial sulfate reduction and precipitation of authigenic carbonate in sediments are also rapid. The rate of bacterial oxidation is such that it could destabilize gas hydrates by removing the free hydrocarbon gases necessary to maintain their stability (Sassen *et al.* 1999b).

It was observed in sediments at both GC 185 and GC 234 that the $\delta^{13}C$ of sediment methane was often depleted in ^{13}C relative to both thermogenic vent gases and gas hydrates This is strong geochemical evidence that thermogenic carbon in sediments (i.e., mainly gaseous *n*-alkanes) can be recycled via methanogenesis to yield a net production of bacterial methane depleted in ^{13}C at chemosynthetic communities (Sassen *et al.* 1999b). This observation has significance to life in extreme environments (Sassen *et al.* 1999b), and also to the geochemistry of the dominant hydrocarbon gas at our other study sites (GC 233 and GB 425).

The origin of flowing methane at brine pools at the GB 425 and GC 233 provides a key example of bacterial recycling of thermogenic carbon. Measurements of both $\delta^{13}C$ and δD unambiguously identify thermogenic methane and bacterial methane of varying origin (Coleman *et al.* 1996). Isotopic properties identify the volumetrically significant methane at brine pool sites as mainly from reduction of CO_2 via bacterial methanogenesis (Sassen *et al.* 1999b, and references therein). The main source of CO_2 at these sites is assumed to be bacterial oxidation of thermogenic hydrocarbons, reinforcing the relationship of the Upper Jurassic source system to even some simple chemosyntheic communities of mussels on the Gulf slope. The $\delta^{13}C$ and δD values of some methane from adjacent sediments are consistent with the atypically high rates of bacterial oxidation, suggesting that concomitant bacterial sulfate reduction rates are also high, tending to increase alkalinity and to drive precipitation of authigenic carbonate.

In summary, all sites share the presence of thermogenic hydrocarbons that drive multiple bacterial processes including bacterial hydrocarbon oxidation to produce CO_2, sulfate reduction to produce H_2S, and methanogenesis to produce methane, fueling the chemosynthetic communities. GC 185 and GC 234 represent more active and recently charged gas hydrate environments with complex communities, whereas GC 233 and GB 425 lack abundant gas hydrate or great biologic diversity, and appear to have received hydrocarbon charge earlier in time. Given the prolific volumetrics of the Upper Jurassic source system, hydrocarbon charge to migration conduits can be expected to continue of a scale of millions of years. Oil and gas production are unlikely to significantly affect overall flow of hydrocarbons to the sea floor. The chemosynthetic communities we studied are stable, and will generally return to their prior condition after disturbance. Intermittent changes in fluid flow rates and location in the more important sources of instability than hydrocarbon production, but only on a geologic time scale.

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*Publication approved by MMS as project-related.

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BEGGIATOA MATS

Dr. Douglas C. Nelson
University of California, Davis

INTRODUCTION

Recently, several studies have been published on natural populations of morphologically diverse, marine, chemoautotrophic, sulfur-oxidizing bacteria belonging to the genera *Thioploca*, *Beggiatoa* and *Thiomargarita* (Fossing *et al.* 1995; McHatton *et al.* 1996; Nelson *et al.* 1989; Otte *et al.* 1999; Schulz *et al.* 1999). Individual cells of these uncultivated bacteria are unusually wide ranging from 12 to 750 mm in diameter vs. a typical bacterial cell dimension of approximately 1 mm. Each of the wide sulfur-oxidizers examined has been found to contain a central vacuole as the majority of the biovolume of each cell, and whenever examined these bacteria have been observed to accumulate nitrate at intracellular concentrations ranging from 40 to 800 mM—roughly 10,000-fold higher than the corresponding ambient concentration.

The physiological role of nitrate, which is presumably stored in the vacuole, has been fairly well characterized for two natural populations (Otte *et al.* 1999; McHatton *et al.* 1996; McHatton 1998). It appears that nitrate is employed by these bacteria as an electron acceptor that allows them to fuel their metabolic processes via oxidation of hydrogen sulfide even in the absence of oxygen. This respiratory process, which converts sulfide to elemental sulfur plus sulfate and nitrate to ammonia, allows the studied populations of *Beggiatoa* and *Thioploca* to dominate the top 10 to 20 cm of marine sediments and reach biomass densities exceeding 1.0 kg wet wt./m^2. When one observes dense mats of these bacteria at the sediment/water interface they are at the one point in their migration cycle where it is possible for them to take up and store nitrate. All of the vacuole-containing, nitrate-accumulating bacteria that have been characterized to date by molecular analysis (Ahmad *et al.* 1999; Ahmad 1999; Teske 1999) fall into a very restricted evolutionary affinity group (Cluster 3, Figure 1C.4), suggesting that they also share numerous other metabolic properties.

RESULTS

Based on samples from a number of sediment cores, the dominant Gulf of Mexico *Beggiatoa* populations are in two main width classes, averaging approximately 40 and 80 mm in diameter (Table 1C.2). Any core taken in the vicinity of the hydrocarbon seeps, regardless of whether a surface mat was present, contained significant biomass of these bacteria distributed over the upper 3 to 5 cm of the sediment (Table 1C.2). There is some tendency for the depth-integrated *Beggiatoa* biomass to be lower for the sites where no surface mat is present (Figure 1C.5), but the core designated GCB3 C9 (Table 1C.2) has a total biomass and vertical distribution typical for those of the orange and white mats (Table 1C.2, Figure 1C.5). For the representative samples of the narrower (approx. 40 mm) Gulf of Mexico *Beggiatoa* tested, the protein to biovolume ratio (Table 1C.3) indicates that they contain a non-cytoplasm-filled vacuole as approximately 80% of their biovolume. That is, like the vacuolate strain from Monterey Canyon, they contain only about 20% of the protein predicted by their biovolume.

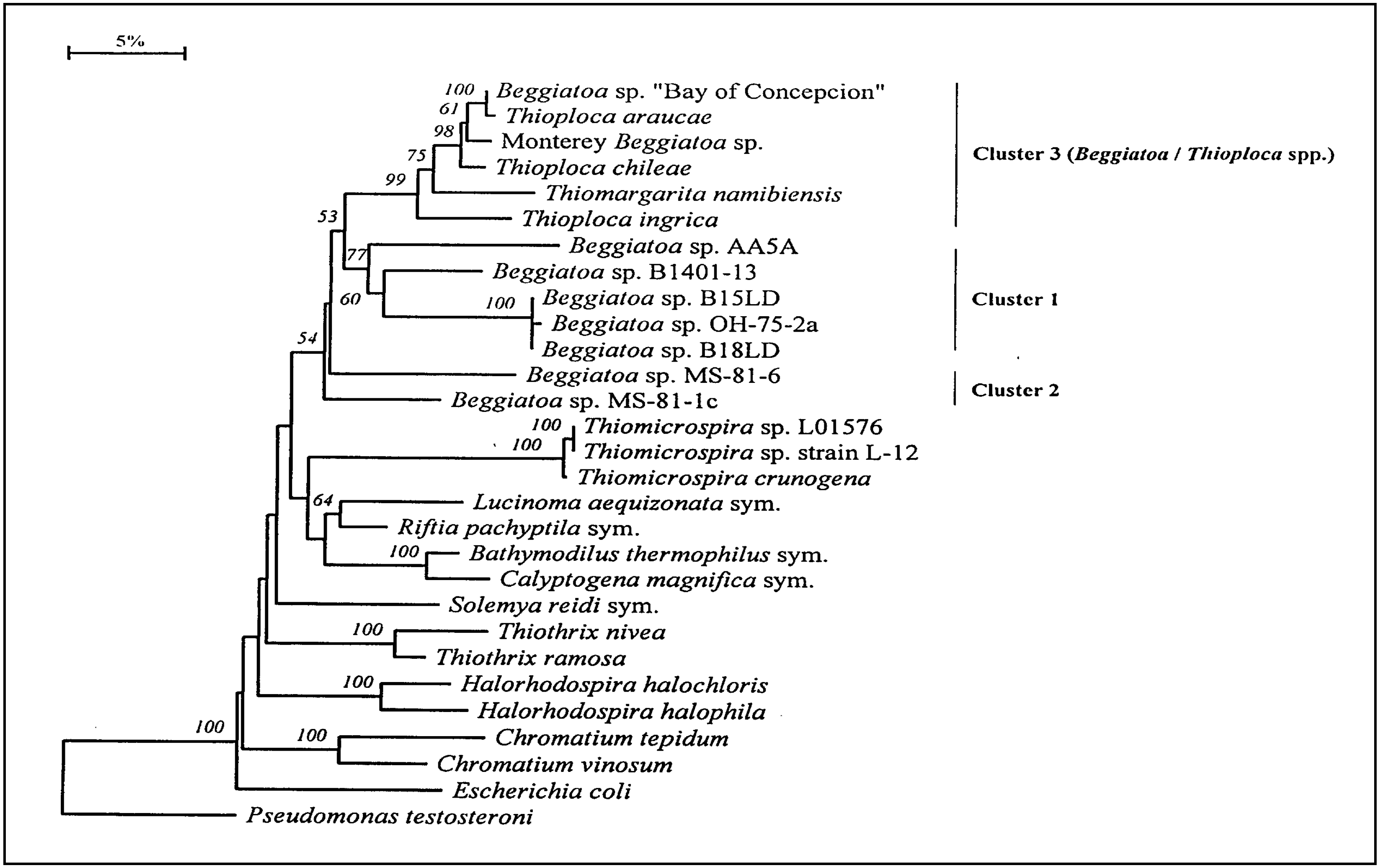

Figure 1C.4. Evolutionary relationships among selected members of the gamma *Proteobacteria* as determined by 16S rRNA sequencing (Ahmad *et al.* 1999; Ahmad 1999). The majority of the strains shown are autotrophic sulfur bacteria. Cluster 3 includes all vacuolate sulfur bacteria known to accumulate intracellular nitrate. Clusters 1 and 2 include all known sequences for, respectively, non-vacuolate freshwater and non-vacuolate marine pure cultures of *Beggiatoa* spp.

Table 1C.2. Depth Distribution of *Beggiatoa* Filaments in Gulf of Mexico Cores, 1998.

Sample	Cell Width	***Beggiatoa* (grams wet st./m sq.) by depth interval**						Comments
	(um)	**0-1 cm**	**1-2 cm**	**2-3 cm**	**3-4 cm**	**4-5 cm**	**Total**	
BPB2 C5	40	1.1	0.7	0.1	0	0	2.2	**No Surface Mat**
BPB2 C7	37	2.2	1.8	0.3	0	0	4.3	Dense Orange Mat
BPB3 C7	40, 81	6.1	3.5	2.3	0.7	0	12.6	Orange Mat
GCB1 C3	38	4.7	2.9	2.3	1.1	0.7	11.7	White/Orange Mat
GCB1 C4	44, 80	8.4	1.5	1.5	0.2	0.2	11.8	Great Orange Mat; **Harvested**
GCB2 C7	41	4.1	2.0	1.5	0.5	0	8.1	Orange Mat; **Harvested**
GCB3 C1	42	9.2	5.3	2.6	1.4	0.7	19.2	Great Orange Mat; **Harvested**
GCB3 C2	42, 81	7.6	3.8	2.1	0.8	0.5	14.8	White/Orange Mat
GCB3 C9	40	4.8	3.2	1.8	1.3	0.3	11.4	**No Surface Mat**
GCBXC1 C3	37	2.6	0.4	0.4	0	0	3.4	**No Mat; Box Core**

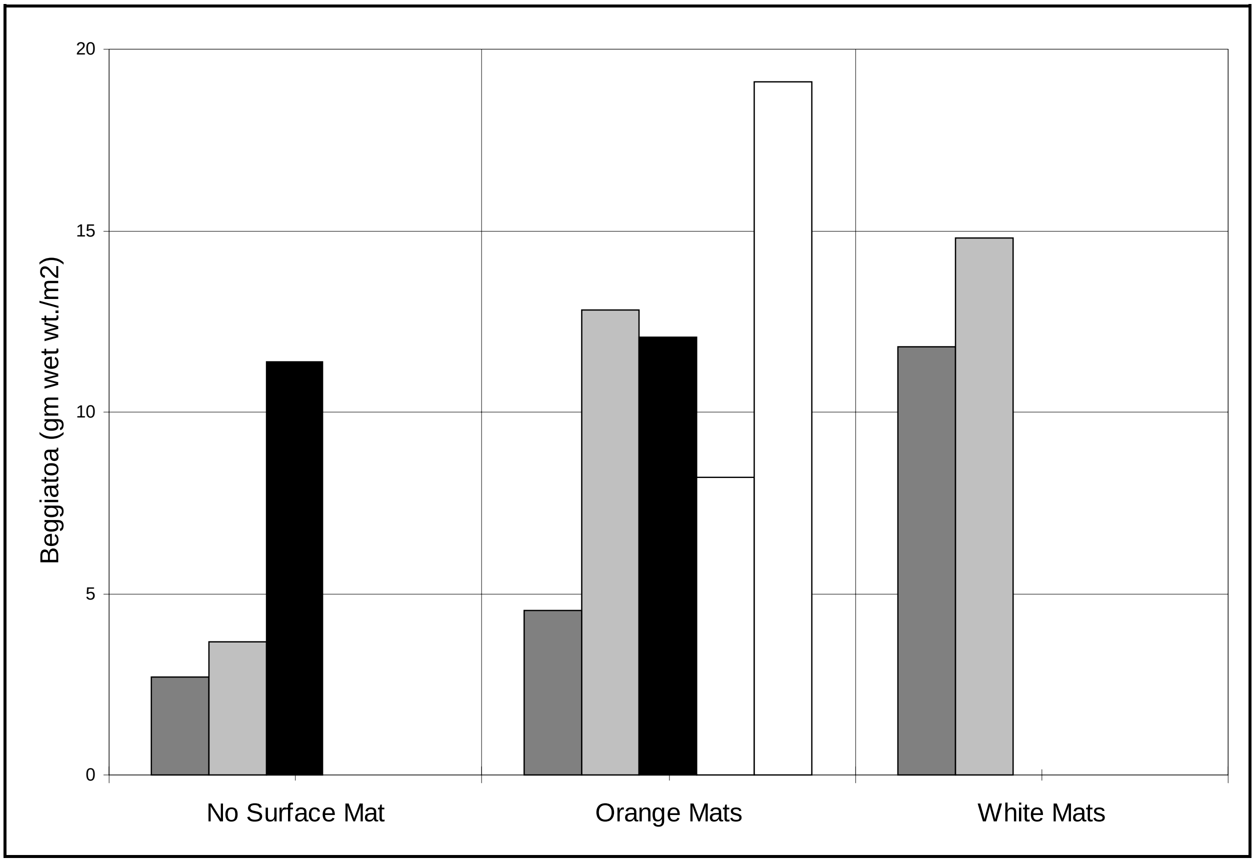

Figure 1C.5. Depth integrated *Beggiatoa* biomass (0 to 5 cm) for 10 representative cores from Gulf of Mexico hydrocarbon seeps. Groupings depend on color of surface *Beggiatoa* mat or its absence. Sites and biomass vs. depth details are presented in Table 1C.2.

Table 1C.3. Evidence that 37 - 44 µm wide *Beggiatoa* from Gulf of Mexico have vacuoles which lack typical bacterial cytoplasm.

Beggiatoa **Sample**	**Filament Diameter**	**Central Vacuole?**	**Protein/Biovolume (mg/cm^3)**
Control strain MS-81-6 (pure culture)	4 µm	No	121 ± 17 (n = 12)
GCB2 C7 Gulf of Mexico Seeps	43 µm	Yes	25 - 27
Monterey Canyon Seeps	75 µm	Yes	24

Table 1C.4. Seep *Beggiatoa*, Gulf of Mexico; enzyme activities and internal nitrate concentrations.

Core/Subcore	RuBPC/O (nmol min-1 mg-1 prot)	AKGdH (nmol min-1 mg-1 prot)	Int. NO3- (mM)	*Beggiatoa* color
BHB1 C3	0	1220	22	**Orange/White**
BHB3 C1	4.8		110	**White**
BPB2 C1	0.22	125		Orange
BPB2 C5		1270		Orange
BPB2 C7	sl. activ			Orange
BPB3 C7	0.16	*b.d.	12	Orange
GCB1 C3	0		19	**White**
GCB1 C4		b.d.	26	Orange
GCB1 C7	0.35	b.d.		**White**
GCB1 C8	0.44	b.d.		Orange
GCB2 C2	0.066		36	Orange
GCB2 C7	0.11		8	Orange
GCB3 C4	0.05	b.d.		Orange

*b.d. = below detection limit

For surface *Beggiatoa* populations taken from various Gulf of Mexico cores, the physiological properties are summarized in Table 1C.4. All populations tested accumulated nitrate to internal concentrations of eight to 110 mM when averaged over their entire biovolume (cytoplasm + vacuole). Activity of the enzyme alpha-ketoglutarate dehydrogenase (AKGdH), indicative of the ability to oxidize organic matter by the Kreb's (citric acid, TCA) cycle, was present in 3 of the 8 samples tested. It was present in some but not all orange mats tested and in the one mixed orange/white mat tested; however, it was not detected in the only pure white mat tested (Table 1C.4). The enzyme ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBPC/O), diagnostic for carbon dioxide fixation via the Calvin cycle, was present in nine of the 11 samples tested. Although the highest activity was observed for a white mat (BHB3 C1; Table 1C.4), other white mats had less activity (including one with no detectable activity) than some orange mats. No pure orange mat that was assayed had zero detectable RuBPC/O activity (Table 1C.4).

Several 80 µm wide Gulf of Mexico filaments hybridized with a 16S rRNA oligonucleotide probe specific to Monterey Canyon *Beggiatoa* sp. (Ahmad *et al.* 1999).

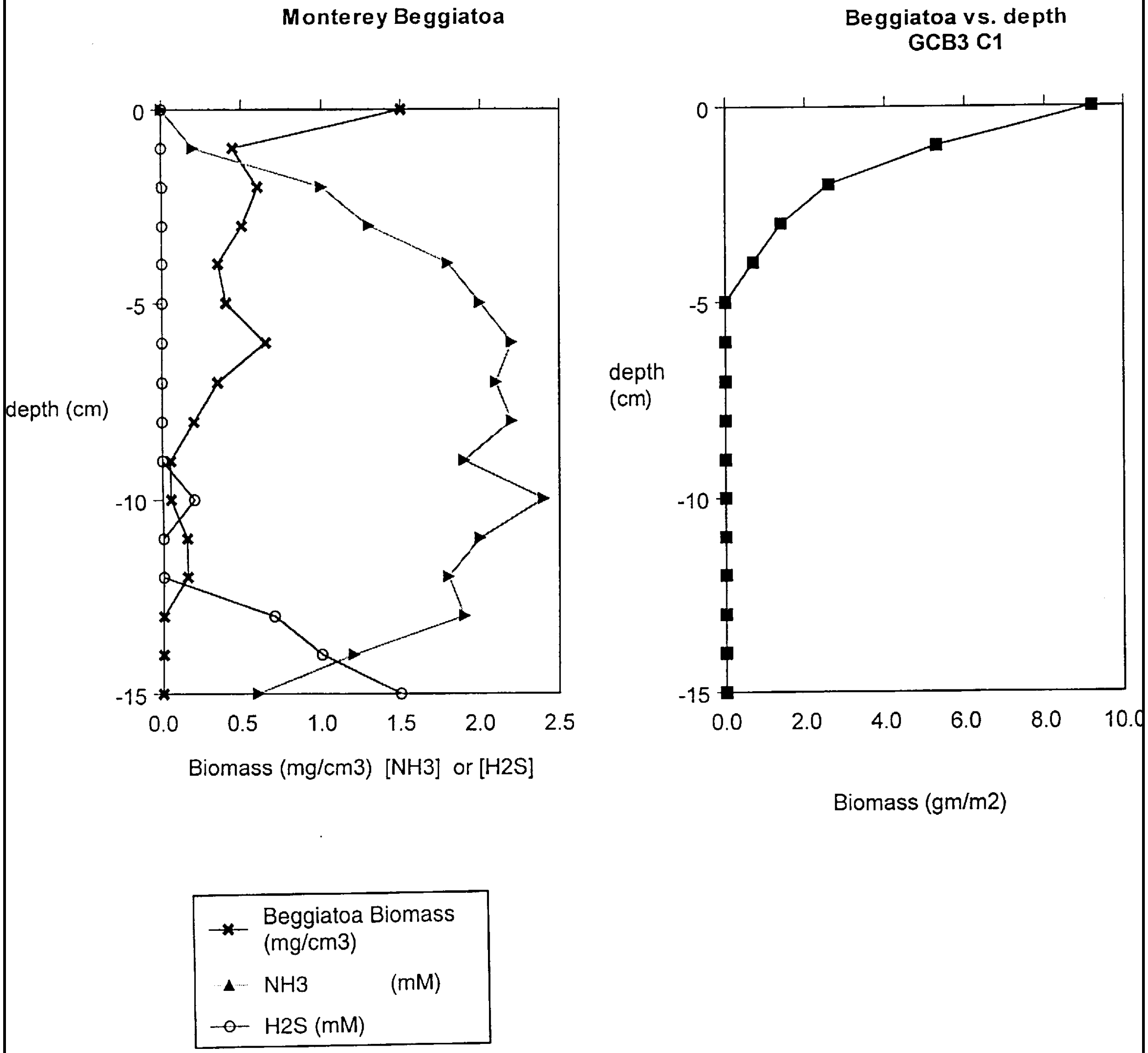

Figure 1C.6. Comparison of sediment depth distributions of (A) Monterey Canyon *Beggiatoa* sp. (75 µm cell diameter) at a cold seep (900 m depth) and (B) a representative Gulf of Mexico *Beggiatoa* sp. (42 µm cell diameter) at a hydrocarbon seep (600 m depth). For panel A, note the absence of free H_2S throughout the range occupied by *Beggiatoa* and the ammonia maximum centered in the same region. These chemical signatures are assumed to be due to energy conserving bacterial oxidation of sulfide to sulfate at the expense of the reduction of internally stored nitrate to ammonia. Although the scale is compressed for panel B, similar metabolism is assumed. For panel A, biomass is measured in mg wt. per cm^3; for panel B, it is in gm wet wt. per m^2 over a 1.0 cm depth interval.

Table 1C.5. Comparison of Gulf of Mexico *Beggiatoa* spp. with non-vacuolate, narrow *Beggiatoa* cultures and other native populations of vacuolate bacteria.

Non-Vacuolate *Beggiatoa* Controls	**Source**	**RuBisC/O activity (nmol min^{-1} mg^{-1} prot)**	**αKGDH (nmol min^{-1} mg^{-1} prot)**	**Internal [NO$_3$] (mM)**	**Fil. Width (µm)**
strain 81-1c (obligate chemoautotroph)	sulfide medium sulfide + acetate	20 ± 2.5 14 ± 1.6	0	0	2
strain 81-6 (facultative chemoautotroph)	sulfide medium sulfide + acetate	23 ± 9.2 3.3 ± 0.2	0	not tested	4

Vacuolate Bacterial Genus	**Source**	**RuBPC/O activity (nmol min^{-1} mg^{-1} prot)**	**αKGDH (nmol min^{-1} mg^{-1} prot)**	**Internal [NO$_3$] (mM)**	**Fil. Width (µm)**
***Beggiatoa* spp.**	**Gulf of Mexico Seeps (this study)**	**0.56 (n = 11)**	**330 (n = 8)**	**32 (n = 8)**	**40 & 80**
Beggiatoa sp.	Monterey Canyon Seeps	7.5 - 15	0	160 (n = 5)	75
Beggiatoa spp.	Guaymas Basin hydrothermal vents	1.47 (n = 8)	not tested	130 (n = 3)	24 - 32 40 - 42 116 - 122
Beggiatoa sp.	Bay of Concepcion	not tested	not tested	42 ± 27 (n = 16)	35 - 40
Thioploca spp.	Chilean oxygen minimum zone	not tested	not tested	150 - 500	12 - 20 30 - 43
Thiomargarita namibiensis	Namibian oxygen minimum zone	not tested	not tested	100 - 800	100 - 750

DISCUSSION

Compared to Monterey Canyon *Beggiatoa* populations, the Gulf of Mexico *Beggiatoa* mats have shallower deep distributions in the sediment and lower overall biomass densities (Figure 1C.6). Monterey Canyon *Beggiatoa* sp. and *Thioploca* spp. appear to consume sulfide completely over the zone they occupy while respiring internal nitrate stores to ammonia (Figure 1C.6, McHatton 1998; Otte *et al*. 1999). It is assumed, based on possession of a nitrate-filled vacuole and the close evolutionary relationships of all vacuolate filamentous bacteria (Figure 1C.4), that the dominant Gulf of Mexico *Beggiatoa* spp. will have similar metabolic properties with respect to sulfide oxidation and nitrate reduction. By hypothesis, their oxidation of sulfide or stored elemental sulfur to sulfate at depths of up to 5 cm in the sediment will serve to re-supply this electron acceptor to the very active sulfate reducing bacterial populations present there (see presentation by J. Morse). Their relatively low internal nitrate stores may reflect either low availability of this compound or rapid oxidation of substrates.

Although one white *Beggiatoa* mat (BHB3 C1) had high activity of the enzyme RuBPC/O (Table 1C.4), the average value for these populations (Table 1C.5) is 3- to 30-fold lower than the corresponding activity found in chemoautotrophic populations from Monterey Canyon seeps and the Guaymas Basin hydrothermal vents. Conversely, certain of the Gulf of Mexico *Beggiatoa* populations contain alpha-ketoglutarate dehydrogenase activity. This is the first such demonstration of this activity for any native *Beggiatoa* population (see Table 1C.5). Obligately chemoautotrophic *Beggiatoa* strains or facultative strains grown as chemoautotrophs lack this activity (Table 1C.5). Only facultative strains grown as chemoheterotrophs (e.g. strain 81-6 in the presence of acetate; Table 1C.5; McHatton *et al*. 1996) possess this activity, which is essential for oxidizing organic matter to carbon dioxide in energy conserving reactions. Thus, although we did not completely confirm the finding of Nikolaus (1995) that orange *Beggiatoa* mats lack Calvin cycle activity while white mats possess it, it seems that the Gulf of Mexico mats are, on average, less autotrophic and more heterotrophic than any natural mats previously studied. Given the high organic content of the sediments they occupy, this is not surprising. These activities do not preclude the possibility that sulfide oxidation rates are also high.

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SESSION 2A

CONTINGENCY PLANNING

Chair:	Ms. Darice Breeding, Minerals Management Service
Co-Chair:	Mr. Rusty Wright, Minerals Management Service
Date:	November 30, 1999

Presentation	Author/Affiliation
MMS Unannounced Spill Drills – Lessons Learned	Mr. Harold Wright Minerals Management Service
OHMSETT: Training Opportunities	Mr. William T. Schmidt MAR, Incorporated Mr. David Jensen Texas A&M University
Update on MMS GIS Oil Spill Related Initiatives: Gulf-Wide Information System Database	Dr. Norman Froomer Minerals Management Service
Update on MMS GIS Oil Spill Related Initiatives: Development of a Deepwater Environmental Data Model	Dr. Richard Lawrence Environmental Systems Research Institute
Deepwater Blowout Bridgeover Potential: Panel Discussion	Ms. Darice Breeding Minerals Management Service

MMS UNANNOUNCED SPILL DRILLS – LESSONS LEARNED

Mr. Harold Wright
Minerals Management Service

Minerals Management Service

- Manages the United States of America’s Natural Gas, Oil and Other Mineral Resources on their Outer Continental Shelf (OCS), and Collects, Accounts for and Disburses Approximately $6 Billion (USD) Yearly in Revenue from Offshore Federal Mineral Leases and from Onshore Mineral Leases on Federal and Indian Lands.

Unannounced Drill Program

- In June, 1989 the Minerals Management Service Initiated the Unannounced Drill Program.
- § 254.42 Exercises for Your Response Personnel and Equipment.
  - (g) The regional supervisor periodically will initiate unannounced drills to test the spill response preparedness of owners and operators.

MMS Initiated Drills

- July 1989 Through December 1999
  - 77 Unannounced Drills
- Full Mobilization to Tabletop Drills
- Evaluated By Comparison With the National Program for Response Preparedness (PREP) Guidelines

PREP Guidelines

- Organizational Design Objectives
- Operational Response Objectives
- Response Support Objectives

Organizational Design Objectives

Notifications
Staff Mobilization
Unified Command - Federal Representation
Unified Command - State Representation
Unified Command - Local Representation
Operations
Planning
Logistics
Finance
Public Affairs
Safety Affairs
Legal Affairs

Operational Response Objectives

Discharge Control
Containment
Recovery - Shoreline
Dispersant Use
Water Intake Protection
Population Protection
Assessment
Recovery - On Water
Protective Booming
In Situ Burning
Wildlife Recovery and Rehabilitation
Disposal

Response Support Objectives

Communications / Internal
Communications / External
Transportation / Land
Transportation / Waterborne
Transportation / Airborne
Personnel Support / Management
    -Berthing
    -Messing
    Documentation
Operational / Administrative Spaces

Maintenance and Support
- Response Equipment
    - Support Equipment
Emergency Procedures
Procurement Personnel

Response Support Objectives – Opportunities for Improvement

Planning

- Deltas

- No Response Plan at the Command Post
- Unfamiliar with the Response Plan
- Lack of Designated Duties

- Positives

- Pre-planned Booming Strategies
- Response Experts Under Contract
- Photos in the Response Plan
- The Consistent Use of the ICS forms

Logistics

- Deltas

- Failed to Explore Alternative Sources of Transportation Equipment
- The Housing and Subsistence for Responders Were Not Addressed

- Positives

- Procurement of Equipment from Oil Spill Removal Organizations Was Quick and Efficient
- Personnel and Equipment Were Procured Quickly and Efficiently

Assessment

- Deltas

- Did Not React to the Leak Continuing
- Volume Estimates Were Not Made
- Volume Estimates Were Ineffectual and Not Updated During the Response

- Positives

- The Responders Made the Right Assumptions on the Slick Size
- Objectives Were Identified and from the Proper Assessment

Dispersant Use

- Deltas

- Did Not Use Proper Procedures / Methods for the Dispersant Application
- Did Not Aggressively Pursue Dispersant Use

- Positives

- Pre-loading the Planes With Dispersant Prior to Approval
- In-depth Knowledge of the Dispersant Use Requirements

Administrative Spaces

- Deltas

- Incident Command Post Would Be Inadequate During Adverse Weather Conditions or Long-term Response
- No Maps or Other Visual Aids to Assist in the Response

- Positives

- Command Post Was Equipped With the Charts, Maps and Other Visual Aids Essential for a Fast and Effective Cleanup Effort
- Multiple Fax Lines
- Computer Linkups

Procurement - Response Equipment

- Deltas

- Proper Use of the Plan Would Have Improved the Response Because of Its Resource Listings
- Lack of A Contract With Primary Oil Spill Removal Organization

- Positives

- Procurement of Equipment from Oil Spill Removal Organizations Was Quick and Efficient

Documentation

- Deltas

- The Documentation Is Inadequate for a Proper Evaluation of an Actual Response
- Improper Tracking of Expenditures Increased the Total Cost of the Response

- Positives

- Properly Completed “Log Books” Were Used for All Documentation
- The Documentation Allowed for the Proper Allocation of Expenses

Questions?

Authors

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OHMSETT: TRAINING OPPORTUNITIES

Mr. William T. Schmidt,
MAR, Incorporated

Mr. David Jensen
Texas A&M University

Oil Spill Response Training at Ohmsett with the National Spill Control School

Ohmsett Background:

The National Oil Spill Response Test Facility

Operated by the Department of the Interior, Minerals Management Service

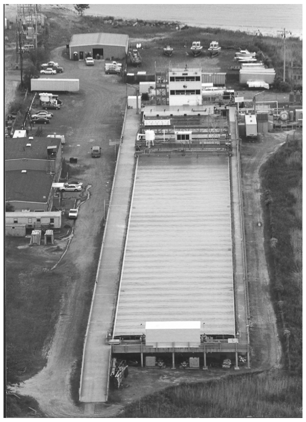
Unique Capabilities

- Largest oil spill test tank in North America.
  - Tank dimensions
    - 667 feet long
    - 65 feet wide
    - 8 feet deep
- Full Scale Training, Test, Evaluation, Research and Development with ***oil***
- Tow bridge capable of speeds up to 6.5 knots
- Wave generator can produce 3-foot waves and harbor chop waves
- Spill up to *1500 gallons of oil* at 300 gpm per run

Ohmsett:

Support Facilities

- Data collection system to measure the efficiency of response equipment as well as operators' performance
- Modern classroom facility for up to 30 students at a time
- Underwater photography systems
- Machine shop and staging area
- Oil analysis laboratory



Oil Spill Management Training with Texas A&M

SPILL CONTROL SCHOOL HISTORY

– 1973	grant from ERDA establishes NSCS
– 1977	First oil spill classes
– 1979-1980	Hazardous waste handlers course for the U.S. Navy
– 1989	HAZWOPER TRAINING in Accordance with 29 CFR 1910.120

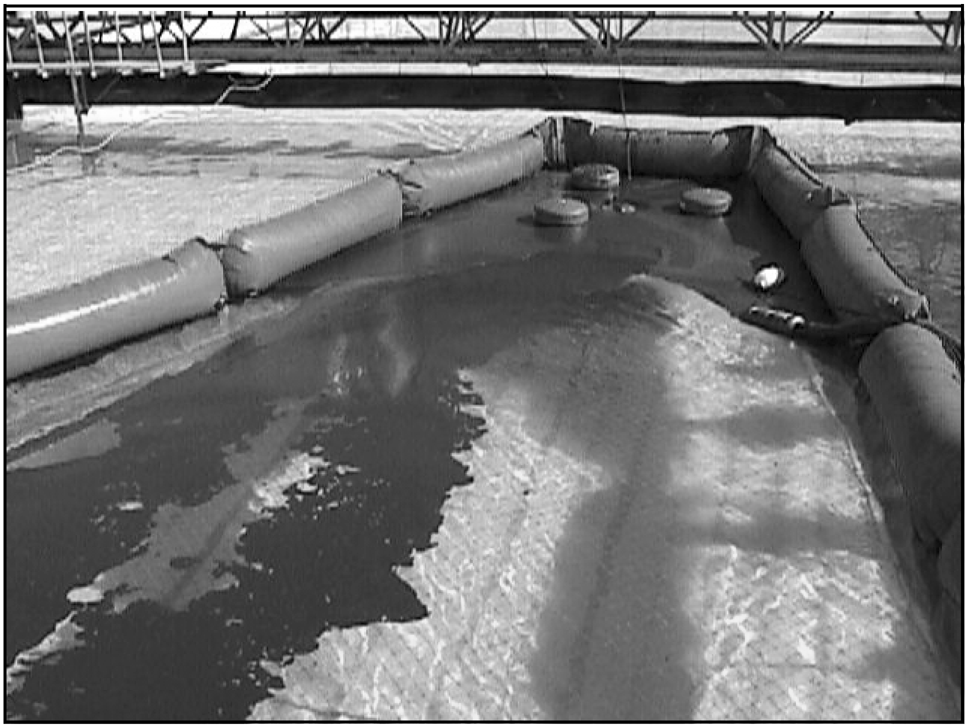
Current Curriculum

- Oil Spill Management
- Hands on Oil Spill Response and Safety Courses
- OSHA/RCRA HAZWOPER Courses in accordance with 29CFR 1910.120

OIL SPILL MANAGEMENT

- Overview of Current Techniques for Oil Spill Response
- National Interagency Incident Management System (NIIMS), Incident Command System ICS
- Table Top Drill
- Working with the Media
- Field Trip to Response Organizations

- Small Boat Handling
- Boom Deployment and Recovery
- Pump and Skimmer Operations
- HAZWOPER Safety Applicable to Oil Spill Responders



8 HOUR SUPERVISOR

8 HOUR REFRESHER

RESPONSE AND SAFETY PLANNING

- **Site Safety Plans**
- **Comprehensive Response Action Plans**
- **Response Team Training Plans**
- **Facility Response Plans**
- **Vessel Response Plans**

SPILL DRILLS

TABLE TOP DRILLS

- **Oil Spill**
- **Hazmat**

EQUIPMENT DEPLOYMENT

- **Oil Spill**
- **Hazmat**

OHMSETT: Both Classroom & Tank Training

TOPICS COVERED

- National Interagency Incident Management System, Incident Command
- Spill Management - Assigning Roles and Responsibilities in the ICS
- Personal Liabilities of the Qualified Individual
- Spill Discovery and Notification Procedures
- How to Establish a Command Post
- Site Characterization and Site control
- Site Safety Planning
- Physical and Chemical Properties of Oil
- Oil Spill Movement, Containment, Control and Disposal
- Alternate Response Techniques – Dispersants/In Situ Burns/Bioremediation
- Ecological Impacts of Oil Spills
- Shoreline Impacts and Cleanup Procedures
- National Pollution Fund
- Spill Management Team Table Top Exercises

Typical Training Schedule while at *Ohmsett*

Day 1, Monday

1300 - 1700	40-hour HAZWOPER class

Day 2, Tuesday

0800 - 0930	Group A - 40-hour HAZWOPER class Group B - Rig response equipment in test tank
0930 - 0945	Morning Break
0930 - 1200	Group A - 40-hour HAZWOPER class Group B - Rig response equipment in test tank
1200 - 1300	Lunch
1300 - 1430	Group A - Rig response equipment in test tank Group B - 40-hour HAZWOPER class
1430 - 1445	Afternoon Break
1445 - 1700	Group A - Rig response equipment in test tank Group B - 40-hour HAZWOPER class

Typical Training Schedule while at *Ohmsett* Cont.

Day 3, Wednesday	
0800 - 0930	Group A - 40-hour HAZWOPER class
	Group B - Training with response equipment using heavy oil on calm water
0930 - 1200	Group A - 40-hour HAZWOPER class
	Group B - Training with response equipment using heavy oil in waves conditions
1300 - 1430	Group A - Training with response equipment using heavy oil on calm water
	Group B - 40-hour HAZWOPER class
1445 - 1700	Group A - Training with response equipment using heavy oil in waves conditions
	Group B - 40-hour HAZWOPER class
Day 4, Thursday	
0800 - 0930	Group A - 40-hour HAZWOPER class
	Group B - Training with response equipment using light oil on calm water
0930 - 1200	Group A - 40-hour HAZWOPER class
	Group B - Training with response equipment using light oil in waves conditions
1300 - 1430	Group A - Training with response equipment using light oil on calm water
	Group B - 40-hour HAZWOPER class
1445 - 1700	Group A - Training with response equipment using light oil in waves conditions
	Group B - 40-hour HAZWOPER class
Day 5, Friday	
0800 - 1200	40-hour HAZWOPER class

TEST WITH OIL! TRAIN IN OIL!

- **Texas A&M instructors have conducted oil spill mitigation classes since 1997 as part of their curriculum.**
- **$800K has been expended to enhance the physical facility and provide classroom space.**
- **USCG Strike Teams, US Navy personnel, MMS responders, and private companies train at Ohmsett.**

Benefits of Training at *Ohmsett*

- Emphasis on practical hands-on use of response equipment with oil and waves.
  - Students are given instruction on the utilization, proper assembly, deployment and rigging of response equipment
- Cooperative training program with Texas A&M University National Oil Spill Control School
- Oil spill response training: Classroom and Tank
- 40-hour HAZWOPER certification
- Students review their performance
  - Through video recording of each training session
  - Using oil recovery effectiveness measurements
- *Typically students improve their oil recovery effectiveness by **<u>80%</u>***

Major Misconceptions about Ohmsett

1. Ohmsett is for government use only.

- Anyone can use the Ohmsett facility on a reimbursable basis.

2. Training is too expensive.

- The cost is $900 dollars per student for a 5-day class.
- Optimum capacity is 15 students per class.

Summary

- ***Ohmsett*** is the only test tank in North America where oil spill responders can train with **full scale** test equipment **in oil** with waves in **controlled environments**

- Training with the ***National Spill Control School*** at ***Ohmsett*** gives students the **confidence** to operate the response equipment efficiently

- 40- hour HAZWOPER training at ***Ohmsett*** combined with training with oil will give the required tools for responders to respond to an oil spill effectively

- Confident and efficient responders will recover oil more effectively

CONTACT THE SPILL SCHOOL AT:

National Spill Control School
Texas A&M University Corpus Christi

Phone: 361-980-3333 **Fax: 361-980-3337**

6300 Ocean Drive
NRC Building, Suite 1100
Corpus Christi, TX 78412
Email: *nscs@tamucc.edu*

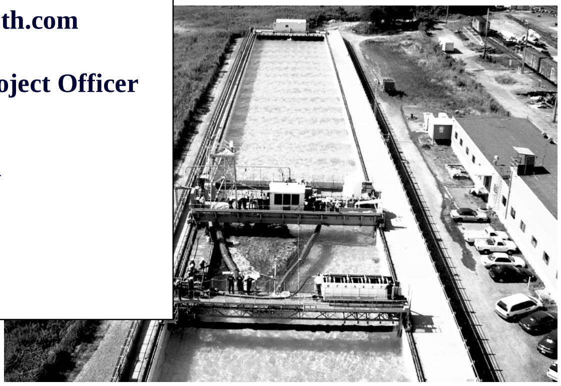
CONTACT OHMSETT AT:

FOR MORE INFORMATION

Bill Schmidt, Program Manager
PH: (732) 866-7183 or 7184
FX: (732) 866-7189
E-mail Ohmsettnj@monmouth.com

Jim Lane, MMS Ohmsett Project Officer
PH: (703) 787-1065
FX: (703) 787-1549
E-mail james.lane@mms.gov

http://www.ohmsett.com



UPDATE ON MMS GIS OIL SPILL RELATED INITIATIVES: DEVELOPMENT OF A DEEPWATER ENVIRONMENTAL DATA MODEL

Dr. Richard Lawrence
Environmental Systems Research Institute

In 1998, ESRI was contracted by the Department of Interior, Minerals Management Service (MSS) Deepwater. Program to develop a Deepwater Environmental Data Model. This project establishes data specifications for future study deliverables so that deepwater environmental and Gulf-Wide Information System (GWIS) data that are currently stored in the MMS Coastal and Offshore Information System database (CORIS) can be effectively incorporated into the MMS environmental information management system for use in regulatory, permitting, and leasing analyses. ESRI staff worked closely with MMS staff and MMS-Information Technology staff to develop data digital standards that would support information needs of MMS managers.

Two specific applications were built to take advantage of this new data structure: NEPA Assessment and Environmental Studies Geobibliography. A NEPA assessment provides environmental resource assessment information pertinent to proposed changes in existing or proposed plans for oil development in the Gulf of Mexico. The Environmental Studies Geobibliography tool is a management tool that allows users to search for plan locations and retrieve metadata and other business attribute information from the MMS database. This application was the first ArcGIS application built independently of other ESRI-based desktop GIS systems.

Using the GIS objects available with ArcGIS and Visual Basic, ESRI built the first plan analysis and geobibliographical tools to be developed in a truly open-GIS developmental environment. This scalable interface represents one option for the platform from which numerous environmental assessment options can be launched, such as mitigation analyses, risk analyses, etc.

DEEPWATER BLOWOUT BRIDGEOVER POTENTIAL: PANEL DISCUSSION

Ms. Darice Breeding
Minerals Management Service

OVERVIEW

Planning oil spill response to deepwater events and analyzing impacts from possible deepwater blowouts depend on our ability to determine whether deepwater wells will naturally bridge over during a blowout and to estimate how long after a blowout this bridging would occur. This issue has recently surfaced as an area of concern for the MMS GOM Region, in part, because the oil industry's experience base in deepwater well control is limited. Because deepwater activity is relatively new, there have not been many blowouts upon which to build experience. For example, the number of wells drilled in water depths greater than 1,500 feet is much smaller than the total number of wells drilled offshore. Therefore, this informal panel session was convened to open a dialogue and to allow for the exchange of information regarding what we do know on the topic and also what we may need to discover to better address this important issue.

As part of this presentation, Mr. Curtis Weddle of Cherokee Offshore Engineering discussed the factors that would impact bridging potential. Factors mentioned include: 1) bulk formation collapse – formation damage, 2) hydrostatic pressure loss, 3) choice of fluid type, and 4) sand face failure. Mr. Weddle also mentioned differences in deepwater and shelf operations. These differences include the fact that 1) sands are generally unconsolidated in these deepwater areas and 2) the seals between zones in the deepwater GOM are generally not strong enough to withstand high differential pressures between two adjacent zones because of the way that deposition occurred in the area. Despite Mr. Weddle's considerable experience with bridging and underground flows in shallow water, he indicated that he was not aware of any surface blowouts in deepwater. Mr. Weddle recommended the following options for future action on this topic: 1) a literature search and 2) an investigation of highly studied close cousins to bridging potential which would include borehole stability and sand control.

Dr. Mike Smith of MMS reviewed the geologic potential for the bridgeover of deepwater wells during drilling. Dr. Smith noted the geologic factors that would influence whether or not bridging would occur if a blowout occurred in deepwater. Geologic factors that would affect the bridgeover potential in deepwater include many of the same factors that affect pore pressure gradients, which are also involved in bridgeover. Bridging over would be most likely to occur in rocks that have a higher content of carbonate, particularly carbonate mud oozes and shales that tend to flow into the well bore and form a bridge. These components are rather common in the early miocene and in older rocks or reservoirs. Dr. Smith then discussed the problems encountered by and the ways to cope with shallow water flows. Dr. Smith expressed the opinion that shallow water flow is the closest analog we have to blowouts in the deepwater areas of the GOM.

Dr. Andrew Wojtanowicz from the Petroleum Engineering Department of Louisiana State University then provided a detailed presentation on the mathematical calculations necessary for determining when a well will bridge over in deepwater. Dr. Wojtanowicz stated that it would be possible mathematically to calculate bridgeover potential. Dr. Wojtanowicz stated that if the well is blowing (experiencing a blowout event), it becomes unstable because the flow rate is dragging the plastic zone into the well; that is what makes the well bridge over. Since the main question needing to be answered is the timing of the bridgeover, Dr. Wojtanowicz indicated that the main factors to be considered in the mathematical calculation of this problem would be the hydraulics of the blowout. Dr. Wojtanowicz explained that the problem could be calculated by looking at when the point comes to the critical rate over time because it is then that the well will bridgeover and collapse.

PANEL DISCUSSION

After these short presentations, Mr. Weddle, Dr. Smith and Dr. Wojtanowicz participated in a panel question and answer session.

As part of the panel discussion, the audience questioned whether maps were available that displayed known areas where shallow water flow was possible could be used to determine where might be higher blowout? Dr. Smith indicated that this type of correlation really had to be done on a case-by-case basis. Dr. Smith indicated that shallow water flow areas cannot be correlated with blowout potential because fairly recent sands are essentially unconsolidated and have different characteristics than the older reservoirs. He recommended looking at areas with increased carbonates and increased shales that would have a better potential to bridgeover rather than younger reservoirs that may not bridge over as readily. Mr. Weddle stated that shallow water flow may present a threat to the stability to any structure placed in their vicinity. He indicated that a present concern was whether the shallow water flow potential would present itself as a problem after the drilling takes place. Would it be reactivated by some action that industry takes after there are several wells drilled? Mr. Weddle also mentioned all of the advances and new methodology now being examined and used to prevent shallow water flow problems such as riser-less drilling.

Another question raised dealt with how different types of completions will affect the potential for the bridging and collapse of a well (i.e. horizontal wells versus vertical wells). The panel agreed that a horizontal well will bridge over inherently much easier than the vertical well because the stress on the vertical well generated by the overburden is not equal to overburden. Instead, the stress is much smaller—about 45-50% of the overburden. On the horizontal well, 100% of the overburden is sitting on the well. Therefore, since the stresses are higher on the horizontal well, its failure is more likely. In addition, panel members indicated that blowouts in deeper water may not be as likely to happen during workovers as in shallow water the majority of wells in deepwater are subsea.

While the panel agreed that a well might never bridge, it was generally felt that most wells would bridge over. One of the panelists indicated that his experience on the shelf has shown that wells can bridge in as little as six days; however, in his experience, some wells never bridged. It was stressed however, that all of these observed blowout events were successfully controlled by intervention despite their not having naturally formed a bridge. It was indicated that the potential and timing for a well to bridgeover depends on a combination of factors. Sometimes it is not purely formation failure, sand face collapse, or failure of the plastic zone—although that is the mechanism by which a well fails. Often, it is a combination of a number of things that cause failure.

The panelists indicated that the initial conditions around a well are the first things you should look at when addressing the time it would take for a well to bridgeover. For example: Is the well cased? Is it screened? Is it already producing? If the answer to any of these questions is yes then the well has already been cemented and has perforations. This would factor in as providing the well additional strength since it is not just an open hole. Boundary conditions to be considered include water depth and whether the well is flowing full strength or encountering some restriction to the flow. The greater the restriction, the lower the pressure impact at the bottom. Also to be considered are the properties of the rock, internal friction angle estimation, cohesion coefficient estimation, etc. in relation to the "timing" question. Once this information exists about a well, the panelists felt that it is possible to have a better idea of answers. Two methods for obtaining these data were suggested 1) standard core tests and 2) use of information submitted by industry obtained through the new seismic work being conducted offshore.

The panel agreed with the suggestion that the agency should work towards developing a "bridgeover risk analysis model" whose final product would be an identification of the time it would take for a well to bridgeover with a certain probability for this occurrence. With such a tool, the MMS GOM would be able to identify what type of data would be needed to determine some estimate of this time. The follow-up questions would focus on the quality of data to which we currently have access internally and the need to request any additional information to run such a model.

PANEL PARTICIPANTS

Dr. Michael Smith is the MMS Operations Geologist for the deepwater Gulf of Mexico. He is responsible for geological reviews of all deepwater exploration and development plans and applications for permit to drill. Dr. Smith has a Ph.D. in geology from the University of Texas.

Mr. Curtis Weddle operates Cherokee Offshore Engineering and is a consultant in well control, drilling, and project management. Currently he is working with the Subsea Mud Lift project and is responsible for developing well control procedures for the new deep water drilling system as well as assisting to develop operations procedures and the equipment. Mr. Weddle graduated from Oklahoma State University in 1978 with a B.S. in civil engineering.

Dr. Andrew Wojtanowicz holds a Ph.D. in petroleum engineering. He presently serves as The Texaco-Endowed Environmental Chair in the Petroleum Engineering Department of Louisiana State University.

Darice Breeding is a senior physical scientist with Minerals Management Service in the Gulf of Mexico office working on oil spill response and environmental assessment related issues.

SESSION 2B

CRANE OPERATIONAL ISSUES

Chair:	Mr. William Hauser, Minerals Management Service
Co-Chair:	Mr. Joseph Gordon, Minerals Management Service
Date:	November 30, 1999

Presentation	Author/Affiliation
Summary of MMS Presentation at the Crane Safety Panel	Mr. William Hauser Minerals Management Service
IADC Crane Resource Subcommittee	Mr. Brian Maness Diamond Offshore Representing International Association of Drilling Contractors
USCG Regulations and Concerns on Crane Safety on the OCS	Lt. Joe Grimes U.S. Coast Guard Marine Safety Office
Chevron Crane Program	Ms. Andrea Recasner Chevron USA
Questions Raised to Lloyd’s Register at the ITM about UK Crane Policy	Mr. William Hauser Minerals Management Service
Issues Raised at the Crane ITM Panel	Mr. William Hauser Minerals Management Service
Crane Operational Issues	Offshore Operators Committee and American Petroleum Institute

SUMMARY OF MMS PRESENTATION AT THE CRANE SAFETY PANEL

Mr. William Hauser
Minerals Management Service

PURPOSE

The Crane Safety Panel provided a forum for interested parties to discuss issues related to the safety of crane operations on the OCS. The panel had representatives from the United States Coast Guard, Offshore Operators Committee, American Petroleum Institute, International Association of Drilling Contractors, Chevron, and Lloyd's Register. Panel members presented their thoughts and concerns about crane operations and participated jointly in discussion after the presentations.

BACKGROUND

MMS formed a workgroup to review crane accidents after a serious crane accident in May 1998 killed 2 workers. The workgroup found that there have been 34 crane incidents on the OCS between January 1995 through September 1998. These incidents involved cranes installed on both fixed and floating facilities. The workgroup found the following:

- 7 fatalities (6 were riggers)
- 20 injuries (l0 were riggers)
- 8 incidents resulting in major damages
- Equipment failure and human error most often listed as major causes of the incidents

The workgroup's full report on the 34 incidents and its recommendations can be found at *http://www.mms.gov/cranes/*.

WORKGROUP RECOMMENDATIONS AND CURRENT STATUS

In the report, the crane workgroup made five recommendations (listed in italics) for improving the safety of crane operations. Those recommendations and MMS's action towards those recommendations are listed below:

1. *Request API to revise API RP 2D.* As a result of the Report, MMS requested API to revise API RP 2D, Third Edition, 1 June 1995, Recommended Practice for Operation and Maintenance of Offshore Cranes, to include rigger training. API formed a work group, which included an MMS representative, and has revised the document. MMS is currently preparing final *Federal Register* notice incorporating the new edition of API RP 2D, Fourth Edition, August 1999, Recommended Practice for Operation and Maintenance of Offshore Cranes,

into our regulations (which include rigger training). At this time, MMS's goal is to have a final rule published in the *Federal Register* no later than January 2000.

2. *Require third party inspections/certifications.* MMS has not examined this recommendation; however, it will be a topic at the workshop MMS plans to hold on the safety of offshore crane operations. The workshop is tentatively scheduled for the first quarter of 2000. In a related topic, MMS is currently preparing a proposed rule to incorporate API SPEC 2C, Specification for Offshore Cranes, by reference into our regulations governing oil and gas and sulfur operations in the OCS. The addition of API SPEC 2C will help ensure that lessees and contractors use the best available and safest technologies for design, construction, and testing of pedestal mounted cranes while operating in the OCS.

3. *Review the need for regulating booms and other material-handling equipment.* MMS has added a new requirement to the regulations that requires lessees to operate and maintain all other material-handling equipment in a manner that ensures safe operations and prevents pollution. This requirement is contained in the Final Rule for Subpart A which was published in the *Federal Register* on 8 December 1999. This new requirement can be found at 30 CFR Part 250.108(b).

4. *Improve accident investigations and reports.* MMS is taking the following actions to improve its accident investigation program:

    - Developing new accident reporting requirements in conjunction with USCG to provide clearer accident reporting thresholds;

    - Developing guidelines with USCG for coordinating accident investigation responsibilities and data sharing;

    - Improving internal accident forms and database management procedures;

    - Establishing the Office of Safety Management in the Gulf of Mexico Region; Developing a better method for tracking and ensuring follow-up of accident investigation recommendations; and

    - Developing a strategy for publicizing more accident data and analyses.

5. *Hold Industry/MMS workshop on crane safety*. MMS will hold a workshop on the safety of offshore crane operations soon. The Offshore Technology Research Center will run the workshop; it is tentatively scheduled for the first quarter 2000.

UPDATE ON CRANE INCIDENTS FROM OCTOBER 1998 THROUGH OCTOBER 1999

There have been 13 OCS crane incidents (plus two serious incidents involving the use of booms or other materials-handling equipment) during this period. The incidents resulted in the following:

- 3 fatalities
- 7 injuries
- 5 incidents resulted in major damages

Human Error and Equipment Failure continued to play a role in most of the accidents. These categories were listed as the cause of 9 of the 13 crane incidents. They were also listed as the cause of the two materials-handling equipment incidents. Additional information on these incidents may be found at our website on crane safety (*http://www.mms.gov/cranes/*).

CRANE SAFETY PANEL

HOW CAN WE IMPROVE

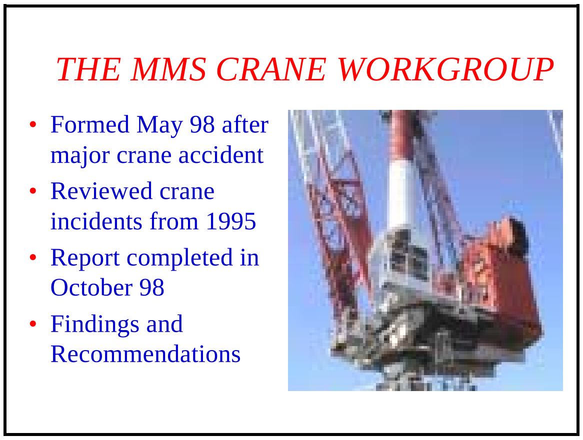
CRANE SAFETY?

PURPOSE FOR PANEL

- Express MMS interest in crane safety
- Update on MMS actions
- Allow interested parties to discuss issues
- Identify and discuss ways to improve crane safety
- Future workshop on Crane Safety

AGENDA

- Presentations by MMS; USCG; API/OOC; IADC; Chevron; and Lloyd's Register
- Short break
- Discuss topics to improve crane safety



THE MMS CRANE WORKGROUP

- Formed May 98 after major crane accident
- Reviewed crane incidents from 1995
- Report completed in October 98
- Findings and Recommendations

1998 REPORT FINDINGS

- 34 Incidents
- 7 Fatalities
- 20 Injuries
- 6 Riggers killed, 10 injured
- 8 Incidents with major damage
- HE and EF listed as major causes

1998 REPORT RECOMMENDATIONS

- Revise API RP 2D
- Require 3rd party certification
- Need regulation for booms and hoists
- Improve accident reports
- Crane Workshop

STATUS OF RECOMMENDATIONS

- API revised API RP 2D
- 3rd party certification as discussion item
- New regulation for booms and hoists on fixed platforms
- MMS revising accident investigation program
- Crane safety workshop in early 2000

1999 UPDATE TO REPORT

- 15 Additional incidents
- 3 Fatalities
- 7 Injured
- 5 Incidents with varying degrees of damage
- HE and EF continued being identified as major causes

POTENTIAL DISCUSSION TOPICS

- 3rd party inspection of cranes on fixed platforms
- Condition of offshore cranes
- Crane inspector qualifications
- Risks associated with mechanical versus hydraulic cranes
- Standards for booms and hoists

IADC CRANE RESOURCE SUBCOMMITTEE

Mr. Brian Maness
Diamond Offshore
Representing International Association of Drilling Contractors

GOAL

The goal of the Crane Operators sub-committee is to identify ways to enhance crane operator training effectiveness in an effort to minimize crane-related incidents.

HISTORY

As a brief history of the Crane Operators Training Sub-committee, the subcommittee was formed on 13 January 1999. Scot Rudolph, Manager of Organizational Development for Transocean Offshore and chair of the International Association of Drilling Contractors (IADC) Training Committee, suggested that a sub-committee identify critical crane operator issues and make recommendations as to the development of a crane operator's certification program. John Vidrine, U.S. HSE Director for Parker Drilling, was appointed chair of the newly formed sub-committee with representatives from R&B Falcon, Platform Crane Services, Infosafe, Noble Drilling, and Diamond Offshore serving as sub-committee members.

REVIEW

The sub-committee sat with the API RP-2D review committee to provide input and comments concerning the work being completed by the API RP-2D document review team. Additionally, the sub-committee reviewed the MMS crane accident workgroup report on rigger accident statistics. Several training programs were then reviewed, including computer based training and full motion crane operation simulators. All the above was completed in an effort to provide a clearer understanding of crane related issues within the petroleum industry and then determine how the sub-committee can accomplish it's goal "to enhance crane operator training effectiveness in an effort to minimize crane-related incidents."

RECOMMENDATIONS

After several meetings and following the review of several crane operator training programs, it was suggested that recommendations be made to the IADC Training Committee on what, if anything, could be done relative to addressing critical crane operation issues. A list of areas for consideration, development and review was presented to the IADC Training Committee on 15 September 1999 and are abbreviated by topic as follows:

1. Adopt the IADC Crane Operator Knowledge Skill and Abilities (KSA) critical skills list

2. Consider requiring a DOT type physical examination to ensure crane operator (CO) physical ability

3. Provide management/leadership training for crane operators

4. Determine and specify minimum course standards for CO training

5. Identify extended learning opportunities (ongoing training, modular training)

6. Identify and provide recommendations concerning varying types of learning technology (CBT, simulators, etc.)

At the 15 September meeting, Scot Rudolph announced he would step down as committee chairman and Dr. Allen Kelly would take over those duties. Following Mr. Vidrine's resignation as chair of the sub-committee, Brian Maness was appointed as chair. The subcommittee then voted to change the sub-committee's name to Crane Resource Sub-committee to reflect the sub-committee's new focus "the development of a database of companies, training courses and materials that could be used as a reference in the development of crane operator training programs." When completed this database is to be posted on a web site for ease of accessibility.

RIGGER TRAINING

The training committee on 15 September suggested putting together a stand-alone committee to produce training videos or computer based training CDs to cover rigger training issues. The original meeting participants included a representative of the IADC and 11 drilling contractors. The attendees of the meeting decided that it would be best to start with a video series since most of what is on the market appears to be somewhat dated. The intention is to make the video in a format that can be converted to digital for use in a rigger training interactive CD, a tool for the future. High interest has been shown in this project and is now proceeding under the guidance of a steering committee made up of drilling contractors and a member of The Crosby Group who volunteered to furnish the company's expertise and experience in the area of rigging. Current work includes defining basic module interest areas, most likely a minimum of five. API RP-2D Fourth Edition and the ANSI B30.9 are being used as reference and resource materials for guidance in this project.

IADC Crane Operator Training Subcommittee

- Goal
  - Find ways to better train crane operators.
  - Minimize crane related incidents.

- History
  - Formed 13 January 1999
  - John Vidrine appointed chairman
- Scope
  - Identify critical items a crane operator must know
- Members
  - Parker Drilling
  - R&B Falcon
  - Diamond Offshore
  - Noble Drilling
  - Infosafe
  - Platform Crane Services

- Resource Material
  - API RP 2D
  - MMS crane accident report
  - CBT programs
  - Full motion simulator
  - Interviewed crane operators
  - North Sea regulations

- Recommendations
  - Adopt KSA for crane operator
  - Require DOT Physical
  - Incorporate CBT & Simulators
  - Focus on ongoing training in all areas

- New Chair
  - John Vidrine steps down
  - Brian Maness appointed
- Subcommittee Name
  - Crane Resource Subcommittee
  - Changed to reflect new scope

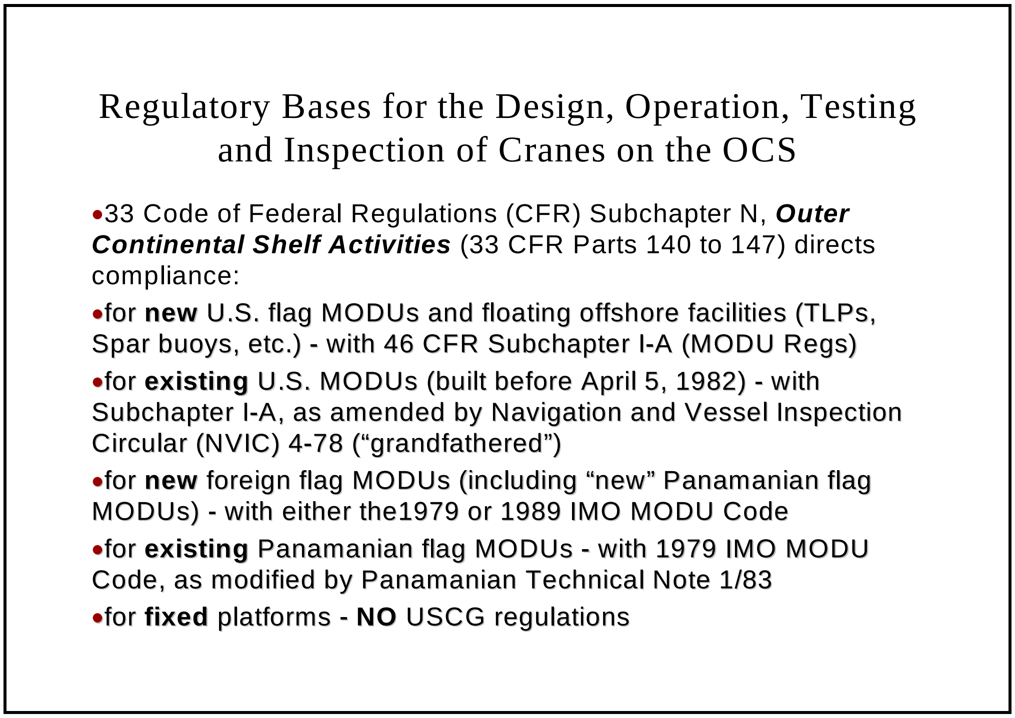
- New Scope
  - Database of training resources
  - Post on web site
  - Develop core curriculum
  - IADC approved

- IADC Rigger Training Committee
  - –Formed 15 November
  - –Members include;
    - The Crosby Group
    - 11 drilling contractors
- Scope
  - –To develop rigger training video

- The Video
  - –Minimum 5 modules
  - –8-10 minutes per module
- Reference Material
  - –API RP 2D
  - –ANSI B30.9
  - –Safe industry practice

USCG REGULATIONS AND CONCERNS ON CRANE SAFETY ON THE OCS

Lt. Joe Grimes
U.S. Coast Guard
Marine Safety Office



Regulatory Bases for the Design, Operation, Testing and Inspection of Cranes on the OCS

- 33 Code of Federal Regulations (CFR) Subchapter N, ***Outer Continental Shelf Activities*** (33 CFR Parts 140 to 147) directs compliance:
- for **new** U.S. flag MODUs and floating offshore facilities (TLPs, Spar buoys, etc.) - with 46 CFR Subchapter I-A (MODU Regs)
- for **existing** U.S. MODUs (built before April 5, 1982) - with Subchapter I-A, as amended by Navigation and Vessel Inspection Circular (NVIC) 4-78 (“grandfathered”)
- for **new** foreign flag MODUs (including “new” Panamanian flag MODUs) - with either the1979 or 1989 IMO MODU Code
- for **existing** Panamanian flag MODUs - with 1979 IMO MODU Code, as modified by Panamanian Technical Note 1/83
- for **fixed** platforms - **NO** USCG regulations

Crane *Design*

•Subchapter I-A MODUs - API Specification for Offshore Cranes, API Spec 2C, Second Edition, February 1972 (with supplement 2)

•NVIC 4-78 MODUs - must conform to the specifications of the manufacturer as originally installed

•IMO MODU Code (1979 or 1989) - to the satisfaction of the (flag state) Administration iaw the requirements of a recognized classification society or with national or international standards or codes

Crane *Inspection* and *Testing*

•U.S. MODUs - cranes inspected and tested in accordance with Section 3 of API RP 2D, *First Edition* (*October 1972*) with supplement 1 ***except*** rated load test must be in accordance with 46 CFR 107.260

•   - 107.260 requires quadrennial routine weight testing and after any major modifications or repairs (“quadrennial” has been extended to 5 years per CG Marine Safety Manual, Vol. II, Chapter 35)

•foreign MODUs - cranes inspected and tested in accordance with the appropriate IMO MODU Code:

•   - 1979 Code requires annual inspection, weight testing every 4 yrs

•   - 1989 Code requires annual inspection, weight testing every 5 yrs

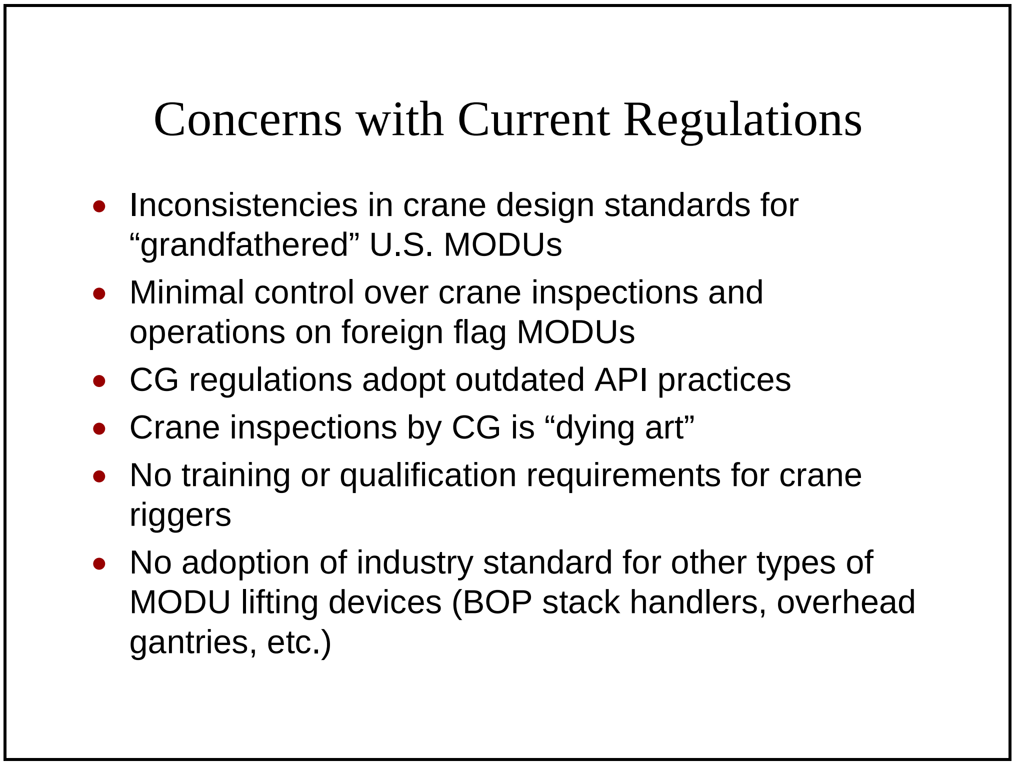
Qualified Inspection and Testing *Personnel*

- For U.S. flag MODUs - three options (107.259):
- 1) by American Bureau of Shipping (ABS) for cranes under certification by them, including;
-   - “registered” cranes
-   - “Statement of Fact” cranes
- 2) by International Cargo Gear Bureau (ICGB) for cranes under certification by them
- 3) by USCG marine inspector
- For foreign flag MODUs - authorized classification society (ABS, DNV, etc.)

MODU Crane *Operation* on the OCS

- For U.S. MODUs - Person-in-Charge ensures crane is operated iaw API RP 2D, First Edition (Oct. 1972) with supplement 1 (109.521, 527)

- For foreign MODUs - (I979 or 1989 IMO MODU Code) - only crane operational requirement is to include “limiting conditions of crane operations” in the MODU’s Operating Manual. USCG may require compliance with Part 109 for items not adequately covered by IMO MODU Code.



Concerns with Current Regulations

- Inconsistencies in crane design standards for “grandfathered” U.S. MODUs
- Minimal control over crane inspections and operations on foreign flag MODUs
- CG regulations adopt outdated API practices
- Crane inspections by CG is “dying art”
- No training or qualification requirements for crane riggers
- No adoption of industry standard for other types of MODU lifting devices (BOP stack handlers, overhead gantries, etc.)

CHEVRON CRANE PROGRAM

Ms. Andrea Recasner
Chevron USA

TRAINING

Processes

Chevron crane training takes place at the company's Employee Resource Training Center (BRTC) in Lafayette, Louisiana. The training center is available to company employees as well as to the public for Crane Operator and Rigger training in accordance with API RP-2D. The classes are one (1) day each with the rigger course being a prerequisite for enrollment in the operator course. The operator course also serves as the required operator quadrennial refresher course. In addition to the training available at the resource center, employees are also offered the option of training at field locations.

Comments, Issues, Concerns

Required Rigger certification has been a Chevron requirement for more than ten years. With the incorporation of the 1999 edition of API RP-2D into government regulations, the company will again review processes verifying that qualified riggers perform all rigging done on Chevron facilities. It will be required that certification documents reference the new edition of 2D.

Chevron qualified inspectors receive mechanical maintenance training from 3rd party vendors. The inpectors do not receive any regular certification refresher in addition to that required for qualified operators.

MAINTENANCE

Processes

The Chevron Crane Program utilizes a computer-based maintenance system. Fundamental to the program is a commercially available work order system used for scheduling maintenance and tracking equipment maintenance and performance. Additionally, many areas electronically record pertinent information on cranes. The Crane Program is available to users via an Internet site, as it is linked to the company's on-line Gulf of Mexico Operations Manual.

Major crane maintenance is handled primarily by company qualified inspectors. Labor to conduct follow-up work and other repairs and inspections is supplemented with 3rd party inspectors.

Comments, Issues, Concerns

Some company locations have resisted going entirely to computerized record keeping in an effort to facilitate access to information on field regulatory inspections. As computer-based processes progress, it is expected that more information will be available electronically.

While the company fully appreciates the flexibility in the presentation of information in API RP-2D, there is concern about the interpretation of some of the requirements in the document as they apply to maintaining regulatory compliance. Some clarification (not stringent mandates) is desired, and it is understood that some efforts are currently underway to address this issue.

ADDITIONAL COMMENT

Chevron is striving to improve the safety of its crane operations in the Gulf of Mexico and values its training and maintenance programs as well as regulatory support and guidance for their contributions to this effort.

QUESTIONS RAISED TO LLOYD'S REGISTER AT THE ITM ABOUT UK CRANE POLICY

Mr. William Hauser
Minerals Management Service

After consulting the UK Health and Safety Executive, Lloyd’s Register (LR), provided the following answers to questions posed at the recent 1999 ITM meeting.

1. How much time is permitted for repair of defects on cranes under Schedule 1, Para 8, sub Para C of the UK regulations?

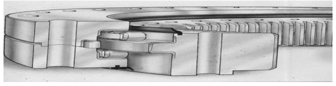
   When any defect is revealed by a competent person, then under Regulation 10 Reports and Defects - LOLER 98, the competent person must notify the employer and make a written report as documentary evidence of the defect. At this stage, the competent person will make an assessment of risk and discuss this risk with the employer. By mutual agreement, the timing of remedial action can be agreed. As there will be many degrees of risk, it is the competent person’s responsibility to ensure that those risks are conveyed clearly to the employer. If there is disagreement and the competent person is overruled then, it is the competent person’s responsibility to notify in writing the appropriate regulatory body, i.e. UK HSE. The overriding consideration must be to reduce risk and prevent accidents. If that means stopping the crane, so be it. If the crane can continue safely and operators are aware of their legal responsibilities, then mutually agreed time intervals, with or without additional conditions, such as an increased monitoring strategy, can be agreed.

2. Does LR permit lifting appliances to continue to be used with an identified defect but at a downgraded capacity?

   If an accident occurs between the reporting of the defect and the scheduled time of repair, it will be the competent person’s responsibility to show clearly that the decision to continue was made by a fully competent person and that the judgment was reasonable given known facts. If insufficient or poor quality data were used to make that decision, the competent person could be considered negligent. The competent person therefore has to ensure that he or she is satisfied with the state of equipment before he or she issues a statement of suitability. An informal analogy to illustrate these points could be made to driving a car: you could carry on driving a car with a cracked windshield, but you would stop the car if you had a tire blow-out.

LQS

Lubricating Grease Analysis in Support of Safe and Effective Crane Slewing Bearing Operation



General Review of Incidents

The percentage of recorded incidents which related to mechanical handling was consistently measured to be in excess of 50% of all incidents.

The ratio of mechanical failures to human error occurrences, has been shown to be, with corrections, to be in the order of 85%.

By the appropriate use of training and the use of third party professionals, incidents caused by human error and the resultant mechanical failures can be significantly reduced.

Lifting Operations and Lifting Equipment Regulations (LOLER)

- SI 2307 - Statutory Requirement *(All lifting Appliances)*
- L113 LOLER- Approved Code of Practice
- OTO 099041 - Technical Guidance Document

Lifting Operations and Lifting Equipment Regulations (LOLER)

Applies to:

- Fixed and mobile installations
- Flotels and diving support vessels
- FPSO's
- FSU

Crane Deferral Packages

- Grease Analysis
- Rocking Motion Reports
- Slewring Bolt Checks
- Ultrasonic Inspection Reports
- Load Monitoring Reports

Specific Indicators of Equipment Condition Using the Lubricant as the Data Transmission Path

- Fact: The only indicators of wear are particles of wear debris.
- Fact: Any other data is secondary and can only be used to fine tune lubricant management systems
- Fact: Only by identifying debris of the type known to be generated during a malignant wear process, where sufficient quantity and with reference to historical trends, can the service provider be confident that a degenerative failure is in effect.
- Fact: If the competent person who performs the analysis will not award "Suitable For Service" statements, then the duty holder retains competency and assumes the responsibility for the quality of the data analysis.

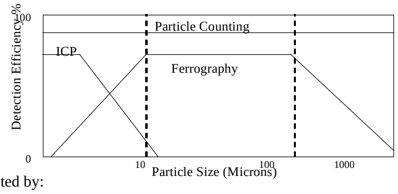
Application of Different Monitoring Techniques

Inductively Coupled Plasma Spectrometry (ICP)
Measures metallic components present in the sample by vaporization and the measurement of emissions by tuned receptors.

Particle Counting (PC)
Measures the size and range of all particles irrespective of source. (Cleanliness)

Analytical Ferrography
Measures the size and morphology(type) of debris, requiring highly trained analysts.

Application of Different Monitoring Techniques



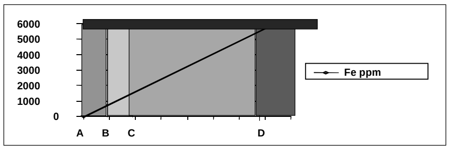
Limited by:

- ICP to ~ 10μm - class by metal and quantity
- Ferrography > 10μm - class by wear system and size(Fe).
- PC All size and quantity but no type classification

Debris by Shape

- Cutting
- Severe sliding
- Fatigue
- Contaminant

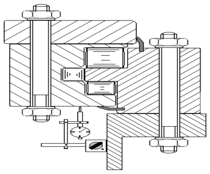
Rating Awards System



A- Suitable for further service
B - Wear values close to alert limits
C - Wear values at limits
D - Unsuitable for further service

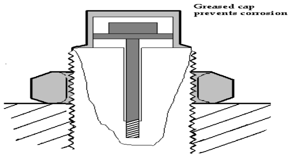
Rocking Tests

At regular intervals, measurements of bearing clearance are taken using a dial test indicator, or some other acceptable measurement technique.



This information can be held within the crane management log and reviewed alongside the lubricant analysis

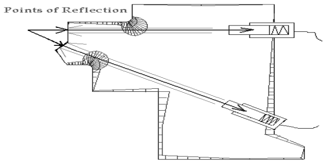
Slewring Bolt Checks



Bolts can be subject to stretch, corrosion and general loss of torque. By routine examination of sample bolts, or by the use of intelligent washers to monitor strain, the incidence of bolt failure is reduced and the confidence in the integrity of bolt management is increased.

Any change in dimension will be measured by the internal device

Ultrasonic Inspections



A sound source and a reference echo is sent to the point of reflection, any flaws will obstruct this and affect the reflection signal. Annual or incident based ultrasonic testing of the bearing raceways will give a clear indication of whether there is any sub-surface crack propagation and/or indicate whether there is any radii damage.

Load Monitoring Reports

The routine measurement/logging of lifts, allows the operator to asses whether the design parameters of the crane have been exceeded. It is required in the UK offshore sectors that in the example where the crane is subjected to an un-planned overload, e.g. a snag load,. and the crane has been overloaded, it is the responsibility of the duty holder to check that the operational efficiency of the system has not been compromised.

Lloyd's Register

Partner in risk management
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Industry Division

ISSUES RAISED AT THE CRANE ITM PANEL

Mr. William Hauser
Minerals Management Service

After the presentations by the panel members, we opened the floor for questions and comments. The following topics, questions, and issues were discussed:

1. *API SPEC 2C, Specifications for Offshore Cranes:* Does MMS require cranes built to earlier editions of SPEC 2C to be upgraded to the current edition? The response was “no.” In fact, MMS regulations do not require that cranes installed on fixed platforms be designed to the specifications of SPEC 2C. However, MMS is preparing a proposed rule that incorporates SPEC 2C into the regulations. One of the issues in that rulemaking is the amount of retrofitting that would be required for current cranes (for example, the installation of anti-two block devices).

2. *API RP 2D, Fourth Edition:* The following issues were raised about RP 2D:

   - It is vague about the appropriate timeframe to repair cranes relative to restricted use.

   - It is too vague about the review frequency of crane usage categories, i.e. more specific time periods must be defined for reviewing crane usage categories.

3. *Mechanical versus hydraulic cranes:* Does the use of mechanical cranes pose a greater risk than the use of hydraulic cranes? The response was “yes,” but only limited discussion ensued on the topic.

4. *Crane operator training:* The following issues were raised about crane operator training:

   - On-station training (OJT) is utilized extensively for crane operators to gain experience with various loading and weather conditions.

   - Chevron requires 20 supervised lifts to/from the deck of a vessel during a three-month period to obtain a “Qualified Operator” status.

   - IADC is developing guidelines for qualifying crane operators for various types of lifts. The guidelines have a tiered system with specific requirements that must be met before an operator can move to next level of more difficult lifts.

   - Decision-making for lifting in marginal conditions probably needs further development (judging immediate needs versus consequences).

5. *Wire rope:* The useful life of wire rope for lifting devices is of concern in the marine environment. USCG allows wire rope on MODUs to be utilized for four years or five years

if a 110% weight test is satisfied. Chevron requires wire rope on hoist to be changed out after five years.

6. *Movement of rental cranes:* The movement of rental cranes on and off platforms needs to be looked at carefully to ensure that all workers know their jobs and responsibilities (it goes for movement of drilling rigs). The movement of rental cranes has resulted in several recent serious crane accidents.

7. *MMS inspection requirements:* The most discussed topic was MMS inspection criteria. It was obvious that company representatives wanted to know what MMS inspectors look for during crane inspections. Judging from the discussion, MMS is also looking for answers to many of the same questions. Many of the questions are about interpretation of API RP 2D and API SPEC 2C. MMS and industry would be well served if both groups met to discuss and get consistency on a number of issues, starting with understanding Potential Incident of Noncompliance (PINC) items for cranes.

8. *Standards for booms and hoists:* With the new regulations for booms, hoists, and other materials handling equipment, both MMS and industry need to determine what needs to be done to operate this equipment safely. This determination includes the development of PINCs and identification of appropriate standards for operation and maintenance.

9. *Third-party inspection of cranes:* This topic was mentioned but not discussed in much detail. MMS should evaluate this regulatory option.

10. *Marine personnel:* It was agreed that marine personnel must be properly informed and trained. This part of the safety loop has not always been addressed.

CRANE OPERATIONAL ISSUES

Offshore Operators Committee and
American Petroleum Institute

In mid-1998, the Minerals Management Service (MMS) formed a work group to analyze an apparent increase in crane incidents and to examine crane Safety issues. By mid-1998, there had been nine incidents involving operations. There had been at least 10 incidents in 1997 and 1996 and five in 1995. Of these, 34 incidents, 19 resulted in some type of injury, with 20 workers being injured and seven workers killed. Riggers suffered 10 of the 20 injuries with six or seven fatalities. Based on these data, one of the MMS workgroup's recommendations was that API be requested to revise API RP-2D. API RP-2D provided state-of-the-art guidance for operation of offshore cranes but provided little guidance applicable to the rigger function. The recommendation was discussed with API during API-MMS coordination meeting in December 1998. API agreed with MMS that it would be beneficial and expedient for both industry and MMS to have API revise API RP-2D rather than for MMS to develop and issue regulations. Three months later, in March1999, MMS requested that API proceed.

The API, working with OOC, formed an Ad-Hoc Task Force composed of over 20 crane experts. MMS, USCG, IADC, OOC, consultants, drilling companies, and OCS operators were all represented. The group focused specifically on addressing revisions to API RD-2D to focus on rigging safety and training that would be consistent with and supplemental to the existing contents of API RP-2D.

The API balloted and approved the revisions in June 1999, and the 4th Edition of API RP-2D was published in August 1999. Revisions to API RP-2D include a new definition of *qualified rigger*: a person with training and experience who has successfully completed a rigger training program. (A rigger is anyone who attaches or detaches lifting equipment to loads or lifting devices.)

A qualified operator is also considered a qualified rigger, since the operator requirements were also expanded to address rigging. A qualifying operator, in addition to attending a hands-on workshop on the proper inspection, use and maintenance of loose gear (slings, shackles, hooks, nylon slings, etc.), must also be trained in all rigger requirements.

The new expectation is that all crane load rigging will only be performed by qualified riggers. Rigger qualification training should incorporate familiarization with rigging hardware, slings and safety issues associated with rigging, lifting loads and lift planning. Training should include classroom, hands-on training, and examination. Hands-on training should include proper inspection, use, selection and maintenance of loose gear (slings, shackles, hooks, etc.).

Since the MMS regulations, as well as the United States Coast Guard regulations, require that cranes shall be operated and maintained in accordance with API RP-2D, these recommendations in API RP-2D will be required for OCS operators. The MMS plans to incorporate this edition into the regulations by year-end 1999.

Going from a request in March 1999 to a revised published API Recommended Practice in August 1999 is quite an achievement and illustrates what can be accomplished by a focused effort representing all sectors associated with crane operations working together: a rapid response to address a critical industry need.

SESSION 2C

CHEMOSYNTHETIC COMMUNITIES, PART II

Chair: Dr. Robert Avent, Minerals Management Service
Dr. Ian MacDonald, Texas A&M University

Date: November 30, 1999

Presentation	Author/Affiliation
A Conceptual Model of Seep Community Physiological Ecology: Growth, Persistence, and Successional Patterns	Dr. C.R. Fisher Dr. D.C. Bergquist Dr. J.K. Freytag Dr. R.T. Ward Dr. D. Julian Dr. J.P. Andras Dr. B. Begly Dr. M. VanHorn Pennsylvania State University
Genetic Exchange Between Seep Communities: Implications for Larval Dispersal, Speciation, and Population Resilience	Dr. Stephen W. Schaeffer Pennsylvania State University
Trophic Networks Among Seep Fauna	Dr. Robert S. Carney Louisiana State University Dr. Steven A. Macko University of Virginia
Parasites and PAH Body Burdens in Seep Mussels	Dr. Eric N. Powell Haskin Shellfish Research Laboratory Rutgers University Dr. Mahlon C. Kennicutt Geochemical and Environmental Research Group Texas A&M University
Stability and Change in Gulf of Mexico Chemosynthetic Communities (CHEMO II)	Dr. Ian R. MacDonald, Program Manager Geochemical and Environmental Research Group Texas A&M University

A CONCEPTUAL MODEL OF SEEP COMMUNITY PHYSIOLOGICAL ECOLOGY: GROWTH, PERSISTENCE, AND SUCCESSIONAL PATTERNS

Dr. C.R. Fisher
Dr. D.C. Bergquist
Dr. J.K. Freytag
Dr. R.T. Ward
Dr. D. Julian
Dr. J.P. Andras
Dr. B. Begly
Dr. M. VanHorn
Pennsylvania State University

Vestimentiferan tubeworms were first discovered associated with hydrothermal vents, and the species found on most mid-ocean ridges are adapted to the energy-rich ephemeral vent environment. Species like *Riftia pachyptila* take up necessary dissolved gasses, including hydrogen sulfide (the energy source required by their symbionts), from the rich hydrothermal fluid bathing their plume. Individual sites may only last months to years, and *R. pachyptila* is one of the fastest growing invertebrates known. The tubeworms found around cold seeps in the Gulf of Mexico are similar to their vent relatives in that they have no mouth, gut or anus and rely on their chemoautotrophic bacterial symbionts for nutrition. However, we have found that the most abundant cold seep vestimentiferan species, *Lamellibrachia* sp., has a very different physiological ecology and life history. Using a new tube staining technique to determine growth rates, we have found that *Lamellibrachia* sp. grows very slowly. Using data on almost 600 individuals from over 20 distinct aggregations we have determined that individuals of *Lamellibrachia* sp. live in excess of 170 – 250 years. Based on our studies of intact tubeworm aggregations (described in part below), the co-occurring Escarpid-like species lives at least as long.

As part of this project, numerous water samples were taken around vestimentiferans. Sulfide was undetectable (<0.1μm) in the gross majority of samples taken near the plumes (gill-like gas exchange organs) of the tubeworms and in most samples taken from points closer to the sediment. On the other hand, sulfide was consistently present in substantial quantities (up to millimolar) in the interstitial waters around the buried posterior ends of the tubeworms. Using new collection devices, we were able to collect intact communities of vestimentiferans and found that each tubeworm had grown a long tortuous posterior extension to its tube which is freely permeable to sulfide. This adaptation provides the tubeworms access to a much more stable and longer lasting source of sulfide and provides the explanation for the growth and abundance of tubeworms in areas where sulfide is not detectable in the water above the sediments. It also has significant implications for the structure of the associated faunal communities.

To obtain collections that allowed a quantitative analysis of vestimentiferan communities, we had new collection equipment designed and built. The collectors, Bushmaster Sr. and Bushmaster Jr., are hydraulically actuated nets that can be placed over vestimentiferan aggregations and allow collection of the entire aggregation and all fauna associated with the aggregation. Three collections were made with a prototype device in 1997. The devices were modified by adding a 64µm mesh liner and 4 collections were made in 1998. A total of 55 species of animals from 11 phyla (4,624 individuals) were collected with the 4 aggregations. Thirty-five species had not been documented from previous collections of seep fauna, and many of those may turn out to be new species. Although the total number of collections is too small to test hypotheses concerning community succession in the long lived vestimentiferan habitat, several patterns emerge from analysis of the collections of different aged vestimentiferan aggregations that are consistent with our working model of cold seep tubeworm life history.

The community associated with the juvenile aggregation was similar to the communities associated with mussel beds (which were also characterized as part of this project). Mussel bed communities were not very diverse but have a substantial biomass of a few species of endemic animals. A total of 12 species of animals were found in ten collections from eight different mussel beds (a maximum of seven species was found in any single collection). A collection of juvenile tubeworms yielded 19 species of associated fauna and the highest biomass of associated fauna of any collection. Most of this biomass was a result of the very high numbers of a few species of endemic animals. Communities associated with adult aggregations are much more diverse, with about twice the species richness of the juvenile community. The communities are still dominated by endemic species, but numerous species of non-endemic animals are present in small to moderate numbers. The biomass of associated fauna is almost one order of magnitude less (per unit area) than in the juvenile aggregation. A single collection of a senescent aggregation contained 20 species, half of which were represented by a single individual. This aggregation was supporting about 20% the biomass of the adult aggregations, and 69% of that biomass was found in two fish and one crab. Even endemic fauna were only present in small numbers, if present at all.

Our current working model for seep tubeworm life history and community succession begins with larval tubeworms settling in areas of active seepage, where precipitation of carbonates forms the hard substrate they need for recruitment. For a few years the high level of seepage is maintained at this point, the carbonate the first recruits have settled on may continue to grow, and recruitment to this aggregation continues as long as sulfide is released from the seafloor and the carbonate remains exposed. Because the young aggregation is in a microhabitat of active seepage, only fauna that can tolerate these conditions are associated with the young aggregations. These fauna include the animals found in mussel beds and are dominated by endemic seep animals. During this time, the very young tubeworms are obtaining sulfide across their plume, but also growing a posterior extension of their tube (a “root”) and supplementing their sulfide uptake from interstitial pools. Over the next century or two, the tubeworms continue to grow while seepage of sulfide from the sediment into the water column progressively decreases.

During this period, there is sufficient primary production associated with the aggregation to maintain a moderately high biomass community, and yet the toxicity of the habitat has decreased to the point that a wide variety of non-endemic fauna can colonize or visit the aggregations. At this point the analogy between the tubeworms and long-lived ecosystem-structuring plants is quite strong. Although they may not be the prime food source for most of the associated fauna, they are providing a habitat for numerous species. As the aggregation continues to age, flow of sulfide into the water column continues to decrease, and some thinning of the aggregation occurs. The tubes are colonized heavily by non-endemic non-mobile fauna, primary production by free living bacteria associated with the aggregation decreases significantly, and the biomass of the associated community drops significantly. This stage in their life history may also last a very long time because the tubeworms in these less dense old aggregations continue to grow and are in very good condition, presumably in part because of reduced competition from the remaining vestimentiferans. The age estimates given above are for two-meter long tubeworms. Our data are limited to animals below this size because of difficulties inherent in collecting larger animals. However, we have occasionally collected animals over three meters in length, and the data on the senescent bushes collected to date does not suggest these animals are dying. This all implies that seep tubeworms may in fact live considerably longer than 170 – 250 years, and that the ecosystems they create are equally long-lived.

Charles (Chuck) Fisher is currently a Professor of Biology at The Pennsylvania State University where he has been on the faculty since 1990. He received his B.S. from Michigan State University and his M.S. and Ph.D. from the University of California at Santa Barbara in 1985. His research emphasis is on the physiology and ecology of the animals that live around deep-sea hydrothermal vents in the Eastern Pacific and cold seeps in the Gulf of Mexico, and he has published over 50 peer-reviewed papers on these topics. His research has largely been supported by the NSF, MMS, NOAA NURPs, ONR, and NASA.

GENETIC EXCHANGE BETWEEN SEEP COMMUNITIES: IMPLICATIONS FOR LARVAL DISPERSAL, SPECIATION, AND POPULATION RESILIENCE

Dr. Stephen W. Schaeffer
Pennsylvania State University

ABSTRACT

Molecular genetic methods provide a powerful tool to infer the past evolutionary history of populations. Each of the major evolutionary forces—mutation, recombination, natural selection, and migration—leave a characteristic signature on the genomic DNA carried by an organism. The evolutionary history of individuals within and between populations as well as relationships among species can be inferred with molecular genetic methods. The chemosynthetic communities that live at the cold seeps of the Gulf of Mexico provide a unique opportunity to examine the role that dispersal plays in evolution of populations and the formation of new species.

The vestimentiferan tubeworms and mussels in association with their endosymbiotic bacteria are the main ecosystem structuring organisms at the cold seeps (Fisher *et al.* 1997). The tubeworms are sessile organisms that lack a mouth, gut, and anus, but thrive at the cold seeps through their association with endosymbiotic bacteria that live in a specialized tissue known as the trophosome.

Two aspects of the vestimentiferan life history are not clearly understood and can be clarified with molecular genetic approaches. First, how are endosymbionts acquired each generation? Male and female tubeworms issue their gametes into the water column where fertilization takes place. Whether the endosymbionts are transmitted with the egg or acquired later in development is not known. Efforts to detect endosymbionts in the egg have failed to find evidence for vertical transmission of the bacteria (Cary *et al.* 1993), yet newly settled juveniles always have endosymbionts. Thus, it appears that the endosymbionts are acquired each generation. Second, the distance that larvae can travel to colonize new seep habitats has profound implications for the long-term stability of these communities. Limited dispersal ability of seep fauna suggests that the chemosynthetic communities are fragile where biodiversity is at risk.

Genetic variation is the raw material of the evolutionary process that allows populations to change in response to environmental flux. Destruction of seep habitats would cause a profound loss of genetic diversity leading to an uncertain future of these fragile communities. Extensive dispersal ability of vestimentiferans and mussels indicates that chemosynthetic communities are robust to disturbance. This model of genetic exchange suggests that loss of a single community may be overcome through recolonization of seep sites from other localities within the Gulf of Mexico.

In this study, we used appropriate types of DNA variation to investigate (1) the migratory history of three seep species found in chemosynthetic communities, two vestimentiferan tubeworms (*Escarpia spicata* and *Lammelibrachia* sp.) and one mussel (*Bathymodiolis childressi*); (2) the phylogenetic history of tubeworms from cold seeps and hydrothermal vents; and (3) the

phylogenetic history of tubeworm endosymbionts. These data are used to address the robustness of the chemosynthetic communities to disturbance from offshore drilling.

The study of dispersal and gene flow in tubeworms and mussels utilizes highly variable genetic loci that are likely to be different among individuals. For this work, microsatellite loci, which are di-, tri-, and tetranucleotide sequences that change rapidly among individuals of the same species, were used to estimate levels of gene flow among four seep populations (GB 425, Bush Hill, Brine Pool, and GC 234). For each species, individuals were sampled from each of the four populations to examine intermediate and long-scale movement of larvae among seep sites. In addition, individuals were sampled from five to six stations within Bush Hill to examine dispersal over a short scale. Microsatellite loci were cloned with standard genetic engineering methods (Armour *et al.* 1994; Sambrook *et al.* 1989).

The two variable microsatellites for *Escarpia spicata* suggest that extensive gene flow occurs over short, intermediate, and long scales because estimates of the migration parameter are greater than one for all comparisons (Table 2C.1). Wright's (1931; 1943) mathematical model of migration shows that one migrant per generation is sufficient to homogenize gene frequencies among populations. Microsatellite alleles are largely not restricted to a single habitat, but shared among the tube worm populations examined in this study. These data suggest that disturbance of a local community will not have a profound effect on genetic diversity within the communities in the Gulf of Mexico. There is potential for large amounts of gene flow provided there are sufficient habitats for the tubeworms to settle. These estimates of gene flow are consistent with those found for the tubeworms that inhabit the hydrothermal vents of the Pacific Ocean (Black *et al.* 1994). How many habitats are suitable for tubeworms to settle into is an open question.

Table 2C.1. Estimates of the number of migrants exchanged between four populations of *Escarpia spicata*.

	GB 425	Bush Hill	Brine Pool	GC 234
GB 425		61.0	2.6	2.3
Bush Hill			3.7	2.6
Brine Pool				8.0
GC 234				

The single variable microsatellite for *Bathymodiolis childressi* suggest that extensive gene flow occurs over short, intermediate, and long scales because estimates of the migration parameter are greater than one for all comparisons (Table 2C.2). Again, this level of exchange is capable of homogenizing gene frequencies among mussel populations and that mussels have the potential to recolonize new seep sites in the Gulf of Mexico. These results are quite striking given the variation in the growth abilities and condition of the mussels in the different populations. The migration data suggest that the condition of endemic mussels in not controlled genetically, but by the selective constraints of the local environment. The high level of gene flow in tubeworms and mussels suggests that the water currents between the four populations are sufficient to allow transport of organisms among these habitats.

Table 2C.2. Estimates of the number of migrants exchanged between four populations of *Bathymodiolis childressi*.

	GB 425	Bush Hill	Brine Pool	GC 234
GB 425		26.2	2.9	14.9
Bush Hill			2.8	11.9
Brine Pool				2.8
GC 234				

The morphological identification of tubeworms from bushmaster collections of entire vestimentiferan communities revealed a new species of *Escarpia*. To clarify the relationship of this new vestimentiferan species, Erin McMullin used the cytochrome oxidase I gene to establish what affinity this escarpid-like species showed toward previously identified species of tubeworms from the Gulf of Mexico and the Pacific Ocean. This work shows that this new *Escarpid* species is most closely related to members of the *Escarpia* genus collected from the Pacific Ocean, but that its genetic distance is sufficient to consider this tubeworm a new species. This new *Escarpia* species was found as a single representative within a large tubeworm bush. No other members of this species were found in any of the tubeworm collections made during the two field seasons. This suggests that rare new species can evolve in these chemosynthetic communities but that destruction of a single bush could have profound effects on the species abundance. How this species fits into the ecology of the chemosynthetic communities is unclear.

Studies of the 16S rRNA gene by Dr. Kimberlyn Nelson and Dr. Fisher were used to infer the relationships among the vestimentiferan endosymbionts. Endosymbionts from pairs of tubeworm species from four sites in the Gulf of Mexico as well as hydrothermal vents in the Pacific Ocean were used to determine whether endosymbionts followed the evolution of the host species. One might expect that endosymbiont evolution would track the host given the close association of the host and symbiont. To their surprise, endosymbionts clustered based on geography rather than host identity. These data are consistent with the environmental acquisition of the endosymbiont each generation. We do not know when the symbiont is acquired during the life cycle except that it must occur after fertilization and before settlement of the trochophore larva.

What have we learned is information about the genetic structure of seep communities and what implications this has for protection of these environments. Each habitat supports a unique form of free-living bacterial endosymbiont for the tubeworms that is likely to be transmitted environmentally to the host. The movement of hosts from different seep habitats may or may not be allowed because of the unique bacterial flora present in each habitat. The currents in the Gulf of Mexico are sufficient to allow transport of mussel and tube worm larvae among the four seep sites sampled for this study. This would suggest that the seep communities are robust to disturbance, but gene flow data provides no insights into the number of suitable habitats that the tubeworms and mussels can colonize. The microsatellite loci developed in this study will provide useful tools for further examination of tubeworm and mussel populations to further refine how these chemosynthetic organisms are transported around the Gulf of Mexico.

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Dr. Stephen W. Schaeffer is an Associate Professor of Biology at The Pennsylvania State University. His expertise is in the area of ecological and population genetics. He has published 21 papers on the population genetics of plant and animal genes that infer the past mutational, selective, recombinational, and migratory history of populations from nucleotide sequence data. His laboratory has sequenced over 600 kilobases of DNA resulting in 384 entries in the National Library of Medicine’s GenBank Database. Dr. Schaeffer received his B.S. degree in biology and chemistry from West Virginia Wesleyan College in 1978, his M.S. degree in biology from West Virginia University in 1980, and his Ph.D. in molecular and population genetics from the University of Georgia in 1985. He was post-doctoral fellow in the laboratory of Dr. Richard C. Lewontin at Harvard University from 1985 until 1988. Dr. Schaeffer has written 21 peer-reviewed papers based on funding from NIH and NSF.

TROPHIC NETWORKS AMONG SEEP FAUNA

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Dr. Steven A. Macko
University of Virginia

INTRODUCTION

During past examinations of the Gulf of Mexico (GOM) chemosynthetic communities, it has been confirmed through stable carbon isotope analysis that the heterotrophic fauna associated with these systems definitely derive nutrition from chemosynthetic sources. The data producing these confirmations, however, were equivocal on two major ecological questions. First, to what extent is seep productivity exploited by the background fauna in the upper-slope environment? Second, to what extent do the resident fauna in the seeps consume food derived from the background and the phytoplankton detritus that fuels it?

Both questions, exploitation of seeps by the background and the reverse exploitation of the background by the seeps, are relevant to the question of whether seep communities are stable, although somewhat peripheral. For a system to persist, the processes of increase (recruitment and growth) must, on an average over some time and space interval, at least equal the processes of decrease (emigration and death). If seeps are heavily exploited by predators and scavengers from the background, then communities may be subject to overexploitation and local extinction. If seep-associated organisms can mix chemosynthetic and photosynthetic food sources, then populations of such organisms may be comparatively stable when experiencing fluctuations in chemosynthetic production.

The trophic component consisted of three distinct sampling efforts followed by extensive stable isotope analysis of the collected fauna. A smaller proof-of-method study using immunoassay to identify specific prey-predators pairs was included. The three sampling efforts consisted of (1) quantitative sampling of mussel assemblages, (2) quantitative sampling of tubeworm assemblages, and (3) trap sampling of larger predators/scavengers. Mussel and tubeworm sampling was conducted according to a design developed by Dr. Fisher and used equipment and procedures developed by Dr. Fisher in conjunction with Harbor Branch Oceanographic Institution. Trap collecting was conducted according to a design developed by Dr. Carney and used equipment and procedures developed by Dr. Carney and the LSU Oceanographic Field Facilities Group. Stable isotope analysis of $\delta^{13}C$, $\delta^{15}N$, and $d^{34}S$ were conducted by doctoral candidate Steven Macavoy under supervision of Dr. Steven Macko using methods developed by by Dr. Macko. Immunoassay was carried out by master's candidate Nick Davidson under supervision of Dr. Robert Feller using methods developed by Dr. Feller.

RESULTS

Sub-deployed and surface deployed traps were successfully used at and 1 km away from three seep sites. Eleven taxa were collected with the vagrants *Eptatretus* (hagfish), *Bathynomus* (giant isopod), and *Rochina* (spider crab) predominating. In general, animals collected off-site had isotope profiles indicating exclusive dependence on the background phyto-detritus system. A notable exception was a single *Rochina* crab for which the $d^{34}S$ values indicated approximately 50% dependence on seep-produced food. Animals collected on site produced mixed results with some high dependence on seep carbon in some specimens in none at all in others.

Resident fauna from within seeps continue to produce equivocal results. The addition of $\delta^{15}N$, and $\delta^{34}S$ did not greatly improve ability to resolve trophic relationships. Seep gastropods and crustaceans definitely consume chemosynthetic production. Their isotopic values, however, reflect shifts from the values associated with such production. Unfortunately, these shifts can be attributed to three separate phenomena: (1) a mixed diet incorporating background food; (2) trophic effects, or (3) consumption of a yet characterized chemosynthetic source.

Immunoassay was attempted only as a proof of method. The results were, however, interesting. Stomach contents of seep heterotrophs and vagrant predators tested positive for both mussel and tubeworm tissue. This result is unexpected since only a few species are suspected of feeding directly upon these two sources. In addition, grazing gastropods would not seem to have a mechanism for such predation. Two possibilities are (1) that exudates from the producer organisms may produce a positive response, or (2) the assay reactions lack sufficient specificity.

CONCLUSION

In certain respects, we end where we began, but with more and better data. It was established that some, but not all, large predators within seeps feed upon seep production. As to whether background vagrants move into and out of seeps, exporting production, the results are less conclusive. Only one crab indicated such export convincingly. The exact trophic relationships among heterotrophs in the seeps remains poorly resolved. Future work must include increased sampling of all possible sources, better replicate species in and off-site, and refined immunoassay tests.

Dr. Robert S. Carney is an associate professor of oceanography at Louisiana State University. He holds a B.S. from Duke University, M.S. in oceanography at Texas A&M, and Ph.D. in oceanography from Oregon State University. Dr. Carney has served as a scientific advisor on three MMS projects, CoPI on three projects, and PI on three CMI projects. He was the founding director of the joint MMS-LSU Coastal Marine Institute program and a member of MMS's national Scientific Advisory Board. Dr. Carney's areas of interest include deep-sea benthic ecology and rigorous assessment of offshore environmental impact.

Dr. Steven Macko is a professor of environmental sciences at the University of Virgina. He holds B.S. and B.A. degrees from Carnegie-Mellon University, an M.S. in chemical oceanography from the University of Maine, and a Ph.D. in geochemistry from the University of Texas. Dr. Macko is internationally recognized expert in isotopic investigation of trophic linkage.

PARASITES AND PAH BODY BURDENS IN SEEP MUSSELS

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INTRODUCTION

Petroleum seep mussels are often exposed to high hydrocarbon concentrations in their natural habitat and, thus, offer the opportunity to examine the relationship between parasitism, disease and contaminant exposure under natural conditions. Because petroleum seep mussels are closely associated with hydrocarbon seepage, the prevalence and infection intensity of parasites, diseases, and tissue pathologies may vary with site chemistry and, as a consequence, may provide a useful early warning signal of long-term changes in the health of seep communities that may eventually result in local extinction. Discriminating populations in decline from healthy ones is a key component to understanding the processes controlling the structure and persistence of seep communities.

This is the first report on the histopathology of cold-seep mussels. The purpose of this study was to (1) document the parasite body burdens in petroleum seep mussels, (2) determine whether parasite body burdens varied spatially between nearby populations and between populations separated on larger scales, (3) evaluate the degree to which parasites might impact population dynamics and the persistence of seep communities, (4) document the rapidity of which parasite infections and physiological condition respond to changes in host population structure and environment, and (4) examine the relationship between parasite and PAH body burdens.

METHODS

Seep mussels were collected by submersible from four primary sites in the Gulf of Mexico (GOM), lease blocks Green Canyon (GC) 184, GC-234, GC-233, and Garden Banks 425 in 550 to 650 m water depth. To evaluate the influence of the seep environment on mussels, a transplant experiment was conducted among several donor (population of origin) and receiver (population of transplant) populations at GC-184, GC-233 and GC-234. Dissection, embedding and staining procedures followed the NOAA Status and Trends protocols. All histological assessments were based on quantitative measures or semiquantitative scales so that parasite infection intensity could be rigorously evaluated statistically.

RESULTS

Five types of parasites were identified in section: (1) “gill rosettes” of unknown affinity associated with the gill bacteriocytes, (2) gill “inclusions” similar to chlamydia/rickettsia inclusions, (3) extracellular gill ciliates, (4) body “inclusions” that also resemble chlamydial/rickettsial inclusions, and (5) *Bucephalus*-like trematodes. Comparison to shallow-water mytilids demonstrates that: (1) both have similar parasite faunas; (2) seep mytilids are relatively heavily parasitized; and (3) infection intensities are extremely high in comparison to shallow-water mytilids *Bucephalus* and chlamydia/rickettsia. In this study, the lowest prevalence for chlamydia/rickettsia was 67%. Prevalences of 100% were recorded from fifteen populations. Bucephalus prevalence was ≥70% in four of 19 populations and ≥50% in six of 19 populations. Excluding GC-233, where *Bucephalus* was not observed, prevalence exceeded 50% in 6 of 14 populations and infection intensities exceeded 1.5 on a 0-to-4-point scale in five. The parasite fauna was highly variable between populations. Some important parasites were not observed in some primary sites. Even within primary sites, some important parasites were not observed in some populations. *Bucephalus* may exert a significant influence on seep mussel population dynamics. Excepting those at GC-233, 64\% of the populations in this study are severely reproductively compromised by *Bucephalus* infection. Only a fraction of petroleum seep mussel populations are maintaining the entire beta-level population structure of this species.

Variation in two parasites, gill ciliates and *Bucephalus*, explained most of the variation in PAH body burden between mussel populations. PAHs are known to be sequestered preferentially in gametic tissue. *Bucephalus* would be expected to reduce overall body burden, at high infection intensities, by replacing gametic tissue. PAH concentrations exceeded 1 ppm in four of nine populations surveyed in year 1, a ratio significantly higher than the eight of 30 mussel locales in the NOAA Mussel Watch Program. Only five Mussel Watch locales exceeded the highest value for a petroleum seep population. Digestive gland and gill tissue atrophy were not significantly correlated with PAH body burden, even though some populations were characterized by body burdens exceeding 1 ppm, suggesting that seep mussels may not be as sensitive to PAH exposure as are some shallow-water mytilid populations.

Transplanted populations came into equilibrium with the receiver populations much faster in cases where a decrease in infection intensity or prevalence was required. Quite the opposite was true for cases where the transplanted population had to gain infections or increase in infection intensity to come into equilibrium with the receiver population. In many cases, these transplanted populations retained the donor population condition. Overall, the single-celled rickettsia responded to the new environment of the receiver population much more rapidly than did the multicellular trematodes. Of the physiological indices, gonadal stage came into equilibrium with all receiver populations in one year. Mussels lost condition rapidly in cases where the receiver population had lower condition, but they gained condition slowly in the opposite case. Digestive gland atrophy and gill tissue atrophy increased slowly, but recovered rapidly.

Transmission rates could be estimated for gill rickettsia and *Bucephalus*. For gill rickettsia, transmission rates varied between 0.3 and 0.55 yr. Loss rates came close to yr $^{-1}$. This suggests a short life span for any individual rickettsial body; it also suggests that infection intensity is a balance between rapid rates of proliferation and loss. Transmission rates for *Bucephalus* were much slower: 0.12 to 0.25 yr^{-1}; nevertheless, infection intensification was rapid, reaching 3 on a 0-to-4-point scale in one year. Mussels live for a relatively long time, and the transmission rates measured for *Bucephalus* are relatively high, yet population prevalences are often well below 100%. The strong suggestion is that these trematode sporocysts have life spans considerably less than their hosts, a fact that is of some consequence because, while infected, the mussels lose any capacity to reproduce.

A highly dynamic process establishing parasite prevalence and infection intensity is corroborated by the rarity of size (and age) dependent prevalences and infection intensities. Infections are gained and lost rapidly in comparison to mussel growth rates. Nearby populations were as different, in may respects, as populations from different major sites (e.g., GC-233, GC-184). Thus, the dynamics controlling parasite acquisition, proliferation and loss are predominately determined by local environmental/biological conditions. The single exception is the absence of certain parasite types from certain major sites. *Bucephalus*, for example, was not observed at GC-233.

Transplanted populations came into equilibrium with receiver populations in PAH body burden after one year, in cases where body burden was higher in the receiver population. Body burden remained high in mussels transplanted to populations with lower body burden. However, an examination of the proportional contribution of 44 PAHs to the PAH body pool indicated that proportions came into equilibrium in all cases. Therefore, the retention of high body burdens in the latter was not due to low depuration rates. Likely, it was due to an inherently higher "storage" capacity in mussels obtained from populations with high body burden. What biological process is responsible is not yet clear.

Dr. Eric N. Powell is Director of the Haskin Shellfish Research Laboratory of Rutgers University. He has published extensively in the fields of oyster ecology and modeling, parasites and diseases in marine bivalves, paleoecology, and benthic ecology. His research experience includes studies on reproductive effort and condition, and the effects of pollutant body burdens on the health and physiology of invertebrate species. Dr. Powell received his B.S. in zoology from the University of Washington and his M.S. and Ph.D. in marine sciences from the University of North Carolina at Chapel Hill.

STABILITY AND CHANGE IN GULF OF MEXICO CHEMOSYNTHETIC COMMUNITIES (CHEMO II)

Dr. Ian R. MacDonald
Program Manager
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Texas A&M University

INTRODUCTION

Chemosynthesis is a bacterial pathway that can generate fresh organic carbon, in the absence of light, by use of energy obtained from chemical reactions. Chemosynthetic bacteria typically live on sulfidic (reduced) aquatic sediments or as symbionts in specially adapted tube worms and bivalves. On the northern continental slope of the Gulf of Mexico, communities supported by chemosynthesis are known to occur between longitudes 94° W and 88° W, at depths between the 400 and 2200 m (MacDonald *et al.* 1996). These communities comprise dense and productive aggregations of benthic organisms that are dominated by chemosynthetic tube worms and mussels but also include many benthic invertebrates and fish that are common throughout the Gulf slope(MacDonald *et al.* 1989). A free-living bacterium, *Beggiatoa*, is ubiquitous at seeps and may form thick mats on surface sediments (Larkin *et al.* 1994). The chemosynthetic fauna are dependent upon methane and hydrogen sulfide dissolved in pore-fluid and very-near-bottom sea water. Methane supports mussels and hydrogen sulfide supports tube worms (Fisher, 1990). The presence of these gases in the Gulf slope sediments is directly linked to migration of hydrocarbons from deep sub-surface reservoirs to the seafloor and the water column (Kennicutt *et al.* 1988). The greatest management concern is directed at communities with aggregations that extend over a large area and where the local high productivity supports a diverse assemblage of heterotrophic fauna. An additional concern, which has emerged during the course of the program, is the role of shallow gas hydrate in chemosynthetic communities and slope stability generally (MacDonald *et al.* 1994; Sassen *et al.* 1998).

Important progress was made in the understanding of chemosynthetic communities in the Gulf of Mexico during the early 1990s, in large part as a result of the MMS Program entitled “The Chemosynthetic Ecosystem Study” (CHEMO I). However, there remained many unanswered questions and many areas where qualified scientists and managers disagreed. The continuation of CHEMO was a new, 42-month program entitled “Stability and Change in Gulf of Mexico Chemosynthetic Communities” (CHEMO II). It was inaugurated at the beginning of the 1997 fiscal year and was designed to aid MMS in the scientifically sound management of seep communities. The CHEMO II team has now completed all of the scheduled field collections. The program principal investigators (PIs) have completed sample analysis and are currently preparing the program’s final report.

This presentation gives a brief overview of the CHEMO II program goals, study design, and participants. It summarizes progress during the program and provides an introduction to the program elements described by individual PIs.

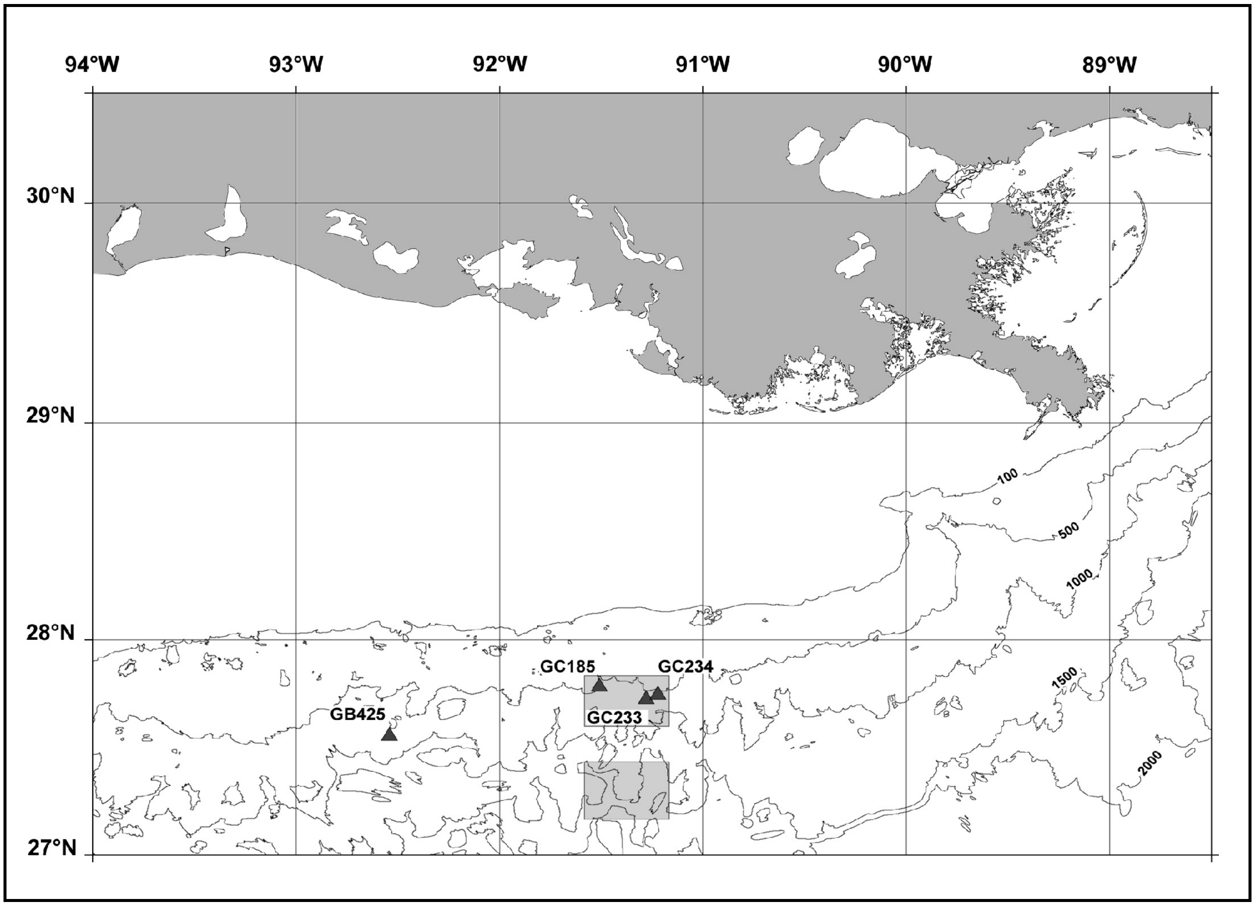

Figure 2C.1. Northern Gulf of Mexico showing study site locations for submersible operations (triangles) and mega-site areas for geophysical survey (shaded rectangles). Depth contours are in meters.

PROGRAM OVERVIEW

The CHEMO II program includes investigations at regional and community scales. At the regional level, the program has been concerned with developing reliable methods for remote detection of significant chemosynthetic communities. During the 1997 field season, side-scan sonar surveys of suspected chemosynthetic communities were carried out in two regional mega-sites (Figure 2C.1). During FY 1998, U.S. Navy Submarine NR-1 was fitted with a laser line scan system and an X-Star Subbottom Profiler and was used to survey known and suspected communities to confirm interpretation of the sonar data.

The size and location of mega-sites were designed to optimize survey operations and provide significant regional coverage. Both areas encompass several types of geological formations. Both contain more than ten perennial sea surface slicks detected by remote sensing techniques. Additional survey data were collected at the Garden Banks (GB) 425 sampling site in support of the community-level studies. Characteristic of the mega-sites are summarized in Table 2C.3 below:

Table 2C.3. Summary of regional mega-site locations and attributes. (For locations, see Figure 2C.1.)

1) Megasite 1 (“Shallow”) - area 1214 km^2
    a) Boundaries - 91˚35'W-91˚10'W; 27˚36'N-27˚50'N.
    b) Contains Green Canyon (GC) blocks 185, 233, and 234 sampling sites.
    d) Water depths range from 400-900 m.

2) Megasite 2 (“Deep”) - area 1214 km^2
    a) Boundaries - 91˚35'W-91˚10'W; 27˚10'N-27˚26'N.
    b) Contains northern Pygmy Basin; eastern Longhorn Basin; and most of Tiger Basin (intrasalt basins).
    d) Water depths range from 950 to 1,250 m.

At the community level, efforts focus on the abiotic factors that control the distribution, abundance, and health of the major chemosynthetic and associated fauna. Investigations of the life history of these organisms are also included. Field work depended upon use of the manned submersibles Johnson Sea-Link II and I, in 1997 and 1998, respectively. These submersibles were used to collect samples from a series of stations within each of four detailed study sites (Figure 2C.1). Characteristics of the sampling sites are summarized in Table 2C.4.

Table 2C.4. Summary of principal community-level sampling sites and pertinent characteristics. (For locations, see Figure 2C.1.)

Sampling Site (abbreviation)	**Latitude, Longitude**	**Depth (m)**	**Fauna present (by dominance)**	**Seepage properties**
GC185 [Bush Hill (BH)]	27˚46.9' N 91˚30.4' W	550-580	tube worms heterotrophs mussels	high molecular weight hydrocarbons free methane to pentane gases
GC234 [Green Canyon (GC)]	27˚44.1' N 91˚15.3' W	525-560	tube worms heterotrophs mussels	high molecular weight hydrocarbons free methane to pentane gases
GC233 [Brine Pool (BP)]	27˚43.4' N 91˚16.8' W	640	mussels heterotrophs tube worms	brine free and dissolved methane gas
GB425 [Garden Banks (GB)]	27˚33.2' N 92˚32.4' W	600	mussels heterotrophs (?) tube worms	brine free and dissolved methane gas high molecular weight hydrocarbons

Efforts by individual PIs were coordinated by implementation of a sampling design. This design designated a series of stations at each site base on what were thought to be robust faunistic attributes. For example, adult tube worm clusters (two each at GC234 and GC185) were marked and repeatedly sampled, with material distributed among the disciplines for separate analyses. With sediment samples, PIs for inorganic and hydrocarbon geochemistry, micro-gradients, and *Beggiatoa* ecology all shared material collected by identical methods. Similar overlap was achieved by PIs for ecology and growth and for parasitism and health. A detailed report will result from these efforts that will break new ground in benthic ecology and biogeochemistry of chemically enriched environments.

PROGRAM TEAM

A multidisciplinary team of investigators is carrying out program objectives. The principal investigators, their area of expertise, and the Scientific Review Board members are listed in Table 2C.5.

Table 2C.5. Program team and roles.

Texas A&M University Investigators
Geochemical and Environmental Research Group

Dr. Norman L. Guinasso, Jr. Physical Oceanography	Dr. Ian MacDonald Program Manager Imaging & GIS	Dr. Gary A. Wolff Data Management
Dr. Mahlon C. Kennicutt II Deputy Program Manager Environmental Chemistry	Dr. Roger Sassen Hydrocarbon Chemistry	

Department of Oceanography

Dr. John W. Morse Inorganic Chemistry	Dr. William Sager Geophysics

Principal Investigators Not at Texas A&M University

Dr. Samantha Joye University of Georgia Electrochemistry	Dr. Steven Macko University of Virginia Trophic Relationships	Dr. Douglas C. Nelson University of California, Davis Microbial Ecology
Dr. Robert Carney Louisiana State University Trophic Relationships	Dr. Paul Montagna University of Texas at Austin Statistical Design	Dr. Eric Powell Rutgers University Histopathology and Community Health
Dr. Charles F. Fisher Pennsylvania State University Physiological Ecology	Dr. Kimberlyn Nelson Pennsylvania State University Molecular Ecology and Genetics	Dr. Steve Schaeffer Pennsylvania State University Molecular Ecology and Genetics

Scientific Review Board

Dr. James Barry Monterey Bay Aquarium Research Institute	Dr. Cindy Lee Van Dover University of Alaska	Dr. William W. Schroeder The University of Alabama

Progress descriptions by individual investigators detailed in the presentation indicate timely completion of contract obligations with few shortfalls and no problems that jeopardize the overall objectives of the program. The need for adequate synthesis of diverse data has led to a more deliberate delivery schedule in the preparation of the final report. This activity is well underway and will be completed in early 2000.

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Ian R. MacDonald is an Associate Research Scientist at the Geochemical and Environmental Research Group of Texas A&M University. His primary research interest is the application of imaging and GIS techniques for marine ecology. He is the program manager for the Stability and Change in Gulf of Mexico Chemosynthetic Communities Program. MacDonald received a Ph.D. in oceanography in 1990 from Texas A&M University.

SESSION 1D

THE GULF OF MEXICO IN THE NEW MILLENNIUM: DRIVEN BY DEEPWATER

Chair: Mr. Chris Oynes, Minerals Management Service

Date: December 3, 1999

Presentation	Author/Affiliation
Introduction	Mr. Chris Oynes Minerals Management Service
The Gulf of Mexico in the New Millennium	Mr. David T. Lawrence Shell Oil Company
MMS Gulf of Mexico Environmental Studies Program	Dr. James Coleman Louisiana State University
Biological Resources in the Gulf of Mexico	Dr. Thomas McIlwain National Marine Fisheries Service

INTRODUCTION

Mr. Chris Oynes
Minerals Management Service

The Gulf of Mexico is one of the most active oil and gas plays in the world. Since 1947, the federal Outer Continental Shelf in the Gulf has produced 10.9 billion barrels of oil and 132 trillion cubic feet of gas. Future production from the deepwater areas is expected to be of a large magnitude. The Gulf also hosts a huge commercial fishing industry; its ecosystem is strongly influenced by the outflow of the Mississippi River and the importation of over 2 billion barrels of oil a year entering U.S. Gulf ports. Fishing efforts conducted in deepwater areas target highly valued species from the surface to the bottom. The presence of deepwater currents, stronger than anticipated, may present challenges to the design and operations of deepwater platforms. The recent discoveries of hydrate "ice worms," along with the 29 species of marine mammals and a growing array of chemosynthetic communities that live in the Gulf, have opened entire new frontiers concerning the ecosystems of the Gulf. Deepwater activities have led to changes in trade and business arrangements which now involve many states and countries. Advances in science and technology, as we enter the millennium, will drive the continued expansion of the industry into deepwater.

CIRCULATION IN DEEPWATERS OF THE GULF OF MEXICO

Two emerging issues where more information is needed:

- Loop Current Variability: Understanding that the Loop Current is a major source of energy for the currents in the Gulf, more knowledge is needed about the seasonal variability. This has important implications for the design of structures in deepwater (We have seen a recent example of the power of the Loop Current in September when some deepwater structures were exposed to a northward intrusion of the Loop Current and those structures began oscillating).

- Deepwater Currents: The scientific community was surprised to learn that energetic deepwater currents (>1000) can occur and modeling them is critical to understanding the circulation patterns in deepwaters for oil spill contingency planning and for operational safety.

DEEPWATER GEOLOGY

We need to understand the slope geology to meet both engineering and regulatory requirements.

New technology in acoustic imaging of both the sea floor and subsurface (particularly 3D-seismic) has provided new insight into the slope's structure and stratigraphy. It has provided new images of salt and sub salt structures and has helped to reduce drilling risk.

The sediments displaced by slumping and submarine landslides at the shelf edge pose a considerable risk to man's activities on the northern Gulfs continental slope.

GAS HYDRATE MOUNDS

Gas hydrates are able to exist at or near the sea floor in water depths greater than 500m and below, because of the special conditions of temperature and pressure which exist at these depths. They can be hazardous to operations and must be carefully mapped around deepwater structures. Gas hydrates also provide chemosynthetic communities with the resources they need to exist.

Because of their energy potential, eventually the mining of hydrates will become a reality.

ECOLOGICAL UNKNOWNS OF DEEPWATERS

Understanding the ecology of Deepwaters is challenging because a small pool of experts exists that have been inadequately supported in a research area that has high logistical costs. Because of limited funding of deepwater research over the past several decades, there are very few proven ideas that are available to MMS to use in guiding its future research activities.

MMS realizes that the public will be just as concerned about impacts to Deepwaters as they are about impacts to the shelf and coastal waters and estuaries. MMS and industry must assume leadership roles in deepwater ocean research through innovative federal-industry partnerships.

One question that MMS can begin to answer is: 'How much of continental shelf management strategy can be effectively applied to Deepwaters?" By avoiding conflicts of resource use, a broad range of management options can be transferred and fine-tuned to the special challenges found in Deepwaters.

While MMS has taken a proactive role in protecting the deepwater chemosynthetic communities, there may be more questions to be answered about avoiding development-related impacts to the typical deepwater environments.

MMS and industry face questions where there are little data or concepts to provide answers. A new mode of information gathering is required which builds not only databases but also ideas. MMS cannot embrace all the unknowns about deep-sea ecology, but they can undertake studies that build on the management's strategies developed in shallow water.

FISHERIES CONFLICT IN DEEPWATER

One source of conflict may involve deep-sea bottom fisheries with deepwater development. But these fisheries are usually destined to failure as old and slowly recruiting stocks are rapidly depleted. Upper-ocean conflicts are far more likely to occur than at depths, but if industry utilizes seafloor facilities, even these impacts may be minimized.

SOCIOECONOMIC IMPACTS

As the socioeconomic program has grown and matured in the Gulf of Mexico region, some very sophisticated studies have been undertaken to measure impacts from the oil and gas industry on human communities. These studies range from examining sustainable development to examining the impacts on port facilities. As we move into Deepwater, the growth in this industry will necessitate studies to understand how the economy has changed to meet this challenge. We are well positioned to begin understanding our past history of socioeconomic development as we move forward to understand the future.

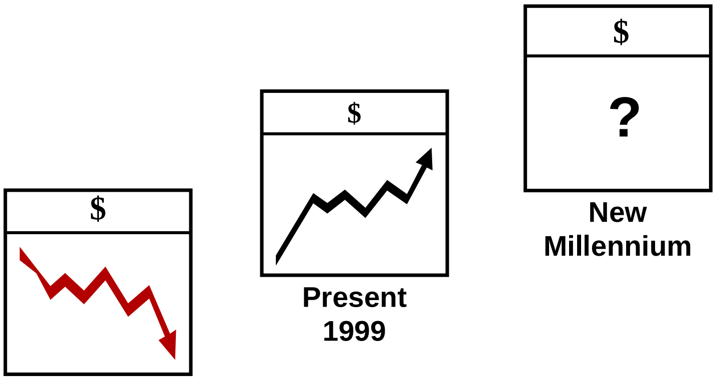
FUTURE SYSTEMS TO BE DEPLOYED

To meet the challenges in working in Deepwaters many systems will be deployed in this environment. They are subsea systems, compliant towers, tension leg platforms, floating production systems, spars, and possible floating production storage and offloading systems.

THE GULF OF MEXICO IN THE NEW MILLENNIUM

Mr. David T. Lawrence
Shell Oil Company

Industry Outlook



**Past
1992**

**Present
1999**

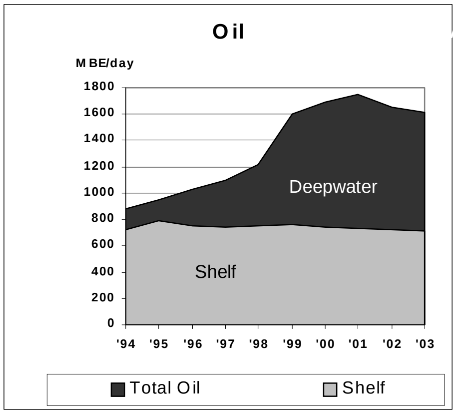
**New
Millennium**

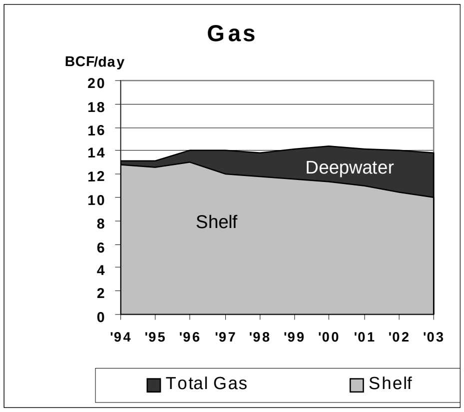
Current Environment

- Higher oil & gas prices with little to no increased activity
- Consolidations, mergers, acquisitions & divestitures are ongoing and will impact current and future activity
- Continued cost reduction, price uncertainty and improved bottom line driving most decisions
- Ongoing reduction in activity will impact levels of production (especially natural gas)
- Will the above environment continue and for how long?

GOM Total Oil and Gas Production

Actual through 1998; Projected 1999 - 2003





GOM Data Source - MMS 99-0016 OCS Report - Projected Data Low/High Average

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Deepwater Discoveries

- 68 confirmed discoveries
  - Shell 38
  - Industry 30
- Estimated 5+ BBE announced
- Development plans publicized on at least 30 projects (>1500’ WD)

The Global Deepwater Opportunity

HSE Management Systems

- HSE Management Systems will drive increased proactive HSE efforts
- Industry will continue to strive for fewer accidents & fewer environmental releases
- Project specific HSE planning will become standard practice throughout the E&P industry
- HSE's sharing of best practices within industry & alignment with contractors is critical

What's Next in OCS Facilities?

- More subsea wells tied back to existing fixed & floating facilities
- Smaller TLPs and spars for medium-sized reservoirs
- FPSO's for reservoirs far from infrastructure
- Improved hydrate inhibition
- Two-phase flow pipelines

Subsea Systems in the New Millennium

- Lower cost flowlines
  - Pigging & protection system
  - Electrically heated
  - Cold flow technology
- Subsea processing
  - Separation
  - Pumping
  - Metering
- Lower cost, high rate well completions
  - Intelligent completions
  - Multi-laterals
  - Rigless intervention systems
  - Tools & processes to reduce time
- Ultra-deepwater, remote systems
  - All-electric subsea systems
  - Control buoys
  - Hardware for increased water depth
  - Hydrate inhibitor distribution with storage
  - High power distribution systems

What’s Next in Drilling?

What’s Required Next (5-10 Years)

- Ability to drill & produce profitably in ultra-deepwater (>5,000 ft.)
- Unlock the technology to exploit the deepwater subsalt potential
- Technology advances to improve operational & cost performance of core business
- Improved reservoir surveillance (4D, etc.)
- Subsea capability & reliability

What’s Next in Drilling?

Well Technology Focus Areas

- Subsea pumping system
- Expandable solid tube technology
- Wellbore stability & lost circulation
  - Stuck pipe avoidance
  - Hold Cleaning
  - Borehole stress prediction
  - Improved drilling fluids
- Drilling optimization
  - Borehole positioning
  - Casing while drilling
  - Extended reach drilling systems
- Marine systems & mooring technology
  - Eddy & loop current tracking & prediction
  - Polyester mooring systems

Loop Current Effect Issues

- Magnitude (speed) of current & depth of current profile
- Operational impact
  - Total time at site (30-60 days)
  - Affects drilling & normal operations
- Can cause vortex induced vibrations (VIV) on well risers, export risers & mooring components

Key Learnings

- **High rate wells are essential & a reality.**
- **Continued cycle time reduction is critical.**
- **Total life cycle costs must continue to be achieved.**
- **Opportunity to discover 20 +/- BBE is achievable.**
- **Industry can drill & will be able to produce in water depths of 10,000 feet or more.**
- **New technology development continues to be key driver to success.**
- **Subsea wells will increase in importance. Success factors are operability & reduced cost.**
- **Deepwater is not an extension of the shelf. Must have a different paradigm.**

Forces Changing the Future

- Intensified competition
- New technology
- Globalization
- Societal expectations

MMS GULF OF MEXICO ENVIRONMENTAL STUDIES PROGRAM

Dr. James Coleman
Louisiana State University

Birth of Offshore Industry

- 1934, Texas Co. drilled one mile from shore in offshore Louisiana
- 1947, a bottom-supported platform in 18 feet of water and twelve mile offshore. Cost: $230,000

Offshore Industry in 1999

- Routinely drilling in water depths exceeding several thousands of feet deep
- Cost: hundreds of millions per site

MMS Mission

- Regulatory and to lease offshore resources

- In addition, to explore and extract those resources in a sound environmental manner, hence the Environmental Studies Program
  - » Prior to program, little known about regional geology, physiO, and biological
  - » Since program initiated, many millions of pages have been published

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MMS Environmental Studies Reports 1995 – 1999

• Biological	73
• Geological	12
• Meteorological	12
• Physical Oceanography	37
• Socioeconomics	19
• Wetlands	29
• Other	31
• TOTAL	213

PhysiO Program Studies

- First major study, 1982 – 1987
- Investigated
  - » optical properties
  - » hydrographic
  - » lagrangian drifters
  - » current velocity and temperature
  - » GEOSAT altimetry
- Most important: revealed nature and variability of loop current and eddy formation

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Use of Satellite Imagery
(PhisiO Program Studies)

- Revealed the complexity of the currents in the GOM that have significant effect on offshore structures

- Eddys were imaged for the first time during this study

Use of Lagrangian Drifters

(PhisiO Program Studies)

- During five-year period, lagrangian drifters, such as those in figure, used to document complexity of these eddys
- Note persistence of eddys over a period of nearly four months in following figure

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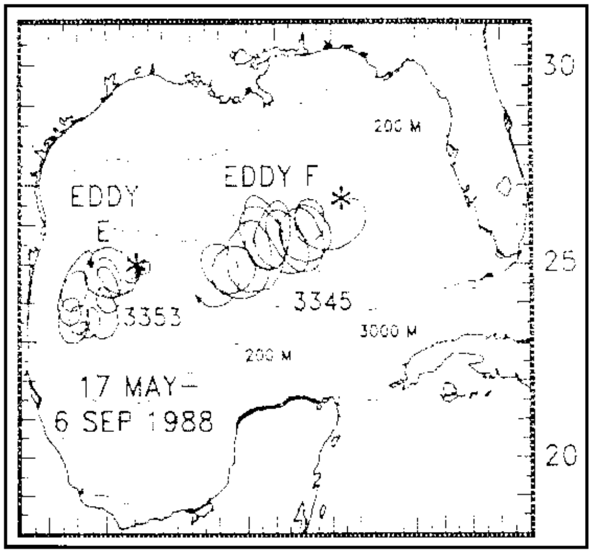
Use of Lagrangian Drifters

(PhisiO Program Studies)



17 MAY–
6 SEP 1988

Analysis of Eddys

(PhisiO Program Studies)

- Enough data obtained during this five-year period to allow statistical analysis of these data
- Following figure shows percentage of distribution of eddys. Note that they coincide with existing deepwater drilling trend

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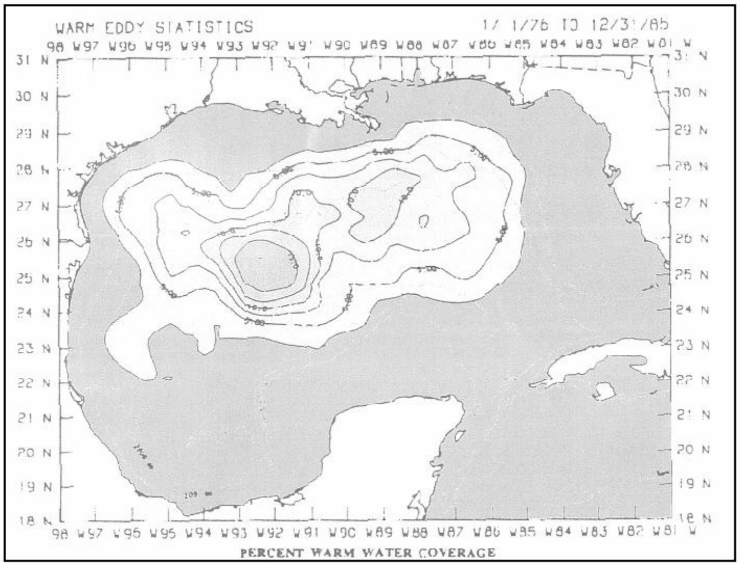
Eddy Map

(PhisiO Program Studies)



LATEX A Study

La-Tex Shelf Circulation & Transport Process

- Field work completed from 1992 – 1994
- Resulted in better understanding of characteristics of shelf and upper continental slope
- Investigated
  - » surface meteorological fields
  - » time series of river discharge
  - » bottom stresses
  - » eddy/shelf interactions
  - » salinity and temp distribution
  - » suspended particles
  - » nutrient distribution
  - » dissolved oxygen and hypoxia

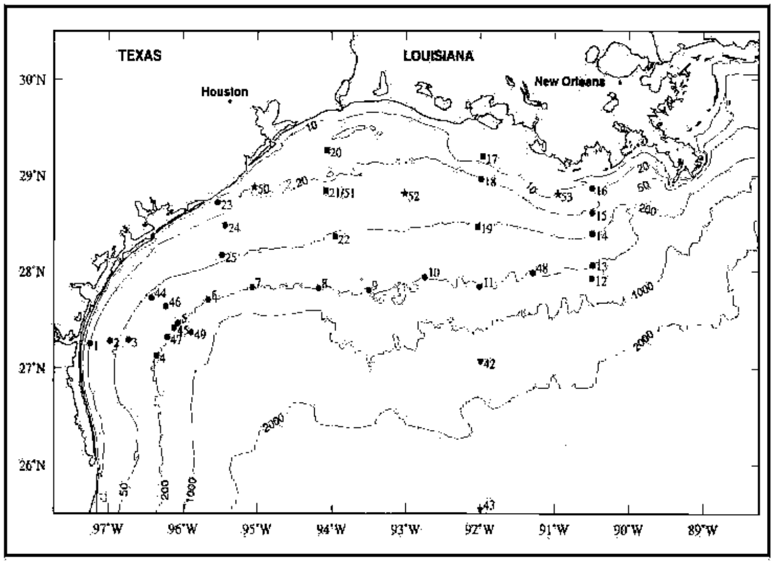
Results

(LATEX A Study)

- First time a major group of instrumentation was installed across shelf and upper slope
- Study resulted in generating extremely large amount of data that will provide background settings for years to come and used as validation of numerical models
- Validated that the Cochrane & Kelly model was valid over inner shelf, but not seaward because of complexity and variability of eddys.
- Demonstrated the seasonal variability of water masses that had been unknown in past

Results Map

(LATEX A Study)



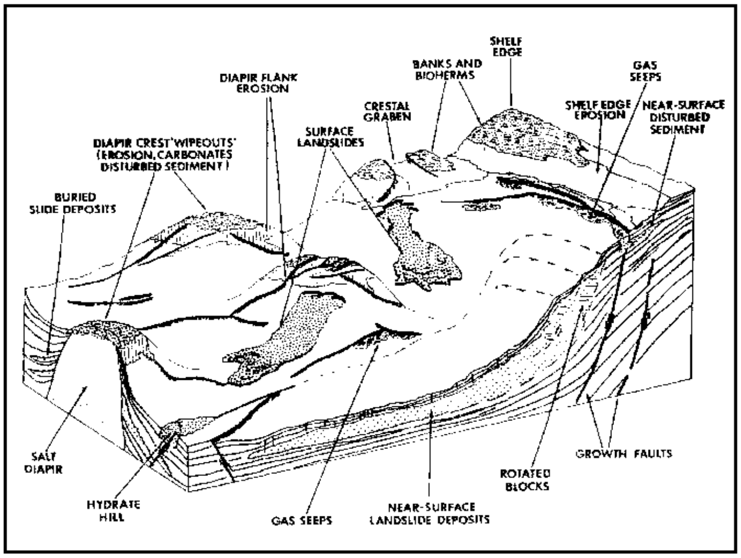
LATEX B – Observational Study of Miss/ Atchafalaya Coastal Plume, 1994 – 1998

- Complex interdisciplinary study to obtain data on
  - » mechanics of coastal plume
  - » sediment flux
  - » light, nutrients, and phytoplankton pigments
  - » phytoplankton and zooplankton characteristics
  - » pollutant chemistry
  - » hypoxia
  - » organic and inorganic sediments
- First synoptic picture of coastal currents in northern gulf
- Data served as a validation for testing numerical models
- Showed the importance of longshore pressure gradients in driving coastal currents

Geological Studies

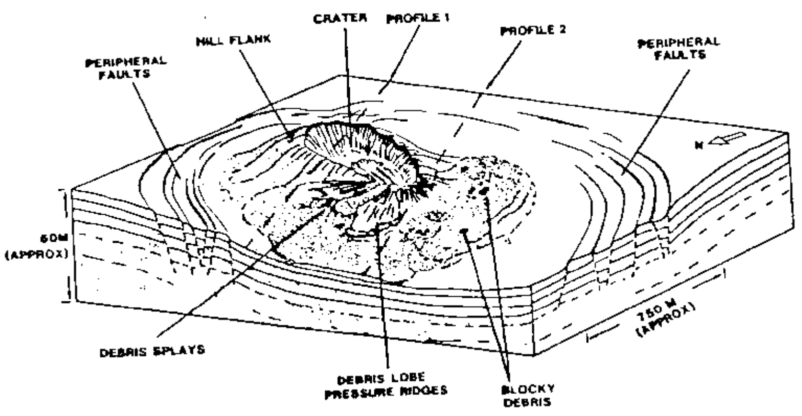
- Numerous completed during the past ten years
- Discovered massive mudflows off the Mississippi River delta
- Mapping of high resolution seismic data revealed the complexity of potential geohazards on the slope (following figure)

Potential Geohazards on the Slope
(Geographical Studies)



Mud Mounds & Craters from Major Seeps

(Geographical Studies)



Socioeconomic Studies

- Increased scope, breadth, and number of studies – effective coordination with environmental analysis
- Social Science Workshop, Park City, Utah
- System for collecting and categorizing data into Technical Info Management System (TIMS)
- Maximized utility of CMI program

GIS Efforts

- Gulf Wide Information System (GWIS)
- Coastal & Offshore Resource Info System **(CORIS)**
    - » Corporate environmental database
- Incorporate both MMS & industry environmental data
- Digitize industry hard bottom survey maps
- Pilot projects: archaeological, hard bottom & chemosynthetic data

GIS Efforts (continued)

- Development of automated GIS: 1,000 exploration, development, pipeline & platform removal data
- Conversion of GIS to an Internet-enabled interactive mapping application
- Partnership: federal, state, industry environmental database

GOM Deepwater Drilling & Production

- If the vision of Hardiman (Policy Committee) is correct, MMS will have to deal with the complexities of deepwater oceanographic and biologic processes
- MMS Strategic plan will reveal what is planned for the next few years

Planned MMS Environmental Studies

- FY 2000
  - » Sperm Whales
  - » Effects O&G Exploration – Cont. Slope Sites
  - » Effects Communities – OCS Platform Extraction
  - » Fisheries Workshop
  - » Workshop – Physical Processes Slope/Rise
  - » Migratory Fish Species

Planned MMS Environmental Studies (continued)

- FY 2001
  - » Oil Spill Trajectory & Assessment Model
  - » NE Gulf Physical/Biological Processes
  - » Physical Ocean – Slope/Rise (POSAR)
  - » OCS Use of Navigation Channels
  - » Deepwater Protected Species
  - » Case Studies – Coastal Communities
  - » Ozone Modeling Analysis
  - » Hydrate Outcrops/Chemosynthetic Communities

Planned MMS Environmental Studies (continued)

- FY 2002 – Topical Areas
  - » Deepwater
  - » Platform Removal
  - » Air Quality
  - » Seismic Activities in GOM
  - » Invasive Species
  - » Fate & Effects
  - » Gas Hydrates
  - » Environmental Justice

Deepwater Problems: Gas Hydrates

- Gas hydrates are ice-like crystalline structures of water that form “cages” that trap low molecular weight gas molecules, especially methane.
- Although they may be a large gas resource in the future, MMS must address their role as safety hazards in the GOM
  - » Hydrates can form on drilling equipment and in pipelines. Plugs of hydrate could stop fluid flow and create pressure that could rupture a pipeline.

Deepwater Problems: Gas Hydrates (continued)

- In GOM, hydrates form near the surface in water depths from approximately 500 m to the bottom of the Gulf
- These hydrates crop out on the surface in numerous areas within the GOM
- Often, hydrates are associated with various chemosynthetic communities, such as where tube worms are attached to an outcropping hydrate deposit

Deepwater Problems: Gas Hydrates (continued)

- As the Hydrate Stability Zone intersects the seafloor at about 500 m, subsea pipelines, platforms, and subsea completions are in the zone of hydrate formation
- Both natural and anthropogenic changes can cause hydrate dissociation and could trigger seafloor slumps and subaqueous landslides

Deepwater Problems: Gas Hydrates (continued)

- It is speculated that drilling itself may cause dissociation since warm drilling fluids and/or production of hot hydrocarbons may cause the hydrates in sediments to destabilize. Roberts and MacDonald has observed the instability of hydrates in deep dives.

Deepwater Problems: Gas Hydrates (continued)

- Although the presence of hydrates has long been known, their distribution, thickness and extent in the GOM is presently unknown. Most that have been discovered have been based on the presence of bottom simulating reflectors (BSRs) seen on geophysical records.

Deepwater Problems: Gas Hydrates (continued)

- Future research is aimed at direct observations of hydrates by deep submersible dives over speculated anomalies based on 3-D seismic records.

Deepwater Problems: Bottom Currents

- Based on high resolution seismic data, geologists have long speculated on the presence of such currents in deepwater
- A hires seismic line from 500 m of water shows that considerable sediment has been eroded.
- A seismic line from 900 m of water and in a region of relatively smooth bottom also shows major erosional events.
- Few cores have been taken in such areas to determine if the erosion is currently taking place or is geological in nature.

Deepwater Problems: Bottom Currents (continued)

- Recent data acquired by Bill Bryant and colleagues have shown the presence of well-developed linear grooves on the seafloor on the continental slope.
- Grooves are fairly continuous along slope and seem to parallel the contours.
- The authors speculate that such grooving is the result of strong bottom currents that scour into the sediments such as have been observed in flume experiments.

Deepwater Problems: Bottom Currents (continued)

- A recent result from current meters moored on the continental slope has suggested that currents slightly in excess of 1 knot have been observed.
- Other than this one observation, however, it is not known whether the erosion was an event in the past or is presently taking place. Continued research and acquisition of hires data, observations from deep submersible dives, and current meter data acquired during POSAR should resolve this dilemma.

2020 and Beyond

- Rapid technological advances
- Mapping at far improved scales
- Data acquisition: free-swimming autonomous vehicles equipped with surface and subsurface imaging, chemical scanners and sensors for water column characteristics
- “No More Paper” – advanced electronic database systems

2020 and Beyond (continued)

- Remotely sensed data coupled with direct sampling ROVs, manned submersibles, and advanced autonomous vehicles
- Advanced numerical models/simulations for real predictive capabilities
- “No More Paper” – advanced electronic database systems

BIOLOGICAL RESOURCES IN THE GULF OF MEXICO

Dr. Thomas McIlwain
National Marine Fisheries Service

Biological Resources
Gulf of Mexico
2000 +

Fisheries

Marine Mammals

World Landings - 1997

- 122.1 million metric tons
  - China - 28.7%
  - Peru - 6.4%
  - Japan - 5.5%
  - Chile - 5.0%
  - U.S. - 4.5%

U.S. Landings - 1998

- » Commercial
- » 4.2 million metric tons
- » Recreational
- » 203,527 million metric tons
- » 60.3 million trips

Gulf of Mexico Landings - 1998

- Commercial Landings
  - CA. 1.6 billion pounds
    - » Shrimp - most valuable
    - » Menhaden - largest volume
    - » 35.5 % of catch from Lower 48

Gulf of Mexico Landings - 1998

- Recreational
  - 12.5 million fish
  - 15.9 million tips

Sustainable Fisheries Act - 1996

- Reauthorized the Magnus on-Stevens Fishery Conservation and Management Act
- Management Objective - To rebuild stocks to maximum production

Managed Species

- Shrimp FMP - White, Brown, Pink, Royal Red, Rock, & Seabobs
- Coral FMP - Fire, Hydro corals, Octocorals, Stoney, & Black Corals
- Coastal Pelagics - King & Spanish Mackerels (Gulf & Atlantic Groups), Cobia, Cero, Dolphin, Little Tunny

Managed Species (con't)

- Reef Fish FMP - Red Vermillion Snapper, Nassau & Gag Grouper, Jewfish, Greater Amberjack, + 43 other species
- Red Drum FMP - Red Drum
- Spiny Lobster FMP - Spiny & Slipper Lobsters
- Stone Crab FMP - Stone Crab
- HMS FMP - Tunas, Swordfish & Sharks

Problems in Gulf Fisheries

- Excess Capacity
- Growing Fishing Effort
- By Catch
- Gear Impacts on EFH
- Habitat Destruction/Alteration
- Dead Zone

Management Tools for Fishery Problems

- ITQs/IFQs
- Limited Access - Seasonal/Area Closures
- License Limitations
- Size Limits

Management Tools for Fishery Problems (con’t)

- Bag Limits
- Trip Limits
- Marine Fishery Reserves
- Stock Enhancement

Fishery/Offshore Development Problems

- Physical presence of oil & gas structures & operations will likely conflict with or enhance fishing activity

- Physical presence of large structures in deepwater will likely act as fads & could impact HMS species (management, feeding & spawning behavior)

Fishery/Offshore Development Problems (con’t)

- Development in deepwater will present old and new environmental hazards
- Development in deepwater will present unique site abandonment difficulties & raise questions concerning artificial reef planning as well as impact traditional fisheries in the area

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Marine Mammals

- The Gulf of Mexico supports 26 species of marine mammals
- 10-year database
- Most occur offshore/deepwaters
- Stocks appear stable

Potentially Impacted Groups

- Deepwater shrimp species
- Deepwater crab species
- Deepwater fish species
- Marine mammals
- Highly migratory fish species
- Unknown species

Conclusions

- Most of the current harvest is from near-shore waters
- Need additional research on which to base decisions/determine impacts
- Fisheries and the oil & gas industry have coexisted in the Gulf for over 50 years

SESSION 2D

FLOATING PRODUCTION STORAGE AND OFFLOADING SYSTEMS IN THE GULF OF MEXICO

Chair: Mr. James Regg, Minerals Management Service
Co-Chair: LCDR William H. Daughdrill, U.S. Coast Guard

Date: December 1, 1999

Presentation	Author/Affiliation
Environmental Impact Statement for the Proposed Use of Floating Production, Storage, and Offloading Systems on the Outer Continental Shelf, Gulf of Mexico	Mr. Gerard A. Gallagher III Ecology and Environment, Inc. Tallahassee, Florida
Merging Marine and Operations Cultures for FPSOs – Document not submitted –	Mr. Charles Steube Conoco
Classification Society Experience with FPSOs	Mr. Robert D. Bowie American Bureau of Shipping
Comparative Risk Study and Other FPSO Work at OTRC – Document not submitted –	Dr. E.G. Ward Texas A&M University Offshore Technology Research Center
The Role of Risk Assessment in FPSO Design and Operation	Mr. Ben Poblete Lloyd’s Register of Shipping

ENVIRONMENTAL IMPACT STATEMENT FOR THE PROPOSED USE OF FLOATING PRODUCTION, STORAGE, AND OFFLOADING SYSTEMS ON THE OUTER CONTINENTAL SHELF, GULF OF MEXICO

Mr. Gerard A. Gallagher III
Ecology and Environment, Inc.
Tallahassee, Florida

BACKGROUND

Recent years have seen a surge in deepwater leasing in the Central and Western planning areas of the Outer Continental Shelf (OCS), Gulf of Mexico (GOM), and operators have spent billions of dollars in obtaining these leases. Many of these leases are located far from existing infrastructure, and operators face difficult challenges developing them. Floating production systems that have been used in the deepwater GOM in the 1990s, such as large tension leg platforms (TLPs), spars, and semi-submersibles, may not be the best options in many of the more remote leases. Many operators have expressed their desire to add floating production, storage, and offloading (FPSO) systems to the suite of development options available for projects in the deepwater GOM. Some potential advantages of FPSOs over other development options include shorter cycle time (time from discovery to first production), lower construction costs, reusability, and the flexibility to transport the crude oil directly to the refining center of choice.

In 1996, operators and FPSO builders began seriously discussing with the U.S. Department of the Interior, Mineral Management Service (MMS) the possibility of using FPSOs in the GOM. Recognizing the increased interest in FPSOs and shuttle tankers, the MMS and DeepStar, an industry consortium for addressing deepwater GOM issues, co-sponsored an FPSO workshop in April 1997 to identify technical, safety, and environmental issues, as well as information needs related to FPSOs. Since then, MMS and DeepStar have worked together in addressing the potential role of FPSOs in GOM development and the various technical, safety, and environmental issues related to the use of FPSOs and shuttle tankers in the GOM. In June 1998, MMS expressed its willingness to prepare an Environmental Impact Statement (EIS), under the implementing regulations of the National Environmental Policy Act (NEPA), that would address the issues associated with the proposed use of FPSOs in the Western and Central Planning Areas on the OCS GOM. In July 1998, DeepStar agreed to provide the funding required for MMS procurement of a contract to complete the EIS process. In addition, DeepStar has been working with MMS to define a representative base case scenario (as well as the potential range of variations in system components, configuration, and operation) for the use of an FPSO on the OCS GOM.

In May 1999, MMS commenced the EIS address industry’s proposed use of FPSOs in the development of deepwater fields on the OCS, in the Western and Central planning areas of the GOM.

WHY ARE FPSOs BEING ADDRESSED BY MMS UNDER NEPA?

NEPA requires that a federal agency prepare an EIS when a major federal action may result in a significant impact to the environment. As FPSO operations and shuttle tankering of GOM-produced crude oil would be new to the United States GOM, and as large volumes of oil would be stored in an FPSO's hull, the MMS has decided that the preparation of an EIS is warranted to assess the potential for significant adverse impacts resulting from these proposed activities. The MMS intends that the EIS process for addressing FPSOs will provide for public involvement in the consideration of benefits and potential environmental impacts associated with the proposed action, and that the resulting EIS will support an informed decision by the federal government regarding the use of such systems in the GOM.

HOW ARE FPSOs BEING ADDRESSED BY MMS UNDER NEPA?

The lead federal agency for preparation of the EIS is the MMS. Given the degree to which MMS and United States Coast Guard (USCG) jurisdictions overlap in waters of the United States, and because of the nature of the proposed activities and associated potential environmental impacts, the USCG is serving as a consulting agency to MMS for the preparation of the EIS. In May 1999, MMS contracted with Ecology and Environment, Inc. (E & E) to provide services for preparation of the EIS. Working with E & E, the principal team members for completing various EIS tasks include Continental Shelf Associates, Inc.; Det Norske Veritas, Inc.; and Aker Engineering, Inc., as well as several subcontractors providing specialty expertise.

The proposed use of FPSOs is addressed in concept by the MMS in the forum of a *programmatic* EIS. The EIS is programmatic in that it addresses the fundamental concepts and issues associated with the proposed use of FPSOs on the OCS, and within the Western and Central planning areas of the OCS GOM. The MMS considers its approach of addressing FPSOs in concept as the first step in understanding the benefits and risks that may be associated with FPSO systems. This approach also allows an opportunity for public involvement in the process before the consideration of individual applications for the approval of site-specific FPSO systems.

To consider the proposed use of FPSOs in a programmatic sense, the EIS defines a generic FPSO system and operation that represents a reasonable configuration and scale of an FPSO anticipated to be deployed on the OCS during the next approximately 10 years (i.e. the base case scenario). The preparers of the EIS have attempted to identify and consider a range of FPSO component variations that could conceivably be proposed by industry as part of various site-specific design scenarios.

The programmatic EIS process will result in selection by the federal government of one of the three basic alternatives: 1) conceptual approval of FPSOs, 2) conceptual approval of FPSOs under certain pre-conditions, or 3) a decision for no action (i.e., no conceptual approval by the federal government). In accordance with the requirements of NEPA, the government's decision will be detailed in a Record of Decision (ROD), and published in the *Federal Register*. Regardless of the decision outcome, it is intended that this programmatic EIS, including the resulting ROD, serve as a planning document and reference tool for "tiering" any subsequent NEPA actions regarding site-specific proposals for use of FPSOs in the U.S. GOM. In line with the President's Council on

Environmental Quality (CEQ) regulations for implementing NEPA, “tiering” would allow MMS to proceed from a broad and regional statement (in this case a programmatic EIS), to a lesser or more focused (e.g. site-specific) statement that would subsequently be prepared. In this case, tiering allows for a step-wise decision-making process.

No approvals of site-specific proposals to use FPSO systems in the U.S. GOM can be granted as a result of the ROD regarding this programmatic EIS. Rather, the government would consider site-specific proposals for use of an FPSO system, and the appropriate NEPA documentation prepared, by tiering from this programmatic EIS.

ACTIVITIES FOR PREPARATION OF THE EIS

The EIS addressing the proposed conceptual use of FPSOs on the OCS GOM is progressing in four phases:

- Phase I: Public Scoping
- Phase II: Scenario Development
- Phase III: Draft EIS Preparation and Public Hearings
- Phase IV: Final EIS Preparation

The schedule for completion of the four phases is approximately 18 months. The project was commenced in mid-May 1999. The Final EIS is scheduled to be delivered to the public in November 2000. The following summarizes the component activities conducted for each of the four phases of this EIS process:

Scoping

The MMS Notice of Intent (NOI) to prepare the EIS was published in the *Federal Register* on 10 June 1999, formally initiating the NEPA process and public scoping. The NOI notified agencies and the public of the schedule and location for public scoping meetings and provided instructions for submitting expressed issues and concerns with respect to the proposed action. More than 830 letters were mailed to interested parties as an additional measure to notify the public of the proposed action, and to solicit involvement through attendance at public meetings and/or through submittal of written comments. Notices were also placed in local newspapers to solicit attendance at public meetings and submittal of written comments. Five scoping meetings were conducted 21 June through 28 June 1999, in Corpus Christi, Houston, and Beaumont, Texas; and Lake Charles and New Orleans, Louisiana, respectively. Several individuals attending the scoping meetings had questions about the proposed action and the Government’s decision-making process regarding FPSOs, while other individuals expressed issues and concerns. A total of six letters containing written issues and concerns were received from the public. All public comments, written and orally expressed, were cataloged and reviewed for consideration in preparation of the Draft EIS.

Scenario Development

The petroleum industry’s proposed action is the use of FPSOs as a viable measure for developing hydrocarbon resources on OCS GOM. Given the programmatic function of this EIS, the purpose of the scenario development process has been to describe a “most likely configuration” for an FPSO system that would operate in the deepwater areas of the Western and Central Planning Areas of the GOM. Hence, the base case scenario for consideration in the EIS is a generic FPSO system that incorporates the components, configuration, and types and levels of activities that are expected to be reasonably representative of industry’s intended applications of FPSO systems. For the most part, major components of the base case scenario FPSO fall within a range of potentially viable design choices and configurations. Therefore, a range of potential options for the main components of FPSO systems that would operate in the United States GOM have been identified and will also be included in the EIS.

After commencing the NEPA EIS process, the project team first built upon the prototypical FPSO configurations identified in MMS deepwater development reference documents and workshop papers, and then further defined a most likely configuration of an FPSO operation in the GOM. The objective was to obtain industry feedback and concurrence (through DeepStar) in determining the range of potentially applicable technical options for FPSO system components, configuration, and operations; it was also to identify within the range of possibilities, the most likely configuration of an FPSO system that would be used in the GOM ¾ otherwise known as the *base case scenario*. The base case scenario was then defined in sufficient detail that: 1) a quantitative risk assessment, including a hazard analysis and accident frequency analysis, could be conducted; 2) factors potentially resulting in environmental impacts could be identified; and 3) an environmental impact assessment could be completed. The potentially applicable ranges of options for FPSO system components and configuration were analyzed sufficiently that risks and impacts could be gauged relative to the base case scenario.

Draft EIS Preparation and Public Hearings

This phase of the EIS process has involved the following analysis and document development tasks:

- Description of the proposed action
- Descriptions and comparison of alternatives
- Description of the affected environment
- Assessment of environmental consequences

Description of the Proposed Action. Industry proposes the use of FPSOs as a viable option for deepwater development in the GOM. The EIS will provide information on the expressed purpose and need for the use of FPSOs; a description of the proposed action (the base case scenario and range of potential options for FPSO components, configuration, and operation); the basis for preparing an EIS to address the proposed action; and a summary of the issues and concerns expressed by the public during the scoping phase.

Descriptions and Comparison of Alternatives. The EIS is programmatic and will consider and compare the following three alternatives: A) Approval of FPSOs; B) Approval of FPSOs under certain pre-conditions; and C) No action. The "Alternatives "section of the EIS considers the approval of FPSOs in concept as the EIS addresses only a representative base case scenario and generic range of potential configurations, and addresses the environmental setting and potential environmental consequences only in a broad regional sense. The pre-conditions for approval that will be identified in Alternative B may include risk and/or impact avoidance or reducing measures, such as stipulations for design features and operations, and/or exclusion of FPSO operations in specific geographic areas within the Western and Central Planning Areas of the OCS GOM. Under the "No Action" alternative, the conceptual approval for use of FPSOs would not be an end result.

Description of the Affected Environment. The EIS describes the physical setting within which the proposed action would occur and which the proposed action could potentially affect. Given the programmatic format of the EIS, the locations and sensitivities of natural resources and systems and the human environment (e.g., socioeconomic systems and coastal infrastructure) are described on a regional scale.

Assessment of Environmental Consequences. This task involves identifying impact-producing factors associated with FPSO installation, operations (including shuttle tankering), and decommissioning, such as assessment of environmental impacts potentially associated with routine operations; a quantitative risk assessment of the potential for accident/upset that would result in a release of oil cargo; modeling of oil spill trajectory for several hypothetical spill launch point locations within the geographic area considered for FPSO operations; assessment of environmental impacts that could occur as a result of oil spill; the potential for any indirect or cumulative impacts that could result; and the identification of potentially applicable mitigation measures that would prevent or reduce potential risks and/or impacts.

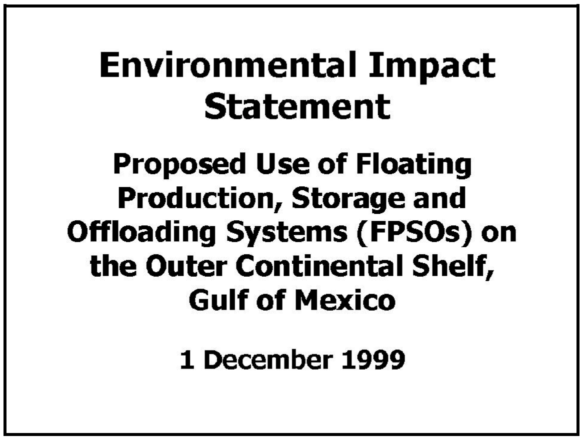
The risk assessment prepared in conjunction with the EIS addresses the base case scenario, including both the FPSO and associated shuttle tanker operations. Accident/oil spill frequencies are quantitatively derived by spill size category for the base case scenario, and are addressed semi-quantitatively for the potential range of system components and configurations, for comparison purposes. Where risk-reducing mitigation measures are identified, the effect of these measures on spill size/frequency is evaluated. The MMS Oil Spill Risk Assessment (OSRA) model and the MMS oil weathering model are also employed as part of the impact assessment process for this EIS. Eight hypothetical spill locations were selected throughout the FPSO study area. The domain for the trajectory model is the rim of the GOM, with coastline segments and environmental features identified on a regional scale. For the trajectory model, 3-, 10-, 20- and 30-day runs were completed for each of four seasons and for each of the launch point locations. Oil weathering model output data was generated for two crude oil types so that issues associated with oil degradation can be considered in the assessment of oil spill impacts.

Public Hearings and Comment. In accordance with the requirements of the NEPA process, the Draft EIS will be distributed to all interested parties for review and comment. During this public comment review period, MMS will conduct a series of public hearings in several Gulf Coast communities to provide a forum for discussion with the interested public and to solicit public comment on the Draft EIS.

Final EIS Preparation

Following the receipt of public and agency comments to the Draft EIS, all comments will be reviewed and addressed. Any additional information and/or revisions to the document will be completed, and public comments and MMS responses to comments will be incorporated into an appendix in the Final EIS. The Final EIS will then be published and distributed to appropriate agencies and other interested parties.

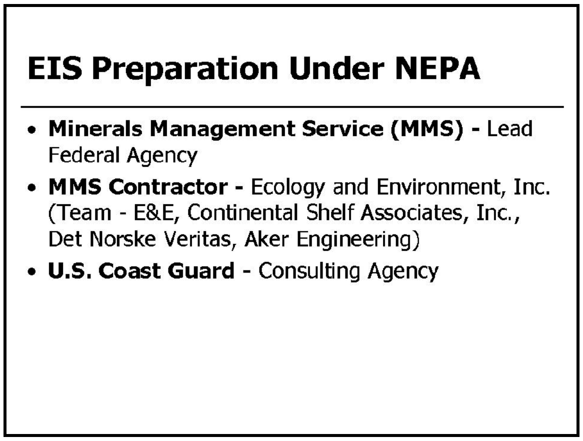
After distribution of the Final EIS, MMS will enter into a decision-making process regarding the three alternatives considered in the document. The decision will be based on consideration of the analyses in the EIS, as well as other appropriate data and information. A formal record of decision (ROD) that documents the agency's decision and the basis for that decision will be prepared. The ROD will be published in the *Federal Register*.



Environmental Impact Statement

Proposed Use of Floating Production, Storage and Offloading Systems (FPSOs) on the Outer Continental Shelf, Gulf of Mexico

1 December 1999



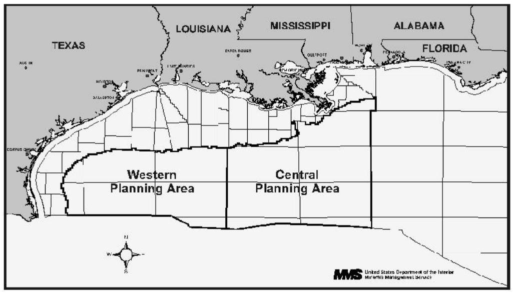
EIS Preparation Under NEPA

- **Minerals Management Service (MMS) -** Lead Federal Agency
- **MMS Contractor -** Ecology and Environment, Inc. (Team - E&E, Continental Shelf Associates, Inc., Det Norske Veritas, Aker Engineering)
- **U.S. Coast Guard -** Consulting Agency

FPSOs

- Would Facilitate Development in Deepwater Areas Beyond Existing/Planned Pipeline Infrastructure
- Similarities to Other Offshore Development
- Differences with Respect to Other Offshore Development
  - Storage
  - Offloading
  - Shuttle Tankering

Areas Under Consideration For FPSOs



What Is NEPA?

- National Environmental Policy Act of 1969
- Requires Federal Agencies to Address the Potential Affect of Major Federal Actions Upon the Human Environment
- Environmental Impact Statement (EIS)

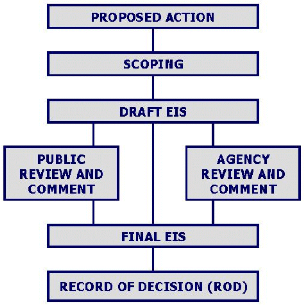
Why Is NEPA Being Applied To FPSOs?

- New Development Technology in the Gulf
- Major Decision by Government
- Assess Potential for Significant Environmental Impact
- Allow for Public Involvement and Informed Decisions by Government

How Is NEPA Being Applied To FPSOs?

- Programmatic EIS
- Proposed Action - Generic in Scope Addressing FPSOs in Concept
- “Tiered” Documentation/Decisions

EIS Process



PROPOSED ACTION

SCOPING

DRAFT EIS

PUBLIC REVIEW AND COMMENT

AGENCY REVIEW AND COMMENT

FINAL EIS

RECORD OF DECISION (ROD)

Phases of FPSO EIS Preparation

I.	Scoping	July 1999
II.	Scenario Development	Sept. 1999
III.	Draft EIS/Public Hearings	May 2000
IV.	Final EIS	Nov. 2000

I. Scoping

- Notice of Intent (NOI)
- Letters to Interested Parties
- Newspaper Advertisements
- Scoping Meetings
- Consideration of Issues and Concerns Expressed by Public

II. Scenario Development

- Range of Options
- Base Case FPSO
- FPSO Operations
  - Installation of FPSO
  - Routine Operations
  - Decommissioning of FPSO

III. Draft EIS Preparation

- Description of the Proposed Action
- Alternatives
- Affected Environment
- Environmental Consequences
  - Routine Operations
  - Accident/Upset (Oil Spill)
- Mitigation Measures

III. Draft EIS Preparation

Description of the Proposed Action

- Purpose and Need
- Proposed Action
- Basis for the EIS
- Public Involvement

III. Draft EIS Preparation

Alternatives

A. Conceptual Approval for FPSOs

B. Conceptual Approval for FPSOs with Pre-Conditions

C. No Action

III. Draft EIS Preparation

Affected Environment-CSA

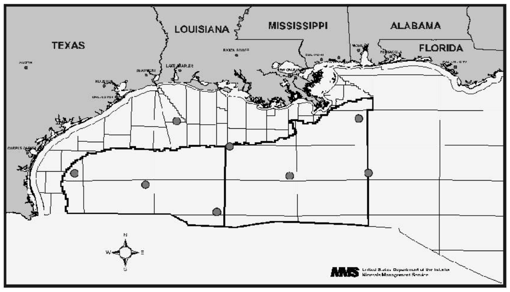
- Natural Resources within the area being considered for use of FPSOs
- Natural Resources within the area that could be affected
- The Built Environment
  - Socioeconomic Systems
  - Coastal Infrastructure

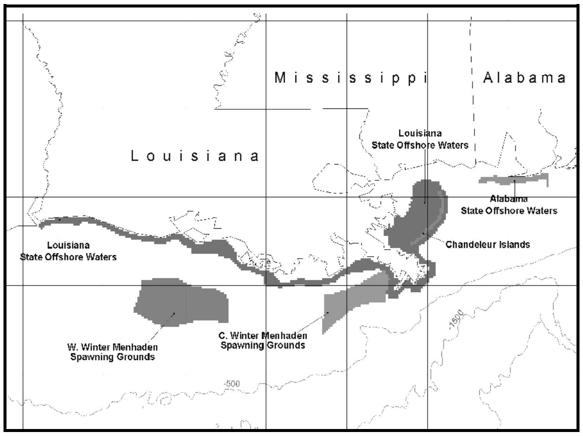
III. Draft EIS Preparation

Environmental Consequences-CSA

- Impact Producing Factors
- Impacts - Routine Operations
- Impacts - Oil Spill
  - Risk Assessment
  - OSRA Model

FPSO EIS - OSRA Model Launch Points

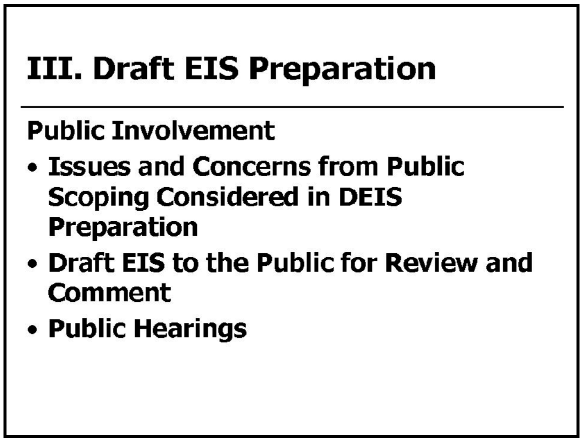




III. Draft EIS Preparation

Risk Assessment - DNV

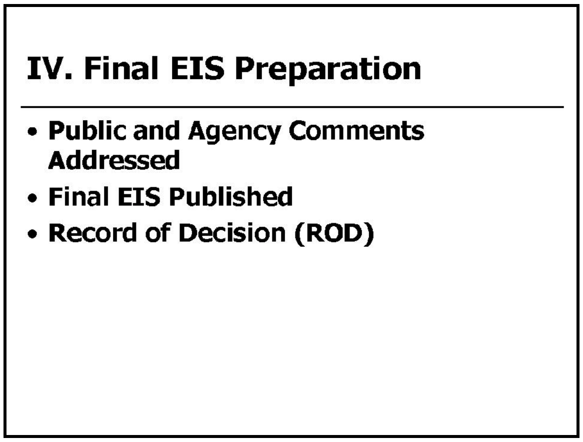
- Hazard Analysis
- Determine Accident/Oil Spill Frequencies for Base Case Scenario
- Evaluate Effects of Design Options
- Evaluate Effects of Mitigation Measures on Spill Size/Frequency



III. Draft EIS Preparation

Public Involvement

- Issues and Concerns from Public Scoping Considered in DEIS Preparation
- Draft EIS to the Public for Review and Comment
- Public Hearings



IV. Final EIS Preparation

- Public and Agency Comments Addressed
- Final EIS Published
- Record of Decision (ROD)

CLASSIFICATION SOCIETY EXPERIENCE WITH FPSOs

Mr. Robert D. Bowie
American Bureau of Shipping

INTRODUCTION

The American Bureau of Shipping (ABS) is one of a number of ship classification societies with worldwide representation whose sole purpose is to promote the safety of life and property at sea. This purpose is achieved through the service of classification. In the same manner as other classification societies, ABS establishes rules for the design, construction, and periodic survey of ships and offshore structures through an international network of committees. These committees are composed of individuals eminent in many marine and offshore disciplines; therefore, the rules they create are considered authoritative and impartial. The classification process attests that a vessel or an offshore structure adheres to the Rules and is structurally and mechanically fit for its intended service.

Drawing on vast experience with ship classification, almost 50 years involvement with the offshore industry, and an in-depth involvement with international statutory regulations, ABS is in a unique position to give added value to the classification and certification of FPSOs designed to operate in the Gulf of Mexico. This paper gives an overview of the relationship between the International Maritime Organization (IMO) and the International Association of Classification Societies (IACS), outlines class, flag and coastal state requirements for FPSO operation in the Gulf of Mexico, and outlines experience gained with worldwide operation of FPSOs.

ROLE OF THE CLASS SOCIETY IN THE OFFSHORE INDUSTRY

ABS has been associated with the offshore industry since the early 1950s and published the first standards on offshore units (1968 MODU Rules). This publication preceded API standards on installations by a year. In recent years, floating production has become commonplace in the industry. ABS and other class societies, therefore, were in a unique position to use their ship and MODU experience to develop rules for Floating Production Systems (FPS).

There are 107,053 floating vessels operating world-wide. The majority of these are either classed or certified to some Government or national standard by a recognized classification society such as ABS. There are also 21 floating production and five storage systems on order and many more in the design stage. These new construction or major conversion projects are taking place in shipyards and fabrication shops throughout the world. Due to their world-wide coverage (offices in almost every port in the world) classification societies are in a unique position to give added value to the safe design and construction of an FPSO.

RELATIONSHIP BETWEEN IMO AND IACS

International Maritime Organization – IMO

IMCO (Inter-Governmental Maritime Consultative Organization), the forerunner to IMO, was formed at the United Nations Convention in 1948; it did not come into force, however, until 1958. Since then, multitudes of regulations relevant to ship safety have been published, such as the 1966 Loadline Convention and Amendments to SOLAS, MARPOL, MODU Code (1979 & 1980). Many of these regulations do not have direct application to FPSO/FSU type vessels, but some (such as the 1996 Loadline Convention, SOLAS and MARPOL) should be consulted during the development of a design.

International Association of Classification Societies – IACS

IACS was formed in 1968 in an effort to unify some of the rules of the various classification societies. Collectively, the IACS members invest more in research and development (R&D) into ship structural and engineering design and other safety aspects than any other single marine-related organization.

IACS working parties and correspondence groups meet regularly to discuss rule and statutory requirements so that the class rules keep up to date with latest technology and to ensure minimal diversity of requirements between the member societies. As an extension of these groups, many of the class society engineers and surveyors represent various governments at IMO. IACS therefore, provides IMO with invaluable technical advice and input to assist in the development, creation and amendment of international conventions. IACS also provides a vital interface with IMO to ensure that the unique relationship between class and the world’s flag administrations’ statutory regulatory regime is in harmony.

CLASSIFICATION REQUIREMENTS

General

ABS classification requirements are essentially the same for either new construction or a conversion. In general the ABS approach to FPS classification is based on:

- treating the entire FPS as a site-specific system;
- combining the requirements of ABS’s various rules and guides, as relevant, to the type of floating system involved in each project;
- identifying and defining requirements for interfacing “marine system” practice with “production system” practice; and
- utilizing existing and new industry standards and recommended practices wherever possible.

The main classification designations offered for a Floating Production Unit are:

- FPSO: AI Floating Production, Storage and Offloading System
  The FPSO notation includes classification of the vessel (structure, stability, shipboard systems and equipment), the station keeping system, and the production facility.

- FPS: AI Floating Production, (and Offloading) System
  The FPS notation includes classification of the vessel (structure, stability, shipboard systems and equipment), the station keeping system, and the production facility.

- FSO: AI Floating Storage and Offloading System
  The FSO notation includes classification of the vessel (structure, stability, shipboard systems and equipment) and the station keeping system.

- FOI: AI Floating Offshore Installation
  The FOI notation may be optionally applied to either an FPSO and or FPS where it is desired to class the vessel and station keeping system but not the production facilities. Although the production facilities are not included in the FOI Classification, the electrical installation, hazardous areas and the fire protection systems associated with the production facilities are included as a minimum.

Rules and Regulations

An FPSO/FPU operating at one site for an extended period of time becomes, in essence, a fixed installation. Therefore rules and regulations other than ship structures need to be considered along with the review of the site specific soil and environmental conditions. See the attached overheads for a list of the appropriate rules.

Structures

For a tanker type FPSO, the steel vessel rules or safehull should be used to determine the hull scantlings, material quality, welding requirements etc. Care should be taken when designing the deck area in the way of the production facility, since the loading will generally be greater than that of a trading tanker. The areas in the way of a turret or connection to a single point mooring need to be specially considered.

ABS requires an FPSO to be evaluated for site-specific loadings and 100-year return period for environmental conditions. This process involves both structural stress and fatigue evaluations.

Stability

Intact and Damage stability of an FPSO is to be in compliance with classification society steel vessel rules and the relevant parts of the 1966 Loadline Convention, SOLAS and MARPOL. Flag and coastal state requirements should also be consulted to ensure complete compliance with all regulatory regimes

Station Keeping

Station keeping systems for an FPS can be spread mooring, dynamic positioning (DP), or single point mooring. DP is often used in conjunction with spread mooring or single point mooring.

Shipboard Systems

Shipboard systems should be designed much a tanker’s systems. The requirements are contained in the ship rules. Care should be taken with integration of the marine systems and the process facility.

Production Systems and Equipment

The ABS Facilities Guide contains requirements for the process and utility systems typically used on fixed offshore platforms. The requirements incorporate standards, specifications and code of practice commonly used by the offshore industry. When applied to an FPSO, these requirements must be harmonized with the vessels’ marine systems and existing classification requirements. The interfaces between the process facilities and the marine system are 1) classification of hazardous areas; 2) piping and electrical systems integration, use of produced gas as fuel; and 3) active fire protection systems.

Surveys

An integral part of the classification process is surveys during construction or conversion of the structure, shipboard and process systems, and ongoing surveys during the life of the vessel. Surveys required while in service are similar to those required for ships, which are:

- Annual Surveys and Annual Loadline Inspection;
- Intermediate Survey, Drydocking or Underwater Survey in Lieu of Drydocking (UWILD) each 2 – 3 years;
- Special Periodic Survey each 5 years; and
- Annual and Special Surveys of the Process System and Equipment to be carried out in conjunction with the relevant hull and shipboard machinery surveys.

STATUTORY CONSIDERATIONS FOR GULF OF MEXICO

The regulatory responsibility for Floating Production Systems in the Gulf of Mexico is shared between the U.S. Coast Guard (USCG) and the Minerals Management Service. (MMS). The division of responsibility is defined in a memorandum of understanding between the USCN and MMS. Essentially, the USCG has responsibility over the marine aspects and MMS has responsibility over the industrial aspects. The USCG and MMS share responsibility for the structure and safety systems.

U.S. COAST GUARD INTERFACE

An FPS installation in the Gulf of Mexico is defined by the USCG as a Floating OCS Facility in 33 CFR 140.10. A Certificate of Inspection (COI) from the USCG is required, and the installation is to comply with the requirements of 46 CFR subchapter IA (MODUs) as applicable, 46 CFR Subchapter F (Marine Engineering) and 46 CFR Subchapter J (Electrical Engineering).

ABS has a long-standing relationship with the USCG. On an ABS classed FPS installation operating in the Gulf of Mexico, most of the design appraisal and surveys required by USCG can be carried out by ABS. There are three Navigation and Inspection Circulars (NVICs) published by the USCG that define the responsibility afforded to ABS by the USCG of work carried out by ABS. These are:

> NVIC 10-82 Change 2, 10-92: Acceptance of Plan Review and Inspection Tasks Performed by the American Bureau of Shipping for New Construction and major Conversions
>
> NVIC 10-92 Change 1, 2-95: Coast Guard Recognition of Registered Professional Engineer Certification of Compliance with Coast Guard Requirements
>
> NVIC 3-97: Stability Related Review Performed by the American Bureau of Shipping for US Flag Vessels

MINERALS MANAGEMENT SERVICE INTERFACE

Working under contract to the United States Geological Survey (USGS), the predecessor to MMS, ABS authored the “Requirements for Verifying the Structural Integrity of OCS Platforms.” This publication subsequently became 30 CFR, Part 250, Subpart I. It contains the criteria by which MMS governs the verification of platform structures in the territorial water of the United States.

ABS work on behalf of the MMS under 250.132 & 133 as the Certified Verification Agent (CVA) for an FPSO project is covered to a great extent by the ABS class requirements. The only additional work necessary beyond the class requirements is preparing reports for the design, fabrication and installation of the vessel. These reports are submitted to MMS for review and approval.

The scope of the CVA work is the review of the design information and survey of the following:

- Site specific environmental criteria
- Hull and deck structure
- Mooring system
- Riser structure

Table 2D.1 details the involvement of the MMS, USCG and ABS as well as ABS’s involvement in USCG/MMS certification for Floating Production Systems.

Table 2D.1. Responsibilities for floating production systems.

Area of Review	MMS Review	USCG Review	ABS Class Review	Included in ABS Class Notations	ABS Involvement in USCG/MMS Certification
Production Equipment including Risers	Yes	No	Yes	FPS & FPSO (Risers Optional)	None
Design & Fabrication of Turret & Turret Hull Interface	Yes	Yes	Yes	FPSO, FPS, FSO & FOI	Review and Survey under NVIC 10-82 Change 2 for USCG and Structural CVA Review for MMS
Fire, Gas & H2S Detection	Yes	Yes	Yes	FPSO, FPS, FSO & FOI	Review under NVIC 10-92 Change 1 for USCG
Fire Extinguishing Systems	Yes	Yes	Yes	FPSO, FPS, FSO & FOI	Review under NVIC 10-92 Change 1 for USCG
Site Specific Considerations (including Geotechnics)	Yes	No	Yes	FPSO, FPS, FSO & FOI	CVA Review for MMS
TLP Tendons and Mooring Systems of Other Floating Production Systems	Yes	Yes	Yes	FPSO, FPS, FSO & FOI	Review and Survey under NVIC 10-82 Change 2 for USCG and Structural CVA Review for MMS
TLP Foundations	Yes	No	Yes	FPSO, FPS, FSO & FOI	CVA Review for MMS
Hull Structure for TLP, SPAR and Hybrid	Yes	Yes	Yes	FPSO, FPS, FSO & FOI	Review and Survey under NVIC 10-82 Change 2 for USCG and Structural CVA Review for MMS
Hull Structure - Shipshape and Semi-submersible	No	Yes	Yes	FPSO, FPS, FSO & FOI	Review under NVIC 10-82 Change 2 for USCG
Accommodations	No	Yes	Yes	FPSO, FPS, FSO & FOI	Review under NVIC 10-82 Change 2 for USCG
Structural Fire Protection	No	Yes	Yes	FPSO, FPS, FSO & FOI	Review under NVIC 10-82 Change 2 for USCG (Approval of Materials reserved by USCG)
Hazardous Areas	Yes	Yes	Yes	FPSO, FPS, FSO & FOI	Review under NVIC 10-82 Change 2 for USCG
General Arrangements	Yes	Yes	Yes	FPSO, FPS, FSO & FOI	Review under NVIC 10-92 Change 1 for USCG
Design Environmental Conditions	Yes	Yes	Yes	FPSO, FPS, FSO & FOI	Review and Survey under NVIC 10-82 Change 2 for USCG and Structural CVA Review for MMS
Station Keeping (DP) Systems	Yes	Yes	Yes	FPSO, FPS, FSO & FOI (Optional)	Review and Survey under NVIC 10-82 Change 2 for USCG and Structural CVA Review for MMS
Stability	No	Yes	Yes	FPSO, FPS, FSO & FOI	Review under NVIC 3-97 for USCG
Design Operating Conditions	Yes	Yes	Yes	FPSO, FPS, FSO & FOI	Review and Survey under NVIC 10-82 Change 2 for USCG and Structural CVA Review for MMS
Non-production Machinery/systems	No	Yes	Yes	FPSO, FPS, FSO & FOI	Review under NVIC 10-82 Change 2 for USCG
Lifesaving systems and Equipment	No	Yes	No	FPSO, FPS, FSO & FOI	Review under NVIC 10-92 Change 1 for USCG
Helicopter Facilities	No	Yes	Yes	FPSO, FPS, FSO & FOI	Review under NVIC 10-82 Change 2 for USCG

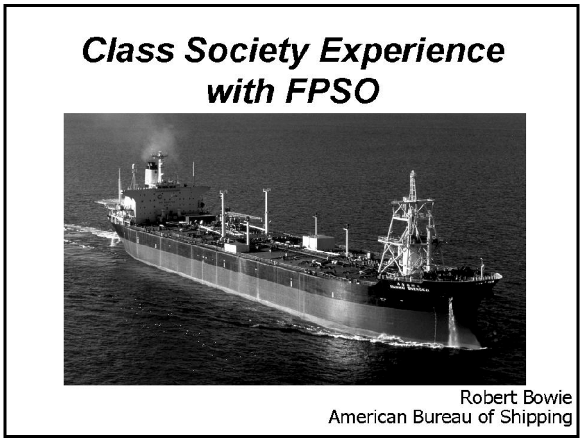
CONCLUSION

This presentation has shown the relationship between IMO and IACS, outlined ABS involvement, and shown the benefits of classification during the design, construction and service life for FPSO operation in the Gulf of Mexico.

The main benefits of classification are continual process through the life of the FPSO involving the following phases:

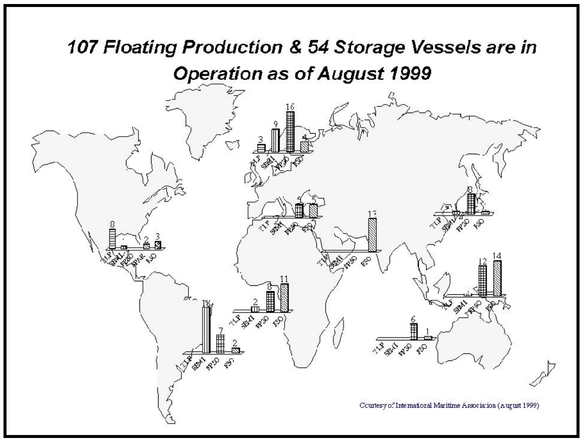
- Development of a design
- Construction in conformance with the design
- Ensure that the operation is consistent with design
- Maintenance of original structural and mechanical integrity by periodic surveys

IACS Members represent many governments at IMO; therefore, they can maintain continuity between the class rules, IMO resolutions and other regulatory requirements.



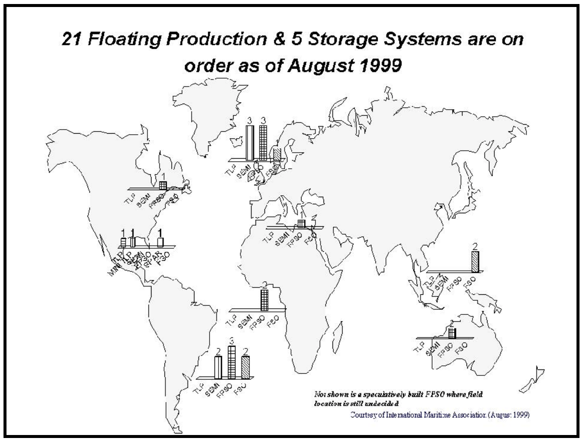
Class Society Experience with FPSO

Robert Bowie
American Bureau of Shipping



107 Floating Production & 54 Storage Vessels are in Operation as of August 1999

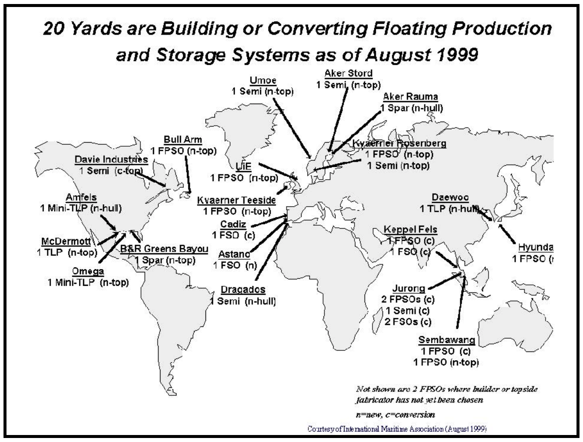
Courtesy of International Maritime Association (August 1999)



21 Floating Production & 5 Storage Systems are on order as of August 1999

Not shown is a speculatively built FPSO where field location is still undecided

Courtesy of International Maritime Association (August 1999)



20 Yards are Building or Converting Floating Production and Storage Systems as of August 1999

Not shown are 2 FPSOs where builder or topside fabricator has not yet been chosen

n=new, c=conversion

Courtesy of International Maritime Association (August 1999)

IMO

- 1948 - IMCO Established
- 1959 - First IMCO Assembly
- First Regulation
  - *1960 SOLAS Convention*
- Other Regulations
  - *1966 Loadline Convention*
  - *MARPOL*
  - *MODU Code 1979 & 1989*

IACS

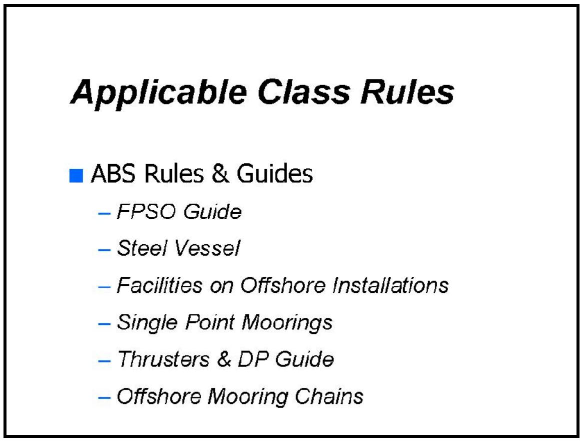
- 1968 - IACS Formed - 7 Members
- Today - 10 Members & 3 Associate Members
- Quality System Certification Scheme
- Unified Requirements for Ships & ODUs
- No Specific Unified Requirements for FPSO's

ABS Major Services

- Classification of Ships & Offshore Systems
  - *Development of Rules & Guides*
  - *Design Appraisal*
  - *Surveys During Construction*
  - *Periodic In-Service Surveys*
- Certification of Ships & Offshore Systems
  - *Flag State Requirements*
  - *Coastal State Requirements*

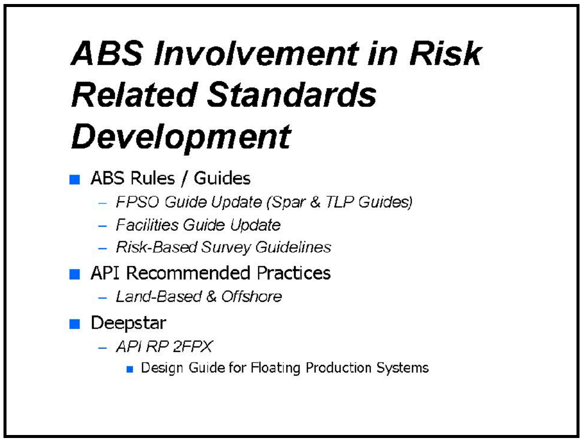
Classification Designations

- AI Floating Production System
- AI Floating Production Storage System
- AI Floating Storage System
- AI Floating Offshore Installation



Applicable Class Rules

- ABS Rules & Guides
  - *FPSO Guide*
  - *Steel Vessel*
  - *Facilities on Offshore Installations*
  - *Single Point Moorings*
  - *Thrusters & DP Guide*
  - *Offshore Mooring Chains*

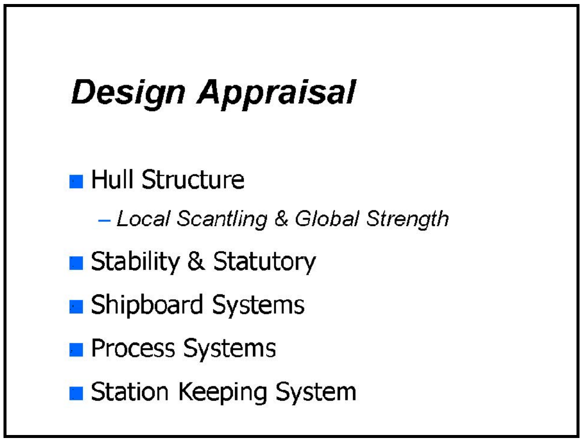


ABS Involvement in Risk Related Standards Development

- ABS Rules / Guides
  - *FPSO Guide Update (Spar & TLP Guides)*
  - *Facilities Guide Update*
  - *Risk-Based Survey Guidelines*
- API Recommended Practices
  - *Land-Based & Offshore*
- Deepstar
  - *API RP 2FPX*
    - Design Guide for Floating Production Systems

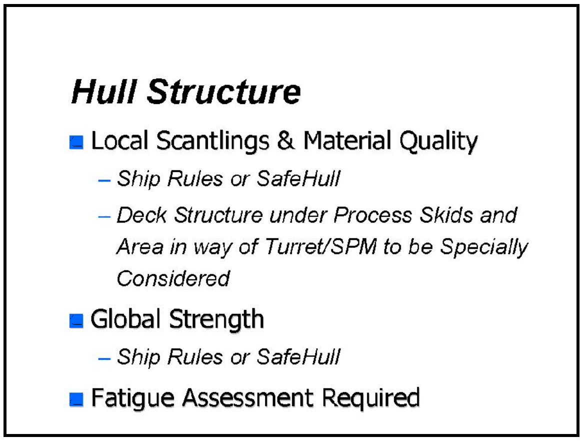
FPSO vs.Trading Tanker

- General
  - *Site-Specific Environment*
  - *Additional Deck Loads*
  - *Operational Characteristics*
  - *Mooring Loads*
- Conversions
  - *Historical Environment*
  - *Wastage*



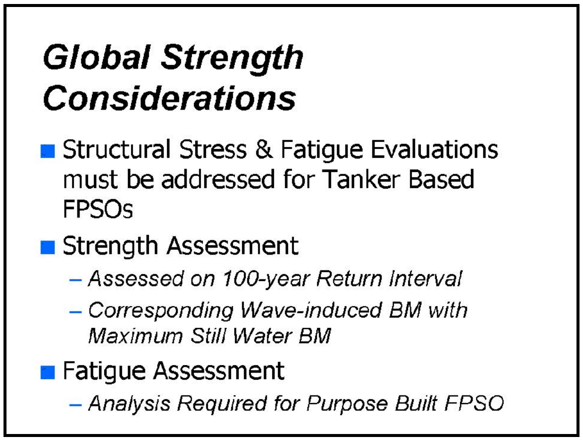
Design Appraisal

- Hull Structure
  - *Local Scantling & Global Strength*
- Stability & Statutory
- Shipboard Systems
- Process Systems
- Station Keeping System



Hull Structure

- Local Scantlings & Material Quality
  - *Ship Rules or SafeHull*
  - *Deck Structure under Process Skids and Area in way of Turret/SPM to be Specially Considered*
- Global Strength
  - *Ship Rules or SafeHull*
- Fatigue Assessment Required



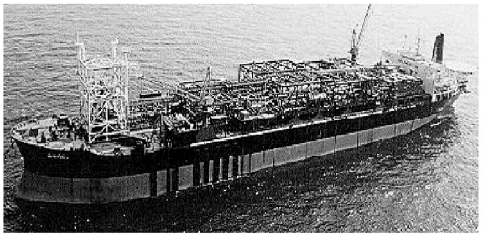
Global Strength Considerations

- Structural Stress & Fatigue Evaluations must be addressed for Tanker Based FPSOs
- Strength Assessment
  - *Assessed on 100-year Return Interval*
  - *Corresponding Wave-induced BM with Maximum Still Water BM*
- Fatigue Assessment
  - *Analysis Required for Purpose Built FPSO*

Application of SafeHull to FPSOs

- Formulations for Adjustment of SafeHull Criteria for Specific Sites are in Place
- Strength/Fatigue Concerns are Considered

Nan Hai Sheng Li



Stability &Statutory

- Steel Vessel Rules
- Applicable Parts of 1966 LL Convention, SOLAS & MARPOL
  - *13 F&G of MARPOL does not Apply*
- Operation Manual
- Flag State & Coastal State Requirements
- Disconnectable System:
  - *Same as Trading Tanker*

Process System

- FPSO Guide & Facilities Guide
- Design Appraisal of:
  - *P&ID's & SAFE Charts*
  - *Facility Layouts*
  - *Process Electrical Systems*
  - *Safety & ESD Systems*
  - *Vendor Equipment*

Stationkeeping

- Mooring System
  - *FPSO Guide*
  - *API RP 2SK*
- Dynamic Positioned
  - *Thrusters & DP Guide*

Surveys During Construction

- New Construction/Existing Vessel
- Mooring Installation
- Import/Export System Installation (optional)
- Start-up and Commissioning

Surveys After Construction

- Annual Hull & Machinery
- Intermediate Surveys
- Special (Continuous) Periodical Surveys
- Dry-docking Surveys
- Damage/Repair Surveys

Unique Survey Requirements

- UWILD is Acceptable for Dry Dock Special Survey of Hull
- Mooring System is Subject to Survey
- Corrosion Protection System Required
- Survey Reports Maintained Onboard

USCG / ABS MOUs

- NVIC 10-82 Change 2
- NVIC 10-92 Change 1
- NVIC 3-97
- ACP

Items Approved by USCG

- Life Saving Equipment
- Safety Equipment
- Structural Fire Protection Material
- Life Saving Arrangement
- Inspection Manual

MMS

- CVA for MMS
  - *Design*
  - *Fabrication*
  - *Installation*
- Most Items addressed during Classification Process
- ABS Interfaces with MMS
- ABS Submits CVA Reports

Benefits of Class

- Continual Process Throughout FPSO Life Involving the Following Phases:
  - *Development of a Design - SafeHull*
  - *Construction in Conformance with Design*
  - *Operation Consistent with Design*
  - *Maintenance of Original Structural & Mechanical Integrity by Periodic Surveys*
  - *Represent many Governments at IMO*

THE ROLE OF RISK ASSESSMENT IN FPSO DESIGN AND OPERATION

Mr. Ben Poblete
Lloyd's Register of Shipping

SUMMARY

This presentation provides a background on the role of risk assessment during the design and operations of an FPSO.

The presentation first focuses on the definition of the different elements of risk management and explains how this concept becomes an essential feature of a Safety Management System (SMS). The continuous improvement steps in a SMS are identified and the importance of risk assessment emphasized. A SMS is a continuous improvement management process that involves the systematic identification and documentation of hazards. The system is intended to be flexible in the incorporation of major or minor design improvements or changes in technology or procedures that will affect the safety of the organization.

The next part of the presentation describes the different types of regulatory regimes around the world, with special emphasis on the U.S. and U.K. regulatory formats. The comparison between prescriptive and goal setting regulations is highlighted here. The goal setting regime is more in line with the SMS because of its more holistic approach. This type of approach is dictated in such countries as Canada, U.K., Norway, and Australia.

Examples of how the effective use of the risk-based approach was successfully performed on an FPSO design are presented. During all the examples, the engineering designers and operators utilized the risk based approach to ensure that the most appropriate amount of protection is incorporated into the design. The resulting effective solutions, from all the examples presented, either exceeded or demonstrated an "equivalent level of safety" to the local regulations and/or the classification technical standards.

The final part of the presentation focuses on risk-based classification. This section describes the reasons for the development of the risk assessment option, the objectives of the new rules, and the different classification routes. It also explains how risk assessment fits in the classification process and the benefits of this option.

SESSION 2E

ENVIRONMENTAL SCIENCE STUDY REPORTS AND RESEARCH INITIATIVES

Chair:	Dr. Ken Deslarzes, Minerals Management Service
Co-Chair:	Mr. Dave Moran, Minerals Management Service
Date:	December 1, 1999

Presentation	Author/Affiliation
Flower Garden Banks Monitoring –Document not submitted–	Dr. Quenton Dokken Texas A&M University
Neotropical Bird Migrations	Mr. Robert W. Russell Center for Coastal, Energy, and Environmental Resources Louisiana State University
Preliminary Review of Direct and Indirect Impacts from Pipelines, Pipeline Canals, and Navigation Channels on Coastal Habitats	Dr. Donald R. Cahoon, USGS Mr. Thomas E. McGinnis, JCWS Mr. Robert E. Greco, JCWS National Wetlands Research Center
Gulf of Mexico Deepwater Information Resources Data Search and Literature Synthesis	Dr. David A. Gettleson Continental Shelf Associates, Inc. Jupiter, FL
Progress Report: Study of Economic Impact of Fishing and Diving Associated with Offshore Oil and Gas Structures	Dr. Robert L. Hiatt QuanTech, Inc. Arlington, VA
Habitats and Benthic Environments of the Deep Gulf of Mexico - DGoMB	Dr. Gilbert Rowe Texas A&M University

NEOTROPICAL BIRD MIGRATIONS

Dr. Robert W. Russell
Center for Coastal, Energy, and Environmental Resources
Louisiana State University

The Gulf of Mexico is a major ecological barrier confronted by hundreds of millions of migrating landbirds each spring and fall. Adaptations for dealing with this barrier include energy storage via massive fat deposition, extreme behavioral selectivity of weather conditions, and in some species, complete avoidance of overwater flight through the evolution of circum-Gulf migration strategies. One of the most important components of birds' migration strategies is their use of local habitats for resting and refueling while en route. Trans-Gulf migrations evolved in the absence of natural islands or other habitats that could serve as en route stopover sites; thus, the installation of an artificial archipelago of nearly 4,000 oil and gas production platforms in the northern Gulf has introduced a novel and potentially important component into the en route environment of trans-Gulf bird migrants.

Since spring 1998, our research group at Louisiana State University has been studying the ecology of trans-Gulf migration and, in particular, the influence of platforms on migrants, using a team of full-time observers deployed on offshore platforms in the northern Gulf. The study is funded by MMS through a cooperative agreement with the LSU Coastal Marine Institute, and is possible through the support of major oil companies (BP Amoco, Exxon, Mobil, Phillips, Newfield, Texaco, and Shell), which are providing access to platforms and support in the form of helicopter transportation and offshore accommodations for our research personnel. During our first three field seasons (spring and fall 1998, spring 1999), we operated on five platforms off the Louisiana coast. During that initial exploratory phase, we discovered that the largest migratory flights often occur to the east (fall) or west (spring) of Louisiana. With the aid of a second MMS contract and additional assistance from our cooperating companies, we recently expanded to 10 platforms beginning with the fall 1999 season.

With the benefit of two full spring field seasons completed to date, we now have a reasonably good understanding of spring dynamics. On days when conditions are unfavorable for departure from Mexico (e.g., northerly winds over the Yucatan), very few birds undertake the flight, and we see little or nothing on radar or on the platforms. On days when conditions are favorable for initiating a trans-Gulf flight and remain favorable for completing the flight (southeasterly winds aloft over the northern Gulf), massive numbers of birds migrate across the Gulf and are spectacularly evident in radar imagery. However, the majority of these migrants continue across the Gulf at high altitudes and do not stop on the platforms. Under such circumstances, we see a trickle of birds on the platforms; arrivals occur almost strictly during the day and correspond with the peak of migration traffic aloft as evident on radar. On days when conditions are favorable for initiating a trans-Gulf migration but unfavorable for completing the flight, larger numbers of birds may be seen migrating at low altitudes, often just over the sea surface. This occurs, for example, of when this occurs is when a cold front moves over the northern Gulf; in this situation, birds that departed the Yucatan with favorable tailwinds are suddenly confronted with northerly or northwesterly headwinds, which accelerate the rate at which fuel reserves must be used. Under these circumstances, and especially with the additional presence of fog or precipitation, many birds land on the platforms throughout the day. During major events, arrivals can continue into the night since the birds' cross-country speed is reduced by the unfavorable headwinds. Birds that land on the platforms are typically very tired and may stay for several days. At least on the platforms closer to land, many of the birds are able to feed successfully, because a large blanket of terrestrial insects—the "aerial plankton"—is transported offshore by the north winds. Most of the mortality we observed in the spring occurred during major fallout events and involved birds which, upon laboratory examination, proved to have no fat left. Many of these birds not only had depleted their stores of body fat, but had also begun to catabolize their own internal organs for flight fuel in a last-ditch effort to avoid perishing in the Gulf.

Migration dynamics are a bit more complicated in the fall. Trans-Gulf migrants that stage along and near the northern Gulf coast departed southward around a half hour after sunset, and migration traffic comprising these birds was aloft over our platforms throughout the night. During the early fall (mid-August through early October), species that winter in the Neotropics arrived on the platforms overnight and reached peak abundance just before sunrise. Most departed the platforms and continued southward at first light. In addition to the expected southbound trans-Gulf movements involving early-season Neotropical migrants (e.g., Prothonotary Warbler), we also detected northbound movements from late September into November. These return movements involved shorter-distance migrants that winter wholly or in part along the Gulf Coast (e.g., wrens, kinglets, sparrows), and that accidentally "overshot" the coastline during the previous night and ended up over the Gulf following nocturnal flights in strong tailwinds. Because of the abundance of migratory moths and other insects offshore during the fall, these "overshoot migrants" often were able to feed successfully during stopovers on the platforms. Other interesting migration phenomena detected during the fall included: 1) return movements involving true Neotropical migrants that evidently departed from the Florida Panhandle but aborted their trans-Gulf flight and returned to the northern Gulf coast flying downwind; 2) "reverse" movements involving birds and insects that apparently flew downwind to the Louisiana coast from south Florida or the Caribbean region; and 3) the seemingly "anticipatory" appearance of migrant Peregrine Falcons on platforms prior to large landbird movements. With respect to the influence of platforms during the fall, a minor adverse impact on true trans-Gulf migrants was evident in the form of small levels of collision-related mortality, especially during tropical storms. In contrast, for the "overshoot" migrants, which are ill-equipped to deal with the rigors of overwater migration, platforms were beneficial and probably enabled many individuals to return to land successfully.

The spatial expansion of our observational network from waters off south Texas to the eastern boundary of the Central Gulf of Mexico OCS Planning Area is enabling us to achieve a more Gulf-wide perspective on trans-Gulf migration and to test some of our radar-derived hypotheses concerning flight routes and platform influences.

Prior to our work, the conventional wisdom within the academic community was that trans-Gulf migration involved a roughly straight-line, shortest-distance flight from the upper Gulf coast to/from the Yucatan Peninsula. Although our platform observations have confirmed that this "Yucatan Express" is indeed a major component of trans-Gulf migration, our radar work has also revealed that trans-Gulf migration has a more complex "texture," involving multiple flight routes probably used by different migrant populations. In both spring 1998 and spring 1999, we observed a previously undescribed flight route across the western portion of the Gulf. On many days, migrants were evident in radar imagery heading north over waters off the south Texas coast. The origin of these migrants was unclear; although parsimony would suggest that these migrants departed from northeastern Mexico, other lines of evidence suggested that they flew downwind from the Yucatan Peninsula toward the western Gulf, and then reoriented toward the northern Gulf coast. Conversely, in fall 1998 we observed via radar that large migrations sometimes arrive in the afternoon on the south Texas coast from the northeast. Thus, radar evidence suggested that two distinct populations of migrants intermix to a variable extent over the northwestern Gulf: one headed to (fall) or from (spring) the Yucatan Peninsula, and the other headed to (fall) or from (spring) the south Texas coast. Our direct observations on three platforms in the western Gulf in fall 1999 confirmed the existence of the major western flight route and allowed us to determine that this route is used by a substantially different assemblage of species than is common to the east. We expect that the expanded platform network will similarly permit us to unravel the complexities of the spring situation during the forthcoming spring 2000 field season.

PRELIMINARY REVIEW OF DIRECT AND INDIRECT IMPACTS FROM PIPELINES, PIPELINE CANALS, AND NAVIGATION CHANNELS ON COASTAL HABITATS

Dr. Donald R. Cahoon, USGS
Mr. Thomas E. McGinnis, JCWS
Mr. Robert E. Greco, JCWS
National Wetlands Research Center

INTRODUCTION

This report is a portion of a larger project about OCS-related canal widening rates and effectiveness of canal mitigation. Previous research has demonstrated that impacts caused by OCS canals differ according to the geologic setting of the canal; therefore, we divided the gulf coast into subareas: Texas Barrier Islands, Chenier Plain, Deltaic Plain, and Mississippi/ Alabama coastal plain.

The goals of this project are to:

- quantify impacts to different coastal habitats by OCS canals;
- provide insights into improving the effectiveness of workable mitigation techniques;
- provide insights into the development of new mitigation techniques that can be used in regions where existing mitigation techniques have not been successful.

METHODS

We combined GIS and pipeline personnel experience. This report focused on the types of adverse impacts by OCS-related pipeline and canal projects found in a literature review. The remainder of the project determined the effectiveness of mitigation efforts to minimize adverse impacts or restore adversely impacted habitats. To evaluate mitigation efforts, we interviewed pipeline personnel to obtain unpublished reports and opinions; collect and review literature; compile GIS habitat analysis data around select pipeline and navigation channels; and conduct field verification and ground truthing of photo interpretation.

RESULTS

To define impacts associated with pipeline installation, we reviewed the history of pipeline activities as a whole. The history of pipeline activities was highlighted by the first authorized navigation channel, the Truman Proclamation, the peak of OCS pipeline installation from 1965-1972, the National Environmental Policy Act, push-ditch installation, the Section 404 of the Clean Water Act, directional drilling, and deep water hydrocarbon production which may necessitate for more pipelines (Table 2E.1). Development of less damaging installation techniques may have been the most effective events in minimizing construction impacts to coastal habitats.

There are five pipeline installation techniques used throughout the coastal zone. Upland trenching is used through accessible, firm, usually dry, substrates such as high dunes, cheniers, natural levees,

Table 2E.1. Chronology of pipelines and navigation canal events.

YEAR(S)	EVENT
1897	First authorized navigation channel completed in Texas Chenier Plain
1899	Section 10 of the Rivers and Harbors Act
1941	300 miles of pipelines in coastal zone
1947	Truman Proclamation claims U.S. rights to continental shelf resources 460 miles of pipelines in coastal zone
1950	First OCS pipeline installed in the Chenier Plain of Louisiana using flotation canal installation
1953	1,570 miles of pipelines in coastal zone
1958	First OCS pipeline installed in Mississippi
1965-1972	53 OCS pipelines installed in the coastal zone
1965	First pipeline installed in Texas Barrier Islands
1967	Greatest number of OCS pipelines (10) installed in one year
1969	National Environmental Policy Act (NEPA)
1970	Push-ditch pipeline installation developed for marshes
1972	Clean Water Act
1980	> 12,000 miles of pipelines in the coastal zone, installation slows
1985	First directional drilled pipeline installed in Texas Barrier Island
1986	First pipeline installed in Alabama
1994	Deep water drilling (>2,000 ft), hydrocarbon production increase expected

and some forests. Typically, a back hoe is used to dig a trench. The pipeline segments are welded together and placed into the trench. The trench is backfilled, and the surface is recontoured by a bulldozer. Jetting is used through large, deeper water bodies such as lakes, bays, and lagoons. A high pressure stream of water is used to excavate a ditch. The pipe is laid into the ditch from a lay barge where the pipe segments are welded. And, the ditch backfills naturally through slumping of the sides of the ditch and sedimentation from the turbid water. This report will concentrate on the following pipeline installation techniques: flotation canals, which were primarily used through wetlands before the early 1970s; push-pull ditches, which have been used through wetlands since the early 1970s;

and, directional drilling, which has been used to pass under beaches and narrow strips of wetlands since 1985.

The flotation canal was the primary pipeline installation technique used until the development of “push-pull” ditch in the early 1970s. To install a pipeline using the flotation canal technique, a canal is dredged by a drag-line mounted on a dredge barge. The spoil is typically deposited in banks on the marsh adjacent to the canal. Occasionally, spoil is also deposited in designated “spoil areas” in open water or on uplands. The pipeline is then placed into the canal from a lay-barge where pipe segments are welded together. The canal must be 12 to 15 m wide and 2.0 to 3.0 m deep to accommodate the barges. The total width of the construction right-of-way (ROW), including canal and spoil banks, is 60 – 70 m. Currently, flotation canals are used only when the wetland cannot support the weight of machinery used in the push-pull ditch technique.

Since the early 1970s, the push-pull ditch technique has been the main installation technique used to cross through wetlands . To install a pipeline using the push-pull ditch technique, a ditch is dredged by a dragline or backhoe mounted on a marsh buggy that operates along the ditch. The spoil is deposited on the opposite side of the ditch from the machinery or behind the machinery. The pipeline is “pushed” or “pulled” through the ditch from a fixed point along a water body large enough to support a work barge where pipe sections are welded together. The ditch is 2.5 to 3.0 m wide and 1.5 to 2.5 m deep. The total width of the ROW, including the ditch, spoil bank, and equipment area, is 30 - 35 m.

Directional drilling was first used in the coastal zone in 1985. Instead of cutting through coastal habitats, directional drilling is designed to pass under them. Directional drilling requires an entrance area and an exit area. It is primarily used to pass under beaches to avoid breaching. Limitations to using directional drilling are short operation distance and a lack of hard substrate in expansive wetlands for the exit hole and equipment. The technique is still being refined. Recently, a pipeline was directionally drilled under Dauphin Island in Alabama from one barge to another.

Because the ultimate goal of our project is to better understand and aid in minimizing habitat loss during the installation of OCS pipeline canals and navigation , we limit the impact definitions in the following ways:

- An *impact* is a conversion from one habitat type to another habitat type.

- A *direct impact* is the immediate conversion of a vegetated habitat to another habitat type directly related to a human activity. (Acute Impacts)

- *Indirect impacts* are habitat changes that occur gradually at a different time and/or place than the initial direct impacts. (Chronic Impacts)

We compiled a list of possible direct and indirect impacts after reviewing literature (Table 2E.2). The following are specific examples of direct and indirect impacts associated with actual flotation canals, push-pull ditch, and directional drill installations. A pair of flotation canals passing through a marsh in the Deltaic Plain has a large variety of direct and indirect impacts. Direct impacts include

Table 2E.2. Possible direct and indirect impacts associated with pipeline and navigation channels. (b = beach and dunes, m = marshes, f = forested wetlands)

IMPACTS	BACKFILLED PIPELINE	OPEN PIPELINE CANAL	NAVIGATION CHANNEL
Direct			
Conversion to open water			
Dredging		b m f	b m f
Insufficient backfill	m f		
Frac-out	Impact of	directional	drilling
Soil compaction			
Spoil banks	f	m f	m f
Machinery	m f		
Backfill and ROW volume deficit	m f		
Conversion to upland		b m f	b m f
Hydrodynamic changes			
Sediment sink	b m	b m	
Long-shore current disruption			b m
Hydrodynamic efficiency	b m f	b m f	b m f
Indirect			
Hydrodynamic changes			
Impoundment		m f	m f
Hydrodynamic efficiency			
Channel theft	b m f	b m f	b m f
Freshwater drainage	m f	m f	m f
Saltwater intrusion	m f	m f	m f
Altered sedimentation	b m	b m	b m
Altered erosion	b m	b m	b m
Ponding and continued erosion			
Spoil banks		m f	m f
Canal and channel erosion		b m f	b m f
Pond expansion	m		

the conversion of marsh to open water, within the canal, and upland, along the spoil banks. The hydrodynamics may have been changed as the shallower, meandering tidal creeks are crossed by deeper, straight canals. A definite indirect impact is the widening of the canal as evidenced by the slim, uneven (absent in some places) spoil bank between the canals. Probable indirect impacts include channel theft, freshwater drainage, saltwater intrusion if near a salty body of water, and changes in sedimentation patterns. Other possible indirect impacts may be impoundment and flank subsidence by the spoil banks.

A push-pull ditch pipeline in the Texas Chenier Plain adjacent to an older push-pull ditch pipeline reveals new and old impacts. A two-year old pipeline, a pipeline installed decades earlier, and marsh buggy tracks are still visible. The main direct impacts are conversion to open water caused by soil compaction. Backfill was insufficient to completely fill the ditch, and marsh buggies caused ponding. These problems could change the hydrology of the system if canals deepen and widen via erosion.

A directional drill site near Coden, Alabama, shows the route of a pipeline through a bay, a thin strip of salt marsh, and a pine savanna. The entrance area was off a barge in the bay, and the exit area is a cleared section within the pine savanna about 150 m from the bay. A cleared ROW is maintained through the pine forest to the production facility so that tree roots do not tamper with the pipeline. The line passes 7 m under the salt marsh and the leading edge of the savanna where the roots are shallow. Other than the maintained ROW, the only visible impact is vegetation removal caused by a “frac-out” of drilling mud, which killed the vegetation. This area will either revegetate or convert to open water.

SUMMARY

Overall, impacts to coastal habitats have decreased as installation techniques have evolved, although the different installation techniques have unique impacts. The decreased right-of-way widths and elimination of spoil banks are major contributors to the this decrease of impacts overall. We will determine whether or not additional mitigation efforts are effective at further decreasing impacts.

ACKNOWLEDGMENTS

We acknowledge the agencies, academic institutions, and industries for working with us on this project. We also acknowledge others involved in this project who will be responsible for GIS analysis:

Jimmy Johnston
Larry Handley
Steve Hartley
John Barras
Steve Robb
Susan Wagner
Karen Eldridge

Dr. Donald R. Cahoon has worked for the past eight years as a Senior Research Ecologist at the U.S. Geological Survey, National Wetlands Research Center, in Lafayette, LA. Dr. Cahoon conducts research on (1) the impacts of sea-level rise on long-term wetland stability through evaluations of wetland accretionary processes, including the effects of major storms, (2) the processes of wetland loss, submergence, and soil erosion in natural and managed coastal systems, and (3) the effectiveness of wetland restoration and management techniques. He has published several papers on the effects of major storms on coastal wetland systems of the southeast U.S. and has studied sedimentation processes in mangrove systems. Dr. Cahoon received his B. A. in botany from Drew University and his M.S. and Ph.D. in wetland plant ecology from the University of Maryland.

Mr. Thomas E. McGinnis has worked at the National Wetlands Research Center since January 1999 as a General Biologist II for Johnson Controls World Services. Prior to this, Mr. McGinnis worked for the University of Southwestern Louisiana (currently the University of Louisiana at Lafayette). Mr. McGinnis has researched geomorphology, plant physiology, ecology, and oil spill impacts in coastal wetlands. He received a B.S. in aquatics and fisheries biology and a M.S. in biology from the University of Southwestern Louisiana.

Mr. Robert E. Greco has worked at the National Wetlands Research Center for the past six years as a GIS Specialist for Johnson Controls World Services. Mr. Greco is currently a graduate student at the University of Louisiana at Lafayette. Mr. Greco has worked on the Coastal Wetlands Planning, Protection, and Restoration Act. He received a B.S. in geology from the University of Southwestern Louisiana.

GULF OF MEXICO DEEPWATER INFORMATION RESOURCES DATA SEARCH AND LITERATURE SYNTHESIS

Dr. David A. Gettleson
Continental Shelf Associates, Inc.
Jupiter, FL

INTRODUCTION

Continental Shelf Associates, Inc. (CSA) in association with Texas A&M University was awarded a contract by the Minerals Management Service (MMS) to conduct an information search and synthesis for the deepwater Gulf of Mexico. The geographic area of study is the deepwater northern Gulf of Mexico extending from the 1,000 ft isobath to the U.S. Exclusive Economic Zone (Figure 2E.1).

STUDY OBJECTIVES

The objectives of the study are (1) to gather socioeconomic information; (2) to develop a computer-searchable bibliographic database; and (3) to prepare a synthesis document that describes the ecosystem including environmental processes that are potentially sensitive to oil and gas operations.

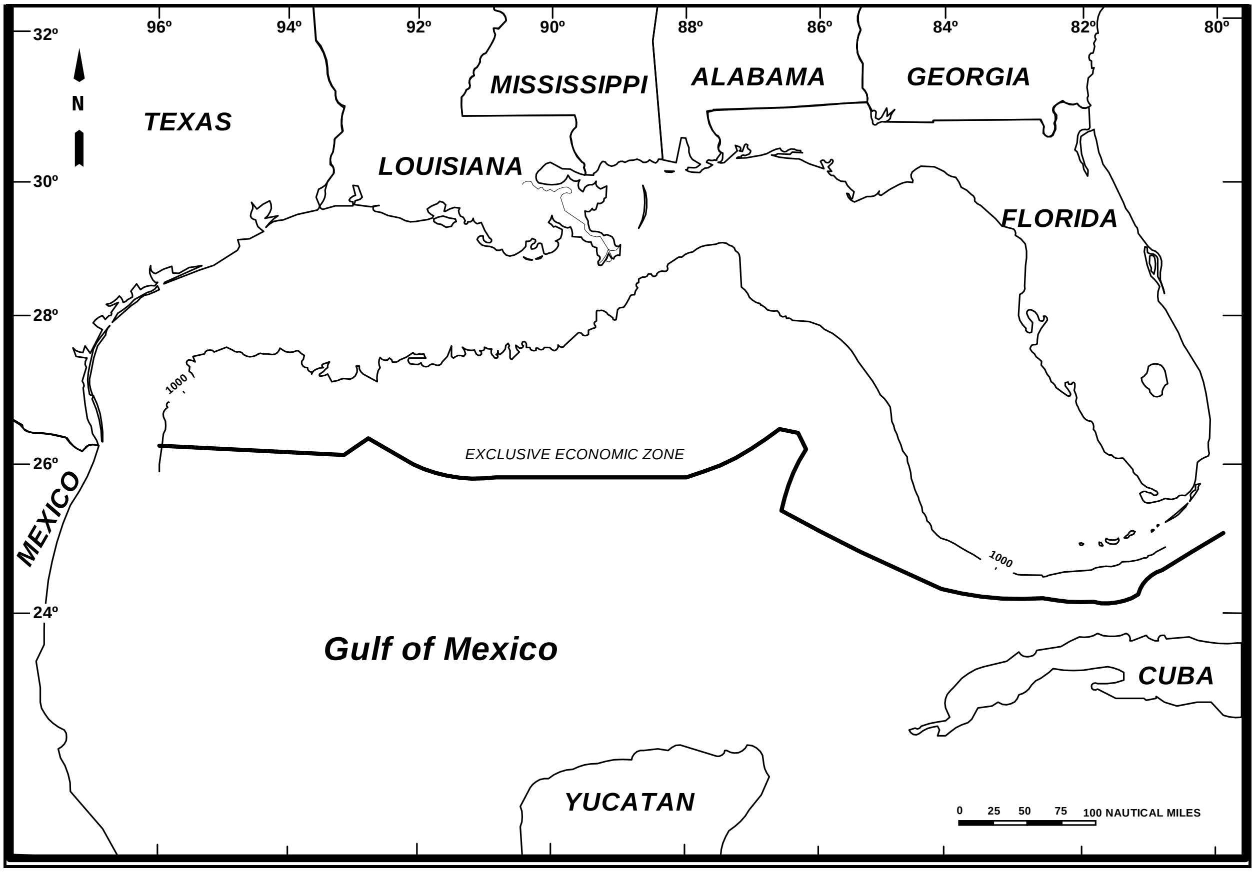


Figure 2E.1. Location of study area.

The database and synthesis report will be used by MMS to develop impact assessment documents and to assist in the identification of data gaps that could be filled by subsequent studies.

BIBLIOGRAPHIC DATABASE

The information for the bibliographic database is being obtained through computer searches of online databases, CSA and principal investigator literature files, and contacts with other individuals. The database will include citations and abstracts. The following list indicates the number of citations per topic area:

300	Geological Oceanography
160	Physical Oceanography
60	Chemical Oceanography
70	Water Column Biology
70	Benthic Ecology (Non-Seep)
50	Benthic Ecology (Seep Communities)
50	Fish and Fisheries
20	Protected Species
120	Socioeconomics
50	Technology
950	Total

SYNTHESIS REPORT

The synthesis report will include chapters on each of the topic areas listed above plus a synthesis chapter. The synthesis chapter will include the following topics:

- Ecosystem description including dominant environmental processes
- Significant differences in oil and gas operations in deepwater versus the continental shelf as relevant to evaluating potential impacts
- Significant differences in deepwater versus continental shelf environments as affected by oil and gas operations
- Critical resources, pathways, and processes in deepwater that may be affected by oil and gas operations
- Data gaps and information needs as related to evaluating oil and gas impacts

---

Dr. David A. Gettleson is President and Scientific Director of Continental Shelf Associates, Inc. (CSA), located in Jupiter, Florida. He has 20 years of scientific management experience with major research programs for federal, state, and industrial clients. He has been involved in the preparation of numerous environmental assessment documents covering a wide range of human activities in the marine environment, including oil and gas operations, dredging and dredged material disposal, beach restoration, artificial reef siting, power plant effluents, sewage outfalls, and waste incineration. Dr. Gettleson received a B.A. degree in biology from Rollins College in 1971 and earned his Ph.D. degree in biological oceanography from Texas A&M University in 1976.

PROGRESS REPORT: STUDY OF ECONOMIC IMPACT OF FISHING AND DIVING ASSOCIATED WITH OFFSHORE OIL AND GAS STRUCTURES

Dr. Robert L. Hiatt
QuanTech, Inc.
Arlington, VA

The purpose of this study on behalf of the Minerals Management Service (MMS) is to estimate expenditures and economic impact associated with recreational fishing and diving near Gulf of Mexico (GOM) based oil and gas structures and artificial reefs created from such structures. The primary method used is a survey of recreational fishermen and divers along the Gulf coast including the states of Alabama, Mississippi, Louisiana, and Texas. Data collection began in January 1999 and will continue throughout the calendar year.

The data collection approach involves interviews in the field as fishermen and divers return from their trips coupled with a follow-up telephone interview with selected respondents, particularly those who fished near an oil or gas structure. The data collection activities include interviews with private boat fishermen, charter boat fishermen, head boat fishermen, divers, captains of charter boats, captains of head boats, and dive shop operators.

The project focus is on the following user groups: recreational fishermen, charter boat fishermen, headboat anglers, and recreational divers. For each of these user groups the requirement is to determine:

- the demand of each of these user groups for offshore-structure-related recreational activities;
- the economic and fiscal consequences of this demand; and
- the distribution of these economic and fiscal consequences among businesses servicing these user groups, among parishes and counties and, finally, between states and the federal government.

As shown in Table 2E.3, the research design calls for data collection using three basic methods. The first are in-person field interviews in which data collectors stationed along coastal areas of the GOM visit predetermined boat launch sites and conduct interviews with fishermen and divers as they return from the day’s activities. The second method involves a telephone follow-up interview with qualified respondents identified during the field interviewing. The third method involves a telephone interview with respondents identified through an independent sample frame, such as a list of charter boat operators. As shown in Table 2E.3, in-person field interviews will be conducted with private boat fishermen, charter boat fishermen, party boat fishermen, and divers. Telephone followup interviews will be conducted with subsamples from these same groups. Telephone interviews (not followup) will be conducted with charter boat operators, party boat operators, and dive shops or guide services.

Table 2E.3. Summary of data collection sample plan.

	MMS Field Interviews	**MMS Followup Telephone**	**MMS Other Telephone**
Private Boat Fishermen	n=6,513	n=3,255	-
Charter Boat Fishermen	n=1,331	n=920	-
Party Boat Fishermen	n=400	n=280	-
Charter Boat Operators	-	-	n=200
Party Boat Operators	-	-	Census (n=50)
Divers	n=200	n=200	-
Dive Shop/ Guide Services	-	-	n=50

Through October, QuanTech has obtained the following numbers of completed interviews in the field:

Private boat interviews	5,252
Charter boat interviews	1,093
Party boat interviews	317
Divers	76

Because data collection is ongoing, only selected results are available. Preliminary analysis of field data obtained from private boat fishermen indicates the following:

- Only 43% of fishing trips taken by private boat fishermen were in Gulf waters. Other areas fished included bays, sounds, rivers, bayous.

- 70% of fishermen have a target species in mind for each trip.

- 24% report fishing with 300 feet of an oil or gas structure or an artificial reef created from an oil or gas structure.

- 43% of those who fish near a oil or gas structure visit multiple locations during a single fishing trip.

- Most fishermen are able to name the specific structures at which they were fishing or to give the general locations.

During follow- up telephone interviewing with private boat fishermen, the following information was obtained:

- Many people go fishing as part of a multi-day trip to the local area (30%).

- The vast majority of people spend some money on a fishing trip.

- The major categories of expenses are food and drink, fuel, boat launch fees, bait, and tackle.

- There is significant boat ownership among those who fish in Gulf waters, with associated expenditures.

Results also indicated that there are significant expenditures every year that are not trip specific. Major expenditure areas of this type included:

- Boat and trailer repairs

- Rod and reel purchases

- Other fishing tackle

- Magazines and books

- Fishing club and organization membership

- Camping equipment

- Fishing licenses

Based upon preliminary data reviews to date and feedback from field interviewers and respondents, it is expected that the following conclusions may result from this study:

1. Oil and gas structures and artificial reefs created from such structures will prove to be very important to Gulf fishing and diving both in terms of numbers of trips annually and expenditures.

2. Not all structures will be equally important to all groups, however.

3. A significant future problem will be that of deciding which structures should remain in place to maximize their value to recreational fishing and diving.

Robert L. Hiett is a senior program manager with QuanTech, Inc., of Rosslyn, VA. Dr. Hiett is an experienced survey research specialist with more than 20 years of experience in the design and management of fisheries-related field research studies. In addition to directing the Minerals Management Service study of the economic impact of fishing and diving associated with Gulf of Mexico oil and gas platforms, he manages the Large Pelagic Survey for the National Marine Fisheries Service and a pilot study to collect economic information from commercial mackerel fishermen along the southeastern U.S.

HABITATS AND BENTHIC ENVIRONMENTS OF THE DEEP GULF of MEXICO - DGoMB

Dr. Gilbert T. Rowe
Texas A&M University

The structure and function of the benthic communities of the deep Gulf of Mexico are being investigated in four consecutive, interdependent phases. The study is based on a conceptual model of the cycling of organic matter through generic food webs distributed from the outer continental shelf out to the Sigsbee Deep. A thorough survey of community structure is being used to test a set of eight hypotheses proposed for the causes of variations in organism density, biomass, diversity, zonation and species composition. Important independent variables being considered are gradients of depth and east vs. west extremes, including proximity to the Mississippi River effluent; topographic features such as canyons and basins; variations in time (such as seasons); and proximity to organics seeping from fossil deposits.

Four sub-disciplinary teams representing physics, geology, geochemistry and biology have been assembled to participate in the incipient studies. The largest of the teams, the biologists, is represented by both process-oriented ecologists and taxonomists. The comparisons of community structure with the “physical environment” will provide insights into how and where best to investigate ecosystem processes. The study of community structure will encompass a wide geographic area whereas the studies of community processes will be focused on a few locations that represent important environmental extremes.

The input of organic matter, including its composition, concentration and variability in time, is hypothesized to be the fundamental control of both community structure and function. Community function is defined as the dynamics of organic matter energy transfers in the food web. In this study we have represented the mechanistic essentials of community “function” as a conceptual model consisting of interacting “standing stocks,” represented as boxes, linked together by a system of exchanges represented by arrows into, out of, or between the boxes (Figure 2E.2). These fluxes include sources of organic matter “feeding” the system, exchanges between the biological state variables, such as predation, and respiratory remineralization to carbon dioxide, represented by arrows out of the “system.”

The first task of DGoMB is a review of previous studies. The principal prior studies began with the wide-ranging explorations of Willis Pequegnat and his students initiated in the 1960s. These have been followed by an intensive survey on the upper slope of the northern gulf by LGL Environmental in the 1980s (the MMS supported NGOMCS study). Based on our initial re-analysis of the polychaete annelid worm component in the NGOMCS data, we can confirm that animal distributions are affected by depth, location (on east, west and central transects) and, to a lesser degree, sediment grain size (Figure 2E.3). Diversity is high, but with maximum values on the upper slope, or shallower than the maximum in other basins. Temporal differences in biomass on the upper slope suggest that seasonal variations in the fluxes of organic matter can be important. Faunal boundaries

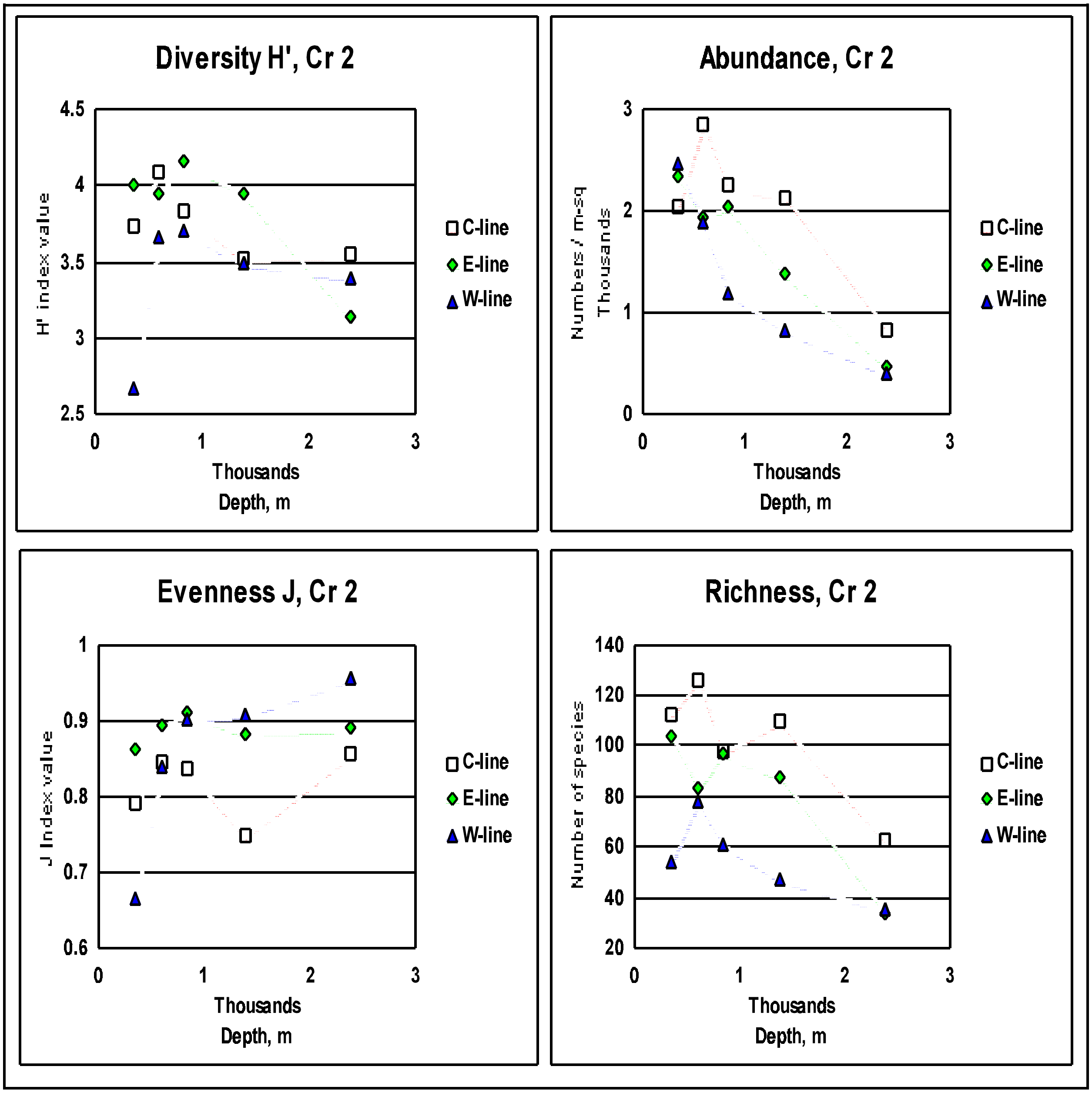


Figure 2E.2. Analysis of Fain Hubbards's polychaete data by Richard Haedrich.

are most pronounced at depths of 1,000 and 1,500 meters. The eastern gulf is somewhat different in species composition from the western transects.

The second phase of the investigation, two years from now, will use the conceptual model and the newly derived community structure conclusions to identify geographic sites for comprehensive measurements of rates of biological processes that characterize community function. At these sites a key instrument will be a deep-sea autonomous benthic "lander." The lander will be used to quantify total sediment community metabolism, followed by associated experiments aboard ship to partition carbon flow through the food web. These studies will be used to predict how the

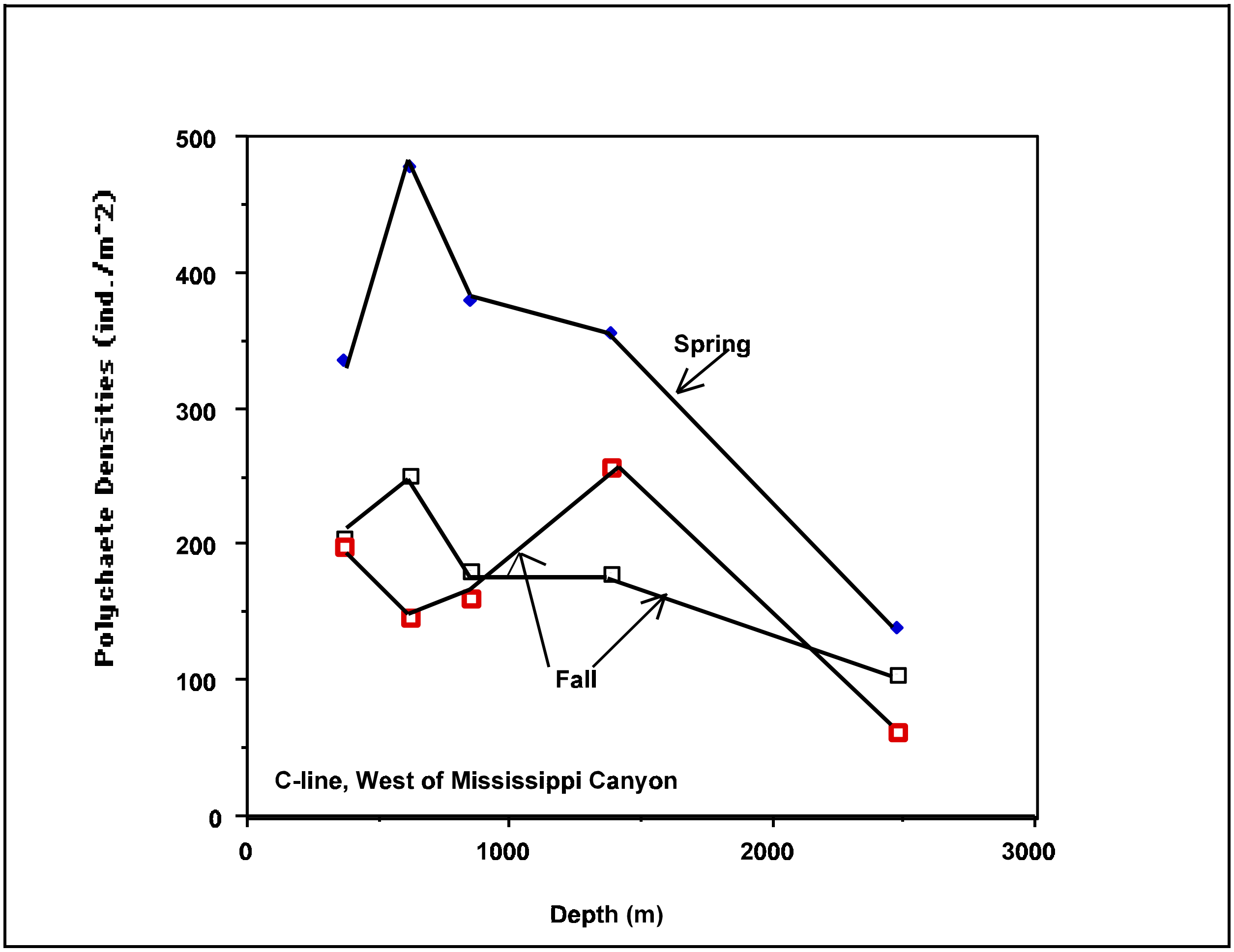


Figure 2E.3. Differences in polychaete densities on the central gulf transect during NGOMCS, courtesy of Fain Hubbard and LGL Environmental.

community would respond to additions of organic matter above that normally encountered in the individual habitats studied. Investigators will go back and forth between model and data. The model will identify "weak" but important data, then new field collections and experiments will attempt to rectify such issues, and the model will be revised with the new information.

A joint investigation of the abyssal plain with the National University of Mexico has resulted in a limited preliminary suite of data on both community structure and function at a depth of 3.65 km, well into the Mexican EEZ, giving DGoMB access to important abyssal plain data for comparison. The input of organics required to balance community metabolism has been estimated from model variables developed by others in the literature. This can be compared to deep bottom lander incubations to measure sediment community oxygen demand. Time varying input of organic matter suggests that the smaller components, which dominate the biomass, vary in response to the input, but the peaks in biomass produced by the input lag behind the input by weeks to months, depending on the values used for first order "feeding" rates (Figure 2E.4). The interplay between the model, community structure information and ecosystem functional processes will be used as an example of approaches to be employed in DGoMB on the continental margin of the northern gulf.

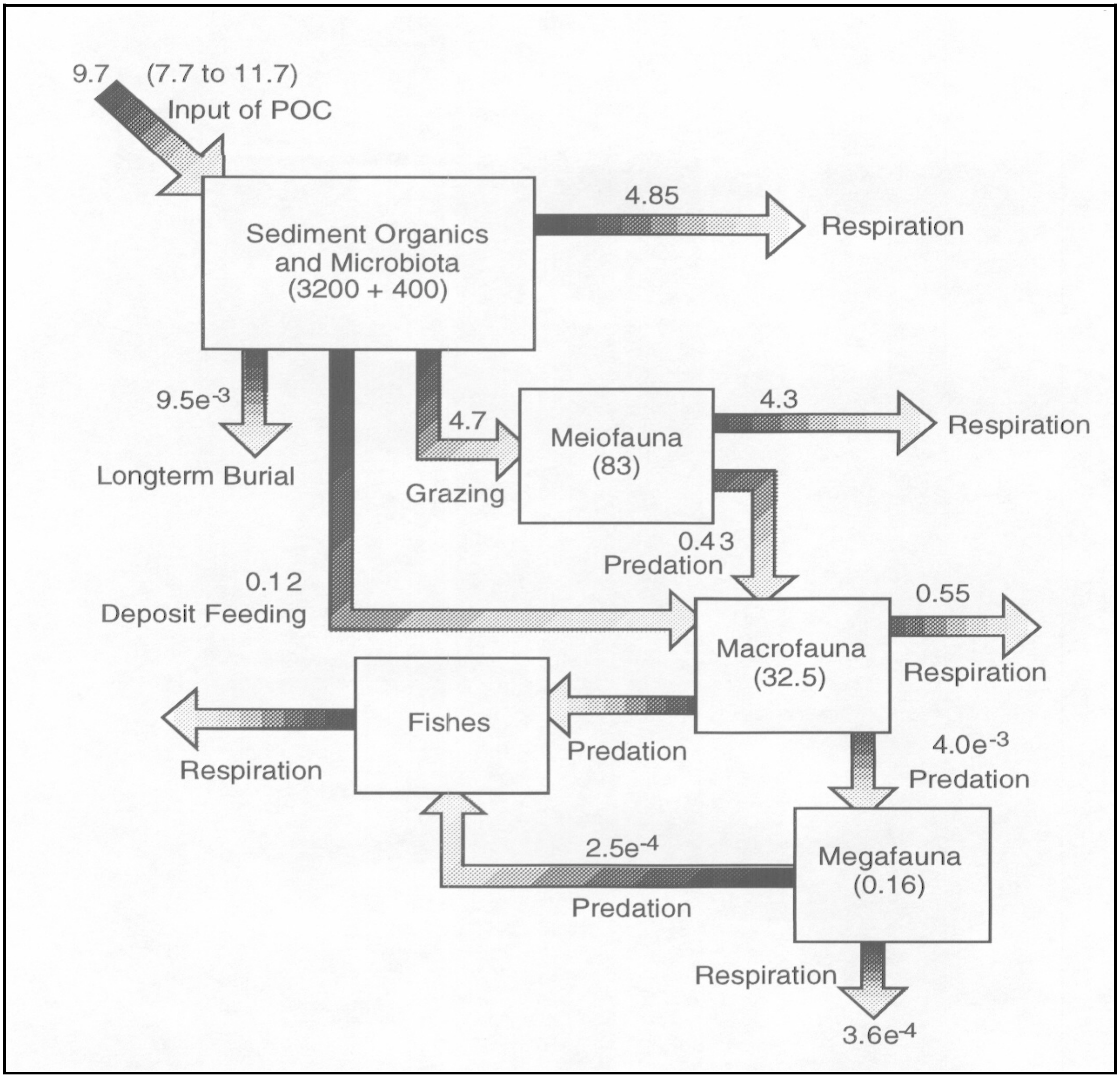


Figure 2E.4. Carbon budget for the Sigsbee Abyssal Plain, 3.65 km depth. In association with UNAM.

Dr. Gilbert T. Rowe, DGoMB Program Manager, is Professor of Oceanography at Texas A&M University. Previously he has held appointments at the Brookhaven National Laboratory and the Woods Hole Oceanographic Institution. His Bachelor of Science and Master of Science degrees in zoology and oceanography from Texas A&M were followed by a Ph.D. from Duke University.

SESSION 2F

SOCIOECONOMICS

Chair: Dr. Harry Luton, Minerals Management Service
Co-Chair: Ms. Vicki Zatarain, Minerals Management Service

Date: December 1, 1999

Presentation	Author/Affiliation
Socioeconomic Baseline and Projections of the Impact of an OCS Onshore Base for Selected Florida Panhandle Communities	Dr. Ronald T. Luke Dr. Eric S. Schubert Dr. Greg Olsson Research and Planning Consultants, Austin Dr. C. Hobson Bryan University of Alabama - Tuscaloosa Dr. Raymond Burby University of New Orleans Dr. F. Larry Leistritz North Dakota State University Dr. Steve H. Murdock Texas A&M University
Regional Economic Stimulus of Coastal Alabama Exploration and Development	Dr. William W. Wade Mr. Jason Plater Foster Associates, Inc., Columbia, TN
The Coastal Division of Industrial Labor Over Time and Space: Continuation and Expansion of a Community Study	Dr. Charles M. Tolbert Dr. Deborah M. Tootle Dr. Edward S. Shihadeh Dr. John J. Beggs Louisiana State University
Labor Migration and the Deepwater Oil Industry	Dr. Katharine M. Donato Department of Sociology Louisiana State University
Forecasting the Number of Offshore Platforms on the Gulf of Mexico OCS to the Year 2023	Dr. Allan G. Pulsipher Dr. Omowumi O. Iledare Dr. Dmitry V. Mesyanzhinov Dr. Alan Dupont Ms. Qiaozhen Lucy Zhu Center for Energy Studies Louisiana State University

SOCIOECONOMIC BASELINE AND PROJECTIONS OF THE IMPACT OF AN OCS ONSHORE BASE FOR SELECTED FLORIDA PANHANDLE COMMUNITIES

Dr. Ronald T. Luke
Dr. Eric S. Schubert
Dr. Greg Olsson
Research and Planning Consultants, Austin

Dr. C. Hobson Bryan
University of Alabama - Tuscaloosa

Dr. Raymond Burby
University of New Orleans

Dr. F. Larry Leistritz
North Dakota State University

Dr. Steve H. Murdock
Texas A&M University

INTRODUCTION

This study was sponsored by the Minerals Management Service. The study explains the impact on each of two Florida Panhandle communities if an onshore base to support Lease Sale 181 or the Destin Dome were located there. Research and Planning Consultants, Inc. (RPC) determined that there would be relatively few demographic, economic, public service, fiscal, or social impacts if an onshore OCS support base were located in the Florida Panhandle.

Research and Planning Consultants, a public policy firm with offices in Austin, Texas, and Tallahassee, Florida, conducted the study on behalf of the MMS. Besides RPC, team members included some of the leading scholars in the country on socioeconomic impact assessment both in general and as specifically related to energy development. The four scholars are Professors Hobson Bryan of the University of Alabama at Tuscaloosa, Ray Burby of the University of New Orleans, Larry Leistritz of North Dakota State University, and Steve Murdock of Texas A&M.

As part of this study, RPC has produced a number of work products:

Research and Planning Consultants, Inc. 1999. Socioeconomic Baseline and Projections for Selected Florida Panhandle Communities. A final report for the U.S. Department of the Interior, Minerals Management Service Gulf of Mexico OCS Region, Metairie, LA. Contract No. 1435-01-96-CT-30821.

Research and Planning Consultants, Inc. 1999. Socioeconomic projection model for Selected Florida Panhandle Communities, and User's Guide for the Model, developed for the U.S.

Department of the Interior, Minerals Management Service Gulf of Mexico OCS Region, New Orleans, LA. Contract No. 1435-01-96-CT-30821.

Research and Planning Consultants, Inc. 1999. Presentation of the project “Socioeconomic projection model for Selected Florida Panhandle Communities,” a Power Point presentation developed for the U.S. Department of the Interior, Minerals Management Service Gulf of Mexico OCS Region, New Orleans, LA. Contract No. 1435-01-96-CT-30821.

In the upcoming Lease Sale 181, scheduled for the end of 2001 or possibly 2002, the MMS will open an area for development in the western edge of the Eastern Planning Area of the Gulf of Mexico. It is 15 miles or more due south of the coast of Alabama and 100 miles or more due south of the Florida Panhandle. Because the experience of Texas and Louisiana has indicated substantial social and economic impacts onshore from Outer Continental Shelf (OCS) activities are possible, the MMS wanted to investigate the potential impacts on affected communities in the Eastern Gulf of Mexico. While the MMS believes that Alabama is the most likely location for any onshore support activities in the western part of the Eastern Planning Area, a possibility exists that limited onshore support activities might occur in the Port of Panama City or the Port of Pensacola. This study addressed the impact of an onshore base in either of these Florida communities.

The onshore base would serve either or both of two lease sales planned for development and production in the 2000 through 2040 period. These are Lease Sale 181 and the Destin Dome project. Although Destin Dome will probably not be served from the Florida Panhandle, we did analyze the effects if it were.

The Destin Dome project is located about 25 miles from the coastline of the Florida Panhandle due south of Pensacola. The Destin Dome 56 Unit is located on the Florida Panhandle shelf. It is a project estimated to produce up to about 20 wells to extract dry natural gas.

This study did not assess the probability of an onshore base being located in the Florida Panhandle. Rather, we asked *if* an onshore base were developed, *then* what would be the demographic, economic, public service, fiscal, and social impacts on the Panhandle area. While analysis of the data showed only a small socioeconomic effect for the potential locations for an onshore support base, several stakeholders did express concern or hostility to the idea of any offshore oil and gas development and related onshore support bases.

OBJECTIVES

The study had two objectives:

- to develop a baseline socioeconomic description for Panama City, Pensacola, and the Fort Walton Beach area, and

- to develop projection models that allowed the MMS and others to project possible socioeconomic effects of various onshore support scenarios on these communities.

The project also includes studies on four local industries that could be affected by the operations of a support base in the Florida Panhandle: sport and commercial fishing, military bases, port facilities, and tourism. The project also analyzed possible user-conflicts or benefits that these industries might encounter with the operations of the support base.

The analysis considered each area to be defined by the Metropolitan Statistical Area (MSA) and the counties that constituted each area: Escambia and Santa Rosa make up the Pensacola MSA, Okaloosa County makes up the Ft. Walton Beach MSA and Bay County is the Panama City MSA. To cover the remainder of the coastal area between Ft. Walton Beach and Panama City, we also include some data for Walton County. Tourism is discussed for this region as a whole and for each of the areas of Pensacola, Fort Walton Beach including Destin, and the Panama City area. During the study we heard repeatedly industry representations that Ft. Walton Beach would not qualify as an onshore support base because it did not have a deep water port.[1]

METHOD OF MODELING

Data were collected from a variety of sources. These included stakeholder interviews, field trips to the Florida Panhandle, and economic data sources. The RPC team gathered historical and projected economic baselines from the Bureau of Economic and Business Research at the University of Florida at Gainesville, the Florida Department of Banking and Finance, and the U.S. Bureau of Economic Analysis. The RPC team reviewed and incorporated into its socioeconomic impact model industry activity, employment, income, migration patterns, social and human services, and fiscal data. Baseline data enabled an assessment of the impact of an onshore base compared to the baseline conditions.

The MMS Florida Panhandle Model

A valuable result of the present study was the development by RPC of a spreadsheet modeling tool, referred to as the MMS Florida Panhandle Model. This model will enable people interested in investigating the multidimensional impact of development of an onshore base in the Florida Panhandle. This tool allows the user to set the expected level of OCS production. The user can also make assumptions about any anticipated change in both the tourist industry and military installation employment. It should be noted that we did not find any evidence that either the tourist industry or the military installation employment would change with deployment of an onshore base. Nevertheless, the user can make assumptions about changes in these areas. The model will then calculate the impact of the input values on the subsequent socioeconomic dimensions.

Potential offshore projects in the Eastern Gulf of Mexico have led to some lively debates among stakeholders on the costs and benefits of such activity. To enlighten and assist stakeholders and government planners in the Florida Panhandle, the MMS will be distributing the Florida Panhandle

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[1] The MMS Florida Panhandle Model uses two counties, Okaloosa and Walton, to represent the Fort Walton Beach area. Okaloosa is the Fort Walton Beach MSA. Therefore, to project employment and population in both counties, RPC used BEA projections of the Pensacola Economic Area (which includes the Pensacola MSA, the Fort Walton Beach MSA, and Walton County) and subtracted the projection from the Pensacola MSA.

computer model. The model will present a range of socioeconomic impacts on the Florida Panhandle of Lease Sale 181 and the pending Destin Dome project off the coast of Pensacola.

Features of the Model

The MMS Florida Panhandle model projects the following variables:

- population by age cohort;
- change in population by component;
- employment & output by industry;
- local government fiscal condition indicators (revenues and expenditures); and
- special industry indicators (tourism, military bases, sport and commercial fishing, and water transportation).

The computer model uses a regional input/output economic projection model and a cohort component demographic model. The employment/labor force balance determines economic-related net migration. Projected changes in population determine fiscal conditions. Employment by industry and historical characteristics determine special industry indicators

Modeling the Socioeconomic Baseline

A key feature of the model is the socioeconomic baseline forecast it produces for the five counties. The baseline represents the expected future conditions absent any OCS-related development in the areas. The baseline is not synonymous with “current conditions.” All three communities and their associated counties have experienced economic and population growth, and projections indicate that this growth will continue. The RPC team calibrated the model using projections by Florida state agencies (Bureau of Economic and Business Research 1994, 1995, 1997) and BEA regional projections (Bureau of Economic Analysis 1998). The BEA data was used to obtain information on employment, income, and population.

Modeling Reasonable Maximum and Minimum Threshold Production

RPC identified characteristics of OCS support industries through literature review, investigation of the Texas, Louisiana, and Alabama experience, and key informant interviews with people in the offshore oil industry. RPC also identified two OCS scenarios for each community: “reasonable maximum” and “minimum threshold.” These two scenarios correspond to the maximum and minimum production levels estimated by the MMS in their Environmental Impact Statement. The user of the model can perform ‘what-if’ analysis by choosing the location of support base. In addition, the user can select what level of production is to be investigated, including intermediate levels between minimum and maximum. The user can also include the Destin Dome option to determine the impact of having an onshore base for this operation in the Florida Panhandle. Figures 2F.1 and 2F. 2 illustrate the projected reasonable maximum and minimum threshold scenario levels. The first chart shows oil production and the second gas production.

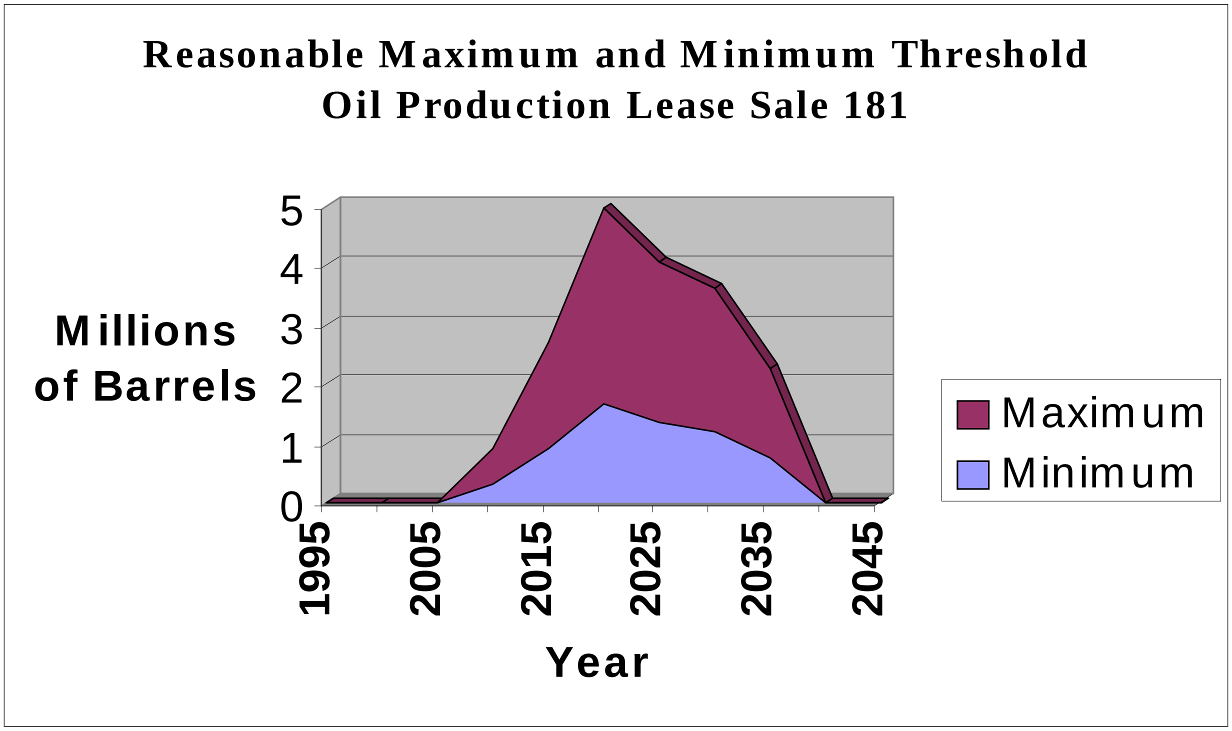

Figure 2F.1. Reasonable maximum and minimum threshold oil production, Lease Sale 181.

Figure 2F.2. Reasonable maximum and minimum threshold gas production, Lease Sale 181.

Using IMPLAN to Generate Modeling Information

RPC used the IMPLAN input/output modeling software package (Minnesota IMPLAN Group, 1997) in the economic module of the MMS Florida Panhandle model. This software provided RPC with substantial flexibility in building the model. While IMPLAN can generate modeling information for as many as 528 industries, or sectors, of the study area, RPC structured the economic module into 23 industries. This was done for each of the three MSAs. These represented the broad industrial groupings the Bureau of Economic Analysis uses in its employment projections for metropolitan statistical areas and the subsectors involved in the impact portion of the model: the tourism industry, the military bases, commercial fishing, and Outer Continental Shelf (OCS) oil and natural gas activity (Table 2F.1).

Table 2F.1. Industrial sectors used in MMS Florida Panhandle model.

Agriculture (excluding Commercial Fishing)
Commercial Fishing
Mining (excluding Maintenance and Repairs of Oil and Gas Wells)
Maintenance and Repair of Oil and Gas Wells
Construction
Non-Durable Manufacturing
Durable Manufacturing
Transportation, Communications, & Utilities (excluding Air & Water Transportation)
Water Transportation
Air Transportation
Wholesale Trade
Retail Trade (excluding Eating & Drinking Places)
Eating & Drinking Places
Finance, Insurance, and Real Estate
Services (excluding the six service categories listed below)
Hotel and Lodging Places
Equipment Rental and Leasing Services
Amusement and Recreation Services, N.E.C.
Engineering, Architectural Services
Accounting, Auditing and Bookkeeping Services
Research, Development & Testing Services
Government (excluding Federal Government - Military)
Federal Government - Military

Sources: IMPLAN and RPC

RPC developed a set of input/output matrices for projecting the impacts that changes in OCS, tourism, or military base expenditures would have on the economy of the three metropolitan areas of the Florida Panhandle over time. The matrices measure the direct, indirect, and induced effects of these impacts based on the size and type of interrelationships among the 23 sectors of the study areas. Population impacts were assessed on the county level within each MSA using a formula that approximated BEA/BEBR county population projections. The model already incorporates the economic impacts of additional spending and any net migration. After the project began, the MMS decided that IMPLAN would be its standard, allowing the MMS to adapt this model in the future without having to completely rebuild it.

Reports Generated by the Model

Reports generated by the model cover the years 1995 through 2045. They include an OCS Scenario report, which estimates oil and gas production, OCS expenditures, the assumed impact on tourism and the military bases. There is also a baseline report on output, the population, employment, and migration. The third report is on the changes projected to occur for the population. The fourth report describes the impact on output and employment. The fifth report is a fiscal balance report detailing the changes in revenues and expenditures expected for county and municipal government. The sixth report is of the impact expected on school-age children and the fiscal impact associated with those changes. The seventh report is of the impact on public services.

Method of Primary Data Collection

Primary data collection involved selective interviews of local and community and business leaders. The interviews were designed to identify baseline projection factors and impact issues that are not reflected in the literature review or secondary data. Interviews with representatives of the port facilities, the tourism, and fishing industries were conducted to supplement and confirm the findings of the literature review and the secondary data collection effort.

The RPC team contacted about 50 different stakeholders, including local, county, and state governments and interviewed about half of these stakeholders. Local and county governments did not for the most part respond to the RPC team’s inquiries. RPC had good responses from the tourism, military bases, and port facilities sectors. There was no response from the fishing industry. Table 2F.2 lists the status of contact with stakeholders.

Background Findings

Baseline Population Growth

The Florida Panhandle will continue to experience the substantial demographic and economic growth that it now faces. The five county area contained 643,000 people in 1990 and is projected to have nearly 898,000 residents by 2010. In an average year in the 1990s, 7,400 people migrated to the Florida Panhandle, which has started to cause strains on the infrastructure. Figure 2F.3 shows the growth.

Table 2F.2. Stakeholder interviews.

Stakeholders or Sources of Information	Contacted	Interviewed
Business Associations/Chambers	3	1
Fishing	3	0
Government	18	7
Federal	2	2
State	6	3
County	5	0
Municipal	4	1
Regional Planning Council	1	1
Military bases	5	4
Oil	3	2
Port Facilities	2	2
Tourism	16	10
Charter Boats	2	2
Committees/Councils	3	2
Environmental	4	2
Parks	3	2
Resident Associations	3	2
Other	1	0
Total	**50**	**26**

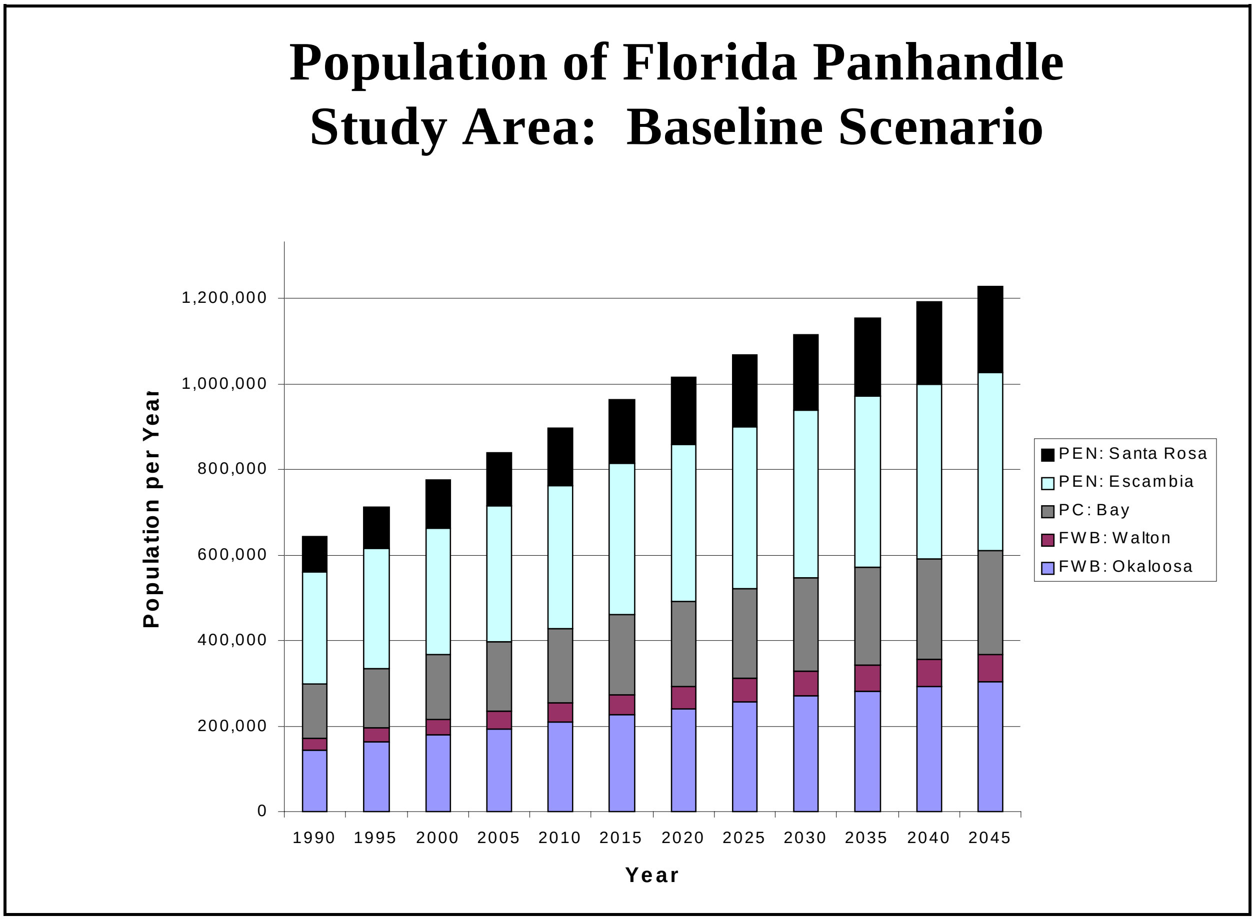

Figure 2F.3. Population of Florida Panhandle Study Area according to the baseline scenario.

An Onshore Base for Operations and Maintenance Rather Than Exploration and Development

The specialized needs of offshore exploration and production are likely to be addressed from states with established services such as Texas, Louisiana, and Alabama, rather than Florida. However, an onshore base would be used during the operation and maintenance portion of any offshore oil and gas development. Because some of the needs have to be supplied by services outside of Florida, potential impacts likely will be different from those associated with oil and gas development. The direct socioeconomic impacts likely will be smaller than those that have occurred in the Western and Central Gulf of Mexico. We estimate that even if a support base develops, only about half of the supplies would be obtained from the Florida Panhandle.

Projected Levels of Production Relatively Small

The projected levels of OCS development and production from the proposed leases in 2001 are small compared to the projected production levels from leases in the Western and Central Gulf of Mexico scheduled for auctions in 1997-2002. Analysis of the MMS estimates shows that the maximum production of both oil and gas from the proposed leases for the Eastern Gulf will each be about two percent of the maximum expected from the Western and Central Gulf. Figure F2.4 compares production estimates for the three regions.

Adjustment made for Commuting Offshore Workers

Another factor to consider is that an adjustment needs to be made for commuting offshore workers in the MMS Model. Gramling and Brabant (1986) estimate that 70 percent of offshore workers live more than 100 miles from where they meet to go offshore (i.e., an onshore support base). If an onshore base were located in Panama City or Pensacola, these commuting workers and their families would not spend their incomes in the Florida Panhandle. This adjustment is made in the model.

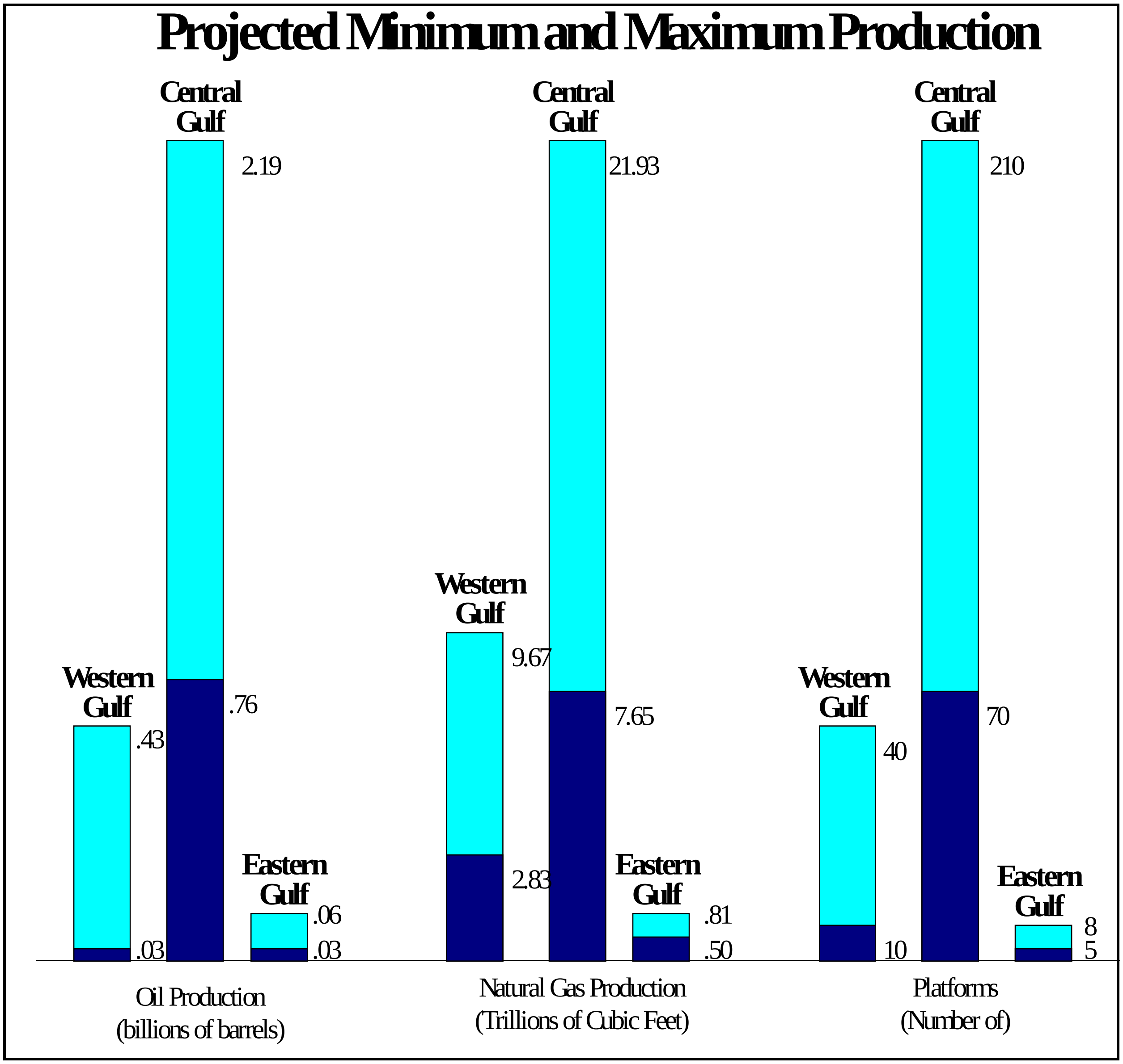

Figure F2.4. Projected minimum and maximum production in the Gulf of Mexico.

QUANTITATIVE ANALYSIS OF IMPACTS USING THE MODEL

Five types of impacts quantitatively analyzed were the economic, demographic, public services, fiscal and social.

Economic Impact

The maximum production estimates, referred to as the "Reasonable Maximum" scenario, and minimum production levels, referred to as the "Minimum Threshold" scenario, became the basis for estimating OCS expenditures in the impact area.

The assumptions used for the model are as follows: for Lease Sale 181, the oil production is assumed to start in 2010, peak in 2020, and end by 2040. The peak economic impact will occur in 2020 if either Panama City or Pensacola hosts an onshore base. For the Destin Dome project, the start would be 2000, with a peak in 2005, and an end in 2020.

At the peak employment year, there would be 229 to 584 new jobs attributable to Lease Sale 181, while Destin Dome would create 735 to 1,087. Some $35.9 to $70.5 million output would be due to Lease Sale 181, and $75.6 to $86.4 million output attributable to Destin Dome, over the 20 to 25 years of the projects.

New jobs attributed to Lease Sale 181 in the peak year are from 0.1% to 0.5% of total yearly employment. New jobs created by Destin Dome would be from 0.5% to 1.0% of total yearly employment in the peak year.

Impact of Lease Sale 181 on the total economy of the community where the base would be located would range from .004 - .02% of the total baseline output of the area over project life. Destin Dome would contribute 0.1% to 0.3%.

If both Lease Sale 181 and Destin Dome 26 used a Florida Panhandle onshore base, the maximum impact would be between .667 - .50% of the total output over the 25- and 20-year life of the projects.

Demographic Impact

The Florida Panhandle will continue to experience the substantial demographic and economic growth that it now faces. Against this backdrop of inmigration, the population increase due to location of an onshore base was viewed as small. As noted earlier, the population increase would be less than 2% of the increase due to inmigration from 2000 to 2035.

Public Service Impact

Increasing economic activity and population growth resulting from offshore energy development typically leads to growing demands on a variety of public services. Service and infrastructure effects have been described as falling primarily into two categories: (1) transportation—new/improved roads, seaports, and airports, and (2) provision of new housing, schools, and related services required by the increased local population. However, given the model estimates we have of the small increases to be expected for population and employment, we conclude these small increases will also occur for public services.

Fiscal Impact

Closely related to the public service effects are concerns about fiscal impacts, particularly for local governments. One concern has been expressed in California that existing residents and taxpayers do not subsidize any financial impacts to the county, municipalities, and public service providers within the county as a result of oil and gas development. In Scotland measures were taken to insure a favorable fiscal outcome for their area. These included (1) the County Council retaining 50% of the shares in the company building and operating the major oil terminal, (2) collecting taxes on every barrel of oil passing through the terminal, and (3) stockpiling some of the funds to minimize impacts as oil activity declines.

Leistritz *et al.* (1985) discuss some of the fiscal effects of oil development in Alaska. Oil development led to substantial increases in the tax base of the North Slope Borough. Oil development also had important implications for state revenues, which allowed increases in state government spending for a variety of purposes.

However, in relation to the impacts expected from the location of a supply base on the Florida Panhandle, the model predicts that a low relative increase in the need for public services, on par with the small increases expected in population. This low relative increase is because increases in the need for public services are largely driven by the size of the increases in population. However, at present tax rates, it is not apparent that OCS development will “pay its own way.”

Social Impact

Some communities have experienced extreme dependence on the oil and gas industry. A series of boom and bust cycles has been shown to be related in some communities to rates of criminal cases, homicides, and suicides. However, other factors such as social networks and education have been identified as possible moderating influences. Regardless, the small increases in population and employment expected if an onshore base is located in the Florida Panhandle tend to minimize any adverse social effects from the presence of the base.

QUALITATIVE IMPACT REPORTED BY THE STAKEHOLDERS REPRESENTING TOURISM, MILITARY BASES, THE PORT FACILITIES, THE FISHING INDUSTRY, AND OTHER CONCERNS

Tourism

The development of the Florida Panhandle as a major tourist area began in the mid-1930s and grew rapidly after the Second World War, becoming what is now a key industry there. “Sugar-white” beaches, fishing, other water-based activities, and natural habitats are key parts of the tourist experience in the Florida Panhandle, a type of tourism known as ecotourism. In the mid-1990s, the area attracted 10 million visitors annually who generated $1.5 billion of business.

The small base being planned should ensure minimal direct user-conflicts between the tourism industry and the support base. However, the “sugar-white” beaches and clean water are vital to the local economy. There are worries about environmental degradation. The benefits are viewed as very small compared to the risks. Several stakeholders expressed concern that even a small base servicing a few platforms could grow over time and transform the aesthetics of the area. One expression of this concern is the idea that an onshore base would be “the camel’s nose under the tent.”

As a result, some tourist stakeholders are extremely hostile to the idea of any offshore oil and gas development and related onshore support bases. Strong peer pressure exists in the Florida Panhandle to oppose anything related to OCS development.

Ecotourism is important to the local economies, and its importance is increasing. Perception of the area having “sugar white” beaches and clean water is vital to the ecotourism in the area.

Stakeholders are worried that even the perception that the Florida Panhandle has suffered degradation of the environment or of the aesthetics of the area could reduce tourism and retiree inmigration. Tourism stakeholders view the benefits of an onshore support base as very small compared to their perceived risks from an oil spill or other environmental degradation.

The Military Bases

The concerns from the military bases involve the fact that support boats and helicopters based in the Florida Panhandle would cross a heavily-used aerial operations area of the military bases. Boats and helicopters based in Mobile would not. There was some concern expressed by the Coastal Systems Station in Panama City about how additional boat traffic might interfere with operations if the support base grew beyond a certain size.

The military bases have had a substantial presence in the Florida Panhandle since World War II. The four main military installations in the study area are the Pensacola Naval Air Station, Eglin Air Force Base (Fort Walton Beach), Tyndall Air Force Base, and the Coastal Systems Station (both in Panama City).

The military bases employ about 30,000 military personnel and more than 15,000 civilians in the Florida Panhandle economy, accounting for 8.6% of all nonfarm employment in 1995, compared with only 1.5% in the United States as a whole. These bases were largely untouched by the downsizing of the military in the 1990s and are expected to remain an important part of the Florida Panhandle economy for the foreseeable future.

The three air bases use the Northern Gulf of Mexico as a weapons testing and training range. The Department of Defense can put stipulations on any oil leases that the MMS sells, which would put the onus of any user-conflicts on the oil industry rather than the military bases.

These are the five types of stipulations the military bases have regarding Oil/Gas Drilling Leases. These concern scheduling, sheltering, and evacuation.

The Port Facilities

Both the ports of Panama City and Pensacola are located away from the beaches. These port facilities would benefit from hosting an onshore support base. The Port of Panama City does have industry associated with some aspects of offshore production.

The two port facilities are both well-suited to house a support base. This is because both offer deep water harbors, and each has adequate storage space. A support base would employ about 10 persons, most of whom would be locals. Offshore workers would assemble at the service base to go offshore. There would be from five to eight platforms. Helicopters would make about 1,248 round trips per year. Supply boats would make about 288 trips per year.

Neither port facility is a large load center nor superport, and both have largely been passed by in the competition among ports for container business. The ports of Pensacola (ranked 78th) and Panama City (ranked 62nd) in 1995 were among the top 100 U.S. ports in the dollar value of goods exported. They ranked 120th and 100th, respectively, in the value of imports.

Fishing

The commercial fishing industry employs around 700 people in the Florida Panhandle. In 1995, fishermen in the area landed 8.9 million pounds of fish and 2.4 million pounds of shellfish. RPC did attempt to contact several representatives of the fishing industry in Florida but had no responses from any of them.

Though the commercial and recreational fishing industry have well-known benefits and conflicts with offshore rigs in the Gulf of Mexico, our research did not uncover any major user-conflicts with onshore bases that would be located in one of the two port facilities.

To summarize, the conflicts are several. First, only a small part of the state’s coastline is available to the public for recreational fishing. Second, environmental degradation is a threat. This can involve threats to the water quality and ecosystem integrity. Third, there may even be interference with normal fishing operations. For example, some shrimpers have contended that discarded oil field trash makes some areas unavailable for shrimping. The placement of pipelines can cause loss of fishing equipment.

The one benefit cited of OCS activity is that oil production platforms act as artificial reefs around which a large number of fish can be found. The recognition of the importance of these structures has led to the building and placing of artificial reefs using a variety of discarded structures throughout the Gulf area.

Other Stakeholders

The business sector is favorable, liking the economic benefits. Several business stakeholders believe the industry to be clean. Governor Chiles' office believed that the risks of a support base and offshore drilling are not worth the benefits.

Concerns among stakeholders in the area's tourism industry about the risks of offshore oil and gas production have lent support to the Governor of Florida's public position that the federal government should not sell new oil and gas leases in Florida federal waters within one hundred miles of the Florida coast.

The MMS reported that on 12 June 1998, President Clinton withdrew from leasing, through 30 June 2012, all areas in the Eastern Gulf of Mexico located outside the Sale 181 (scheduled in 2001) area as identified in the Final Outer Continental Shelf 5-Year Oil and Gas Leasing Program 1997-2002.

Few economic incentives are present to drive OCS support industries into the Florida Panhandle at the projected levels of OCS development in the Eastern Gulf of Mexico because support bases are most efficient when close to offshore wells. According to industry sources, Pascagoula, MS, and Theodore, AL, have enough spare capacity to service all current or proposed projects in the Eastern Planning Area of the Gulf of Mexico.

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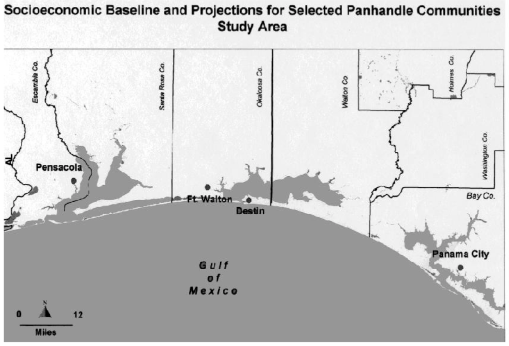
RPC

Research & Planning Consultants, Inc.
Austin • Tallahassee

Study Objectives

- To develop a base line socioeconomic description for Panama City, Pensacola and the Fort Walton Beach areas
- To develop projection models that allow MMS and others to project possible socioeconomic effects of various onshore support scenarios on these communities

Study Area



Socioeconomic Baseline and Projections for Selected Panhandle Communities
Study Area

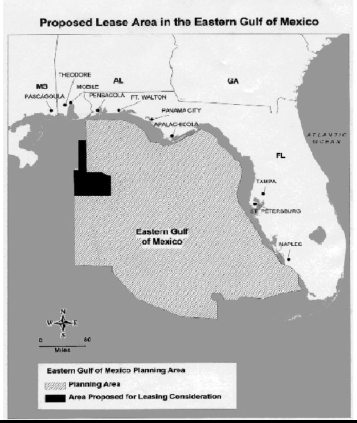
Project Description

- Collect data and information on three Florida Panhandle communities to develop a baseline socioeconomic description
    - Pensacola (Escambia and Santa Rosa Counties)
    - Ft. Walton Beach (Okalossa and Walton Counties)
    - Panama City (Bay Country)
- Design and develop projection models to assess the impact of possible OCS onshore support activities on these communities
- Assess the potential impacts of OCS onshore activities on four special industries:
    - Military Bases
    - Tourism
    - Port Facilities
    - Sport & commercial fishing

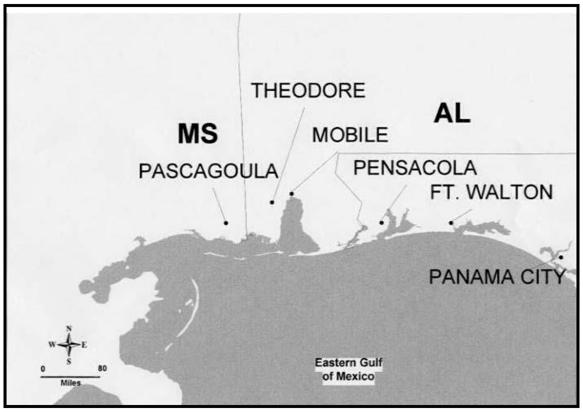
Presentation Objectives

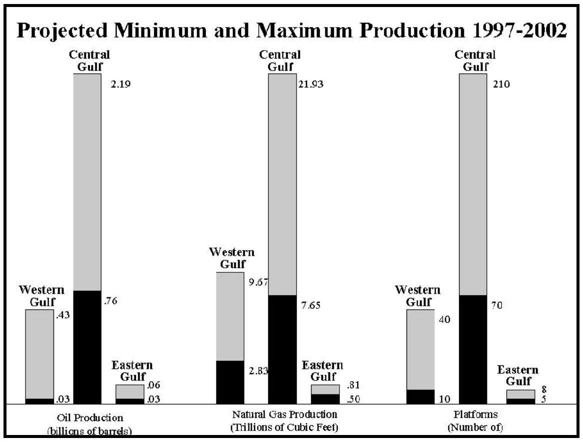
- Discuss lease sale 181
- Identify economic stakeholders and issues
- Explain spreadsheet model
- Present findings

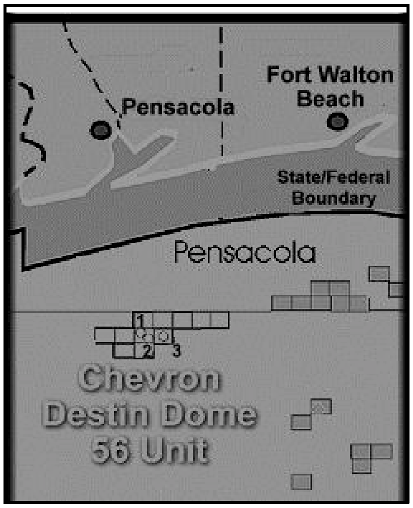
Lease Sale 181



Proposed Lease Area in the Eastern Gulf of Mexico




Projected Minimum and Maximum Production 1997-2002



Economic Stakeholders & Issues: Data Collection and Baseline Identification

- Field trips to Florida Panhandle
- Interviews with:
  - Economic stakeholders
  - Industry representatives
- Baseline economic data - BEA, BEBR, Florida government agencies
- Update MMS socioeconomic database

Primary Research

- Interviews with economic stakeholders
- Interviews with industry representatives
- Supplement literature review and secondary data collections

Stakeholder Interviews

Stakeholders	Contacted	Interviewed
Business Associations / Chambers	3	1
Fishing	3	0
Federal	2	2
State	6	3
County	5	0
Municipal	4	1
Regional Planning Council	1	1
Military	5	4
Oil	3	2
Ports	2	2
Charter Boats	2	2
Committees / Councils	3	2
Environmental	4	2
Parks	3	2
Resident Associations	3	2
Other	1	0
Total	**50**	**26**

General Conflicts and Benefits

- Business sector is favorable, liking the economic benefits and believing the industry is clean.
- Governor Chiles' Office believed that the risks of a support base and offshore drilling aren't worth the benefits.

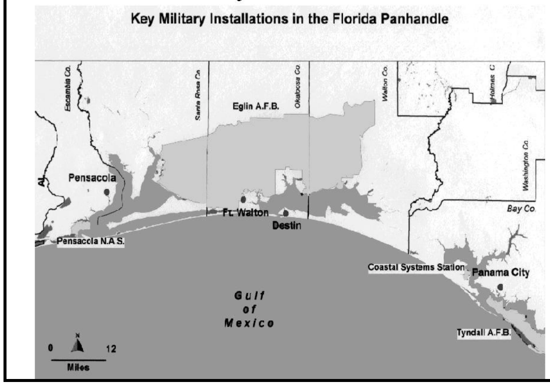
Economic Stakeholders

- Tourism industry
- Military bases
- Port facilities
- Sport & commercial fishing

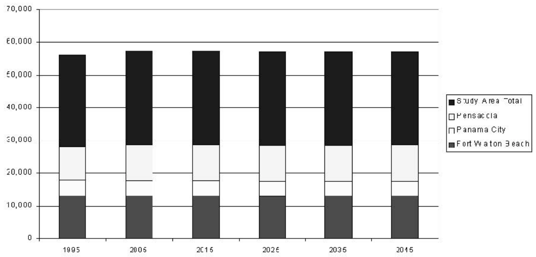
Tourism: Conflicts and Benefits

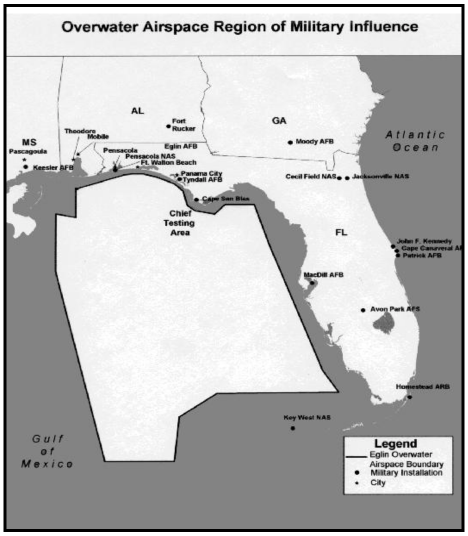
- **Direct user-conflicts with a small onshore support base seem small. A larger base could cause direct user-conflicts in Panama City.**
- **"Sugar-white" beaches and clean water are vital to the local economy.**
- **Tourism industry believes that tourists might vacation elsewhere if a support base were located in the Florida Panhandle.**
- **Tourism industry views the benefits of a support base as very small for perceived risks.**
- **Tourism industry is extremely hostile to any offshore oil and related onshore support bases.**

Military Installations



Military Employment





Military Conflicts and Benefits

- Florida-Based boats and helicopters would cross a heavily-used aerial operations area, while Mobile-Based boats and helicopters would not.
- Coastal Systems Station (in Panama City) is concerned a large support base would cause problems.
- The DOD can put stipulations on MMS leases

Military Stipulations on MMS Leases

- Schedule all air traffic through test wing scheduling
- Schedule all surface/boat traffic through test wing scheduling
- Schedule all electronic emissions through test wing scheduling
- Sheltering agreement
- Evacuation agreement

Port Facilities: Selected U.S. Ports Ranked by Total Tons

Rank	Port Name	Total Tonnage
4	New Orleans, LA	89,441,772
11	Tampa, FL	55,333,607
14	Mobile, AL	49,120,007
105	Panama City, FL	2,878,245
122	Pensacola, FL	1,674,188

Ports Suitable for Onshore Bases

- Pensacola and Panama City are well-suited
  - **Deep water harbors**
  - **Adequate storage space**
- Base would employ about 10 people; all but two could be locals
- Offshore workers would depart from the service base (going to 5 to 8 platforms)
- 24 helicopter roundtrips weekly (1,248 roundtrips per year)
- 24 boat roundtrips monthly (288 trips per year)

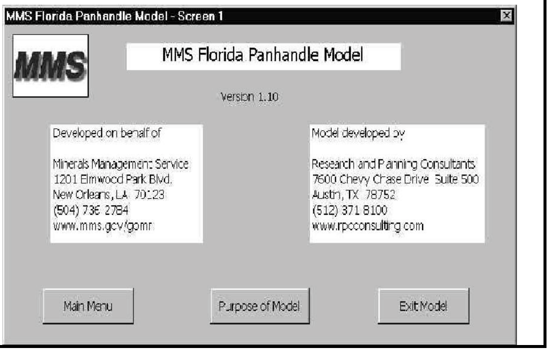
Port Facility Conflicts and Benefits

- Both Panama City and Pensacola are located away from beaches.
- The ports would benefit from hosting a support base.
- Panama City has industry associated with offshore production.

Sport & Commercial Fishing: Conflicts and Benefits

- Only a small part of coastline available for recreational fishing
- Threat of environmental degradation
- Interference with normal fishing operations
- Oil production platforms attract a large number of fish

Spreadsheet Economic Model



MMS Florida Panhandle Model

Version 1.10

Developed on behalf of

Minerals Management Service
1201 Elmwood Park Blvd.
New Orleans, LA 70123
(504) 736 2784
www.mms.gov/gomr

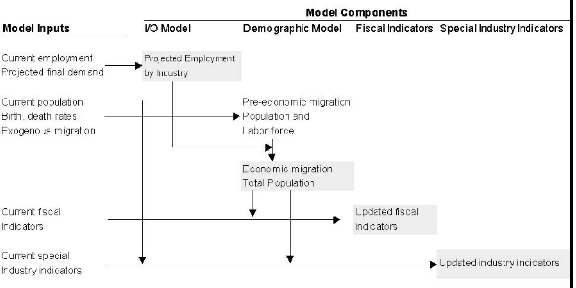
Model developed by

Research and Planning Consultants
7600 Chevy Chase Drive Suite 500
Austin, TX 78752
(512) 371 8100
www.rpcconsulting.com

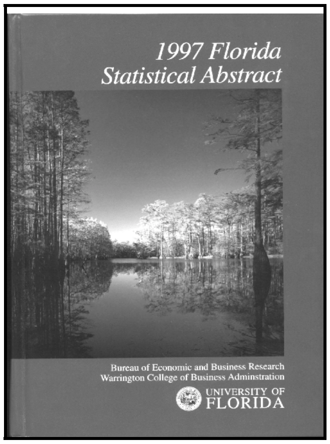
The Model Projects:

- Population by age cohort
- Change in population by component
- Employment & output by industry
- Local government revenues and expenditures
- Special industry indicators

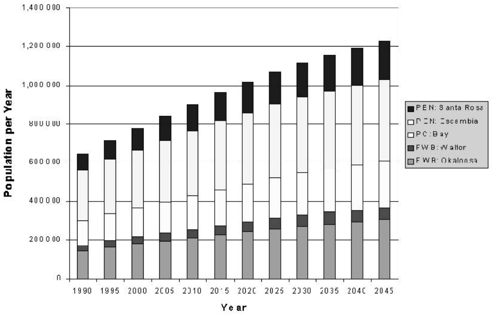
Model Schematic



Boxes show model outputs



Baseline Scenario Population



Annual Net Migration into Three MSA's

Year	FWB	Panama City	Pensacola	Total
Avg. 1980s	1,487	2,056	2,361	5,904
Avg. 1990s	2,306	1,100	3,993	7,398
2000	1,466	1,250	4,267	6,983
2005	1,554	1,406	2,804	5,764
2010	1,599	1,483	3,032	6,114

Note: These data exclude Walton County
Source: Florida Bureau of Economic and Business Research
"Florida Long-Term Economic Forecast: State
and MSAs," 1997

Private Housing Starts in the Florida Panhandle

Year	Bay	Escambia	Okaloosa	Santa Rosa	Walton	Total
Avg. 1980s	1939.80	2371.30	1969.20	1043.40	715.80	8039.50
Avg. 1990s	1060.83	1390.67	1655.83	1259.83	617.50	5984.67
2000.00	1067.00	1495.00	1621.00	1166.00	397.00	5746.00
2005.00	1401.00	1682.00	1809.00	1236.00	492.00	6620.00
2010.00	1328.00	1895.00	1856.00	1192.00	446.00	6717.00

Source: Florida Bureau of Economic and Business Research,
"Florida Long-Term Economic Forecast: State
and MSAs," 1997

Model I/O Sectors

- Commercial Fishing
- Other -Agriculture
- Maintenance and Repair of Oil and Gas Wells
- Other - Mining
- Construction
- Durable & Non-Durable Manufacturing
- Air & Water Transportation
- Other - Transportation, Communications & Utilities
- Wholesale Trade
- Eating & Drinking Places
- Other - Retail Trade
- Hotel & Lodging Places
- Equipment Rental & Leasing Services
- Amusement & Recreation Services
- Engineering, Architectural Services
- Accounting, Auditing & Bookkeeping Services
- Research, Development & Testing Services
- Other - Services
- Federal Government - Military
- Other - Government

Goal of OCS Development Scenario

- Provide the means for defining OCS development scenarios
- Input the scenarios into the Economic, Demographic and Fiscal models
- Answers questions people have about "what-if"

Approach to OCS Scenario Development

- Identify characteristics of OCS support industries
- Review experience with offshore development in Gulf of Mexico
- Key informant interviews
- Define OCS scenarios

Florida Support Base Operations and Maintenance Expenditures

Sector/Item	Percent Total Spending for Base
Other oil and gas services*	18.4%
Water transportation	4.0%
Air transportation	3.8%
Eating and drinking places	1.7%
Miscellaneous equipment rent / lease	1.4%
Environmental and engineering services	14.7%
Accounting / miscellaneous business services	4.2%
Test / research services	4.5%
Total for Florida Panhandle onshore base (compared to 100% for a typical onshore base)	52.6%

Quantitative Impacts Analyzed using the Model

- Economic
- Demographic
- Public Service
- Fiscal
- Social

Reports Generated by the Model

- OCS Scenario Report
- Baseline Report
- Population Report
- Output and Employment Report
- Fiscal Balance Report
- Schools Report
- Public Services Report

MMS Florida Panhandle Model
OCS Scenario Report

Impact Area	Panama City	Scenario Name:	PC: Reason Max
Report Area	Bay County	Date:	November 23, 1999
Production Scenario in Lease Sale 181:	Reasonable Maximum	Destin Dome:	Not Serviced in Florida

Item	2010	2015	2020	2025	2030	2035	2040	2045
Oil and Gas Production in Eastern Gulf of Mexico								
Lease Sale 181								
Oil Production (Millions of Barrels)	0.6	1.8	3.3	2.7	2.4	1.5	0.0	0.0
Gas Production (Billions of Cubic Feet)	8.1	28.4	40.5	36.5	32.4	24.3	0.0	0.0
Destin Dome								
Oil Production (Millions of Barrels)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gas Production (Billions of Cubic Feet)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OCS Expenditures in Impact Area	2.2	7.3	11.2	9.8	8.7	5.2	0.0	0.0
Lease Sale 181	2.2	7.3	11.2	9.8	8.7	5.2	0.0	0.0
Destin Dome	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scenario Impact on Key Industries								
Tourism								
Percentage Change in Level	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Percentage Change in Growth Rate	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Military								
Percentage Change in Level	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
OCS-Related Activities								
Boat Trips from Service Base	288	288	288	288	288	288	0	0
Helicopter Trips from Service Base	1248	1248	1248	1248	1248	1248	0	0

Study Findings:
Economic Impact of Onshore Base

- **At the peak employment year, there would be 229 to 584 new jobs attributable to Lease Sale 181, while Destin Dome would create 735 to 1087.**
- **$35.9 to $70.5 million output due to Lease Sale 181, and $75.6 to $86.4 million output attributable to Destin Dome, over the 20 to 25 years of the projects.**
- **New jobs attributed to Lease Sale 181 in the peak year are from 0.1% to 0.5% of total yearly employment. New jobs created by Destin Dome would be from 0.5% to 1.0% of total yearly employment in the peak year.**
- **Impact of Lease Sale 181 on total economy of community where base located would range from four one-hundredths to two tenths of a percent of the total baseline output of the area over project life. Destin Dome would contribute 0.1% to 0.3%.**

Study Findings:
Demographic Impact:

- The population increase will be ***less than two percent*** of the expected increase due to immigration from 2000 to 2035.

Study Findings:
Public Service Impact

- Because population is the driving force behind increases in public services, and because of the small increase in population due to the projected impact of an onshore base, the model predicts a small increase in the need for public services.

Study Findings:
Fiscal Impact

- The model predicts a low relative increase in the need for public services, on par with the small increases expected in population. This is because increases in the need for public services is largely driven by the size of the increases in population.
- However, at present tax rates, it is not apparent that OCS development will "pay its own way".

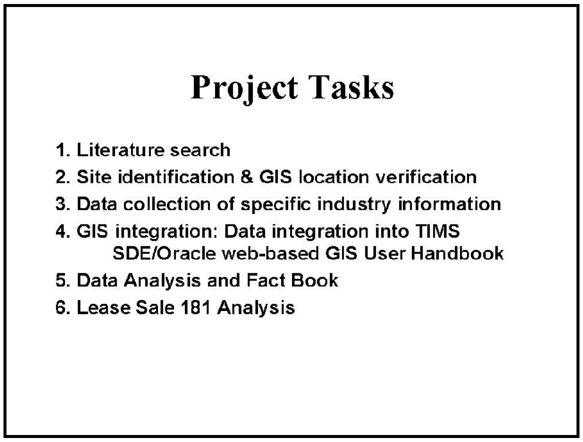
Study Findings:
Social Impact

- The small increase in population and employment expected if an onshore base is located in the Florida Panhandle tends to minimize any adverse social effects from the presence of the base.

New Project: Inventory of Offshore Support Infrastructure

- Project Team:
  - Louis Berger & Associates, Inc. (Prime)
  - Research and Planning Consultants, Inc.
  - National Ports and Waterways Institute (LSU)
  - LSU Energy Center

- Objective: to document pertinent data, including location, capacity, and capabilities, of different supply bases and other onshore infrastructure support facilities that serve MMS projects.



Project Tasks

1. Literature search
2. Site identification & GIS location verification
3. Data collection of specific industry information
4. GIS integration: Data integration into TIMS SDE/Oracle web-based GIS User Handbook
5. Data Analysis and Fact Book
6. Lease Sale 181 Analysis

Dr. Ronald T. Luke, President of Research and Planning Consultants, has worked as an economist, planner and policy analyst since completing undergraduate studies in 1970. During this time he has conducted planning and policy studies in most areas of the U.S. The studies include water resources planning, socioeconomic impact analyses, economic and demographic forecasting, environmental permitting, and development of coastal zone management policies. These studies have been on behalf of both public and private clients.

Dr. Eric S. Schubert has been an economist with Research and Planning Consultants since 1993. He has bachelors, masters, and doctorate degrees in economics from the University of Illinois at Urbana-Champaign. While at RPC, Dr. Schubert has developed regional input/output models for impact assessment and forecasting on projects in Alabama and Florida, and he has also regularly worked on projects involving regional economics in Florida.

Dr. Greg Olsson is Senior Consultant at Research and Planning Consultants. He has worked as a planner, policy analyst, and information systems manager for more than 13 years. His work includes demographic, health planning, and economic analysis, as well as analysis of very large data bases.

Dr. Hobson Bryan presently serves as Professor of Sociology, Department of Geography Regional and Urban Planning Program at the University of Alabama - Tuscaloosa. His teaching, research and consulting have included social impact assessment and policy analysis, with projects involving the social consequences of alternative resources. He has authored more than 80 publications in the fields of natural resource management, social assessment and social impact analysis.

Dr. Ray Burby presently is the DeBlois Chair in Urban and Public Affairs and Professor of Urban and Regional Planning, University of New Orleans. Dr. Burby's professional experience includes five years as the co-editor of Journal of the American Planning Association. Dr. Burby is the author of 12 books and more than 100 chapters, articles and monographs in the planning, management and environmental management fields.

Dr. F. Larry Leistritz is a Professor of Agricultural Economics at North Dakota State University with more than 25 years experience in socioeconomic impact assessment research and practice. His research and assessment experience has focused on socioeconomic impacts of resource and industrial development in rural areas. He has made presentations at conferences around the world and has authored 12 books and more than 100 journal articles and book chapters on impact assessment.

Dr. Steve Murdock is Professor and Head, Department of Rural Sociology, Texas A&M University, as well as Chief Demographer, Texas State Data Center, State of Texas. Dr. Murdock is the author of nine books on the determinants and consequences of demographic and social change and of more than 100 technical articles and book chapters on the demographic and social impacts and implications of resource development and environmental. He has extensive experience in the conduct of socioeconomic assessments of the Gulf Coast Region and has served on the OCS Scientific Advisory Committee for the Environmental Studies Program of the Minerals Management Service.

REGIONAL ECONOMIC STIMULUS OF COASTAL ALABAMA EXPLORATION AND DEVELOPMENT

Dr. William W. Wade
Mr. Jason Plater
Foster Associates, Inc.
Columbia, TN

COASTAL ALABAMA NATURAL GAS EXPLORATION AND DEVELOPMENT

Following the 1979 discovery of Norphlet gas in Mobile Bay, the Coastal Alabama region experienced the emergence of a large offshore gas industry. A report by Foster Associates, *Historv of Coastal Alabama Natural Gas Exploration and Development*, (MMS 99-0031), documents the history of leasing, exploration, development and production of natural gas offshore Coastal Alabama in state and federal fields, and projects likely future development and production.

After nine years of regulatory delay, MobilProduction, Inc.'s first well encountered natural gas at 21,113 feet 28 November 1979, having discovered Norph let formation gas. At the apex of America's Energy Crisis, Mobil had discovered a giant gas field in 14 feet of water in America's backyard. The Coastal Alabama/Panhandle Florida Norphlet trend would later become one of the most important U.S. natural gas producing regions.

Between 1981 and 1984, Alabama leased tracts in state waters for $800 million in bids. MMS leased tracts in federal Mobile OCS waters between 1982 and 1985 for $562 million in bids, $1.36 billion combined state and federal. The State of Alabama set up a perpetual trust fund to ensure that the state would continue to benefit from interest on the lease proceeds. At the end of FY 1998, the balance of Alabama's trust funds had grown to more than $1.5 billion, having increased with production royalty payments. Annual interest from the funds, averaging about $100 million since 1986, had grown to nearly 140 million at the end of FY 1998, accounting for more than 10% of the state's general fund. Foster forecasts that interest earnings plus tax revenue collections will grow to over $200 million annually by 2008. The trust funds and interest earnings will continue to grow so long as gas is produced from state and nearby federal 8(g) waters, and their principal will never decline.

Seventeen Norphlet wells were spudded between 1981 and 1984, 13 of which became gas discoveries—extraordinary accomplishment before 3D seismic revolutionized offshore exploration. Through year-end 1997, 75 Norphlet wells had been drilled in state and federal waters off Coastal Alabama: 28 exploration, the balance delineation and development wells. These wells discovered 20 gas fields. Twenty Norphlet discoveries for 28 exploration wells represents a 71% success ratio. All but three discovered fields were producing gas at year-end 1998.

Only a few oil and gas companies have risked the hundreds of millions of dollars and years of lead times necessary to bring the Norphiet into production. Mobil's Mary Ann Field began production in 1988, nine years from first discovery to first production. Shell's Fairway Field started up in late

1991 along with Mobil's federal 823 Field, ten years after the lease sales. Exxon started its three fields in late 1993,12 years after the 1981 lease sale.

Union and Chevron have become the dominant operators in acreage developing the eastern and western edges of the Mobile OCS. Chevron took nine years from its first Norph let discovery in Mobile 861 in 1985 to first production in 1994. Alabama state and federal production surpassed I BCFD for the first time in February 1997. Forthcoming and planned Alabama wells will take Norphlet and Miocene production to 1.4 BCFD by 2000. Destin Dome production, planned to start in 2001, will sustain regional production near 1.6 BCFD through 2004, before production from discovered fields goes into decline. Cumulative production is forecast to total about 9 TCF from discovered Norphlet and Miocene fields by 2015. Operators' remaining discovered reserves show that all but Shell will produce Norphlet for many years into the future.

ECONOMIC EFFECTS

The emergence of a large offshore gas industry in the Coastma region during the early 1980s spawned thousands of jobs in Mobile County, state of Alabama, Louisiana, and Texas. Foster Associates' report, *Economic Effects of Coastal Alabama and Destin Dome Offshore Natural Gas Exploration Development and Production* (MMS-2000-044), estimated the economic effects of the offshore gas industry on Mobile County, the state of Alabama, and the combined economies of Louisiana and Texas resulting from Alabama state, Mobile OCS, and forthcoming Destin Dome OCS natural gas exploration, development and production.

Total gas industry spending on exploration, development, and infrastructure to fully develop existing Coastal Alabama fields will total close to $4 billion. Expenditures for ongoing operations and maintenance will add over $3 billion more through 2020—on top of the $1.4 billion paid to Alabama and the federal government for offshore leases.

The state of Alabama and coastal counties will spend close to $6 billion through 2020 from trust fund earnings and tax revenues—almost as much as the operators will spend to develop and produce the gas resources. Because the principal in the trust funds is never drawn down, spending of trust fund earnings will provide a sustained and large economic stimulus to Alabama long after gas reserves have been exhausted.

Spending on exploration and development in the Destin Dome OCS will extend for another five years the significant offshore gas industry infrastructure investments, and related onshore economic effects in the Gulf region.

Coastal Alabama gas development has supported at least 7,000 jobs Gulfwide annually since the early 1980s. During the early 1990s, employment created by Coastal Alabama natural gas rose to nearly 14,000 annual jobs. Planned development activity for Destin Dome will cause another spike in offshore gas industry-related employment during 2000-2001, boosting Gulfwide employment from offshore gas activities over 10,000 once again.

Spending by the natural gas industry has added between 2,000 and 3,000 FTE jobs to Mobile County since the early 1990s. Spending of state trust fund earnings and tax revenues has sustained over 6,000 jobs since th early 1990s. Regional employment from offshore gas production will be sustained well into the 21 century as Norphlet fields, including the forthcoming Destin Dome field, continue high production levels. Tax and trust fund interest spending will sustain statewide employment over 7,000 FTE indefinitely according to Foster's forecast.

COASTAL INDUSTRIES COEXISTENCE

Foster Associates' report, *Economic Baseline of the Coastal Alabama Region* (OCS Study MMS 98-046), analyzed the interplay among three major users of the region's coastal natural resources: tourism, fishing and offshore natural gas. Tourism and natural gas industries grew up together post-Hurricane Fredric (1979) stimulating economic growth in Coastal Alabama and the rest of the state of Alabama. The economic evidence shows that both industries have been extremely beneficial to the local coastal region and to the State of Alabama.

The cities of Gulf Shores and Orange Beach along Alabama's Gulf Coast are home to a densely developed tourism and second-home industry Gulf Shores experienced rapid growth throughout the 1980s. The total volume and value of construction in Orange Beach, east of Gulf Shores, grew ten-fold from 1991 to 1995. Baldwin County sales tax revenues to the state have grown by more than 300% since 1979, totaling about $20 million in 1995. It leads the state in lodging tax collections.

The offshore natural gas industry in Alabama is over 15 miles away from the bulk of Gulf Shores development and nearly 25 miles away from Orange Beach. No platforms can be seen from the tourist areas of Baldwin County except in the Fort Morgan vicinity on the western tip of the Gulf Shores peninsula. Support bases for the gas industry are on the western side of Mobile Bay, in Mobile County.

The recreational fishing industry along Alabama's coastal region relies on a healthy and abundant marine supply. The natural gas industry has enhanced the quality of fishing. The presence of offshore gas structures, which act as artificial reefs, has benefited the party boat charter fleet and other recreational anglers. Commercial fishing, staged mostly from Bayou La Batre, has not been affected by the natural gas industry.

Tourism tax receipts are important to the state budget, but earnings from offshore gas development are a much larger source of revenue to the state.

William W. Wade is Senior Vice President of Foster Associates, Inc. He received his Ph.D. in agricultural and resource economics from the University of Minnesota. Dr. Wade has been involved in energy- and environmental-related research since 1973 and associated with offshore exploration and development issues for the last 20 years. He was principal investigator for economics for all of the MMS OCS Petroleum Development Scenario studies funded in the Alaska Socio-Economics Study Program (SESP) during the period, 1978-1983, and project manager for the 1984 MMS deepwater California OCS Petroleum Development Assessment. The MMS Alaska studies led to related studies of Beaufort Sea and Bering Sea onshore facilities siting and impact evaluations.

Dr. Wade has worked on Gulf of Mexico OCS studies since 1994, first for Chevron on its Destin Dome project and subsequently for MMS GOM. He is Project Manager of a three-phase study completed for MMS, Gulf of Mexico. Three reports have been issued:

- *Social and Economic Consequences of Onshore OCS-Related Activities in Coastal Alabama*;
- *History of Coastal Alabama Natural Gas Exploration and Development*;
- *Economic Effects of Coastal Alabama and Destin Dome Offshore Exploration and Development*.

He is currently working on the social and environmental impacts of the next Five-Year Leasing Plan, 2002-2007. In other recent petroleum industry research, Dr. Wade developed for Shell Western E&P a model of California's onshore petroleum producing fields by producing district capable of estimating annual production related to changes in the wellhead price. This model is linked to IMPLAN models of the producing districts to estimate the economic effects of the changes in the oil patch—jobs and taxes. The results of this research were instrumental in demonstrating that the proposed Btu tax would have had significant negative effects on California's oil producing industry. Dr. Wade served as project manager for the 1993 Division of Oil and Gas study of *The Cost of Regulatory Compliance* in the producing sector. This study yielded a data set showing the range in costs of regulatory compliance by producing district and pinpointed regulatory overlap. Dr. Wade worked on economic and environmental protection trade-offs in Santa Barbara during the mid-1980s dealing with the risks of oil spill in the tankers-versus-pipeline controversy.

Jason Plater is a Senior Resource Economist at Foster Associates, Inc. He received his M.S. in environmental and natural resource economics from the University of California, Davis and his B.A. in economics from the University of Florida. His specialty is development of computer models to assess economic and financial aspects of natural resource projects and policies. Mr. Plater was a principal investigator throughout the three-phase Gulf of Mexico study. He took the lead in analyzing onshore and offshore constraints to expanded OCS natural gas production in the Gulf of Mexico. He developed a 25-year production forecast for offshore natural gas production in the Gulf of Mexico utilizing historical production data, estimates of total reserves, and planned pipeline gathering system capacity. The gas production forecast, combined with estimates of offshore operator spending on exploration and development, infrastructure installation, and ongoing operations and maintenance provided the input data Mr. Plater then used to forecast regional employment, population, and income from the offshore gas industry in the Gulf.

Mr. Plater has also participated in a Chevron study to determine economic impacts and constraints associated with offshore gas development in the Gulf of Mexico. His spreadsheet-based model was used to analyze impacts of offshore gas development on employment, personal income, and population. The model allows for changes to inputs such as gas field reserves, pipeline transmission capacity, and onshore treatment capacity to examine onshore changes with economic multipliers.

THE COASTAL DIVISION OF INDUSTRIAL LABOR OVER TIME AND SPACE: CONTINUATION AND EXPANSION OF A COMMUNITY STUDY

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SUMMARY

We are using Coastal Marine Institute (CMI) funding for continued research on a small community in Southwestern Louisiana (Abbeville) and extending the scope of our initial work to test hypotheses derived in a previous community study. Previous CMI-funded research on census places in coastal Louisiana indicates that Abbeville experienced relatively less of the economic upheavals often associated with the downturn of the oil and gas industry in the early 1980s. Our findings suggest that the industrial base in the Abbeville area, unlike that in most oil and gas dependent locations, is diverse. This industrial diversity is reflected in part by relatively large routine manufacturing and producer services sectors. This producer services sector is largely oil and gas-related as Abbeville appears to be a center for operations and logistics.

These findings are particularly relevant to oil and gas interests and community leaders. First, the closure of the one of the largest manufacturing plants in the area (Fruit of the Loom) has led to the displacement of a large number of workers. Although oil and gas activity was a direct cause of economic disruptions in Louisiana coastal communities during the 1980s, it is possible that it has the opposite effect more recently. Second, the presence of a large oil and gas-related producer services sector in the Abbeville area suggests the existence of a division of labor within the oil and gas industry over space and time. Such divisions of labor typically result in uneven economic development. In this study, we are using community field study techniques to continue our focus on the Abbeville community. But, we also employ important, confidential longitudinal establishment and household data to analyze the distribution of coastal industrial labor over time and space. In doing so, we hope to identify other coastal communities which exhibit robust responses to episodic volatility in the oil and gas industry and the factors that contribute to their resilience. This project will provide information to the MMS, coastal communities, and oil and gas stakeholders that will enhance their ability to assess and predict economic impacts of renewed oil and gas activity, including deepwater development, on local economies.

This is a two-year, intensive project involving both Louisiana Population Data Center faculty and graduate students. We draw on the following:

- the Center’s traditional data resources and technical strengths
- our increasing expertise in community-level socioeconomic development, and

- a newly developed working relationship with the Center for Economic Studies (CES), U.S. Bureau of the Census

INTRODUCTION

This project continues our research on a small community in Southwestern Louisiana and expands the scope of our initial work to test hypotheses derived from our community study. Abbeville, a small town in rural Vermilion Parish, appears to be particularly resistant to the income volatility generally associated with periods of increasing and decreasing oil and gas development activities. Previous CMI-funded research on census places in coastal Louisiana indicates that Abbeville experienced relatively fewer of the economic upheavals often associated with the downturn of the oil and gas industry in the early 1980s (Tolbert and Shihadeh 1995). Subsequent community-based research on Abbeville suggests that its resiliency during the 1980s reflects a historical and cultural legacy that fosters rich social resources, facilitates economic development, and yields a local industrial structure that enables it to weather economic disruptions (Tootle, Tolbert and Shihadeh 1999). Our findings suggest that the industrial base in the Abbeville area, unlike that in most oil- and gas-dependent locations, is diverse. This industrial diversity is reflected in part by

- relatively large routine manufacturing

- extractive (agriculture), and

- producer services sectors.

This producer services sector is largely oil- and gas-related, as Abbeville appears to be a center for operations and logistics.

These findings are particularly relevant to oil and gas interests and community leaders. First, the shutdown of the one of the largest manufacturing plants in the area (Fruit of the Loom) means that a large number of workers have been displaced. Although oil and gas activity was a direct cause of economic disruptions in Louisiana coastal communities during the 1980s, does it have an opposite effect today? Can oil and gas activity in the 1990s counteract economic downturns associated with other industrial sectors? Second, the presence of this large oil and gas-related producer services sector suggests the existence of a division of labor within the oil and gas industry over space and time. Such divisions of labor typically result in uneven economic development. In this study, we use community field study techniques to focus once again on the Abbeville community. But, we also employ important, nonpublic longitudinal establishment data to analyze the distribution of coastal industrial labor over time and space. In doing so, we hope to identify a cadre of coastal communities that exhibit robust responses to episodic volatility in the oil and gas industry.

Thus, building on our earlier Abbeville community study, we identify two foci for further research:

1. how oil and gas activity might offset some of the economic downturns associated with other industrial sectors (especially manufacturing), and

2. whether spatial and temporal divisions of labor within the oil and gas sectors similar to those of Abbeville exist elsewhere along the Gulf coast and the implications of these divisions for coastal communities.

FRAMEWORK

Socioeconomic conditions are primarily dependent upon patterns of industrial organization. Local economies are based on the allocation of employment across distinct industrial sectors. Each sector is associated with different working conditions, opportunities and job outcomes (Lobao 1990). Industrial organization theory generally divides industries into extractive, manufacturing and service categories. The manufacturing and service sectors can be further divided into four more discrete sectors, defined on the basis of the magnitude of the complexity of their operations and earnings/benefits of workers: complex and routine manufacturing, and producer and consumer services (McGranahan 1988). In general, complex manufacturing and producer services are associated with higher wages and stable employment while routine manufacturing and consumer services are associated with lower wages and unstable employment.

In rural areas (where much of the oil and gas activity is staged), sound economic performance is often a function of a diversified economy. This diversification tends to produce consistent economic growth. Specialized economies, on the other hand, can expand rapidly but are particularly vulnerable to local and national level swings in the economy. Because of a division of labor across space, most rural areas tend to specialize in low-wage routine production (such as that found in Fruit of the Loom) and consumer service sector jobs. Typically dominated by a single industrial sector, these communities are vulnerable to business cycles and foreign competition, which encourage capital flight (Bluestone and Harrison 1982; McGranahan 1988).

Because diversified local economies are not dependent on any single sector source of employment and earnings, they are better prepared than more specialized economies to weather the economic downturns associated with specific industries (Killian and Hady 1988), such as the impending shutdown of the Fruit of the Loom plants throughout southwestern Louisiana (Acadiana). Abbeville, unlike many of the communities in Acadiana, is not solely dependent upon Fruit of the Loom. Oil and gas activity is an integral part of its industrial structure and may help counter the economic downturns associated with Fruit of the Loom’s flight to the Caymen Islands by either absorbing some of the surplus labor from the Fruit of the Loom plants or increasing local earnings.

Because of the tendency for rural areas to specialize in routine manufacturing and consumer services, the industrial organizational and rural research literatures pay very little attention to producer services in rural areas. It is readily apparent that producer services in rural areas are closely associated with a dominant industrial base, such as mining (Glasmeier and Howland 1995). However, it is not at all clear how these linkages develop across time and space. The Abbeville area differs from other oil activity centers because it appears to be more of a center for oil field logistics and operations than it is for oil field fabrication. We think that the concentration of oil-related producer services in Abbeville is a major factor in Abbeville’s resiliency to the decline in oil and gas activity. For the most part, these oil-related producer services firms remained active, albeit at a diminished rate, throughout the 1980s. However, we currently do not have the necessary spatial and temporal data to examine and compare the distribution and differential impact of oil and gas activity across time and space.

The foregoing discussion raises a number of questions: How may specialized service firms are there in Abbeville? How long have they been there? Have these oil and gas service establishments agglomerated in identifiable clusters or is there considerable regionalization or spatial dispersion among them? Lastly and most importantly, are these firms sufficiently embedded in the local economy to assist in cushioning the impact of a major plant closure or some other episode of economic volatility? Answering questions of this sort requires a combination of qualitative and quantitative data and methods that we outline in the following section.

METHODOLOGY

With CMI funding, we are conducting research that will help us develop a better understanding of how oil and gas activity contributes to local economic diversity. Our work entails:

1. examining the potential for oil and gas employment to compensate for the loss of employment with Fruit of the Loom, and

2. determining whether a spatial and temporal division of labor exists within the coastal oil and gas sector, and the socioeconomic implications for coastal communities.

This is an in-depth, multi-method study that encompasses community field study and procedures and comparative techniques that permit analysis of enterprise-level data over time and space.

Field Study

We are using field study techniques to determine whether expanding oil and gas employment opportunities might counter some of the economic challenges facing the community with the loss of employment at the Fruit of the Loom plant. This type of analysis requires more in-depth analysis than we can conduct with existing place or establishment level data. The use of field research for gathering detailed information in a specific location is a long-standing and highly significant, but often overlooked, tradition in the social sciences. However it is one of the most effective means of collecting data that reflect social processes, such as economic adaptation, at the community level (Orum, Feagin and Sjoberg 1991). One of the major advantages of using a field study methodology is that it involves the collection of data from various sources and covers numerous time periods, allowing the systematic analysis of social patterns and processes unavailable from more conventional cross-sectional and aggregated data collections. In this study, we gather information from state and local economic development officials, oil and gas stakeholders, and social support agencies to determine if the increased oil and gas activity is compensating to any extent for the loss of Fruit of the Loom employment.

We are conducting guided conversations (Lofland and Lofland 1995; Snow and Anderson 1991; Tootle, Tolbert and Shihadeh 1997) with those people who can best contribute to our understanding of whether and how employment in the oil and gas industry compensates for employment lost to the closure of Fruit of the Loom. A guided conversation consists of a face-to-face conversation with key contacts. In guided conversations, discussion with key contacts is "guided" by a series of topics relevant to the issue(s) being addressed. This somewhat unstructured technique is particularly useful in preliminary stages of community investigations when researchers are in the process of "discovering" information because researchers are not subject to the constraints of prior assumptions. In some cases, the topics that we discuss with contacts emerge from previous guided conversations. This means that to some extent we sacrifice elaborate research design for research opportunities (Fitchen 1991). We try to elicit information on employment and socioeconomic changes associated with plant closure. In this study, we are talking to those people who are knowledgeable about the impacts of the FOL plant closure on the community, as well as the ability of the local labor force to absorb former FOL employees and/or their dependents.

Our group of potential respondents includes individuals who were directly or indirectly affected by oil and gas development (oil and gas stakeholders—see Gramling, *et al.* 1995), community (business, civic, and local government) leaders, and agents within various social support services. However, as is often the case in the beginning of field research, the population and the units of analysis are somewhat ambiguous, making sampling frames difficult to construct (Babbie 1979). However, following the lead of Janet Fitchen (1991), an anthropologist known for her work in rural communities (and plant closings), we are relying on a type of nonprobability sampling technique, referred to as purposive sampling. In community studies, investigators often use nonprobabilty sampling designs. A nonprobability sample is legitimate, and often preferable to probability sampling in small studies, especially where the probability of selecting an element from the universe is unknown, such as when the universe consists of respondents who are knowledgeable about a particular issue. In many community studies, investigators use snowball sampling, a process in which the investigators begin with an initial list of key informants and subsequently ask each informant to name another person (or persons) who is knowledgeable about the issue in question. A problem with the snowballing technique is that it can compromise the internal validity of a study if snowballing does not lead to a diverse enough group of respondents. Therefore, we depend primarily on another type of nonprobability strategy, the purposive sample, and incorporate elements of systematic selection into it where possible.

We are building upon our previous work in the community. We have in place sampling frames of oil and gas stakeholders and community leaders. We constructed the stakeholder sampling frame from existing lists of stakeholders; we used phone, city and parish directories and membership lists. Oil and gas stakeholders, and members of the business community were pulled from Yellow Page listings and the membership lists of the Greater Abbeville-Vermillion Parish Chamber of Commerce. We included owners, operators and managers of businesses with direct and indirect linkages to the oil and gas industry. We compiled a sampling frame of community leaders from city and parish government lists (i.e., Abbeville City Council, and Vermilion Parish Police Jury) and augmented it with names of community leaders mentioned frequently in the newspaper for the last year. We have constructed a sampling frame for social service agents from existing lists. Within each category of respondents we use some form of systematic selection as we did in the previous study. Because most of the stakeholders are also members of the community, our three sets of respondents are not mutually exclusive.

During the guided conversations, we have taken field notes on laptop computers and expanded our field notes immediately following. We tape conversations if the respondents are comfortable talking with a tape recorder running. These techniques help us maximize the conversational aspects of the interviews (Lofland and Lofland 1995). All of our contacts are guaranteed confidentiality.

We meet frequently to discuss the progression of the research. Days in the field are followed by debriefing sessions whenever possible. During this time we can discuss our experiences, methodology, and emergent issues and findings. In this way, we can take advantage of the flexibility inherent to field work, and determine which new directions we need to take. This phase of the data collection process will be completed when we are turning up no new information (Babbie 1979).

We supplement and verify the information that we generate through the guided conversations with secondary data collection. The secondary data help us determine past and present economic conditions, verify events, and provide more information on social processes. We collect these data from a wide array of historical and current records and written documents. These records include data compiled and published by the Abbeville-Vermilion Parish Chamber of Commerce, the Abbeville Harbor and Terminal District, and the minutes of the Abbeville City Council, most of which are published in the *Abbeville Meridional*. The *Meridional* has been printed since the 1850s and the Louisiana State University Library has most of the issues on microfiche. In addition to collecting secondary data from the city, we also attend public meetings, such as the Abbeville City Council and appropriate task force meetings.

Analysis of our data which will be conducted this winter will employ an emergent process based on what Lofland and Lofland (1995) refer to as a “derivative ordering” of the data and gradual induction, an admittedly ambiguous concept. Nonetheless, there are several tangible strategies that we will use to ensure a systematic analysis of the data. These strategies include forming propositions, codifying , or categorizing and sorting, the data into conceptual (theoretical and relational) categories, elaboration of the coding categories, systematically assessing the conditions under which events occurred, and possibly diagraming the social relationships and processes. Conceptual categories will be suggested, but not limited, by the original research questions: (1) social and economic changes associated with oil and gas activity, (2) responses to those changes, and (3) the social relationships and processes that led to these responses. In the second year of the project, we will use PC software especially designed for qualitative analysis wherever feasible. Such software should be particularly useful in codifying and presenting the data.

Analysis of Enterprise Data over Time and Space

We believe our findings in the Abbeville case study are sufficiently robust to recommend a hypothesis for testing on other communities. The hypothesis is based on our observation of a thriving producer services sector in the Abbeville economy. Are similar service sectors evident in other coastal communities? Can such sectors be shown to be statistically related to the desirable outcomes we have observed in our Abbeville research?

To adequately assess the development of a producer services sector in Abbeville and other coastal communities, we are developing models of the coastal division of industrial labor, comparing socioeconomic outcomes for coastal areas with varying industrial and service sector compositions over time. We are especially interested in the extent to which industrial divisions of labor similar to that of Abbeville exist in other coastal communities. Assuming we can identify areas with similar industrial profiles, we will analyze socioeconomic outcomes and compare those to the results we have in hand for Abbeville.

To accomplish this modeling task, we need data on the location and age of establishments, as well as very detailed industry classifications. These data requirements surpass readily available public data sources such as *County Business Patterns* or published versions of data from the Economic Censuses. While these data compendia are generally very useful, they frequently do not report data for small areas and small numbers of establishments to ensure confidentiality. Such establishment-level microdata are not in the public domain, but are being accessed through an agreement with the Center for Economic Studies, U.S. Bureau of the Census (CES).

The current research here would permit us to broaden initial ongoing work at CES to include longitudinal data with great geographic detail on the all-important producer services sector. Researchers who work under agreement with CES are permitted to analyze confidential establishment and household microdata from the various economic censuses (e.g. Census of Manufactures, Census of Services, Census of Minerals Industries) and decennial population censuses. The data provide very detailed geography for georeferencing, and access to them is highly regulated. Researchers must receive Special Sworn Status. Moreover, all analysis must be done at CES. We are not be permitted to remove data from the premises, unless is is model-based (i.e., in the form of regression coefficients or the like). However, all database development work at CES is archived and made available to researchers through CES facilities.

CES has developed a longitudinal establishment register (SSEL) which can be used to track the origin and longevity of establishments. The SSEL also provides detailed industrial classification (six-digit SIC codes) and establishment type (single- vs. multiple-unit) information. Access to these data represents a significant step forward for socioeconomic analysis. All previous work of which we are aware has necessarily been based on public domain data, which are often suppressed for reasons of confidentiality and which do not contain information on establishment age or type. By contrast, establishment microdata at CES contain no suppression and constitute the universe of U.S. establishments. We are using these data to develop a longitudinal database on coastal oil and gas producer services for all states adjacent to the Gulf of Mexico.

Establishment microdata from the Census of Minerals have been of particular interest to us. We are the first researchers at the Center for Economic Studies to have used the minerals census data. We discovered early on that the data contained only state-level geography. However, we have been able to improve greatly on the geography by matching establishments in the census data to establishments in the business register file (SSEL). Subsequent researchers will have access to a file with much more geographic detail. This is a very useful by-product of our ongoing work at the Center.

We have also gained access to long-form data from the 1990 decennial Population Census. Unlike “PUMS” or public-use files which are small samples, we have access to all 40+ million long-form responses to the 1990 Census. In focusing on the Gulf Coast region, we can report that a wealth of data exist. For example, there are more than 1900 completed long questionnaires for the Abbeville area. We gained access to these data earlier this fall and will continue to work with them through the coming year.

Working with these data resources at CES, we are developing models of the coastal division of industrial labor, comparing socioeconomic outcomes for coastal areas with varying industrial and service sector compositions over time. We are especially interested in the extent to which industrial divisions of labor similar to that of Abbeville exist in other coastal communities. We are identifying areas with similar industrial profiles and are analyzing socioeconomic outcomes and comparing them to results we have in hand for Abbeville. Ultimately, we hope to conclude with some sense of the likelihood that other communities have industrial mixes that buffer them from episodes of increasing and decreasing oil and gas industry activity.

POST-SCRIPT

Our three-year acquaintance with Abbeville has left us impressed with the community's resilience in coping with an oil and gas industry downturn and the closure of a large manufacturing establishment. One of our prevailing explanations is the substantial proportion of the local economy involved in agriculture, especially large-scale rice production. It is this sector of the local economy that has most recently experienced a downturn. Commodity prices for rice products have plummeted in the last two years, partly as a result of the Asian economic crisis. Far fewer acres are in rice production in Vermilion Parish than just a few years ago. Economic stress is evident, especially among local banks (as opposed to regional and national banks). While rice production accounts for a relatively small share of local employment, the decline in production may set off a series of events that ripple through the local economy. Our presence in the community uniquely positions us to monitor and compare this consequence to others that we have chronicled. We look forward to presenting empirical results at next year's ITM.

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LABOR MIGRATION AND THE DEEPWATER OIL INDUSTRY

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INTRODUCTION

The principal objective of this project is to assess the impact of international immigration on port communities in the state of Louisiana, where deep-sea offshore drilling has rapidly increased labor demand since 1995. The increase in activity is in part due to technological advances in oil extraction in shallow and deep water (Abernathy 1996), and a decline in the economic risks associated with offshore oil production. Although Louisiana has not been a common destination area for U.S. immigrants in the past, many Mexican migrants reportedly are working in ship and fabrication yards in Louisiana port cities. Their growing presence is consistent with nationwide changes in the economic and social mobility of immigrants. Several studies emphasize the consequences of immigration in new receiving areas throughout the United States (Massey and Durand 1997; Murphy and Dameron 1997; Rees 1997; Taylor, Martin and Fix 1997).

This research project examines consequences of the new immigrant presence in three Louisiana port communities situated along the Gulf of Mexico. It aims to gain an in-depth understanding of the major issues that communities face when they import many foreign laborers to meet a strong demand for labor. In addition, it describes how immigration affects community life and predicts how it may continue to do so in the future.

The project builds on previous insights that emerged from a study of immigrants in rural communities throughout the United States since 1990 (Taylor, Martin and Fix 1997). In southeastern California, for example, new agricultural markets that emerged due to changes in irrigation technology and water distribution have attracted many Mexican migrants. Their increased presence created an enormous housing crisis, which produced an impressive community response leading to the acquisition of millions of federal dollars to build new, low-cost housing in areas where none existed just five years ago. In Iowa, as the meatpacking industry restructured in the early 1980s, it increasingly relied on ethnic labor—first Vietnamese and other Indochinese refugees, and then, one decade later, Mexicans. Unlike Coachilla Valley in California, the small Iowan communities had enough reasonably-priced housing to meet the needs of new immigrants. However, the key challenge for immigrant integration in these small communities was overcoming the language barrier, and having enough educational resources to teach English to both children and adults. For this project, I use these findings plus those from my own fieldwork of Mexican migrant communities in Forest Hill, Louisiana, in Houston, Texas, and in Oceanside, California, to compare the lessons learned in Louisiana port communities to those in other parts of the United States.

Although recent case studies suggest that the face of rural America has become increasingly foreign because rapid growth in certain industries has created a shortage of qualified workers for many jobs, virtually no studies have examined this process using a comparative case study design. This is not surprising, given that immigration to many rural areas has occurred only since 1990, and that U.S. immigrants were concentrated in just a handful of states and localities before then (U.S. Department of Justice 1997). Therefore, in this study, I explore differences in immigrant adaptation and integration in three communities whose economies are linked to recent surges in oil production and extraction.[2]

The project involves two separate, but related, components. It involves data collection from residents, community officials, employers, and immigrants to provide key insights about the impacts of new immigration on Louisiana port cities. Included in this effort is data collection about the three different communities and their salient attributes, such as economic behavior, educational opportunity, and average income. Second, it involves the analysis of these data to identify the ways in which new immigrants integrate and accommodate to local contexts, the roles that employers play in facilitating integration, and what communities and employers do to improve or mitigate impacts.

SPECIFIC RESEARCH QUESTIONS

From in-depth case studies of three port cities, I address the following questions.

1. How many immigrants are working in these communities? In what occupations and specific industry sectors are they located? What are the characteristics of their jobs (salaries, length of labor contract, etc.)?

2. What are the salient characteristics of this migration flow? What are the critical factors pushing and pulling immigrants to these port cities? From where do they migrate—other places in the United States? Or do they migrate directly from their national origins? What kinds of social networks are they linked to?

3. What best affects the success of immigrant integration–the size of the immigrant population, its characteristics, the amount of community resources, other community attributes, the situation and attitudes of community residents, or some combination of these? What does this suggest about community efforts necessary to improve the pace of integration–should housing, jobs, education or crime, for example, be tackled first?

4. Some studies suggest that smaller cities and rural communities are different from cities like Los Angeles, where immigrants are tightly concentrated at the top and bottom of the skill and earnings distribution. In smaller places, without role models, immigrants may not be confined to low-wage jobs. Do small communities with no prior history of immigration confine immigrants to low-wage jobs, or do they offer a diverse set of opportunities to new immigrants?

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[2] As mentioned earlier, the PI will further strengthen its comparative design by comparing its results to findings from a project in Forest Hill, LA, where many Mexican immigrants have found jobs in the nursery business, and in Houston, TX, and San Diego, CA, where the PI has recently completed fieldwork on a different, but related, project.

5. Which type of immigrant integration is occurring in the community? Why? What are the major factors affecting integration in this community, e.g. jobs, housing, schooling? What public policies are most important in regulating the speed and extent of integration in the community, e.g. housing for families, jobs for adults, or education for children?

6. What are the major issues—advantages and disadvantages—that communities face when immigrants become part of the local labor force? How do communities view immigration, and why do they have these views? How would these issues change if the inflow of new immigrants were stopped, significantly reduced, or increased into the community?

7. Do employers and communities have preferences about who is hired for jobs? If so, what are they, on what bases were they formed, and how have they changed over time? What implications do the preferences have for workers in these communities in the future?

8. What are the costs of immigrants to communities? For example, do decentralization and block grants affect immigration patterns in these communities, and if so, how? Is it helpful or harmful to allow local leaders to decide how to spend assistance funds, and what implications do these policies have for local communities? Do the new welfare restrictions on the eligibility of legal and illegal immigrants affect the costs of immigrants in these communities?

9. Finally, what solutions may be implemented to resolve the problems communities face?

ECONOMIC AND SOCIAL CONSEQUENCES OF IMMIGRANTS

In this section, I review findings from prior studies about immigrants and their communities in the United States. As you will see, immigrants usually produce two types of effects. The first is economic and involves issues related to employment, labor markets, and the education of immigrants. The second set refers to social consequences and concerns issues related to social service use and English language competency.

Although there is no accepted definition of immigrant integration, when two or more groups share a geographic area, two extremes are possible. Boundaries between groups may be eliminated by encouraging convergence in language and values, or cultural diversity may be maintained by establishing ethnic enclaves. Social scientists have long studied how the salience of group boundaries and its attributes (such as contact, identification, commitment, and resource competition) are sustained. For example, when individuals perceive between-group competition to be high, then boundaries between groups may become more salient (Hogg and Abrams 1988; Tajfel 1981). This often leads to activities commonly observed in immigrant enclaves: greater identification with the group; more intra-group cohesion, conformity, loyalty, and commitment (Grant and Brown 1995; Hogg and Abrams 1988; Tajfel 1978, 1981); greater inter-group hostility (Bonacich 1972; Olzak 1989); and stronger perceptions of out-group homogeneity resulting in stereotyping of minority groups (Blalock 1967; Tajfel 1981).

Although the importance of ethnic enclaves has long been recognized in sociological studies (Nee 1991), past work has been limited to aggregated national data or to case studies of one traditional immigrant-receiving area in the United States (see Zhou 1993; Portes and Stepick 1993). The present study therefore represents a unique opportunity to understand whether and how immigrants integrate in local contexts by comparing their experiences in three settings: Morgan City in St. Mary Parish, New Iberia in Iberia Parish, and Port Fourchon in Lafourche Parish. Although all three actively participate in the manufacture of goods related to oil production and extraction, Table 2F.3 documents considerable differences by place.[3]

Table 2F.3. Selected characteristics of Morgan City, New Iberia, and Lafourche Parish: 1990 and 1995.

	Morgan City	New Iberia	Lafourche Parish
Race and Ethnic Composition			
% Black	22.8	33.3	13.0
% American Indian	1.0	1.0	2.0
% Asian	0.5	2.0	1.0
% Hispanic Origin	3.0	2.3	2.0
Population (1995)	14,985	33,101	87,625
Average Family Income	$27,368	$21,610	$24,219
% Below Poverty Line	24.0	28.7	22.9
Unemployment (1995)*	7.0	7.0	4.9

* Unemployment figures refer to St. Mary, Iberia, and Lafourche Parishes.
Source: U.S. Bureau of the Census, 1990 and 1995

Notable are differences in race and ethnic composition and economic activity. In 1990, for example, there was considerable heterogeneity in race and ethnic diversity across the three areas. Blacks comprised one-third of all residents in New Iberia in 1990, 23% of residents in Morgan City, and just 12% of those in Lafourche. Asians were by far most prevalent in New Iberia, whereas persons of Hispanic origin were more likely to be found in Morgan City and New Iberia rather than Lafourche Parish.

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[3] Note that data are not published for Port Fourchon because it is not a Census-designated place. Because an MMS study now in progress uses the same definition, I will consult with that PI to gain insights about how to define the population and boundaries of this community, and the new immigrants appearing in the workplace (Keithly, personal correspondence 1997).

Although differences in economic indicators appeared, the gap in family income and living below poverty line was biggest between Morgan City and New Iberia. In 1990, the typical family in Morgan City earned approximately $5,600 more than the average family in New Iberia, and the percent living below the poverty line was almost 29% in New Iberia compared to 24% in Morgan City. Most interesting was that unemployment did not differ significantly across these two areas. With respect to this dimension, the key contrast was between Lafourche Parish, where unemployment was just 4.9%, and the two cities, where unemployment rates were at least 7%.

Therefore, despite similarities in sector activity, there was considerable heterogeneity in the baseline attributes of communities. I expected it was related to the different ways in which immigrants integrate into U.S. communities. For example, in communities where the competition for resources between new and existing residents is direct and intense (i.e. unemployment is high), new immigrants have adopted enclave strategies. On the other hand, in places where the competition for resources is weak (i.e. unemployment is low), new immigrants integrated more freely into their local communities. Moreover, in receiving communities where there is little variation in ethnicity and/or race, community response to foreign migrant labor was more negative than in more diverse settings in part because the presence of foreigners threatens traditional forms of everyday life.

Sociological studies also indicate that employers use job queues to rank order potential employees for hire (Reskin and Roos 1990; Hodges 1973). Although this is a provocative idea in theory, in practice past studies have provided only indirect evidence of queuing theory (for an exception, see Kirschenman and Neckerman 1994). In our discussions with employers, we have asked about their hiring queues and how they have changed during periods of economic growth and decline. I am especially interested in understanding where Mexican migrants fit in these queues, whether employer's preferences toward Mexican workers are relatively new, and how they link to the growing demand for workers on deep-sea rigs.

In this project, I have also investigated the skills and education of foreign laborers. Together with secondary data from the U.S. Census, I examined the educational levels of immigrant and native U.S. workers and assessed the extent to which immigrants earn low wages because they have few skills. Although this situation has been documented in a recent study of Mexican migrants in Los Angeles (Waldinger 1996), it is now clear that this effect exists in new immigrant destination areas in southern Louisiana. But it operates differently than in large urban areas. In small port cities, immigrants' skill levels and hourly wages were considerably higher than those of their urban counterparts. For example, in August in Morgan City, an employer described his Mexican immigrant workers as high-skilled blue-collar workers, who, if experienced, were paid as much as $1,000 a week in August 1997. Nonetheless, most immigrant workers in these areas are contract (or day) laborers and do not receive benefits.

Despite high wages, many immigrants do not experience a lot of upward occupational or income mobility (Sassen 1996). Discrimination appears to be part of the story, but this is also explained by the fact that these communities represent specific local labor markets, and once linked to migrant origins, they have become close systems where only insiders have access to jobs. The result has been increased job access but limited mobility.

Another topic of interest is whether and how the economic rewards received by immigrants and worker displacement (if any) influences local communities. In theory, entrepreneurs, investors, and other owners of capital may be big winners. If employers are paying foreign laborers less than they would pay natives, then they may receive a higher return for a given capital investment. Furthermore, with an influx of new workers earning a reasonable wage, local economies and businesses are likely to flourish and new establishments are likely to open. So far, our results are consistent with this story.

The presence of immigrant workers also leads to social consequences. From the data, we have found that although some immigrants may be eligible for welfare, few apply for or use public assistance programs, including unemployment compensation or means-testing income transfer benefits, and essentially no one receives formal housing supplements. However, many migrants are housed by their employers—either informally or formally. In addition, we have found that when immigrants use health, education, and social services in these communities, their use has resulted in problems for the community because immigrant's use of Spanish creates problems for service providers.

Using our data, we have begun to consider the impacts of unauthorized immigrants on local communities. Although most studies agree that immigrants comprise a fiscal burden on local governments, there is disagreement about the size of this burden (Passel and Fix 1992). Using "best estimates" of the illegal migrant population, we are working on an estimate of the extent of this burden and where most of it appears–either at the doorsteps of elementary and secondary schools, or in issues related to housing. Guided conversations with school officials have furthered our understanding of educational impacts, and the extent to which they have created other concerns on the part of local communities, sometimes leading to ethnic tension.

METHODS

As mentioned earlier, I am studying three communities: Morgan City, New Iberia, and Port Fourchon. (Houma has been recently added as a fourth community.) Morgan City is a place with a unique geographic location and a long history of recruiting workers during periods of rapid economic growth. New Iberia also has a similar history, but it is a city that has more racial and ethnic diversity than Morgan City. Most immigration occurred after 1980, when Vietnamese and Laotian refugees resettled there. Port Fourchon is a very different place altogether, because it is an area without a city center and the typical infrastructure that supports it. These differences have resulted in differences in the use of migrant labor and the ways in which communities respond to immigrants.

Our methods are twofold. First, I rely on guided conversations with approximately 10 community leaders (such as the mayor, school board president, medical expert, and director of social services), 20 employers, and 30 immigrants to provide the basis for assessing the impacts of immigration (Lofland and Lofland 1995). This type of field research has been an effective means of data collection to capture the social processes underlying social science research (Orum, Feagin, and Sjoberg 1991; Tolbert and Tootle 1996). Second, I will rely on results from a telephone survey of

200 randomly selected households in each community.[4] Using CATI technology residing in the Louisiana Data Population Center, our survey lab will implement and supervise a household survey to all randomly selected households during spring 2000. This survey will be approximately 40 minutes in length, and it will included a wide variety of questions that tap the concerns stated above. Many of the questions derive from prior surveys designed by the principal investigator. Finally, we will randomly choose approximately 30 heads in each community from the households we surveyed for a final set of in-depth guided conversations.

Collection of new data is critical to the integrity of this project for two reasons. First, because the presence of immigrants is a very new phenomenon in these communities, 1990 data from the U.S. Census fail to capture the immigrants now settling in these areas. Second, although data from the 2000 Census will be useful in teasing out the effects of immigrant settlement, they will not become available until the year 2002 (at the earliest). Even more critical than the five-year wait, the 2000 Census data may miss the earliest community impacts as foreign laborers now begin to work and live in communities where they have no history.

Our fieldwork began in the summer of 1998. I implemented the guided conservation methodology with people who I expected would contribute best to our understanding of how communities respond to newly arrived immigrants. These included community officials involved in civic organizations and local government, and stakeholders such as employers and immigrant workers, of whom both have been directly affected by recent oil and gas development activities (Grambling *et al.* 1995). With permission from respondents, I have taped and recorded these conversations so that I have a comprehensive recording without the normal interruptions from taking notes (either on a computer or by hand). This practice has yielded better data and consumed less respondent time than other methods.

Conversations with employers have provided a critical part of the story, and one that has been difficult to obtain in the past because employers have been reticent about participating in projects such as this one. Luckily, we have avoided this problem in part because the PI has been supervising a project that involves employer interviews in Forest Hill, Louisiana, where many Mexican immigrants live as employees in the nursery business. This has given her some expertise on issues related to immigrant labor and private business in Louisiana.

As we have completed the conversations, I have worked with Dawn Robinson (associate professor in the Department of Sociology at LSU). She is well versed in a set of computer-based tools for representing and analyzing mental models of individuals using data from qualitative interviews (Carley 1988; Carley and Palmquist 1992). This methodology uses network techniques and Venn diagram logic to construct mental "maps" of individuals' knowledge structures, attitudes, and beliefs within a particular domain, and then statistically compares the overlap and departure among pairs

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[4] I prefer this method of interviewing community residents because I think it is efficient, cost-effective, and yields results that are easily replicable in the future. At the moment, I have begun the process to secure OMB approval to implement it. I will pursue OMB approval, but if it is denied, takes too long, or MMS decides it is too difficult, I will move to implement my second choice— conversations with a smaller, nonrandom sample of households in these communities.

of maps. The maps are represented as networks, allowing for clustering analyses and systematic comparison. From the recordings of the guided conversations, we have begun to employ these analytical techniques so that we can make explicit the internal representations of the social world implicit in respondents' spoken text. We will continue with this work throughout the next six months so that we can compare the mental representations of the new immigrants, employers, community leaders and residents, both within and across the three communities.

The author is grateful for support from Minerals Management Service, U.S. Department of the Interior.

FORECASTING THE NUMBER OF OFFSHORE PLATFORMS ON THE GULF OF MEXICO OCS TO THE YEAR 2023

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INTRODUCTION AND BACKGROUND

The last forecast available to the public of the number of new offshore structures that will be built and operated on the U.S. Outer Continental Shelf (OCS) was done in 1984 by a study committee organized by the National Research Council's Marine Board. The Marine Board's interest was the disposition of the platforms that would be retired and removed over the next 20 years. Installations of platforms and the total number of operating platforms were forecast only for five years (1985 to 1990) because such a forecast was needed to forecast the number of structures to be removed for the entire period (1985 to 2000). The Marine Board's forecast was based on the professional judgement of the committee members. Our forecast uses econometric and statistical methods to measure the relationship between economic activity and information and decisions to install or remove platforms.

A numerical forecast of offshore structures is relevant and useful for various purposes. For example, an important aspect of offshore platforms in the Gulf of Mexico is that they provide habitat for highly valued reef fish such as snappers and groupers. Such habitat is scarce in the Gulf. Offshore platforms have increased the total amount of reef habitat available by as much as 100% and have become important destinations for recreational fishermen and party boats. A forecast of the number of platforms installed, removed, and operating over the next 25 years will be useful to those responsible for planning, managing, and preserving fish habitat and fish stocks through artificial reefs and other management programs.

The internal content and mechanics of the forecast also are important. For example, the economies of coastal areas adjacent to offshore petroleum producing areas are affected in important ways by offshore oil or gas development. In our forecast, the decline in the number of operating platforms takes place because the number of platforms removed each year increases significantly above historical levels. The annual number of platforms installed, on the other hand, increases as well, albeit very slowly.

Since most of the platforms installed are expected to be larger platforms located in deeper water further from shore while more of the platforms forecast to be removed are smaller platforms located in shallower waters, expenditures on installing and operating new platforms and pipelines (as well as on removing old platforms) will dwarf expenditures lost as smaller platforms cease operating.

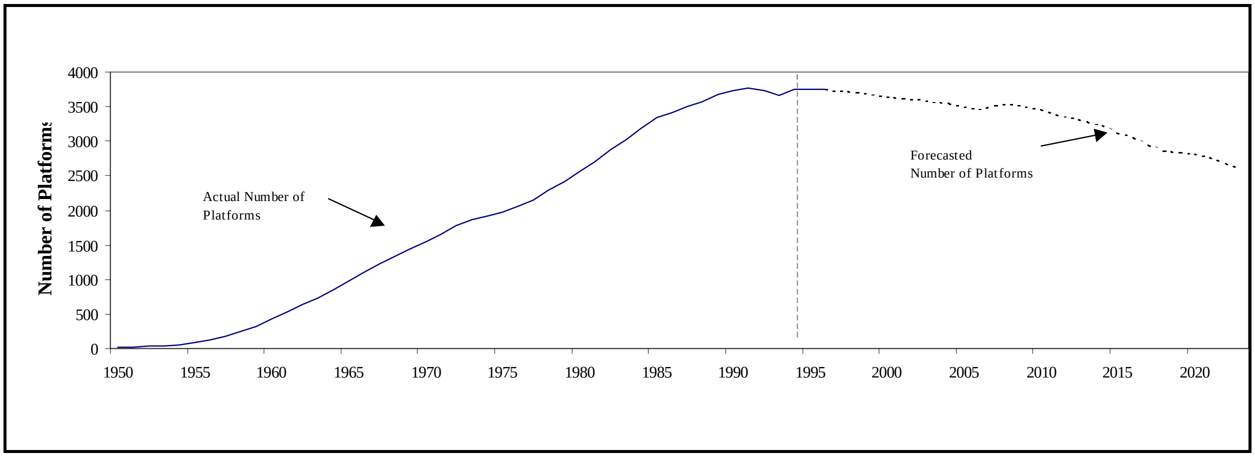

Figure 2F.5. Platforms operating on the Gulf of Mexico OCS.

Thus, the net effect on the economies of adjacent coastal areas may be quite positive despite the overall decline in the number of platforms operating.

In contrast, if the same decline in the operating platforms as in the reference forecast were to come about largely because of a decline in the number of platforms installed, with a more modest decline relative to the reference forecast in the number of platforms removed, such a decline would likely have a very significant negative effect on adjacent coastal areas.

METHODS AND RESULTS

The forecasts predict the number of new offshore structures to be installed, removed, and operated on the Gulf of Mexico OCS over the next 25 years–1999 to 2023. The forecasts were made by using econometric modeling techniques on historical data from1947 through 1996. The historical record and predicted path (under the most likely, or reference, forecast) of the number of platforms operating in the Gulf over the 1947 to 2023 time period are illustrated in Figure 2F.5.
The principal trends in the forecast are:

- A decline in the number of operating offshore structures from 3,687 to 2,612: a decline of about 29% over the 1999 to 2023 period.

- An annual average rate for installation of new platforms of not quite 142 per year: a total of 3,543 platforms installed over the 25-year period.

- Removal of old platforms at an annual rate of about 186 per year: a total of 4,645 structures removed over the period.

The model results on which this forecast were based explain nearly 80% of the variation in the historical values of the principal dependent variable–new offshore structures–and tracks very closely the historical trend in platform installations. Alternative forecasts, based on changing the values of the forecasting variables, did not result in major changes in the reference forecast.

Spreading the range of the values used for both the cumulative size of new oil and gas fields discovered and for the Energy Information Administration's forecast of oil prices had only a modest impact on the forecast. The high forecast (based on both oil prices and the cumulative size of new fields increased by two standard errors) predicted the number of operating platforms would decline by slightly more than 20%, as compared to 29% in the reference forecast. The decline in the corresponding low forecast was about 35%.

The forecast is made by forecasting the number of platforms to be installed and the number to be removed, with the difference being the change in the number of platforms operating. The platform installation relationship is specified as follows:

$$INS*_{t} = \beta_0 + \beta_1 \log(CFZ_t) + \beta_2 CPR_t + \beta_3 TEK_t + \beta_4 D86 + \epsilon_t$$

where:

INS^*_t = desired or planned number of installations in period t

CFZ_t = cumulative total field size at the beginning of period t

TEK = interactive variable between D86 and time trend

CPR_t = the average current crude oil price on the Gulf OCS

D86 = dummy variable, such that, D86 = 1 for time period after 1986 and zero otherwise

ϵ_t = independent random error term

The dummy variable D86 is included to capture the effects of changes in expectations and behavior of the oil and gas industry in the Gulf of Mexico OCS subsequent to the collapse of the world crude oil market in the summer of 1986.

A comparison of the fit of the estimated equation and the historical record of platform installation is shown in Figure 2F.6. The properties of the estimation are summarized in Table 2F.4. In order to use the equation to forecast platform installations, forecasts of cumulative total field size and of future crude oil prices is required. The Energy Information Administration's long term forecast was used for crude oil prices. The cumulative total field size (CFZ) estimate was made by using a discovery and a drilling model developed by Alan Dupont to forecast the size of new fields based on historical data.

A different, more purely statistical, approach was used to forecast platform removals. In essence, all possible "lags," *i.e.*, the number of years between the installation of a platform and its removal, were tested as independent determinants of annual platform removals. Iterative estimates found that an equation with lags of 33 years and 21 years was able to "explain" more than 95% of the observed variation in historical platform removals. Parameter estimates of the independent variables are also statistically significant. The mean absolute percent error and the root mean square percent error of the predicted values were relatively high at 22 and 21%, respectively. However these are measures of annual, short range accuracy and our objective was to estimate a long run trend. Figure 2F.7 plots the actual and predicted number of removed platforms for the period 1947 - 1997.

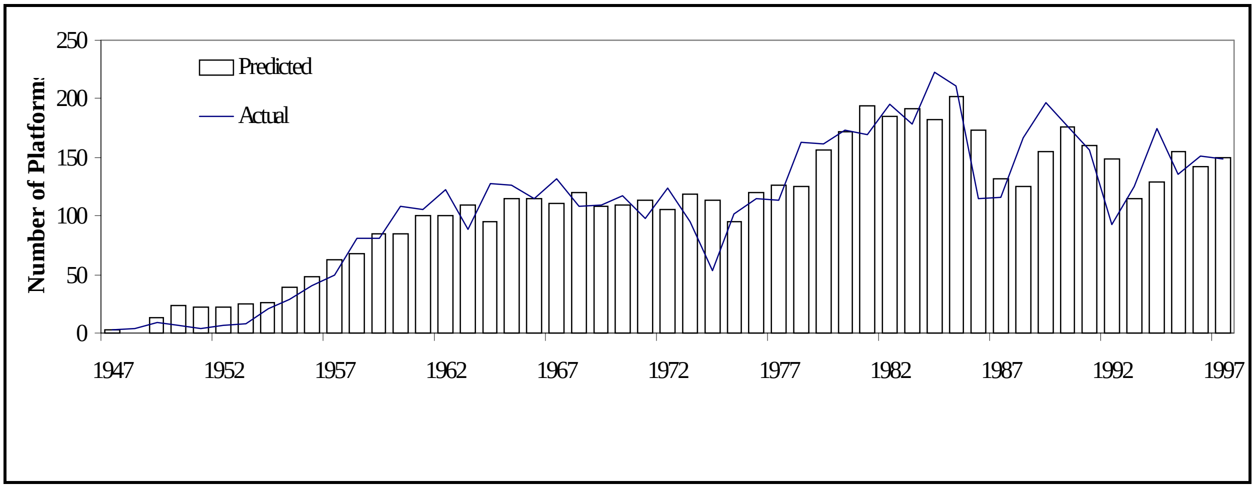

Figure 2F.6. Actual and predicted number of platforms.

Table 2F.4. OLS estimates of the Platform Installation Model (t-statistics in parenthesis).

Variable	Coefficient
Intercepts	-113.931 (-2.847)
Cumulative New Fields (CFZ)	16.618 -3.118
Average Current OCS Oil Price (CPR)	2.089 -2.416
Number of Platform Installed (INS_{t-1})	0.457 -3.641
Interactive Dummy	-0.163 (-0.706)
Observations	49.000
Adjusted R^2	0.791
Error of Regression	27.000

SUMMARY AND CONCLUSION

The use of an econometric forecast, tying platform installations to economic information and expectations, while using a statistical method which rests solely on historical data to forecast removals may be unorthodox, but, in our case, seems appropriate. Many external factors are involved in the decision to install a platform, but the determining factor is the expected productivity and profitability of the field the platform is intended to produce from. When production falls below profitable levels, the platform will be shut down and removed. When new fields are discovered, new structures will be installed if expected revenues exceed expected costs sufficiently to compensate the operator for the risk, uncertainty, and opportunity cost of capital inherent in the installation decision. Factors that increase expected revenues or decrease uncertainty and risk will accelerate installations; factors having the opposite effects will decrease installations.

The decision to remove a platform, on the other hand, is more tightly constrained. Economic and cash flow considerations may influence the timing of decisions at the margin, but regulations require structures to be removed within one year after production on the lease has stopped. Structures may be removed before that time if economic or technical factors so dictate, and operators may ask that removal be postponed, but the range of managerial discretion is much narrower than it is for installations.

The reference forecast, despite its hybrid ancestry, also fits fairly well with current industry trends and opinion. Although longer-term forecasting is not a topic to which the industry has paid much attention, a common industry view is that as exploration and production move into the deep (and deeper) Gulf, larger and more complex platforms will be installed. This, when coupled with advanced seismic imaging and directional drilling, means that more wells can be drilled from a single platform. On the other side, these same factors also make feasible the production of smaller fields in shallow and intermediate depth waters with smaller, simpler and frequently re-used platforms. Indeed, although about 80% of the approximately 1,500 platforms removed from the Gulf

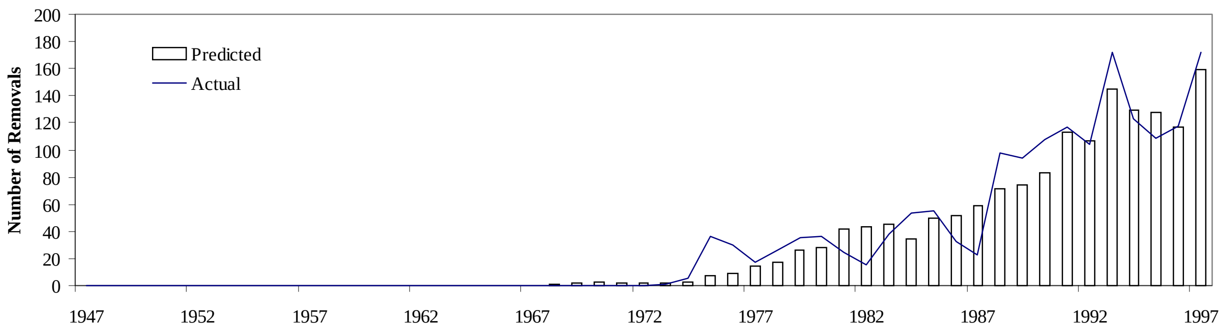

Figure 2F.7. Actual and predicted number of platform removals.

were non-major structures (major structures having at least six completed wells and two pieces production equipment) about 25% of the smaller, non-major structures were less than five years old. But the net result, in our view, is that shown in the reference forecast– a slow but steady decline in the number of platforms operating in the federal OCS Gulf of Mexico.

A slow and steady decline in the number of platforms does not necessarily imply a decline in oil and gas production or less economic activity related to the development of the offshore. Indeed, production per platform has increased since the early 1990s. As more and more production comes from the very large deep Gulf wells, we expect this trend to continue. Similarly, with the number of installations increasing, albeit very slowly, and expenditures to install each platform increasing as the proportion of larger platforms located in deeper waters grows, coupled with a significant increase in the number of platforms removed, economic activity associated with offshore oil and gas exploration and production is likely to increase.

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Qiaozhen Lucy Zhu was a Graduate Research Assistant at the Center for Energy Studies at Louisiana State University. She received her B.S. in economics and foreign trade from the Shanghai Institute of Foreign Trade in the Peoples’ Republic of China and an M.S. in economics from LSU.

SESSION 1G

TECHNOLOGY ASSESSMENT AND RESEARCH PROGRAM ACTIVITIES

Chair:	Mr. Paul Martin, Minerals Management Service
Co-Chair:	Mr. George Guillen, Minerals Management Service
Date:	December 2, 1999

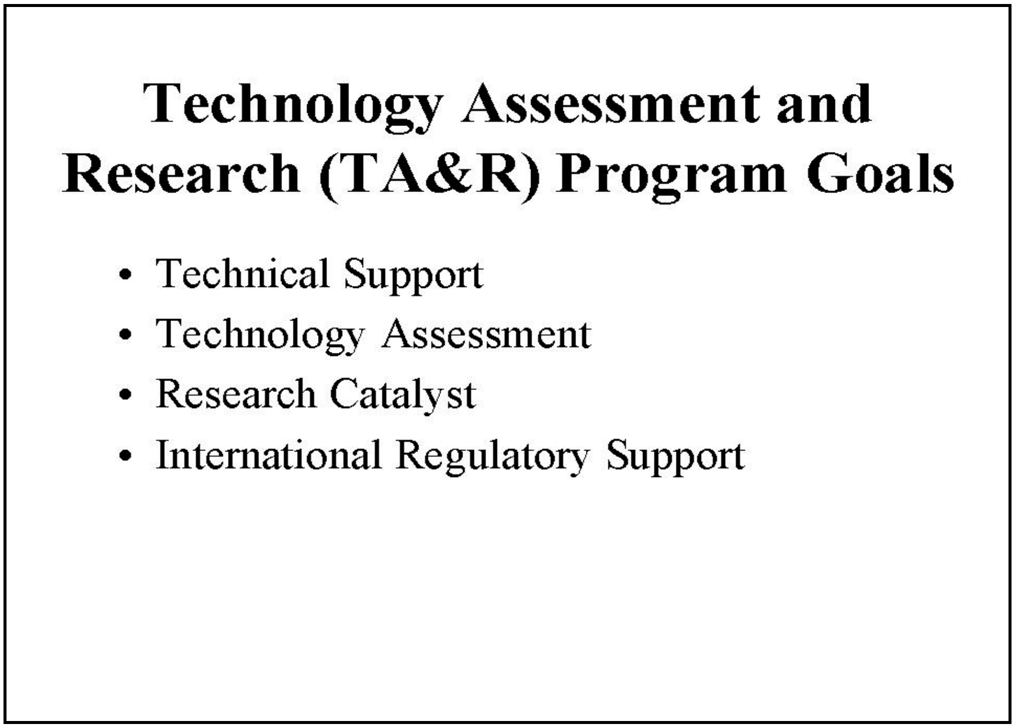
Presentation	Author/Affiliation
Introduction and Technology and Assessment Research Program Overview	Mr. Paul Martin Minerals Management Service
Oil Spill Research	Mr. Joseph Mullin Minerals Management Service
OHMSETT Activities and Tests	Mr. William T. Schmidt MAR, Incorporated
Operations Safety and Engineering Research (OSER)	Dr. Charles Smith Minerals Management Service
MMS Activities/Project at the Offshore Technology Research Center	Dr. E.G. Ward Texas A&M University

INTRODUCTION AND TECHNOLOGY AND ASSESSMENT RESEARCH PROGRAM OVERVIEW

Mr. Paul Martin
Minerals Management Service

Information Transfer Meeting Session Outline

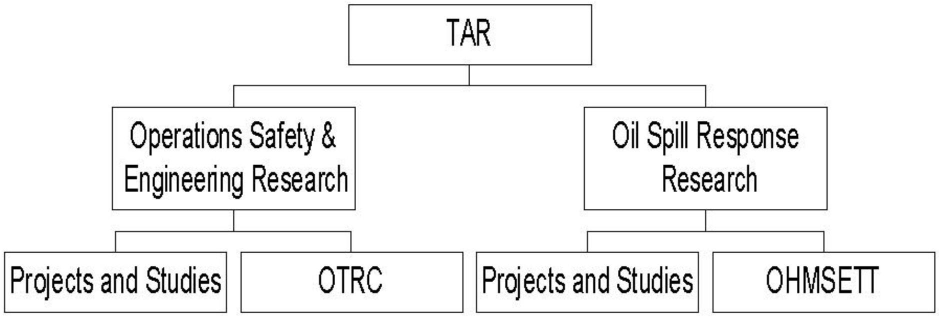
- Program Overview
- Oil Spill Response Research
- OHMSETT
- Operations Safety and Engineering Research
- Offshore Technology Research Center (OTRC)



Technology Assessment and Research (TA&R) Program Goals

- Technical Support
- Technology Assessment
- Research Catalyst
- International Regulatory Support

TA&R Program Components



TAR

Operations Safety & Engineering Research

Oil Spill Response Research

Projects and Studies

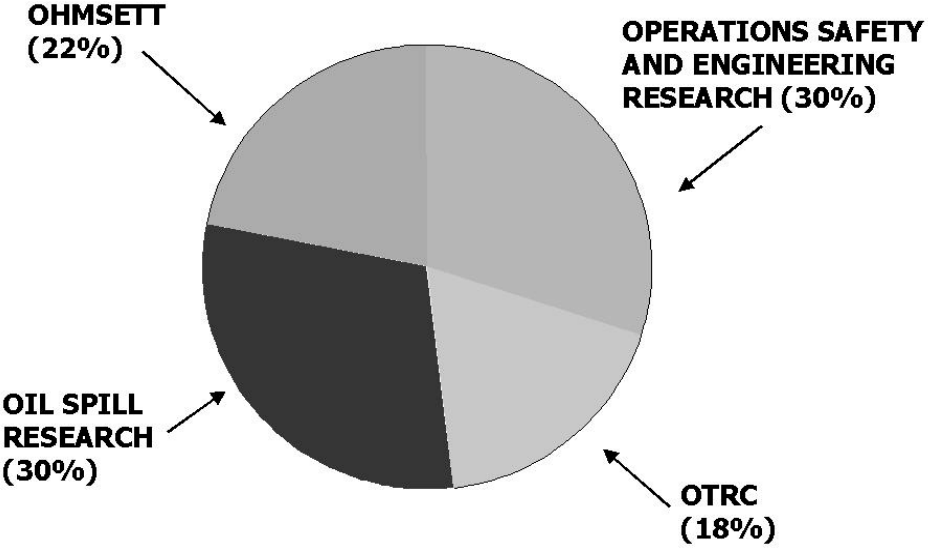
OTRC

Projects and Studies

OHMSETT

TA&R Spending

(FY '99)

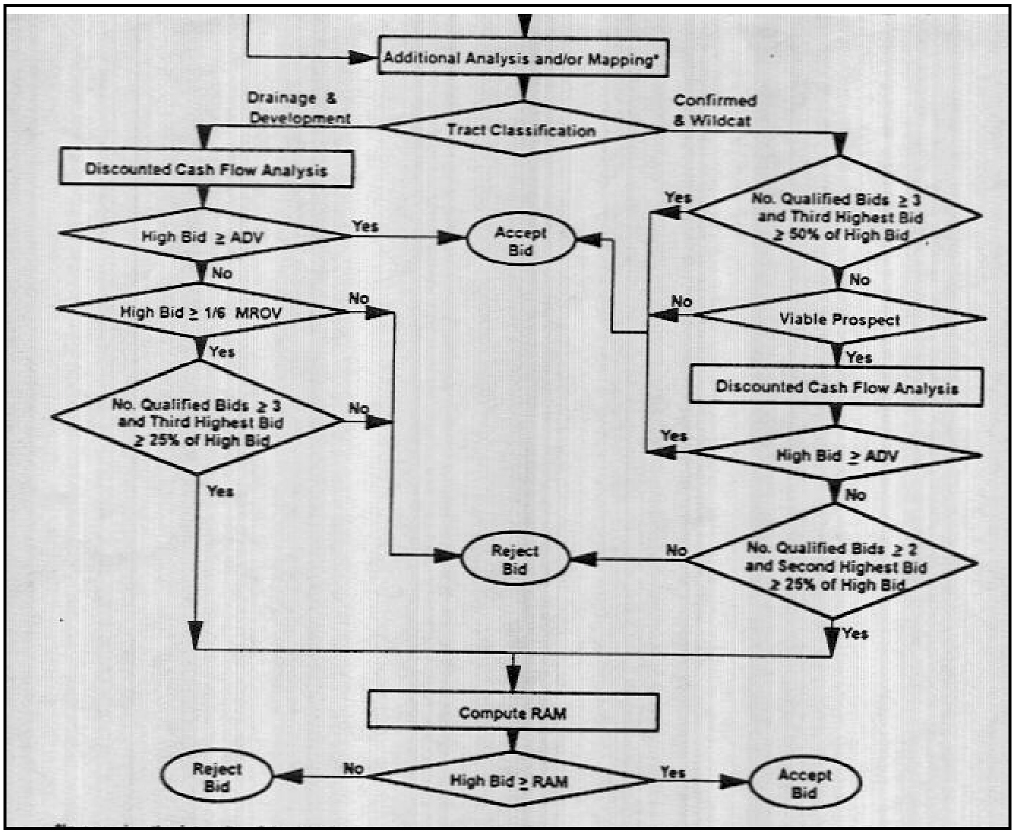


Funding Priorities

OSER		OSR
30%	Direct Technical Support	10%
40%	Technology Assessment	15%
15%	Research Catalyst	30%
15%	International	45%

TA&R Organizational Units

- Engineering and Research Branch
- Regional Units/Coordinators
  - Gulf of Mexico/Atlantic
  - Pacific
  - Alaska
- Technical Teams
- Contracts Office



How are topics identified?

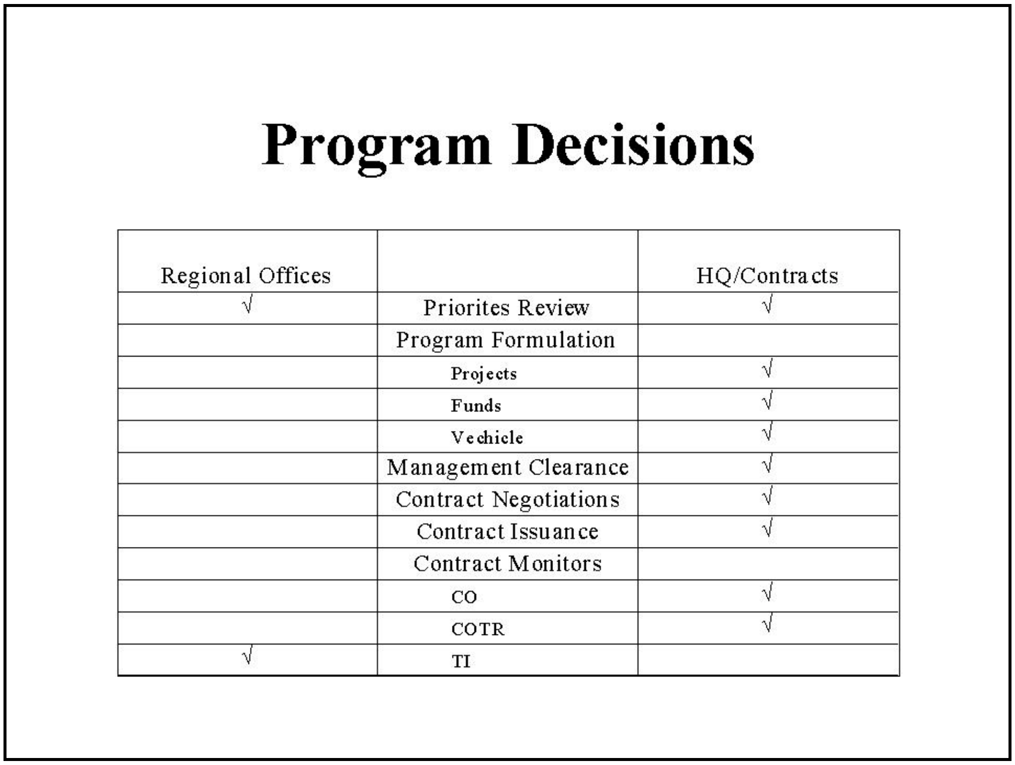
- ROTAC
- Accident Reports
- New Technology Proposals/Plans
- Regulatory Reviews/Issues
- Workshops/Conferences
- Academia/Industry Research
- Technical Experts - Regions and Headquarters
- Policy Directives
- Other Regulatory/Non-Regulatory Agencies
- “Other”

How are topics evaluated?

- Priorities and Needs
- Technical Merit
- Funding Availability

Technical Evaluations

Technical Teams		HQ/Contacts
√	Sort Ideas	
√	Conceptual Studies	
	"White Paper" Solicitation	√
√	White Paper Reviews	
	Proposal Requests	√
√	Proposal Evaluation	
√	Proposal Recommendations	
	Priorities	
	Contract Vehicle	



Program Decisions

Regional Offices		HQ/Contracts
√	Priorites Review	√
	Program Formulation	
	Projects	√
	Funds	√
	Vechicle	√
	Management Clearance	√
	Contract Negotiations	√
	Contract Issuance	√
	Contract Monitors	
	CO	√
	COTR	√
√	TI	

What types of activities are funded?

- Joint Industry Projects
- Formal Cooperative Agreements
- Sole Source
- Workshops/Conferences
- Unsolicited Proposals
- Inter-Agency Agreements
- Other Contract Research

How can I find out the topics being considered?

- Commerce Business Daily Notice
- Web Site: WWW.MMS.GOV
- Other

How can I submit proposals?

- Respond to CBD Notice
- Web Site Notices
- Other (unsolicited proposals, etc.)

How long do projects last?

- Short term
- Multi-year
- Institutional Support

How can I get information on past studies?

- Web site: WWW.MMS.GOV
- Direct mail request

How can I find out about on-going studies?

- Web site: WWW.MMS.GOV for updates

How are TA&R research results used?

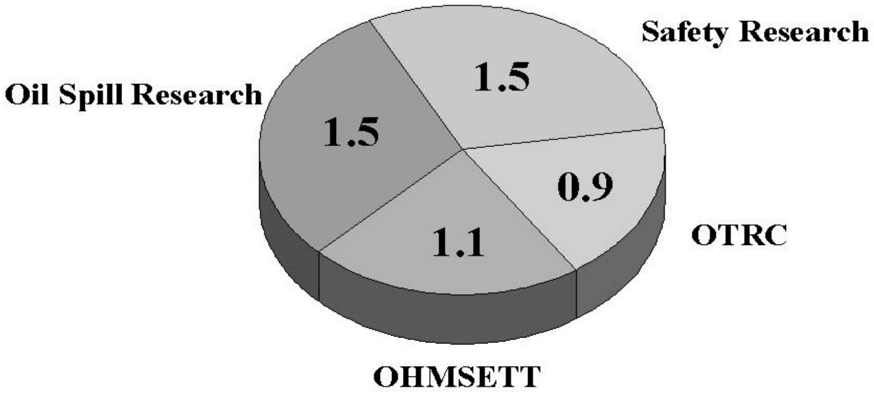
- Decision Support
  - Regional Actions
    - Applications
    - Plans
    - Permits
    - Mitigating Measures
  - Regulatory Initiatives
  - Policy Development
- Research Catalyst
  - Industry
  - Academic
  - Government
- International
  - Regulatory Agencies
  - Policy Formulation
  - Training & Assistance

OIL SPILL RESEARCH

Mr. Joseph Mullin
Minerals Management Service

- The Minerals Management Service (MMS), is the principal U.S. Government agency funding offshore oil spill response research
- For more than 20 years, MMS has maintained a long-term comprehensive international research program to improve oil spill response technologies and procedures
- Funds to conduct MMS's Oil Spill Response Research Program and to operate Ohmsett are appropriated from the Oil Spill Liability Trust Fund (OSLTF)
- Potential polluters, companies that produce and transport oil are supporting research to improve oil spill response capabilities
- Visit our website at *www.mms.gov/tarp*

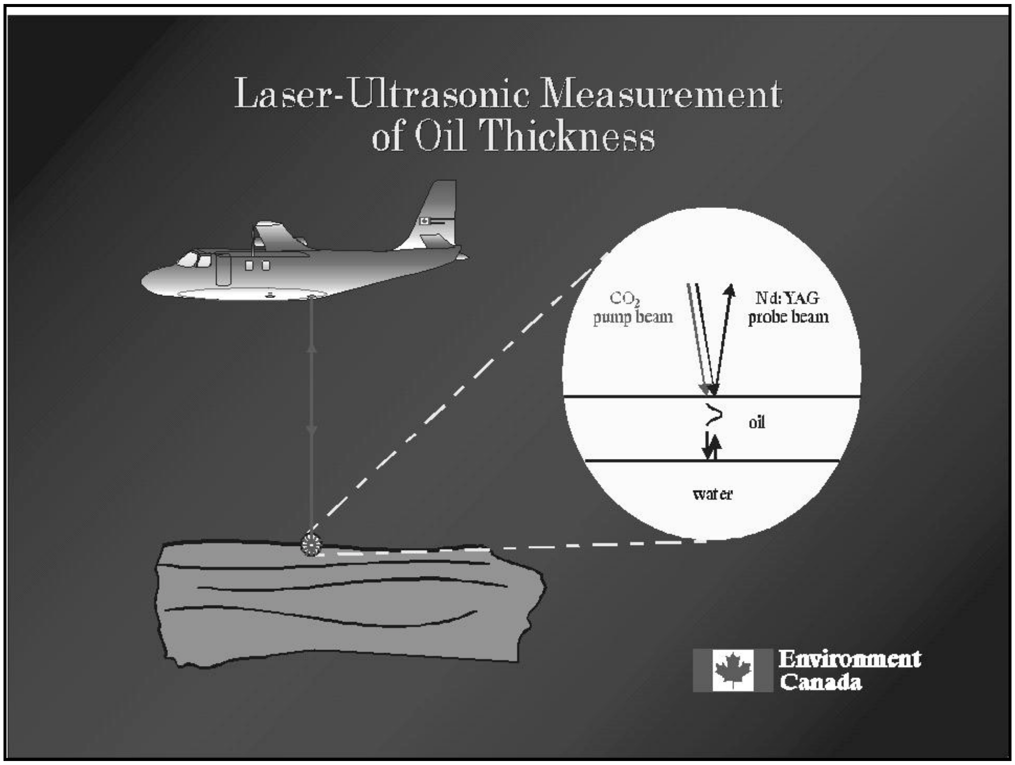
TAR FY 1999 Expenditures (in U.S. dollars)



Total = $4.09 Million

Remote Sensing

- Laser Fluorosensor Technology
- Oil Slick Thickness Sensor Development



Laser-Ultrasonic Measurement of Oil Thickness

Environment Canada

Properties & Behavior of Oil

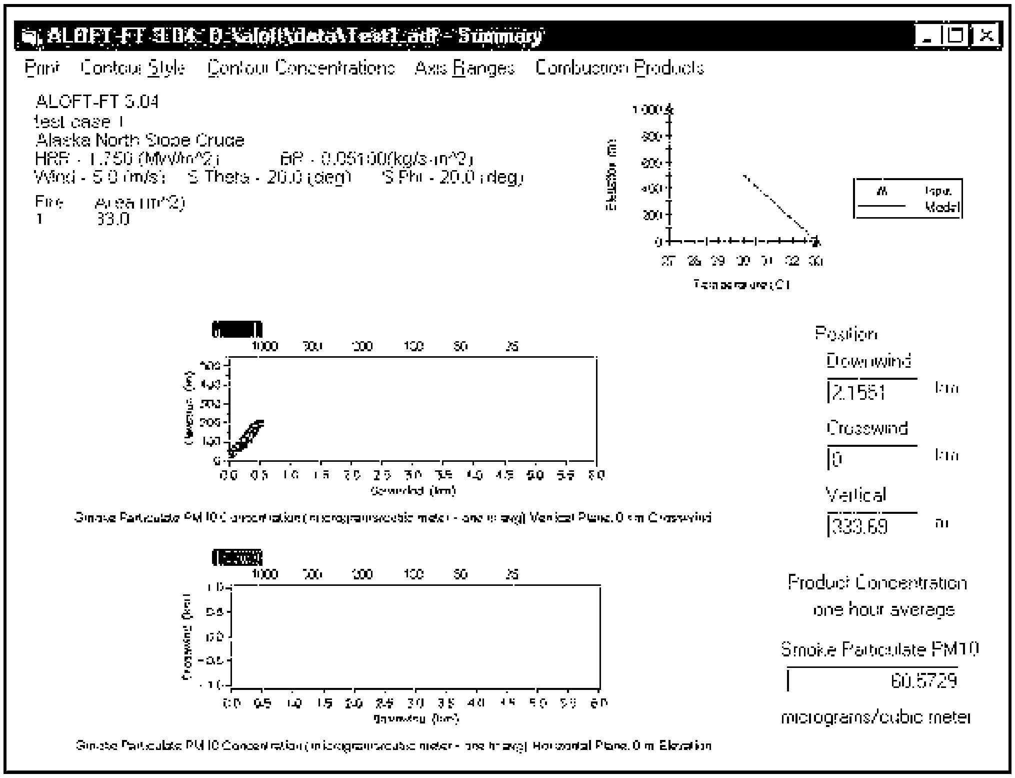
- Oil Properties Catalog
- Evaporation
- Emulsion Formation and Stability
- Oil Analysis
- BOSS and the Basics Book

Chemical Treating Agents

- Dispersant Effectiveness
- Use of Dispersants from MMS Regulated Facilities
- Dispersant Ecological Effects

In-Situ Burn Research

- **Development of Standard Test Procedures**
- **Fire Resistant Boom Development and Testing**
- **Smoke Plume Modeling**
- **In Situ Burning of OCS Crude Oil Spills**
- **Burning in Wetlands**



ALOFT-FT 3.04
test case 1
Alaska North Slope Crude
HRR - 1.750 (MW/m^2)   BR - 0.05100(kg/s-m^2)
Wind - 5.0 (m/s)   S Theta - 20.0 (deg)   S Phi - 20.0 (deg)

Fire   Area (m^2)
1   33.0

Smoke Particulate PM10 Concentration (micrograms/cubic meter - one hr avg) Vertical Plane, 0 km Crosswind

Smoke Particulate PM10 Concentration (micrograms/cubic meter - one hr avg) Horizontal Plane, 0 m Elevation

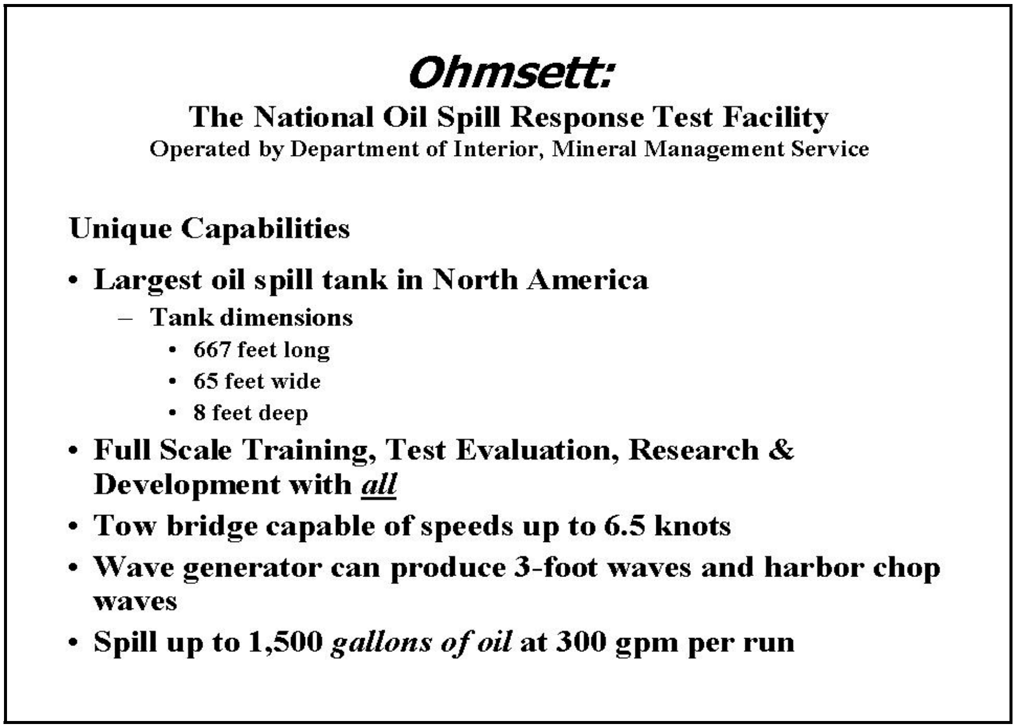
Position
Downwind 2.1551 km
Crosswind 0 km
Vertical 333.69 m

Product Concentration
one hour average

Smoke Particulate PM10
60.5729
micrograms/cubic meter

OHMSETT ACTIVITIES AND TESTS

Mr. William T. Schmidt
MAR, Incorporated



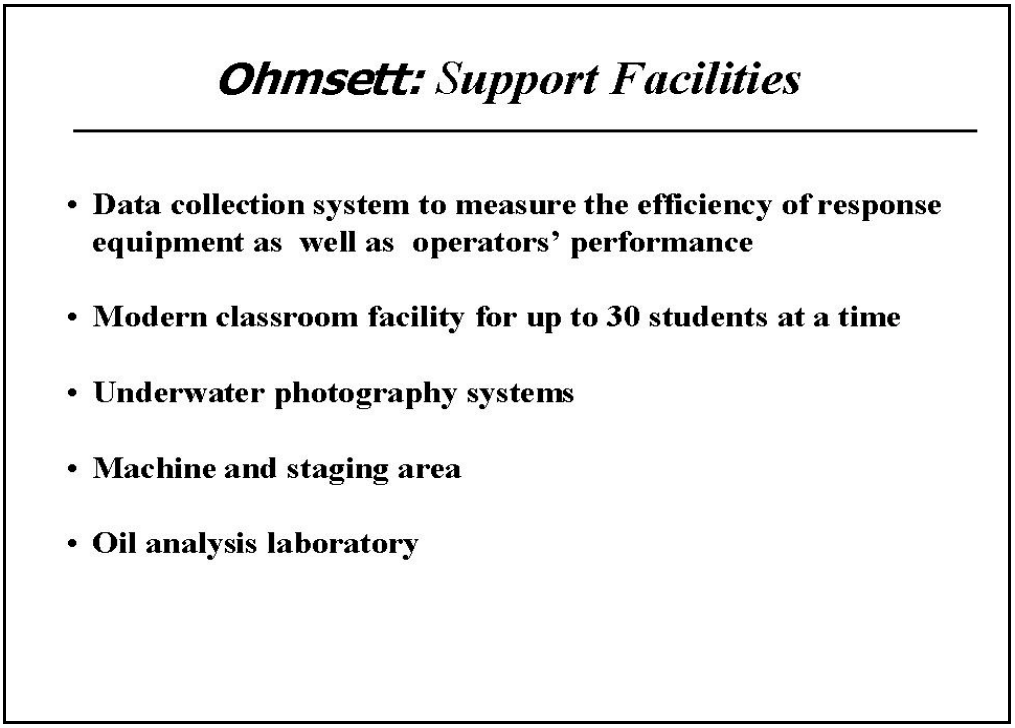
Ohmsett:

The National Oil Spill Response Test Facility

Operated by Department of Interior, Mineral Management Service

Unique Capabilities

- **Largest oil spill tank in North America**
  - **Tank dimensions**
    - **667 feet long**
    - **65 feet wide**
    - **8 feet deep**
- **Full Scale Training, Test Evaluation, Research & Development with *all***
- **Tow bridge capable of speeds up to 6.5 knots**
- **Wave generator can produce 3-foot waves and harbor chop waves**
- **Spill up to 1,500 *gallons of oil* at 300 gpm per run**

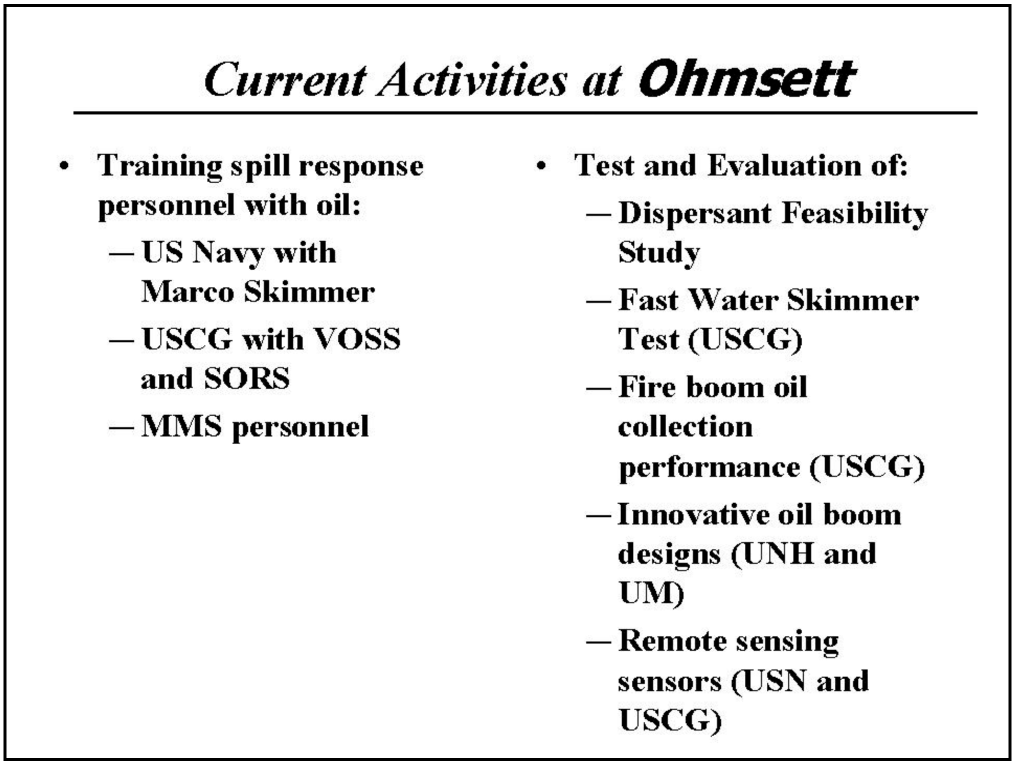


Ohmsett: *Support Facilities*

- **Data collection system to measure the efficiency of response equipment as well as operators' performance**
- **Modern classroom facility for up to 30 students at a time**
- **Underwater photography systems**
- **Machine and staging area**
- **Oil analysis laboratory**

Types of Testing & Training

- Training Sessions-USCG, Navy, Private, MMS
- Booms & Skimmers
- *In-Situ* Burns
- Oil Spill Treating Agents (Sorbents)
- Research and Development
- Oil/Water Separator & Decant Experiments
- Dispersant Feasibility Test
- Remote Sensing



Current Activities at **Ohmsett**

- Training spill response personnel with oil:
  - US Navy with Marco Skimmer
  - USCG with VOSS and SORS
  - MMS personnel
- Test and Evaluation of:
  - Dispersant Feasibility Study
  - Fast Water Skimmer Test (USCG)
  - Fire boom oil collection performance (USCG)
  - Innovative oil boom designs (UNH and UM)
  - Remote sensing sensors (USN and USCG)

Oil Spill Response Technician Course

Purpose:

- **To provide training to USCG, Strike Team, MMS, and Navy personnel on:**
  - **Non-fixed components of the Spilled Oil Recovery System (SORS)**
  - **Vessel of Opportunity skimming system (VOSS), Standard and Fast Sweep Boom (FSB)**
  - **Partial fulfillment of the requirements for qualification as Response Technician**
  - ***Available to private and public clients***

Benefits of Training at Ohmsett

- **Students are given instruction on the utilization, proper assembly, deployment and rigging of response equipment**
- **Cooperative training program with Texas A&M University NATIONAL OIL SPILL CONTROL SCHOOL**
- **40-hour HAZWOPER certification**
- **Students review their performance**
  - **Through video recording of each training session**
  - **Using oil recovery effectiveness measurements**
- ***Typically students improve their oil recovery effectiveness by 80%***

Testing at Ohmsett

USCG Burned Fireboom Test

- **Applied Fabrics PyroBoom**
- **SL Ross Dome Boom**
- **Elastec/American Marine Hydro-Fire boom**
- **Spill Tain**

USCG Fast Water Equipment Test

- **JBF DIP 600**
- **Vikoma FasFlo Skimmer**
- **Combi Hydrodynamic Circus**
- **NOFI CurrentBuster**

Propane Burn Test

In-situ Burns

- **Near full scale screening tests for the *effectiveness* & *durability* of fire resistant oil containment booms**
- **Ability of boom exposed to fire to *contain thick, hot oil & survive extended exposure to wave action***
- **Propane flames produce a *total heat flux* to the surface in the range of *110-130 kW/m^2* and *flame temperatures near* 900 C°**
- **Underwater bubbler has a propane *flow rate of 1500 kg/hr* over a *water surface area of ~10m2*, yielding a *heat release rate of 2 MW/m^2***
- **Compressed *air injected* near the base of the flame *at a rate of 2900 kg/hr* to enhance the combustion process and increase total heat fluxes and flame temperatures**
- **ASTM Standard Development**

Tow Force: Oil Spill Containment Boom

Objective: To determine the tow forces on booms of various drafts and profiles under differing wave conditions and towing speeds.

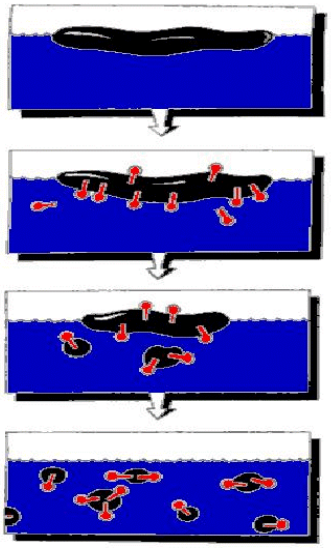
- **Full-scale tow tests were conducted using several specific representative boom profiles**

- **Towing forces were measured and recorded for various boom drafts, profiles, wave conditions and towing speeds**

Dispersant Feasibility Study

Objective: To examine various ways that dispersant testing can be accomplished at Ohmsett and to evaluate the feasibility and cost.

Dispersant Rationale



Untreated Slick

Application of Dispersant

Formation of Small Droplets

Dilution of Dispersed Oil

Purpose: **To investigate and find a cost-effective method for filtering out the dispersed oil, and dissolved dispersed.**

Possible Complications:

1. Increasing the concentration of dispersants in the tank water may negatively affect subsequent tests

2. A large concentration of dissolved dispersant & dispersed oil in tank water may affect slick behavior and interfere with underwater visibility and photography.

3. Removal of all dissolved dispersant & dispersed oil may be difficult & expensive to accomplish

Dispersant Feasibility Study Approach

- **Task 1. Determining Critical Dispersant Concentrations**
  - **1-a. Interfacial Tension Work**
  - **1-b. Water Clarity/Turbidity Work**
- **Task 2. Estimating Dispersant Used**
- **Task 3. Evaluation of Current Filter System**
- **Task 4. Full Scale Verification Testing**

Major Misconceptions about **Ohmsett**

1. Ohmsett is for government use only.

-- Anyone can use the Ohmsett facility on a reimbursable basis.

2. Training is too expensive.

-- The cost is $900 per student for a 5-day class.

-- Optimum capacity is 15 students per class.

Test with Oil! Train in Oil!

- — **Texas A&M instructors have conducted oil spill mitigation classes since 1997 as part of their curriculum.**
- — **$800K has been expended to enhance the physical facility and provide classroom space.**
- — **USCG Strike Teams train at Ohmsett.**
- — **Both Classroom and Tank Training**

- **_Ohmsett_ is the only tank in North America where oil spill responders can test and train with FULL SCALE EQUIPMENT with oil and waves in controlled environments**
- **Training at _Ohmsett_ gives students the confidence to operate the response equipment efficiently**
- **40- hour HAZWOPER training at _Ohmsett_ combined with training with oil will give the required tools for responders to respond to an oil spill effectively**

FOR MORE INFORMATION

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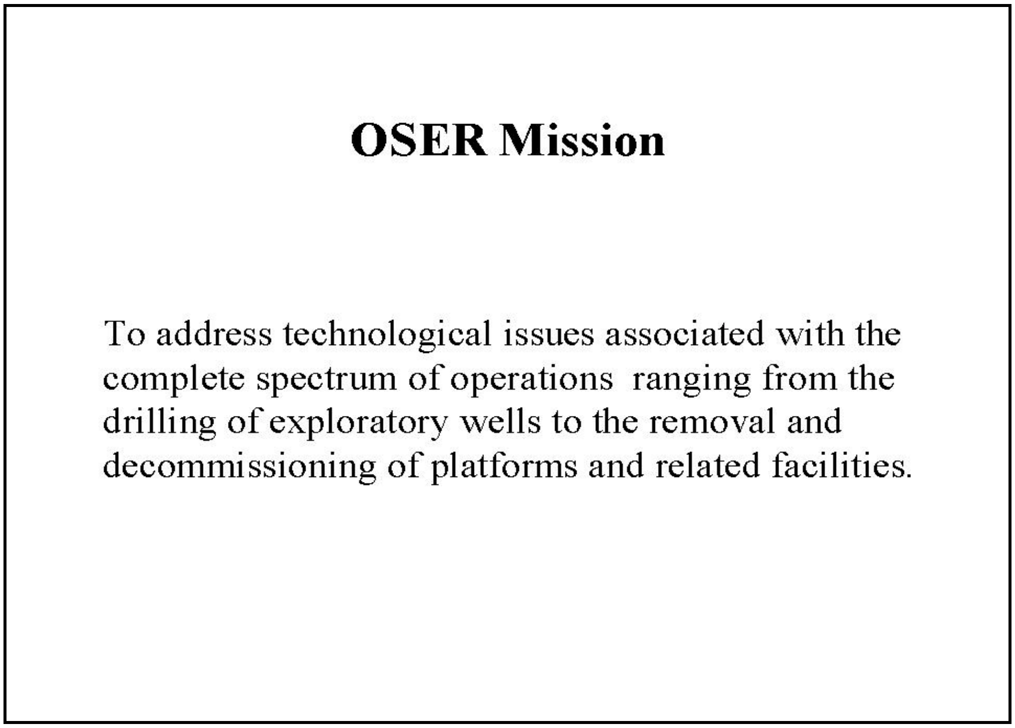
http://www.ohmsett.com

The MAR, Inc. authors would like to gratefully acknowledge James Lane and Joseph Mullin of the U.S. Minerals Management Service, and CDR Christopher Doane, Kenneth Bitting, and Kurt Hansen of the U.S. Coast Guard for making it possible for Ohmsett to conduct research and training. Special thanks are also extended to the Texas A&M University National Spill Control School and to SL Ross Environmental Research, who lent their knowledge, expertise and manpower during many of these tests.

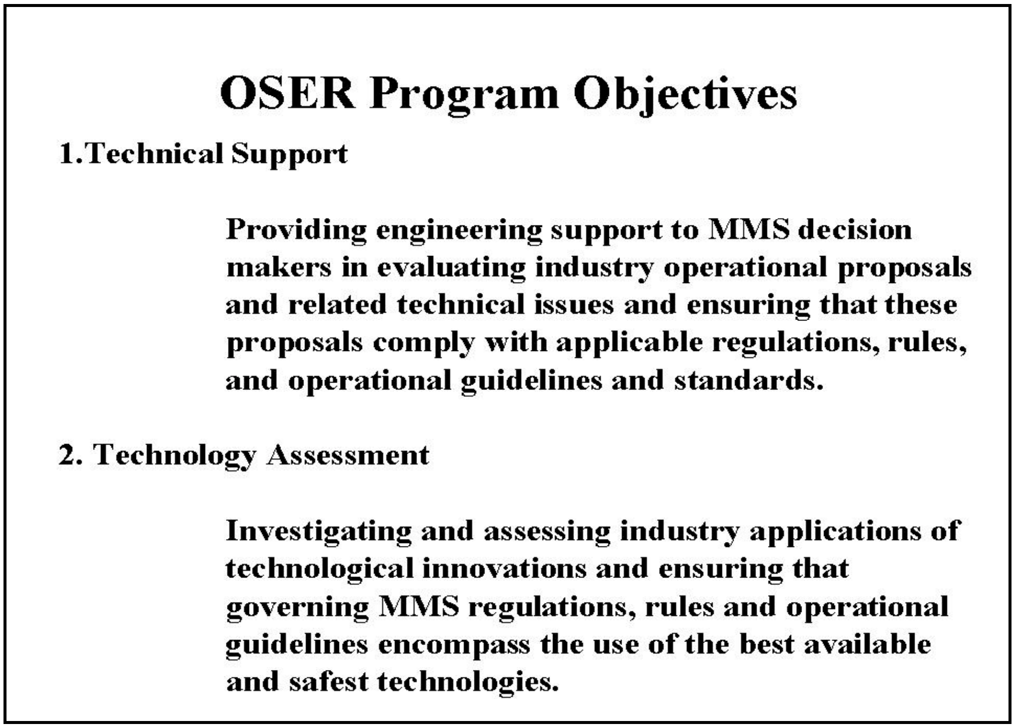
OPERATIONS SAFETY AND ENGINEERING RESEARCH (OSER)

Dr. Charles Smith
Minerals Management Service



OSER Mission

To address technological issues associated with the complete spectrum of operations ranging from the drilling of exploratory wells to the removal and decommissioning of platforms and related facilities.



OSER Program Objectives

1.Technical Support

Providing engineering support to MMS decision makers in evaluating industry operational proposals and related technical issues and ensuring that these proposals comply with applicable regulations, rules, and operational guidelines and standards.

2. Technology Assessment

Investigating and assessing industry applications of technological innovations and ensuring that governing MMS regulations, rules and operational guidelines encompass the use of the best available and safest technologies.

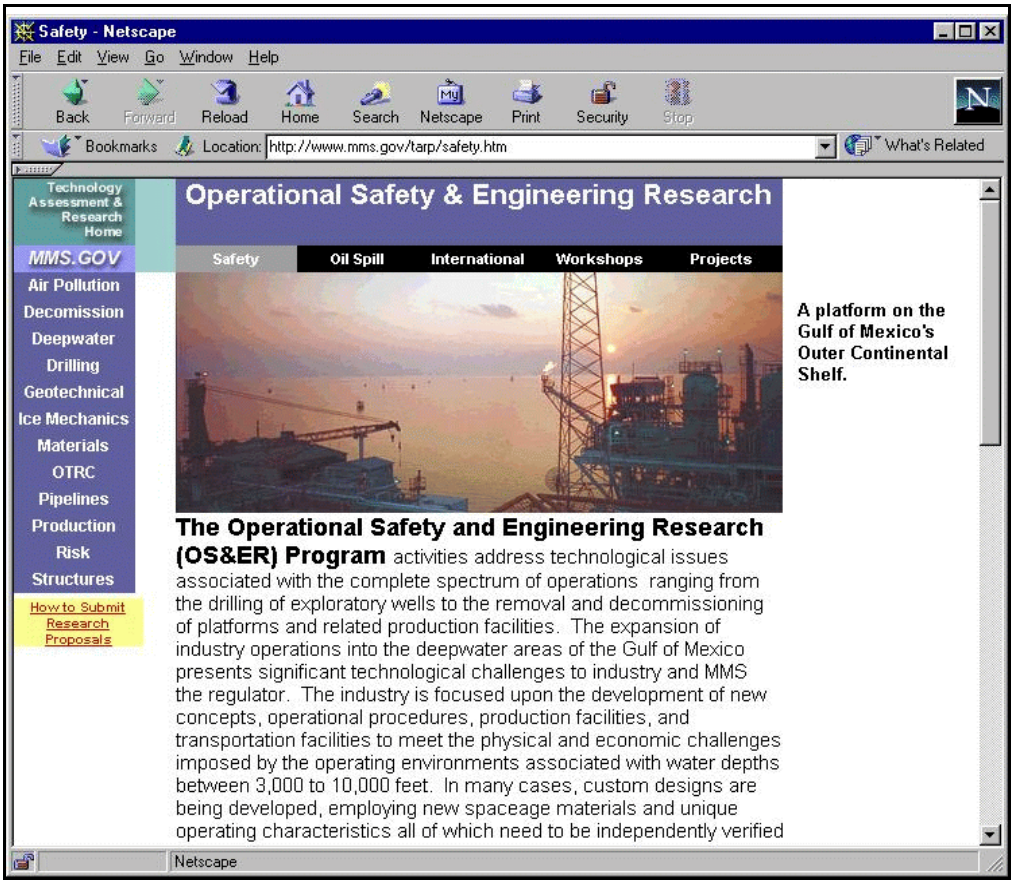
OSER Program Objectives (cont.)

3. Research Catalyst

Promoting leadership in the fields of operational safety and engineering research activities by acting as a catalyst for industry research initiatives.

4. International Regulatory

Providing international cooperation for research and development initiatives to enhance the safety of offshore oil and natural gas activities and the development of appropriate regulatory program elements worldwide.



Location: http://www.mms.gov/tarp/safety.htm

Operational Safety & Engineering Research

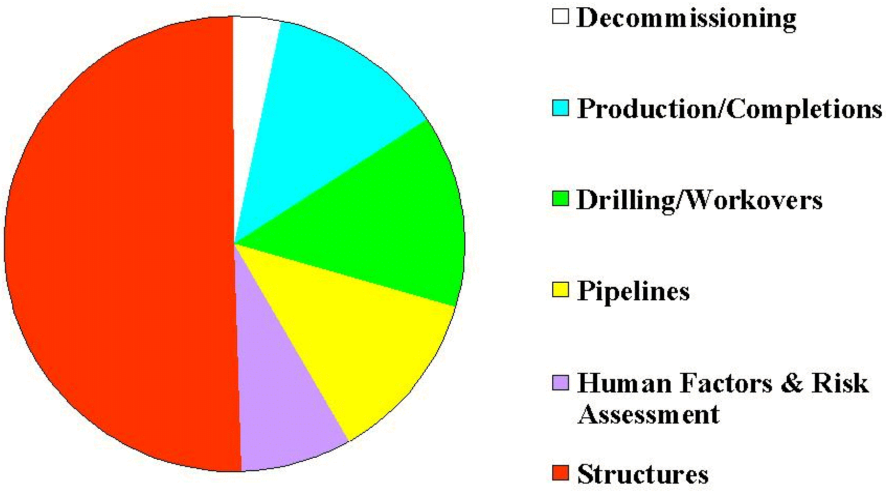
A platform on the Gulf of Mexico's Outer Continental Shelf.

The Operational Safety and Engineering Research (OS&ER) Program activities address technological issues associated with the complete spectrum of operations ranging from the drilling of exploratory wells to the removal and decommissioning of platforms and related production facilities. The expansion of industry operations into the deepwater areas of the Gulf of Mexico presents significant technological challenges to industry and MMS the regulator. The industry is focused upon the development of new concepts, operational procedures, production facilities, and transportation facilities to meet the physical and economic challenges imposed by the operating environments associated with water depths between 3,000 to 10,000 feet. In many cases, custom designs are being developed, employing new spaceage materials and unique operating characteristics all of which need to be independently verified

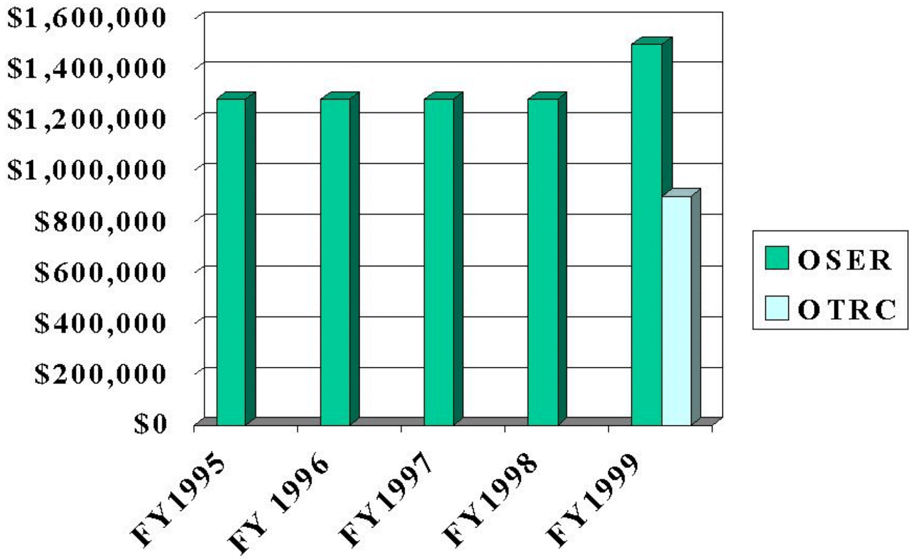
Components of the OSER Program

Component	Team Leader
Decommissioning	Sharon Buffington
Drilling/Workovers	Bill Hauser
Human Factors & Risk Assessment	Amy White
Pipelines	Bob Smith
Production/Completions	Larry Ake
Structures	Charles Smith

Historical Project Distribution



Historic Funding Levels



International Workshops

International Workshop On Advanced Methods of Corrosion Mitigating for Marine Structures and Pipelines

February 9-11, 1999 Galveston, Texas

Offshore Pipeline Risk Assessment & Management International Workshop

November 4, 1998, Houston, Texas

International Workshop on Advanced Materials for Marine Construction

February 5-7, 1997

Decommissioning of Oil and Gas Facilities Offshore California International Workshop

September 23-25, 1997, Ventura, California

International Workshop on Human Factors in Offshore Operations

December 16-18, 1996, New Orleans, Louisiana

Decommissioning Component Research

Purpose:

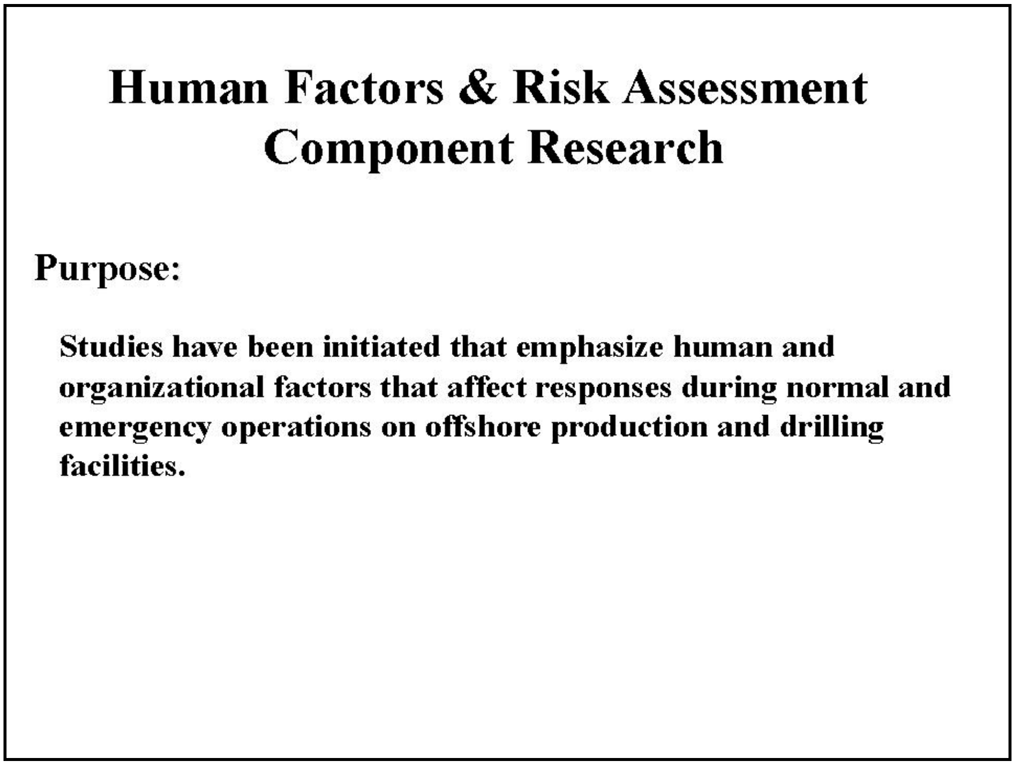
To ensure that the following decommissioning obligations can be technically and financially met when facilities are no longer needed:

1. **Plug wells to prevent pollution;**
2. **Decommission pipelines to prevent seepage of hydrocarbons and to minimize conflicts with other uses of the OCS; and**
3. **Clear sites of obstructions to minimize use conflicts.**

Drilling Component Research

Purpose:

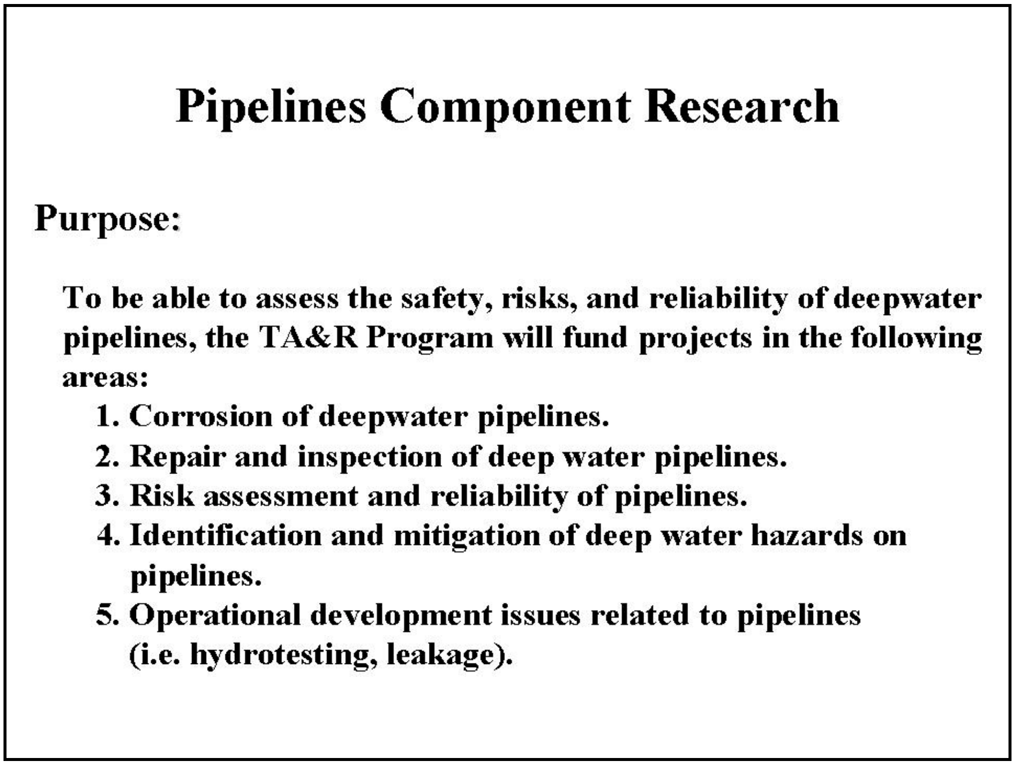
To focus on research that relates directly to the regulation of drilling operations. Research topics will include the performance and reliability of safety equipment; new and evolving technology and its application to offshore drilling; assessment of various operational problems; and advanced well control techniques.



Human Factors & Risk Assessment Component Research

Purpose:

Studies have been initiated that emphasize human and organizational factors that affect responses during normal and emergency operations on offshore production and drilling facilities.



Pipelines Component Research

Purpose:

To be able to assess the safety, risks, and reliability of deepwater pipelines, the TA&R Program will fund projects in the following areas:

1. **Corrosion of deepwater pipelines.**
2. **Repair and inspection of deep water pipelines.**
3. **Risk assessment and reliability of pipelines.**
4. **Identification and mitigation of deep water hazards on pipelines.**
5. **Operational development issues related to pipelines (i.e. hydrotesting, leakage).**

Production Component Research

Purpose:

Recent MMS studies in this area have concentrated on the technologies needed for moving into deepwater as well as looking
for solutions to current problems. Examples of deep water production research include studies of production riser technology, deepwater multiphase flow, and investigating the safety and reliability of new production systems. MMS is also studying gas migration and buildup in wells in hope of finding new solutions to this persistent problem.

Structures Component Research

Purpose:

To assess the safety, risks, and reliability of the deepwater facilities, the TA&R Program will fund projects in the following areas:

1. **Fluid/structure interactions;**
2. **Fatigue life and reliability of a wide variety of deepwater facilities; and**
3. **Operational developments relative to structures.**

Offshore Technology Research Center (OTRC) Cooperative Agreement

Cooperative Agreement

between the Minerals Management Service and
the Offshore Technology Research Center
College Station, Texas

Driving Force:

As industry moves into ultra deep waters of the GOM, new technical, safety, and environmental challenges will need to be addressed by the MMS to accomplish its regulatory mission. The cooperative agreement between MMS and OTRC will greatly support this effort.

Objectives of the Cooperative Agreement

1. **Conduct research and assessment studies to promote the development of deep water oil and gas resources**
2. **Facilitate the development of emerging technologies**
    - *** workshops and seminars**
    - *** assessment of technologies**
    - *** participation in JIPs**
3. **Promote the awareness and advocate the use of technologies addressed under the Cooperative Agreement**

Objectives (cont.)

4. **Encourage academia and industry to conduct basic and applied research jointly**
5. **Serve as a catalyst for developing research and assessment initiatives**
6. **Utilize and promote the OTRC's unique relationship with industry to facilitate, promote, and coordinate interactions and cooperation between the industry and MMS**

Scope of Work

The MMS and the OTRC shall implement a plan where the OTRC shall carry out a research program on issues and technical barriers jointly identified and which are deemed critical and where an impact can be made with available human and financial resources

* **Enable the safe and economically viable production of oil and gas resources from water depths up to 12,000 feet.**

Program Development / Projects

1. Support two general classes of projects and activities:
    - * Projects and activities to meet specific near-term needs identified by MMS
    - * General research initiatives to support the overall mission of the MMS
2. The amount of funding allocated to the two classes of projects will be designated by the MMS and agreed to by the OTRC

Program Development / Projects (cont.)

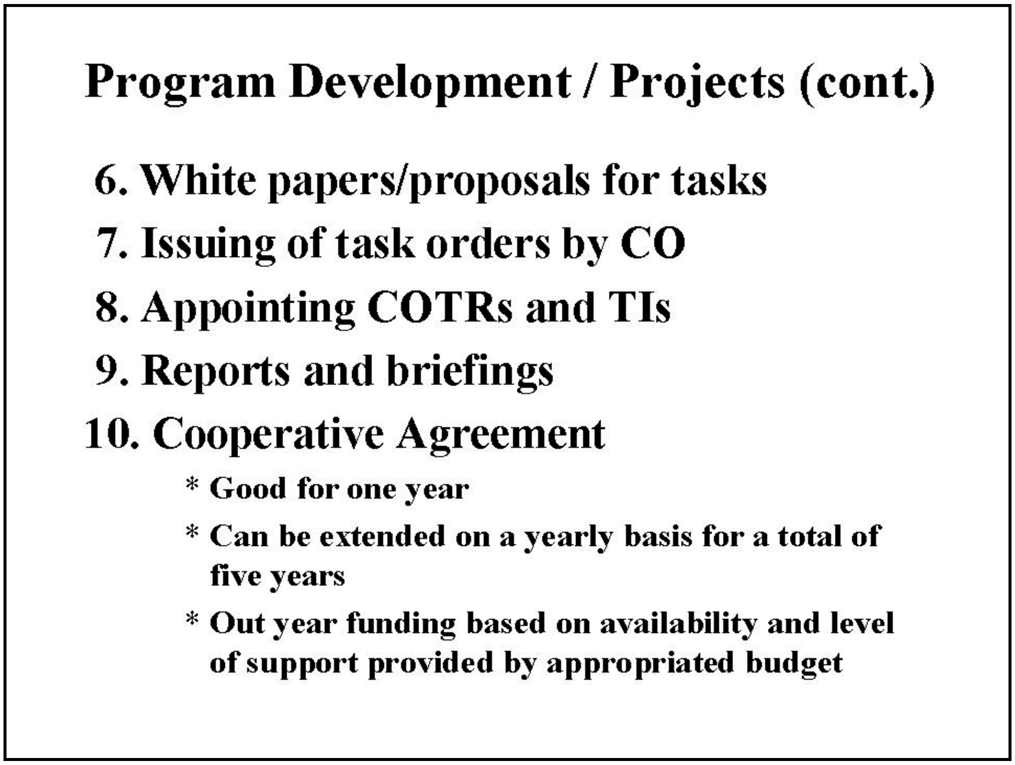
3. Project/activities for MMS identified needs
    - * Specific technology assessments;
    - * Technical assistance for near-term support of MMS specific issues;
    - * Workshops to assess specific regulatory issues;
    - * Conduct seminars/projects to promote the transfer of technology or to assist in the MMS/OTRC collaboration;
    - * Advise MMS on pertinent international deep water research activities and/or technologies.

Program Development / Projects (cont.)

4.General Research Initiatives

- Approximately two-third of these funds will support research projects relative to the MMS regulatory mission
- The remainder will support the MMS mission and will encourage basic research to develop technologies to assess future deepwater development projects

5. Projects in both subcategories above will encourage joint participation with industry.



Program Development / Projects (cont.)

6. White papers/proposals for tasks
7. Issuing of task orders by CO
8. Appointing COTRs and TIs
9. Reports and briefings
10. Cooperative Agreement
    - Good for one year
    - Can be extended on a yearly basis for a total of five years
    - Out year funding based on availability and level of support provided by appropriated budget

Important

Representative

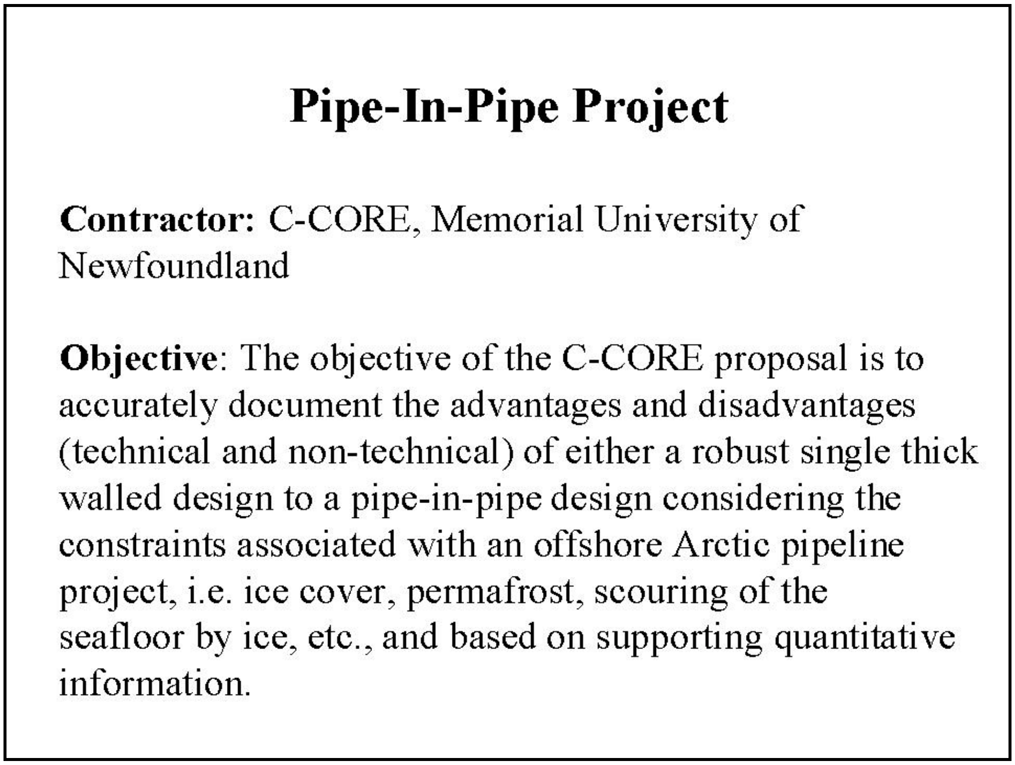
Studies

Underway

L S U Well Control Project

Contractor: Louisiana State University

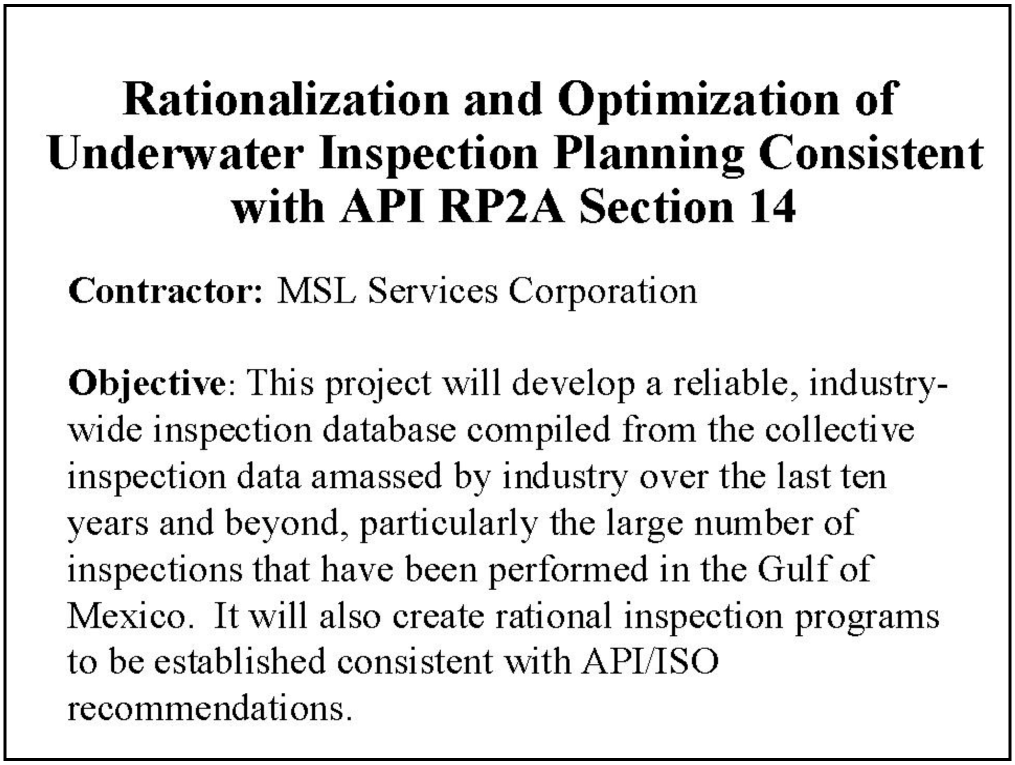
Objective: To develop improved well control procedures and systems by theoretical and experimental investigations into overpressured flows, formation fracture, measurements while drilling, diverter operations and related aspects pertaining to operational safety



Pipe-In-Pipe Project

Contractor: C-CORE, Memorial University of Newfoundland

Objective: The objective of the C-CORE proposal is to accurately document the advantages and disadvantages (technical and non-technical) of either a robust single thick walled design to a pipe-in-pipe design considering the constraints associated with an offshore Arctic pipeline project, i.e. ice cover, permafrost, scouring of the seafloor by ice, etc., and based on supporting quantitative information.



Rationalization and Optimization of Underwater Inspection Planning Consistent with API RP2A Section 14

Contractor: MSL Services Corporation

Objective: This project will develop a reliable, industry-wide inspection database compiled from the collective inspection data amassed by industry over the last ten years and beyond, particularly the large number of inspections that have been performed in the Gulf of Mexico. It will also create rational inspection programs to be established consistent with API/ISO recommendations.

Assessment and Reliability of Production and Tubing Design

Contractor: Mohr Research and Engineering, Inc.

Objective: To examine the design and reliability of production tubing used in oil and gas wells on the Outer Continental Shelf. The study will assess the current design criteria for production tubing as well as assess actual practices for wells in the Gulf of Mexico.

Deepwater BOP Reliability Study

Contractor: SINTEF

Objective: The study will:

- Investigate the performance of deepwater subsea BOP systems for drilling rigs operating in the Gulf of Mexico;
- Compare BOP reliability in the Gulf of Mexico to that of other areas, such as the North Sea; and
- Examine how the various maintenance programs effect BOP reliability.

The project is now complete and the final report is available to the public. SINTEF will present the findings of the study in January or February 2000.

Comparative Risk Assessment

Contractor: Offshore Research Technology Center

Objective: To develop a methodology and tools that will compare the risks of offshore systems that introduce new technologies with the risks of existing systems in the following areas:

1. Allow the consistent comparison of risk for new systems versus existing systems.
2. Illustrate the impact of the new technologies at the subsystem or operational level.
3. Illustrate the impact of selected risk mitigation options on overall system risk.

Effectiveness of 50 Pound Bulk Charges in Cutting Platform Members

Contractor: TEI Construction Services, Inc.

Objective: This project will identify what type of platform member that a 50# bulk charge can sever. It will take into account different diameters, whether or not the members are hollow or cement filled and different grades of steel.

Focus on FY 2000

Broad Agency Announcement (BAA) published in the Commerce Business Daily (CBD) for FY 2000, identified the core OSER research needs and are listed as follows:

- Risk Assessment of Mechanical versus Hydraulic Cranes
- Supervisory, Control and Data Acquisition (SCADA) Systems
- Assessment of Risks Associated with Carbon Monoxide Gas (CO) During Well Perforation
- Assessment of the Physical Properties of Mixed Gases Members
- Temporarily Abandoned or Shut-in Wells

Summary / Conclusion

- More focussed on regional needs
- Projects tend to operational concerns as opposed to components (pipelines etc.)
- Tend to participate with industry (JIP's) domestically and internationally
- Support regulatory needs

MMS ACTIVITIES/PROJECT AT THE OFFSHORE TECHNOLOGY RESEARCH CENTER

Dr. E.G. Ward
Texas A&M University

Offshore Technology Research Center

- **Basic Research**
- **Applied Research**
- **Education**
- **Service**

Offshore Technology Research Center

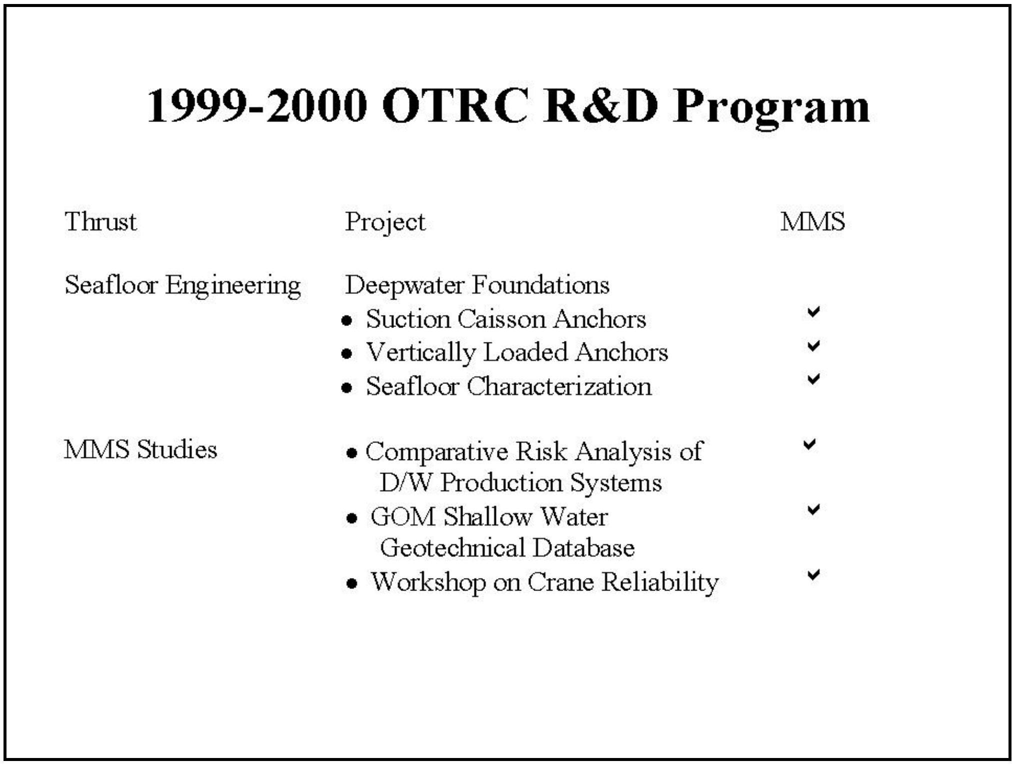
- NSF Engineering Research Center
  - NSF + Industry supported
- Present OTRC
  - MMS + Industry supported
  - Program developed through workshops & discussions of needs
  - MMS + Industry funded projects
  - MMS funded projects

Thrust Areas

- Fluid/Structures Interaction
- Materials/Structural Integrity
- Seafloor/Structures

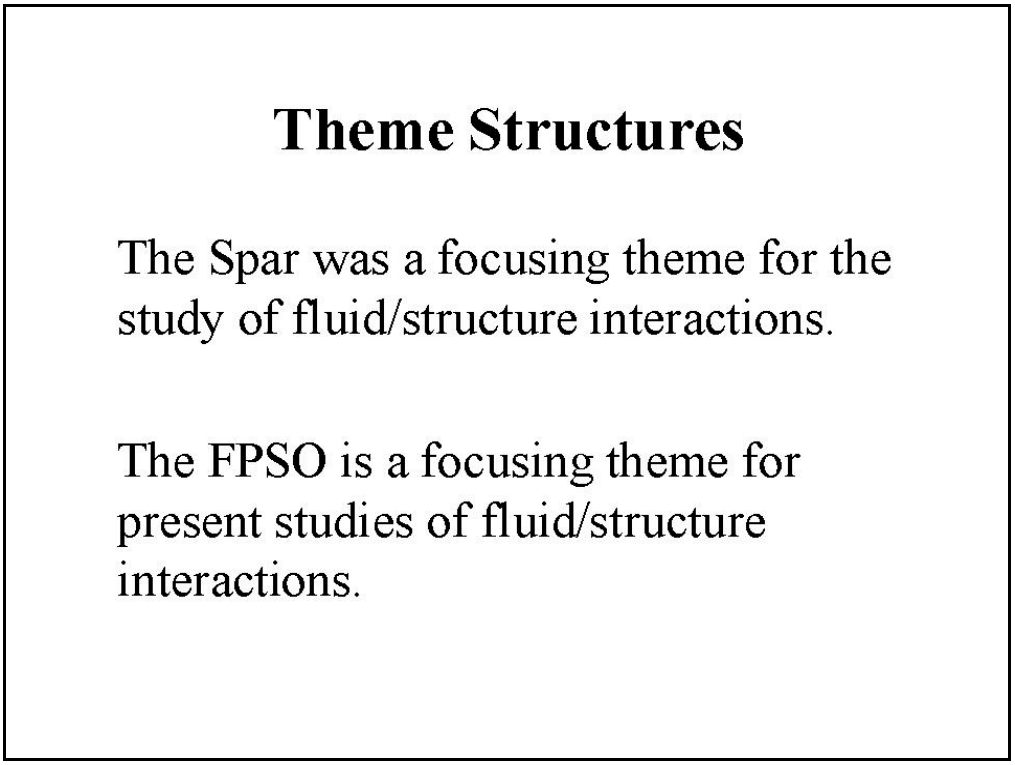
1999-2000 OTRC R&D Program

Thrust	Project	MMS
Fluid/Structure	• Dynamics of FPSOs	✓
	• Responses of FPSOs	✓
	• Risers Interaction	✓
	• Riser Vortex-Induced Vibrations	✓
Materials	Spoolable Composite Tubulars	
	• Design Methods	✓
	• Time Dependent Effects	✓
	• NDE Testing	✓



1999-2000 OTRC R&D Program

Thrust	Project	MMS
Seafloor Engineering	Deepwater Foundations	
	• Suction Caisson Anchors	✓
	• Vertically Loaded Anchors	✓
	• Seafloor Characterization	✓
MMS Studies	• Comparative Risk Analysis of D/W Production Systems	✓
	• GOM Shallow Water Geotechnical Database	✓
	• Workshop on Crane Reliability	✓



Theme Structures

The Spar was a focusing theme for the study of fluid/structure interactions.

The FPSO is a focusing theme for present studies of fluid/structure interactions.

Fluid/Structures Interaction

- Combined wind, wave and current forces on floating structures
- Wave and current forces on slender bodies (tendons and risers)
- Tendon dynamics
- Collisions of multiple tendons & risers

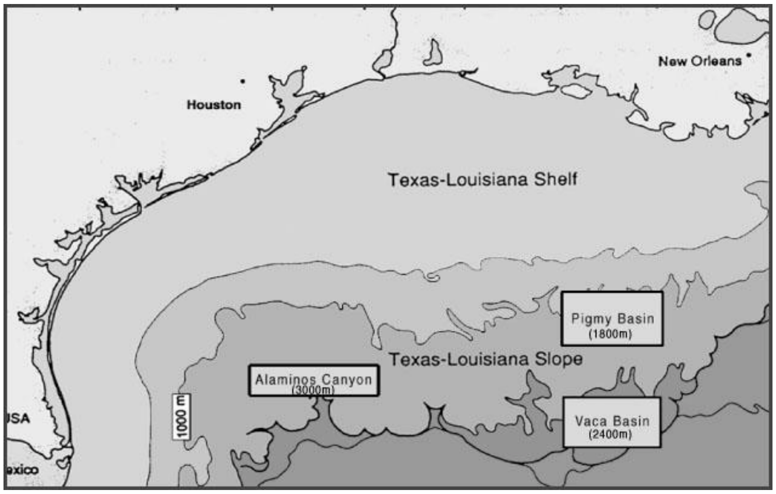
Materials

- Long term durability of composites
- Moisture effects on interfaces
- Microbiological degradation
- Time dependent effects
- Fatigue crack growth under pressure
- Composite-metal joints

Seafloor Engineering

- Methods for characterizing deepwater sites
- Evaluate potentially hazardous conditions
- Solutions for deepwater foundations
- Reliability of seafloor/structure systems

Theme Sites



Representative deepwater sites at depths from 4,000 to 8,000 feet to focus seafloor studies.

Education

- Well over 200 undergraduates have been employed in OTRC’s research, enriching their education
- Graduated
  - 97 MSs
  - 62 PhDs

Applied Research Projects

- Homopolar Welding
- Nonlinear Wave Kinematics
- Spar Buoy
- NIST Drilling Riser

SESSION 1H

NORTHEASTERN GULF OF MEXICO ENVIRONMENTAL ISSUES

Chair: Dr. Alexis Lugo-Fernandez, Minerals Management Service
Co-Chair: Dr. Carole Current, Minerals Management Service

Date: December 2, 1999

Presentation	Author/Affiliation
Destin Dome and Sale 181 –Document not submitted–	Dr. Ann Scarborough Bull Minerals Management Service
Physical/Biological Oceanographic Integration Workshop for the DeSoto Canyon and Adjacent Shelf: How, and Why, We Got Here	Dr. William W. Schroeder Marine Science Program University of Alabama and Dauphin Island Sea Lab Dr. James J. Kendall Chief, Environmental Sciences Program Minerals Management Service
Northeastern Gulf of Mexico Coastal and Marine Ecosystem Program: Ecosystem Monitoring, Mississippi/Alabama Shelf	Dr. David A. Gettleson Continental Shelf Associates, Inc. Jupiter, Florida
Shelf Hydrography over the Northeastern Gulf of Mexico	Dr. Ann E. Jochens Dr. Worth D. Nowlin, Jr. Dr. Steven F. DiMarco, Dr. Matthew K. Howard Mr. Robert O. Reid Mr. Ou Wang Dr. Joseph Yip Department of Oceanography Texas A&M University
Northeastern Gulf of Mexico Modeling Research –Document not submitted–	Dr. Robert Weisberg University of South Florida

(continued on next page)

Presentation	Author/Affiliation
Linkages Between Biological and Oceanographic Processes in the Northeastern Gulf of Mexico	Dr. Frank Muller-Karger Dr. Robert Weisberg Dr. John Walsh Mr. Bisman Nababan University of South Florida Department of Marine Science Dr. Fred Vukovich Science Applications International Corporation Dr. Robert Leben University of Colorado

PHYSICAL/BIOLOGICAL OCEANOGRAPHIC INTEGRATION WORKSHOP FOR THE DE SOTO CANYON AND ADJACENT SHELF: HOW, AND WHY, WE GOT HERE

Dr. William W. Schroeder
Marine Science Program
University of Alabama and
Dauphin Island Sea Lab

Dr. James J. Kendall
Chief, Environmental Sciences Program
Minerals Management Service

INTRODUCTION – THE AREA

The U.S. Department of the Interior’s Minerals Management Service (MMS) conducts all leasing and resource management functions on the Outer Continental Shelf. The MMS sponsors scientific research to effectively manage and protect the environment. While MMS has sponsored substantial oceanographic studies in the northeastern Gulf of Mexico, demand for additional scientific information continues to be high. Recently completed, and ongoing, MMS studies in the northeastern Gulf also suggest that more integration is needed between the physical and biological oceanographic disciplines.

The Northeastern Gulf of Mexico continental shelf is an ecologically heterogeneous marine ecosystem. The shelf region is bounded onshore by a number of estuaries and bays acting as nutrient sources and serving as fertile nursery areas. Offshore, the De Soto Canyon, an area serving as an important fisheries ground and upwelling site, dominates the shelf. The health of the shelf ecosystem depends on physical habitat, environmental and climatic factors, nutrient availability, and oceanographic processes. These physical processes link the biotic components of the ecosystem. Hydrographic and sedimentological information suggest an east-west change of water column nutrients and physico-chemical properties near Cape San Blas; however, the information available is not enough to elucidate and characterize this change. Ongoing oceanographic studies in this region will provide a comprehensive and synoptic data set that can help prove this transition or provide an alternative paradigm. Ongoing biological studies suggest a number of data gaps that need investigating. This includes levels of production, taxonomic and trophic structure of coastal and shelf communities, coupling between water column and benthic communities, impacts of freshwater on shelf ecosystems, impacts of catastrophic events, and status and trends in fisheries resources and management.

To assess our state of knowledge for the area and to address the issue of additional information needs, particularly that of the integration of any future data collection and analysis efforts, a workshop was sponsored by the MMS and co-hosted by The University of Alabama and the Dauphin Island Sea Lab. This workshop brought together experts who summarized what was known about the area; determined critical issues; and provided input to the design of an integrated physical and biological study. Such an integrated study would be intended to bring to closure the

Northeastern Gulf of Mexico Physical Oceanography Program and the Northeastern Gulf of Mexico Coastal and Marine Ecosystem Program.

SPECIFIC AREA OF DISCUSSION

From the perspective of information needs concerning any future OCS activities, the geographic area of interest for this workshop is defined as an area encompassing the western portion of the Florida panhandle westward into the Alabama and Mississippi and includes the De Soto Canyon and adjacent areas going into deeper waters. Figure 1H.1 depicts the area of interest for this workshop, and shows the major physical exchange paths and forcing functions. This geographic area, of course, cannot be studied by itself, it must include the influences from coastal bays and estuaries, as well as the offshore currents including the Loop Current and eddies impinging on the continental shelf. Figure 1H.2 is a depiction of the Eastern Planning area including the area to be available for the proposed lease Sale 181. Part of the proposed lease sale area was brought up during workshop discussion.

RESEARCH HISTORY OF THE AREA

Physical Oceanography

In 1994, the MMS and the Florida State University hosted the Northeastern Gulf of Mexico Physical Oceanography Workshop (Clarke 1995) to assess the state of knowledge of the circulation in the shelf and upper slope region of the Northeastern Gulf, and to develop a strawman plan of possible studies.

Shortly thereafter, the MMS entered into a cooperative agreement with the University of South Florida to conduct the Northeastern Gulf of Mexico Satellite Oceanography Study. This study was designed to summarize the meso- to small-scale surface circulation on the continental shelf from the Mississippi River to Cape San Blas, using existing archived sea surface temperature, color camera, and coastal zone color scanner imagery. The three most relevant remote sensing data sets (sea-surface temperature, color photos, and digital color scans) are all now available from Federal archives, and can also be pre-scanned by available browsing routines to reduce search effort. A number of public-domain computer codes are also easily accessible for further analysis.

The project provided charts of selected frontal locations, statistical characterizations of the ensemble of frontal locations (based on the total imagery database); dynamical interpretations of these characterizations, and summary graphics for use by MMS decision-makers. The only previous MMS physical oceanographic study of currents and sea surface characteristics in the area occurred during the Mississippi-Alabama Marine Ecosystems Study (Brooks, 1991) which included five current moorings and numerous analyses of satellite images, sea-surface temperature, and currents in the western end of the study area. (A small amount of hydrographic data was taken during the Mississippi-Alabama-Florida study in the early 1970's.) The ultimate product of the work was an atlas of surface current patterns and meso- to small-scale frontal locations in the study area, plus associated documentation of methods, datasets used, and results.

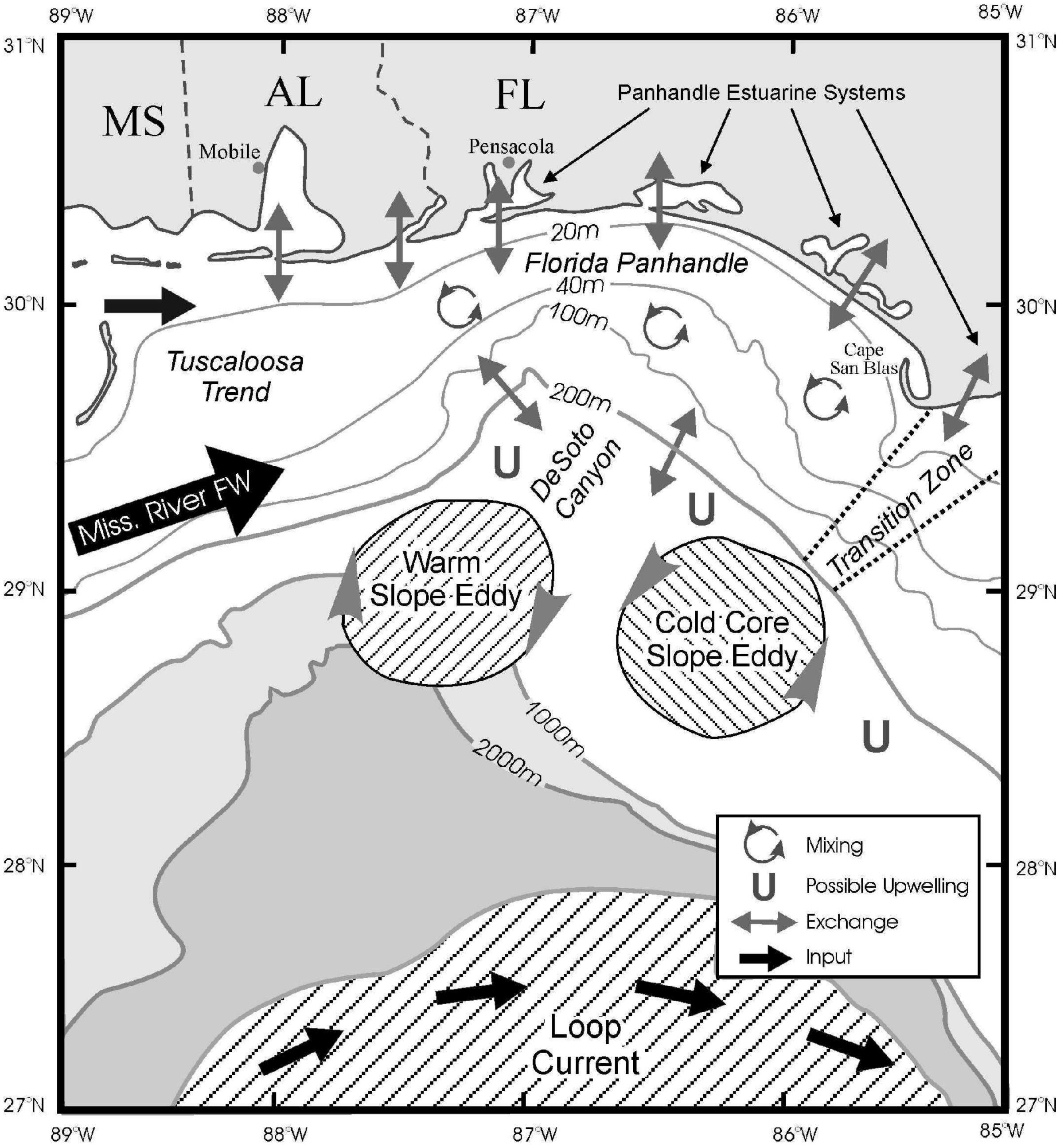


Figure 1H.1. The geographic area of interest for this workshop is defined as an area encompassing the western portion of the Florida panhandle westward into Alabama and Mississippi and includes the DeSoto Canyon and adjacent areas going into deeper waters.

Figure 1H.2. This is a depiction of the Eastern Planning Area including the area to be available for proposed lease Sale 181.

Concurrent with the Northeastern Gulf of Mexico Satellite Oceanography Study, the MMS entered into a Cooperative Agreement with the Florida State University to conduct the Northeastern Gulf of Mexico Inner Shelf Circulation Study and the Northeastern Gulf of Mexico Modeling Program. With the addition of environmental assessment responsibilities for State waters, mandated by the Oil Pollution Act, the MMS is required to analyze oil spill risks within the inner shelf zone, the 3- to 10-mile wide band of marine waters adjacent to the coast. The inner shelf zone has significant differences in circulation from the open shelf, due to the overlap of the benthic and surface Ekman boundary layers, due to complex lateral boundary geometry, and due to wave energy focusing and concentration. An approach to successful assessment of environmental risk in the inner shelf zone adopted by the MMS is the use of actual field measurements (i.e., data, as opposed to model results). This effort involves a mixture of Lagrangian drifter measurements, current meter moorings, and synthesis of existing information (through a coordinated Coastal Marine Institute study) to develop an adequate database for these assessments. This field measurement study provided the data for oil-spill risk assessments, skill assessments, and validation of numerical models.

These three efforts formally initiated the highly integrated MMS Northeastern Gulf of Mexico Physical Oceanography Program and led to the design of six other studies proposed during the workshop (Clarke 1995):

- Meteorology of the Northeast Gulf of Mexico
- De Soto Canyon Eddy Intrusion Study
- Operational Remote Sensing
- Eddy Monitoring & Remote Sensing
- Chemical Oceanography & Hydrography, and
- Circulation Regimes Affecting Living Marine Resources

Because one of the principal forcing mechanisms for coastal circulation on the continental shelf is wind forcing, and because the shelf is relatively wide area (approximately 100 km), any other physical oceanographic studies for the area would require additional meteorological measurements. If the wind field is not resolved in this way (both in terms of horizontal variations and possible differences in local stress, i.e., forcing strength) then expensive physical oceanographic datasets would be impossible to analyze fully. This being the case, the Meteorology of the Northeastern Gulf of Mexico was initiated in 1977 and is scheduled for completion in 2000.

It is well known that the Loop Current (and/or warm-core eddies believed derived from the Loop Current) can be observed to intrude onto the Mississippi-Alabama-Florida shelf in the area of the De Soto Canyon. Speculation on the specific mechanisms involved center on a “steering” effect of the canyon. Observations during the MMS-funded marine ecosystems work offshore Mississippi and Alabama indicate that significant water column effects can be observed during these intrusions. Further, workers in Florida argue that remote sensing images indicate considerable nutrient enrichment (and enhanced primary production) occurring at the head of the Canyon during intrusions. The De Soto Canyon Eddy Intrusion Study was conducted to quantify and characterize the physical scales and dynamic mechanisms associated with Loop Current intrusions in this area.

Critical parts of any circulation study attempting to address meso-scale dynamics are sufficient remote sensing. The Operational Remote Sensing and the Eddy Monitoring & Remote Sensing studies are providing this information. Further, the data gathered constitute a stand-along synthesis of meso-scale features. This study involves satellite analyses of ocean thermal fronts and other relevant thermal structures using AVHRR imagery; satellite analyses of sea surface height; and timely public dissemination of feature analyses and processed images.

The marine waters of the Northeastern Gulf are characterized by the transition from the highly turbid Mississippi River effluent (approximately 30% of which flows toward the east) and typical "blue" shelf water. Bottom sediments reflect this gradient, with a marked decrease in clay fraction from west to east. Previous work during the Mississippi-Alabama-Florida studies showed that there may be a sharp boundary between nutrient-rich mid-column water west of Cape San Blas and nutrient-poor water to the east. No studies have attempted to relate these characteristics to the physical circulation regime on the shelf, nor to the presumed periodic injection of new (possibly nutrient-rich) open Gulf water during eddy intrusions. Because the mean circulation in the area is believed to be quite weak, it is possible that the best means to identify any patterns might be through the careful study of the chemical regime. The Chemical Oceanography & Hydrography of the Northeastern Gulf of Mexico effort (initiated in 1997) is surveying the region to determine the overall levels and balances of chemical constituents and to identify and describe the chemical, physical, and biological mechanisms responsible for the observed levels, gradients, "sources," and "sinks."

Finally, the area possesses a rich mixture of benthic and pelagic faunas, dependent on the many different types of physical habitat present. As is typical of the coastal environment everywhere, a large part of the offshore fishery is dependent on the presence (and environmental quality) of estuaries for juvenile stage development or spawning. For these reasons, links between physical circulation and the habitat preferences or requirements of living marine resources are important. One notable example (although outside the area of discussion) is the very restricted timing and location for grouper spawning offshore Florida, and the known juvenile recruitment area in the grassbeds of the Florida Big Bend. The general current patterns on the west Florida shelf appear to be entirely contrary to the required transport of eggs and larvae, so unknown circulation mechanisms must be responsible for this critical movement. The study Circulation Regimes Affecting Living Marine Resources in the Northeastern Gulf of Mexico was originally scheduled to be the final study if this program. It was intended to make measurements at locations selected for their importance to significant marine resource species, in order to assess the importance of "normal" circulation regimes versus occasional extreme (or anomalous) events.

BIOLOGICAL/ENVIRONMENTAL SCIENCES

Concurrent with the Northeastern Gulf of Mexico Physical Oceanography Program, the MMS initiated the Northeast Gulf of Mexico Coastal and Marine Ecosystem Program. This program designed with input from the State of Florida and the National Biological Service (now the Biological Resources Division of the USGS) was designed to characterized the environment; identify the biological resources at risk, leading to an understanding of ecological relationships of the area; characterize rare and endangered species and communities; and examine the effects of immediate and long-term impacts.

The component studies of the Northeast Gulf of Mexico Coastal and Marine Ecosystem Program include:

- Northeastern Gulf of Mexico Offshore Data Search & Synthesis
- Northeastern Gulf of Mexico Coastal Characterization and Data Information Management System
- Distribution and Abundance of Marine Mammals
- Ecosystem Monitoring, Mississippi/Alabama Shelf, and
- Ecosystem Monitoring, Northeastern Gulf of Mexico OCS

The Northeastern Gulf of Mexico Offshore Data Search and Synthesis (SAIC 1997) was a regional data search and synthesis effort identifying and summarizing important information pertaining to the environmental and socioeconomic characteristics of this area. A conceptual model was drafted to serve as a framework to identify interactions in the ecosystem and look at critical pathways that may be uniquely sensitive to environmental impacts. Source materials were published documents as well as unpublished literature, theses, and dissertations. An annotated bibliography was compiled and a synthesis report brought together physical, chemical, ecological, and socioeconomic information into an ecosystem framework.

The Northeastern Gulf of Mexico Coastal Characterization and Data Information Management System characterized the coastal communities from the Mississippi Delta to Apalachicola Bay. The study area included all coastal counties extending offshore to the Federal leasing boundary. This study furthered our understanding of the coastal environment, how coastal habitats are impacted by offshore processes, and the interrelationship of coastal environmental and socioeconomic factors. The overall study purpose was to collect, organize, and analyze available information from various disciplines that would describe each part of the system in terms of its relation to other parts and to the region as a whole. As an integral component of this coastal characterization, a community profile describing the ecology of live bottom habitats was drafted (Thompson *et al.* 1999). This synthesis effort summarized available data on the living biological resources between the Mississippi River Delta and Cape San Blas, Florida.

Upon the receipt of the findings of its marine mammal field study, GulfCet I Program (Davis and Fargion 1996), the MMS identified the need for the further study of marine mammals. The Distribution and Abundance of Marine Mammals (GulfCet II), initiated in 1996, focused on the distribution, abundance, and behavior of these animals both on the OCS and in the deeper Gulf waters. The study area overlapped somewhat with the GulfCet I study area, but extended into shallower waters and into the area from approximately the Mississippi/Alabama state line eastward at least to Cape San Blas, Florida. The study produced data compatible with and comparable to that of the GulfCet I to produce a larger data set to be re-analyzed together. A two- to three-year extension of field observations provided for up to five years of seasonal distribution and abundance data in selected areas. This “cumulative” analysis provides better estimates of population variability, possible trend information, and increased detection for some species.

The study, Ecosystem Monitoring, Mississippi/Alabama Shelf, also initiated in 1996, is monitoring environmental conditions at three distinct types of topographic features present along the

Mississippi-Alabama OCS. These features include: (1) high profile pinnacles of 2-20 m relief; (2) medium relief, flattop features of approximately 5 m; and (3) low relief hard bottoms of less than 5 m. Seasonal information is being gathered regarding populations and diversity of biological organisms related to turbidity, zonations, and other physical environmental parameters. The program includes observations of reef morphology, as well as sessile organism growth rates and diversity, changes in the nepheloid layer, and general community health. The third interim report for this study was received in 1999 (CSA and TAMU 1999).

As mentioned earlier, the Offshore Data Search & Synthesis effort brought together existing data, literature, and information relevant to the marine ecosystem and synthesizing it into a narrative report and conceptual model. This information was intended to identify data gaps and form the basis for planning of the last component of Program, Ecosystem Monitoring, Northeastern Gulf of Mexico Outer Continental Shelf. This monitoring study was to be designed to describe this ecosystem, including unique habitats and resources. It was to emphasize delineating processes at work on the OCS and critical processes that may be affected by OCS gas and oil operations.

FUTURE RESEARCH

With oil and gas industry interest in the area under discussion (Figure 1H.1), the results of this workshop will be instrumental in designing the climax to the Northeastern Gulf of Mexico Physical Oceanography and Coastal and Marine Ecosystem Programs. As noted above, these two final studies, Circulation Regimes Affecting Living Marine Resources in the Northeastern Gulf of Mexico and Ecosystem Monitoring, Northeastern Gulf of Mexico Outer Continental Shelf, were identified early in the process, long before any preliminary results of the other studies were available. Discussion of such results now suggests that these two studies can not be designed separately. In fact, there is a strong reason to believe that these two efforts are so dependent upon one another that a single combined effort is called for. This study (or series of studies), now referred to as Northeastern Gulf Integrated Study of Physical and Biological Processes, is now intended to identify and increase the qualitative and quantitative understanding of currents and circulation patterns which help establish links and redistribute primary and secondary productivity within the ecosystem. It may also lead to a better understanding of the distribution of nutrients and sediments; larval dispersal; and the impacts of extreme or occasional events such as eddy intrusions, upwelling, floods, and hurricanes on the ecosystem.

This new venue was used to design Figure 1H.3 which shows how the component studies of the two aforementioned Programs, building upon other research in the area, lead to this meeting.

WORKSHOP STRUCTURE

As a basis with which to begin a multidisciplinary discussion, MMS presented a list of “Initial Issues for Discussion” (Table 1H.1) to pre-workshop registrants and workshop participants. On the first day of the workshop invited experts summarized knowledge of the De Soto Canyon and adjacent continental shelf region. Appendix A contains the schedule of invited presentations. Presentation summaries are given in section II.

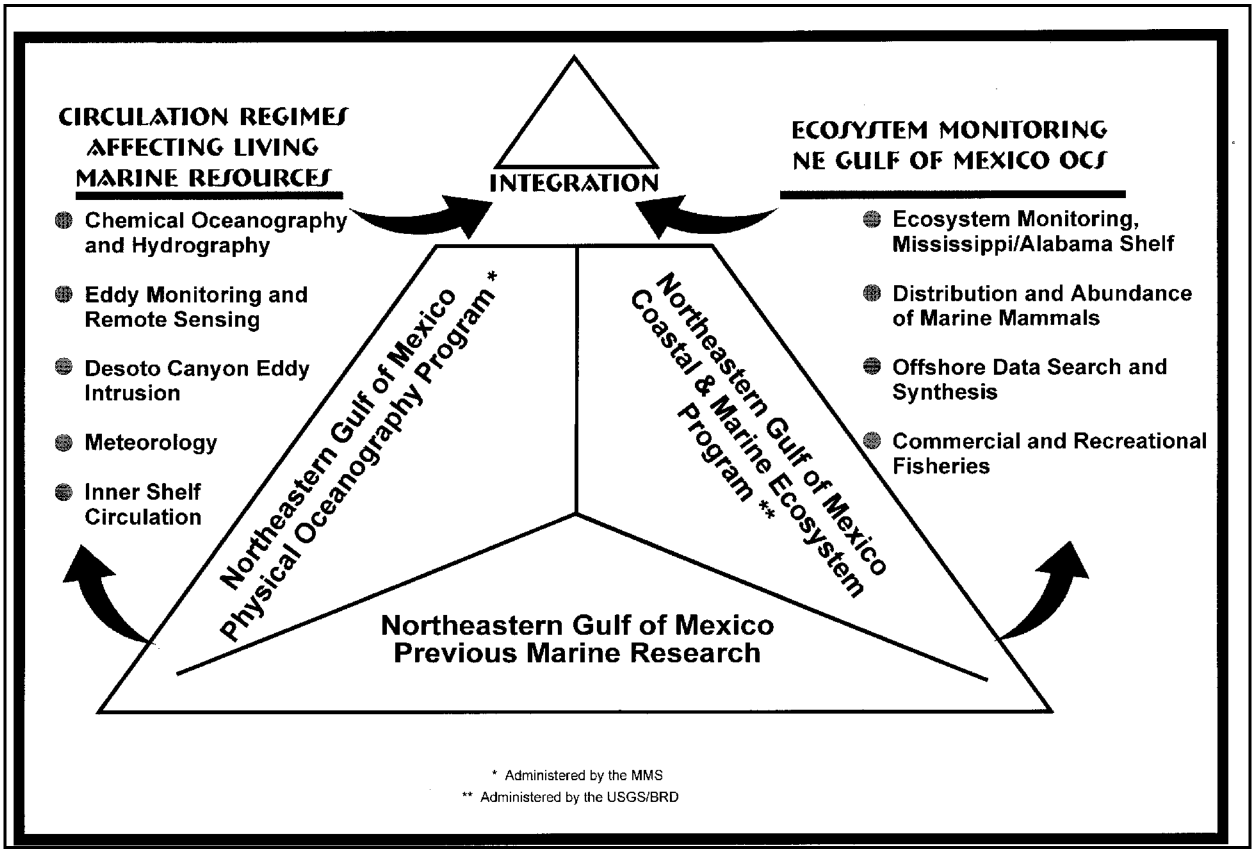


Figure 1H.3. The physical/biological interaction workshop of the DeSoto Canyon and adjacent shelf; the culmination of two regional research programs build on previous research.

One the second day, three multidisciplinary working groups were formed by equally dividing, by area of expertise, the workshop attendees. Each working group was led by an invited chair and an MMS chair with the assistance from an MMS rapporteur.

The members of each working group were asked to utilize the information syntheses provided by the speakers, combined with their own expertise, to: 1) identify the critical components and processes which need to be delineated, measured and modeled in order to understand the important physical and biological phenomena that occur in De Soto Canyon and adjacent continental shelf region; 2) identify significant knowledge and/or data gaps germane to these components and processes; and 3) formulate recommendations for research elements, based on the results from items 1) and 2). These discussions would then be used to assist MMS in designing an integrated physical and biological study to complete the Northeastern Gulf of Mexico Physical Oceanography Program and the Northeastern Gulf of Mexico Coastal and Marine Ecosystem Program.

Each of the working groups employed different, but effective, approaches in their deliberations. The full day allocated for this phase of the workshop permitted sufficient opportunity for all conferees to present their views and interact constructively. The chairs and rapporteurs organized and recorded

Table 1H.1. Initial issues for discussion.

Integration between the physical and biological components of the northeastern Gulf of Mexico:

1. Consider the transport of inorganic nutrients as these relate to supply and source(s). What are the utilization rates and their residence times on the shelf?
2. Consider the transport, deposition, and resuspension processes of materials (e.g., DOM, POM, POC, fecal pellets, corpses, marine snow, inorganic fines, and organisms) as these relate to supply and source(s). What are the proximate and ultimate fates of these materials?
3. What types and how do the ecosystems utilize the energy as subsidy? For example, how is the flow energy used to orient, disperse, clean, remove, and replenish wastes, oxygen, etc.
4. How, and to what extent, are the benthic assemblages related to substrate type (e.g., hard, soft), quantity (e.g., depth, patch size), and “quality” (e.g., percent organics, metals, depth or reduction potential discontinuity layer, or RPD)? Consider life stages of species and of faunal assemblages.
5. In addition to substrata, what specific physical environments “control” benthic communities?
6. How does the shelf ecosystem respond to prolonged and strong pulses of energy and materials? Is the response similar to those of other areas?

all the relevant material from discussions for inclusion in the working groups written reports. On the morning of the third day a plenary session was convened. This session began with the invited chairs presenting preliminary summaries of the draft reports being prepared by each of the working groups. The workshop ended with an open floor general discussion that allowed conferees to comment on the working group reports and/or to present any additional information or views. The working group reports appear in the last section of these proceedings.

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NORTHEASTERN GULF OF MEXICO COASTAL AND MARINE ECOSYSTEM PROGRAM: ECOSYSTEM MONITORING, MISSISSIPPI/ALABAMA SHELF

Dr. David A. Gettleson
Continental Shelf Associates, Inc.
Jupiter, Florida

INTRODUCTION

Continental Shelf Associates, Inc. (CSA) was awarded a contract by the U.S. Geological Survey, Biological Resources Division to conduct an ecological study of an area offshore Mississippi/Alabama. The project team consists of CSA, the Geochemical & Environmental Research Group of Texas A&M University, University of Texas, Applied Marine Sciences, and independent consultants.

GEOGRAPHIC AREA OF STUDY

The geographic area of study is the Mississippi-Alabama pinnacle trend area in approximately 50 to 150 m water depths (Figure 1H.4). Several studies have been conducted in the area, which was first described by Ludwick and Walton (1957). There have been four Minerals Management Service-funded studies (Woodward-Clyde Consultants 1979; Brooks 1991; Continental Shelf Associates, Inc. 1992; Shinn *et al.* 1993) and an oil and gas lease block clearance survey (Continental Shelf Associates, Inc. 1985) conducted in the area.

STUDY OBJECTIVE

The objective of this study is to describe and monitor biological communities and environmental conditions at hard-bottom features located within the geographic area of study. A number of oil and gas lease blocks are encompassed by the study area with at least one oil and gas production platform present. Information gained from this study will be used to review existing lease stipulations to determine their adequacy in protecting the biological communities present on the hard-bottom features. This study also meets several objectives of the National Research Council (1992) regarding the assessment of environmental impacts from oil and gas operations. These objectives include (1) identifying representative species; (2) describing seasonal patterns; (3) acquiring basic ecological information for key or representative species; and (4) obtaining information on factors that determine sensitivity of biota to outer continental shelf activities and their recovery potential.

STUDY COMPONENTS

The 4-year study is divided into four phases of one-year duration each with annual reports planned at the end of each phase. The phases are as follows:

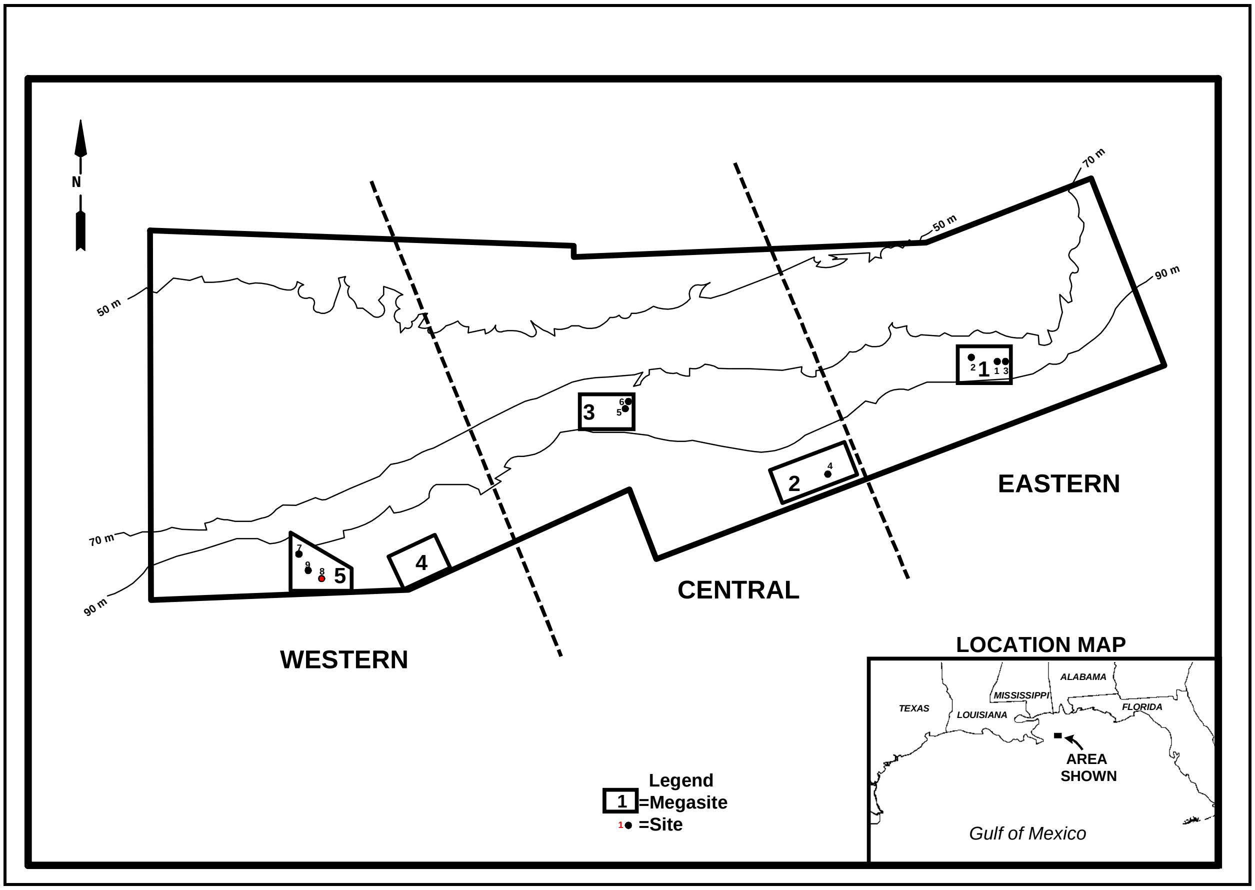

Figure 1H.4. Locations of final monitoring sites.

Phase 1 - Reconnaissance, Baseline, and Monitoring;
Phase 2 - Monitoring;
Phase 3 - Monitoring; and
Phase 4 - Data Interpretation and Information Synthesis.

All of the 11 cruises planned for the study have now been completed. These encompassed reconnaissance (two cruises), baseline (one cruise), monitoring (three cruises), and mooring servicing (five cruises).

Reconnaissance

During the reconnaissance portion of Phase 1, five "megasites" (Figure 1H.4) (approximately 25 to 35 km^2 areas) were selected for detailed study. These sites were selected as being representative of the hard-bottom features previously identified in the area (Brooks 1991; Continental Shelf Associates, Inc. 1992). The megasites were surveyed in November 1996 using swath bathymetry, high resolution side-scan sonar (11 and 72 kHz), and a subbottom profiler (2 to 8 kHz). Nine areas of approximately 0.2 to 1.5 km^2 size were selected during the cruise and surveyed in more detail. Previously collected video and still photographic data from these nine sites were reviewed and additional visual data collected during a second reconnaissance survey using a remotely operated vehicle (ROV) to aid in the selection of nine study sites. The study sites were selected to provide representative hard-bottom features of high, medium, and low relief in the eastern, central, and western portions of the study area (Figure 1H.4).

Baseline and Monitoring

The focus of the baseline and monitoring portions of the study is to understand the geological and oceanographic processes as factors in controlling/influencing the hard-bottom communities at the nine study sites. Data were gathered during the reconnaissance survey on substrate characteristics; hard-bottom orientation, size, and morphology; and depth of surrounding soft sediments. One baseline and three monitoring cruises have been completed (April 1997, October 1997, August 1998, and August 1999). Data on microtopography are being obtained from the collection and analysis of rock samples and video and photographic data during these cruises. Grab samples collected during the monitoring cruises are being analyzed for grain size (four cruises) and concentrations of hydrocarbons and metals (first cruise only). Six instrument arrays comprised of current meters; sediment traps; and temperature, salinity, dissolved oxygen, and turbidity (optical backscattering) sensors were deployed during the first cruise in the vicinity of the hard-bottom features. The arrays were recovered and redeployed at 3-month intervals and recovered on the final monitoring cruise. Sediment trap contents are being analyzed for grain size, total inorganic and organic carbon, and metals. During each of the four cruises, water column profiles were made for conductivity, temperature, dissolved oxygen, transmissivity, and optical backscatter, and samples were collected for analysis of particle sizes, dissolved oxygen, and salinity. Water column profiles also were made during the five mooring servicing cruises.

Biological Data

Hard-bottom communities were sampled at the nine sites by ROV. At each site, random photographs were taken and random video transects were surveyed using an ROV during the baseline and monitoring cruises. Random photographs are used to estimate the abundances of sessile and motile epibiota, whereas video images are used to quantify larger and more widely dispersed organisms including fishes and to broadly characterize substrates and species composition. In addition, fixed video/photoquadrats were established and resampled on subsequent cruises; the data will be used to describe temporal changes related to growth, recruitment, competition, and mortality. Voucher specimens also were collected to aid in species identification. Together with geological and oceanographic data collected during the program, these data will be analyzed and interpreted to describe hard-bottom community dynamics, variation within and among sites, and relationships between the biota and physical variables.

A total of 1,675 random photoquadrats have been analyzed from the baseline and first monitoring cruises. A total of 42 taxa comprise the 10 taxa with the highest mean density at each site. Cnidaria was the most-represented phylum with 10 taxa of octocorals, five taxa of ahermatypic corals, four taxa of antipatharians, and single taxa of hermatypic corals and actinarians (anemones). Porifera was the next most-represented phylum with seven taxa, followed by Ectoprocta with five taxa. The phylum Echinodermata was represented by three taxa (two crinoids and one echinoid). Algae were represented by two taxa of rhodophyta. The phyla Urochordata and Arthropoda were represented by single taxa of ascidians and galatheids, respectively. Hard-bottom community composition revealed by the percent cover data from the random photoquadrats was only slightly different from that revealed by the density data. Although octocorals were represented by the most taxa in both density and percent cover data, ahermatypic corals had the highest mean abundances with 279.3 organisms per m^2 and 5.62% cover over all sites, due to the dominance of Rhizopsammia manuelensis. Octocorals had the second highest mean density and percent cover over all sites with 13.60 per m^2 and 3.00% cover. The relative ranking of antipatharians, poriferans, and ectoprocts varied between density and percent cover data. The aggregate percent cover data for major groups represented by the 40 most abundant taxa suggest substantial variation among sites. Mean percent cover for ahermatypic corals ranged from 0.03 at Site 1 to 10.96 at Site 7. Mean percent cover for antipatharians also was quite variable among sites, ranging from 0.04 at Site 1 to 16.18 at Site 4. Octocorals, poriferans, and ectoprocts displayed relatively less variation among sites. Despite the high variation among sites, there was little difference between sampling times. Abundances at high relief sites (Sites 1, 5, and 7) were neither obviously greater nor more diverse than at sites with lower relief. Little of the biological variation among sites is apparently due to consistent effects of habitat relief. Some taxa occurred in high abundances in all relief categories and others varied inconsistently among relief categories.

Fish assemblages associated with the study sites also are being described from the available visual data collected during the surveys. There are also two additional biological “companion” studies. The first is a geographic information system (GIS) and microhabitats study that focuses on relationships between the physical environment and the hard-bottom communities. The microhabitats study is being conducted at Sites 7 (medium relief) and 9 (low relief). The second involves the deployment of settling plates on fixed arrays to study epibiota recruitment, growth, and community development. Settling plate arrays include enclosed and non-enclosed plates plus controls to study predation/disturbance effects. Plates were placed near bottom and above any identified nepheloid layer.

Data Interpretation/Synthesis

The data interpretation and synthesis efforts will involve understanding the relationship of the measured geological and physical factors to the hard-bottom communities through statistical analyses. A series of questions determined by the study objective with clearly stated null hypotheses also will be identified and statistically tested.

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SHELF HYDROGRAPHY OVER THE NORTHEASTERN GULF OF MEXICO

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Texas A&M University is conducting the Chemical Oceanography and Hydrography Study (NEGOM-COHS), which is one of the components of the Northeastern Gulf of Mexico Physical Oceanography Program, supported by the U.S. Minerals Management Service (MMS). The major objective of NEGOM-COHS is to describe the spatial and temporal distribution and variation of hydrographic variables and the processes responsible. The variables of interest are sea water salinity, temperature, dissolved oxygen, nutrients, particulate material, particulate organic carbon, transmissivity, fluorescence, pigments, and light penetration. The objective is being met through the completion of a field program of nine hydrography/acoustic Doppler current profiler (ADCP) cruises, one in each of the spring (May), summer (August), and fall (November) seasons over three years. The observations, together with collateral data, will be synthesized, interpreted, and reported to provide a more complete understanding of circulation and transport of properties over the study area.

The study area encompasses the east Louisiana, Mississippi, Alabama, and west Florida continental shelf and upper slope from the Mississippi River Delta to Tampa Bay in water depths of 10 to 1,000 m. The first cruise was conducted in November 1997, the last will be in August 2000. Approximately 100 CTD and 90 XBT stations, in a configuration of 11 cross-shelf lines and one alongshelf line on the 1,000-m isobath, are occupied on each cruise (Figure 1H.5). Station locations are approximately the same for each cruise to facilitate comparisons between cruises. Additionally, ADCP, thermosalinograph, and 3-m flow-through fluorescence measurements are made continuously along the track.

Although the final year of hydrographic surveys remains to be done, the six cruises already completed provide a preliminary look at the seasonal variability of the properties and inferred circulation over the region. To extracted gridded current vector fields from the ADCP data for the near surface (10-14 m) and several subsurface layers. We compared the near-surface ADCP fields to the geopotential anomaly fields computed from the hydrographic data and to sea surface height anomaly fields derived from satellite altimeter data.

We examined the seasonal circulation on three sub-regions: the western inner shelf, eastern inner shelf, and outer shelf/upper slope. Here “inner shelf” extends from approximately 10 m to 100 m and “outer shelf” is seaward of 100 m. The western inner shelf consists of the region west of Cape

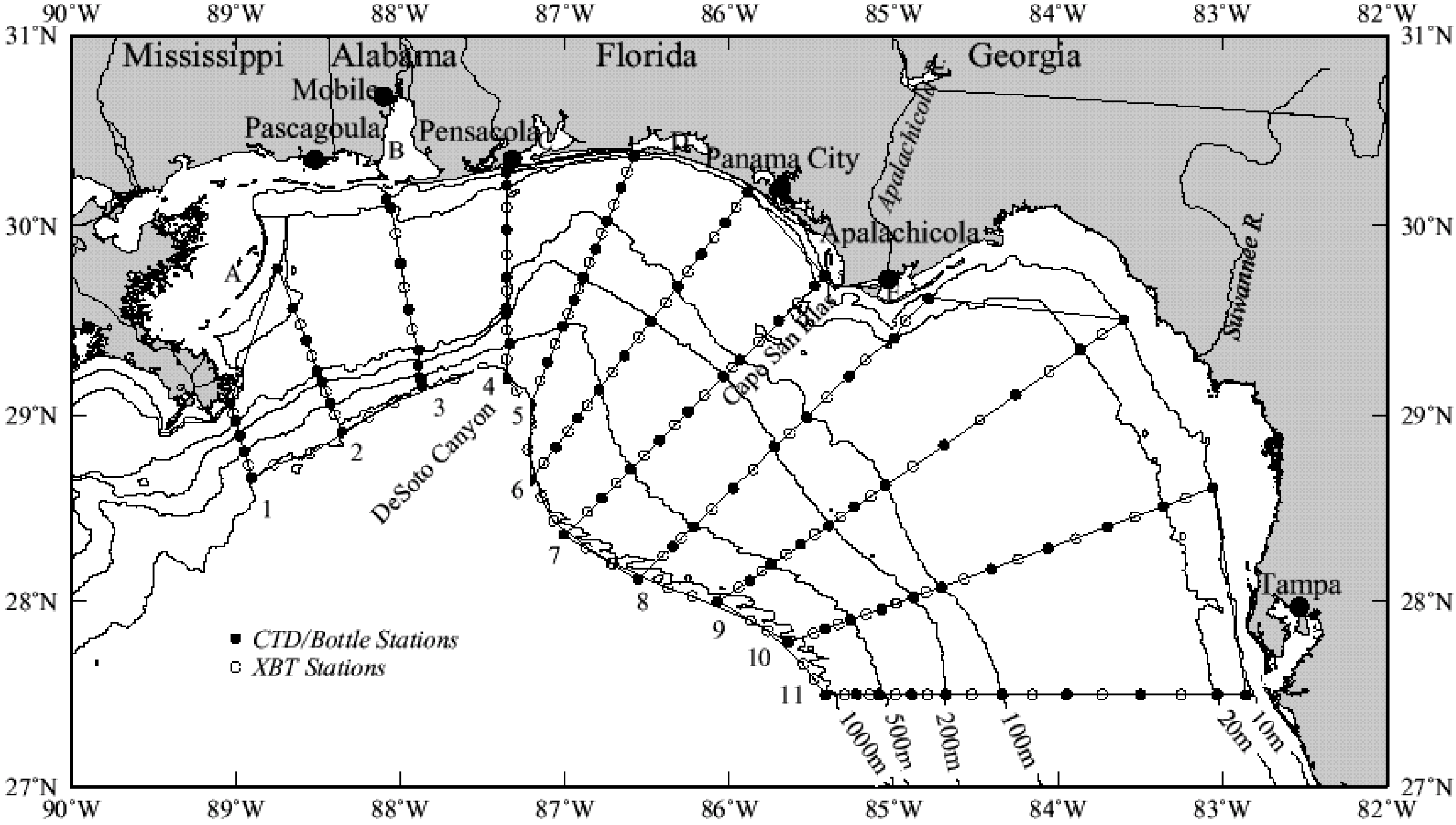

Figure 1H.5. Station locations and cruise track for NEGOM hydrographic/ ADCP cruises (actual N2) and geographic locations in the study area. Cross-shelf line numbers are given at the offshore end of the lines. Legend: A- Chandeleur Sound; B-Mobile Bay; C- Pensacola Bay; D- Choctawhatchee Bay; E- Apalachicola Bay.

San Blas. The eastern inner shelf includes that part of the shelf southeast of Cape San Blas in the Big Bend region to Tampa. The outer shelf/upper slope is that region in water depths from about 100 m to 1,000 m. The focus of this paper is on the near-surface circulation and property distributions.

SPRING (MAY 1998 AND MAY 1999)

Western Inner Shelf

The springtime near-surface currents flow downcoast from Mississippi toward Tampa (Figure 1H.6a). This is mainly in response to the eastward alongshelf component of the wind, which also induces some nearshore coastal upwelling. The currents moved fresh water being discharged onto the shelf from the Mississippi and other rivers along the inner shelf to the east (Figure 1H.6b). In 1998, both the Mississippi and Tombigbee Rivers were discharging at above their record-length mean discharges, resulting in 3-m salinities of <32 over much of the western inner shelf extending east to Cape San Blas. The salinity pattern shows large volumes of fresh water coming from the Mississippi and out of Mobile Bay. In 1999, however, the salinity pattern shows a smaller region with salinity of <32, extending only to Choctawhatchee Bay.

River water carries nutrients into the Gulf. The 3-m silicate, which is not a limiting nutrient for biological activity, had high concentrations (>3 µM) all along the western inner shelf during both spring cruises. The 3-m nitrate values, however, were high (>1 µM) mainly in the region adjacent to the Mississippi River Delta and seaward off the Chandeleur Islands. Concentrations near the mouth of the Mississippi were exceedingly high (>30 µM) in 1999 as compared to ~15 µM in 1998. There were localized high nitrates adjacent to Choctawhatchee Bay in 1998. The 3-m phosphate values were <0.1 µM everywhere except immediately off the mouth of the Mississippi River; concentrations in 1999 were higher than in 1998. Chlorophyll *a* concentrations showed response to the nutrients from the river water and were relatively high (>500 $\text{ng}\bullet\text{L}^{-1}$) along the entire western inner shelf in 1998 and from Choctawhatchee Bay west in 1999. The near-bottom dissolved oxygen concentrations in spring 1998 generally were lower and less variable than those in spring 1999, although lowest, hypoxic values occurred in 1999. Lowest values, at 2.1 $\text{mL}\bullet\text{L}^{-1}$ in 1998 and 1.5 $\text{mL}\bullet\text{L}^{-1}$ in 1999, were off the Chandeleur Islands.

Eastern Inner Shelf

In spring 1998, near-surface currents were weak and directed mainly downcoast over the broad middle shelf, possibly in response to the northeastward-directed winds (Figure 1H.6a). Inshore of about the 20-m isobath, currents were directed mainly toward the shore. The pattern of spring 1999 currents in this region is very different. Here there is indication of a cyclonic circulation over the broad middle shelf centered at about 28.75˚N, 84.5˚W, with flows inshore of this feature directed mainly westward. The 3-m salinities were fresher in 1998 than 1999, with lowest values in 1998 being <32 inshore of the 20-m isobath off the Suwannee River (Figure 1H.6b) and lowest in 1999 being ~35. The salinity contours in 1998 generally parallel the isobaths with salinities increasing offshore, but in 1999 they indicate a tongue of higher salinity (>36) water moving upcoast from the south. This likely is due to the cyclonic circulation drawing saltier water to the north and east, possibly from offshore.

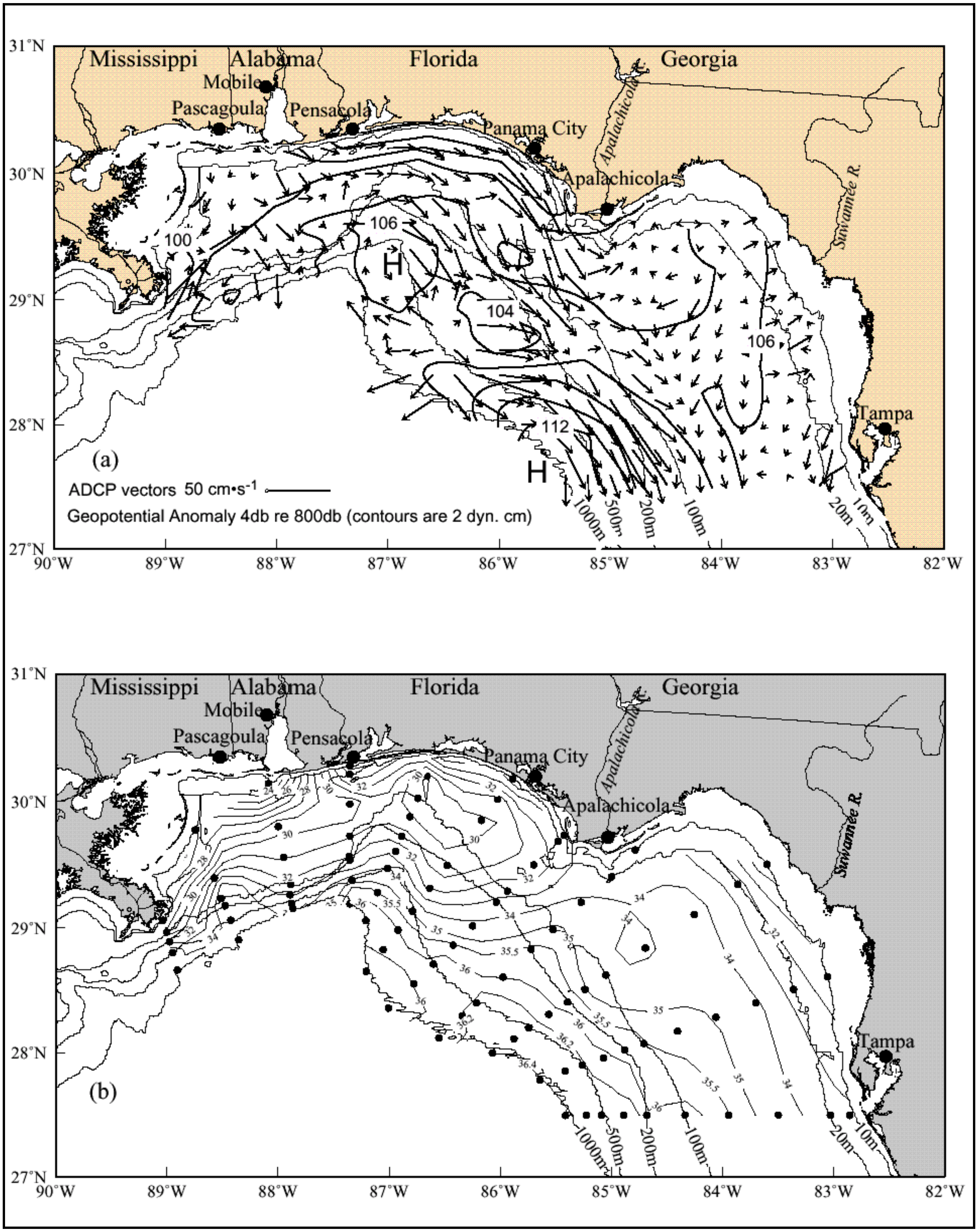

Figure 1H.6. Spring NEGOM Cruise N2, 5-16 May 1998, (a) gridded ADCP-measured currents at 14 m and geopotential anomaly (4db re 800db) and (b) salinity at ~3.5 m.

Nutrient, chlorophyll *a*, and dissolved oxygen patterns also differ between the two springs. In 1998, a tongue of locally high silicate extended from Cape San Blas south over the broad eastern inner shelf. This likely was due in part to the downcoast movement of waters associated with the river discharges over the western inner shelf, coupled with the downcoast movement of discharge from the Apalachicola River. Nitrate and phosphate concentrations, however, were very small. Much of the eastern inner shelf in 1998 had chlorophyll *a* concentrations in excess of 300 $\text{ng}\bullet\text{L}^{-1}$, increasing inshore. Bottom oxygen concentrations were generally less than 4 $\text{mL}\bullet\text{L}^{-1}$, except inshore of the 10-m isobath where they were <5 $\text{mL}\bullet\text{L}^{-1}$. In contrast, the 1999 concentrations of all nutrients, including silicate were very small everywhere over the eastern inner shelf, and near-bottom dissolved oxygen concentrations were approximately 5 $\text{mL}\bullet\text{L}^{-1}$. There was a local high in chlorophyll *a* (300-500 $\text{ng}\bullet\text{L}^{-1}$) centered about 29.3˚N, 84˚W offshore of the Suwannee River.

Outer Shelf/Upper Slope

Satellite altimeter data allow the estimation of the sea surface height anomaly (SSHA) fields that can provide information on the presence or absence of anticyclonic (highs in SSHA) or cyclonic (lows in SSHA) features seaward of the shelf edge. SSHA maps indicate that during spring 1998, an anticyclonic eddy was located seaward of the western shelf edge. The anticyclone had two centers: one situated over DeSoto Canyon and the other centered at 27.5˚N, 86.3˚W. The stronger SSHA gradients were over the outer shelf/upper slope adjacent to the eastern inner shelf. The centers from the SSHA data match reasonably well the centers in geopotential anomaly, although those of the SSHA are offset mainly to the west. The SSHA gradients, which are greatest adjacent to the eastern inner shelf, match well with the regions of stronger currents in ADCP (Figure 1H.6a). The 3-m salinity field shows a tongue of more saline water extending up the axis of the DeSoto Canyon. This is in the region where the anticyclone generates northeastward currents. The resulting chlorophyll *a* field shows a region of lower concentrations up the axis of the canyon. The circulation and property distributions over the outer shelf/upper slope, therefore, were responding to the presence of this anticyclonic eddy. During spring 1999, a cyclonic eddy was located southwest of DeSoto Canyon with weak lows adjacent to the shelf edge. The Loop Current was adjacent to the upper slope south of Tampa. The ADCP field shows the circulation over the outer shelf/upper slope was not as well organized as in spring 1998. The influence of the Loop Current was apparent in strong, anticyclonic, southward currents over the upper slope west of Tampa; these currents extended at least to 100 m as measured by the ADCP. In both springs, the salinity was higher over the outer shelf/upper slope than over the inner shelf (Figure 1H.6b). The region with the higher nutrients and chlorophyll *a* concentrations was off Louisiana, Mississippi, and Alabama and was associated with the discharge of the Mississippi River.

SUMMER (AUGUST 1998 AND AUGUST 1999)

Western Inner Shelf

Summertime currents over the western inner shelf were weak and not well organized, but with some indication of reversal of the springtime downcoast flow conditions to upcoast flow (Figure 1H..7a). Winds were weaker than in spring, and differed in direction between the two cruises with a

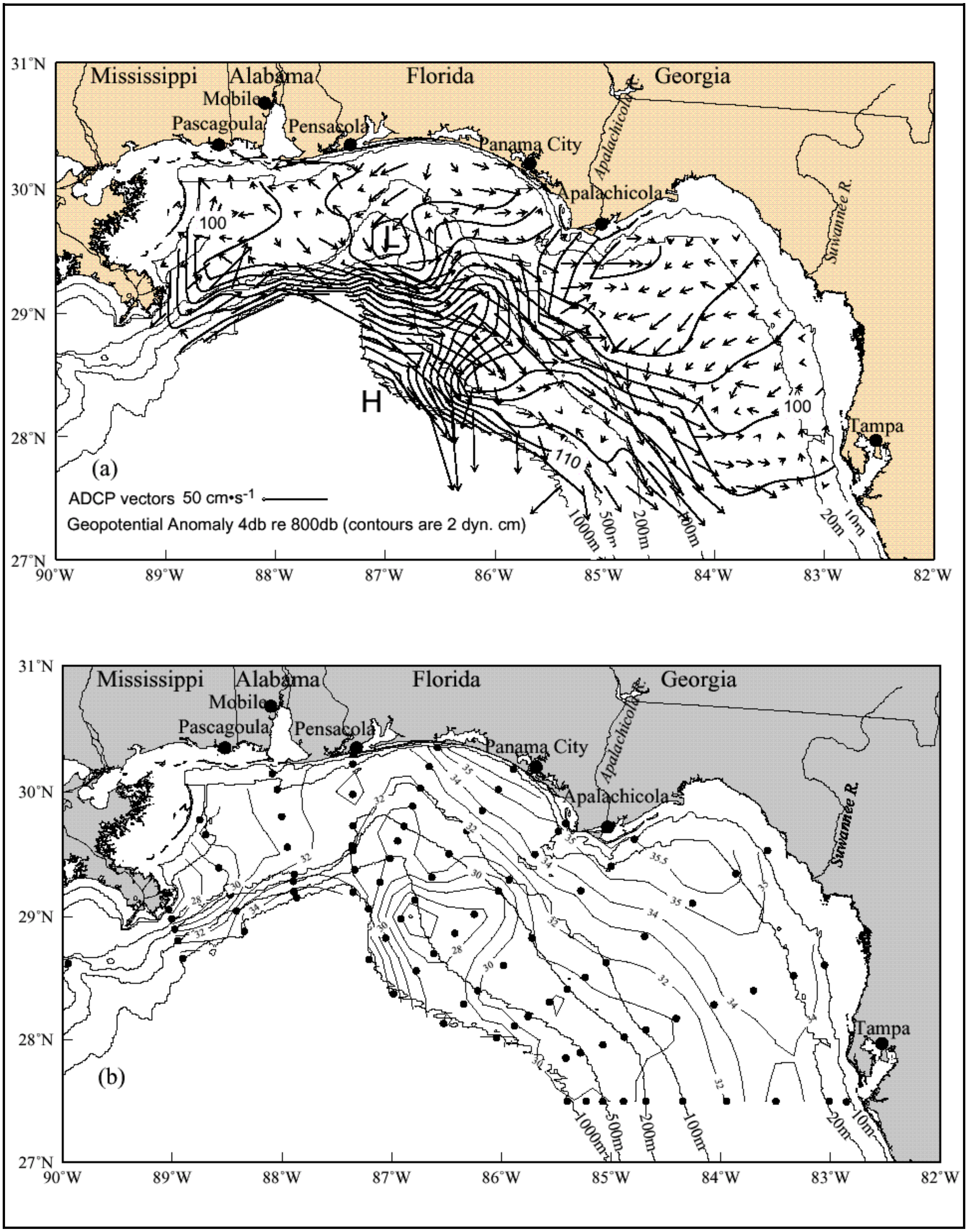

Figure 1H.7. Spring NEGOM Cruise N3, 25 July-7 August 1998, (a) gridded ADCP-measured currents at 14 m and geopotential anomaly (4db re 800db) and (b) salinity at ~3.5 m.

westward component during 1998 and an eastward component during 1999. During 1998, there was a low in geopotential anomaly over the head of DeSoto Canyon associated with a cyclonic circulation along the 100-m isobath there. In 1999, the currents show no such cyclonic circulation, but rather exhibit downcoast flow along the 100-m isobath. The 3-m salinity in both summers was freshest off the Mississippi River Delta and was generally greater than 32 elsewhere (Figure 1H.7b). Off Panama City, salinities were highest nearshore; this was circulation discussed below. Silicates were high off the Mississippi River and also off Pensacola Bay. Nitrates and phosphates were elevated only off the Mississippi River Delta, where chlorophyll *a* concentrations also were the highest over the western inner shelf. Lowest bottom oxygen concentrations (<3 mL•L^{-1}) were associated with the region of highest chlorophyll *a*. Hypoxia at the bottom occurred along line 4 in about the 25-m water depth (Figure 1H.8).

Eastern Inner Shelf

Summertime near-surface currents over the eastern inner shelf were weakly cyclonic, with a center at about 28.5˚N, 84˚W in 1998 (Figure 1H.7a). The pattern extended into the water column, but with the center shifted westward. In contrast, the near-surface currents in 1999 (not shown) were weakly anticyclonic, mainly north of 28.7˚N, with a center at about 29˚N, 84.3˚W. Inshore of the 20-m isobath south of 28.7˚N, currents were directed south. The 1999 pattern did not extend into the water column. The contours of 3-m salinity in 1998 generally paralleled isobaths, with higher salinities inshore (Figure 1H.7b). Preliminary results indicate a similar pattern for 1999. This pattern is related to the conditions at the outer shelf. In 1998, nutrients were low and bottom dissolved oxygen concentrations were high over all the eastern inner shelf. Chlorophyll *a* values were less than 300 ng•L^{-1} everywhere except between the Apalachicola and Suwannee rivers. This is consistent with the movement of Suwannee River water northwest in association with the cyclone located over the shelf.

Outer Shelf/Upper Slope: The SSHA map for the summer cruise 1998 shows an anticyclonic eddy was located seaward of the western shelf edge, with its center near 28.5˚N, 87.5˚W and elongated NW-SE between the Mississippi River Delta and the west Florida terrace. The ADCP near-surface currents show the strong anticyclonic response of the upper slope circulation to this eddy (Figure 1H.7a). The eddy drew water from the Mississippi River along the outer shelf/upper slope from the delta eastward. The effect can be seen in the 3-m salinity map (Figure 1H.7b) which shows very fresh waters (<30) over the eastern flank of DeSoto Canyon and along the 1000-m isobath. This results in the condition of saltier water being located inshore over the shelf east of about 87˚W. Silicates are high (up to 10 µM) over the upper slope east of DeSoto Canyon as compared to the inner shelf values of order 1. Other nutrients are very small, due to consumption as indicated by the region of high chlorophyll *a* (>500 ng•L^{-1}) co-located with the low salinities/high silicates at the outer shelf/upper slope. Indications are the results for 1999 will be similar, which might be expected from the presence of anticyclonic features adjacent to the 1000-m isobath during the summer 1999 cruise.

Also present over the outer shelf/upper slope in summer 1998 was a small cyclone located at the head of DeSoto Canyon (Figure 1H.7a). Associated with this feature is an uplift in the various water properties, including dissolved oxygen as shown in Figure 1H.8. This is an example of localized upwelling. The presence of small cyclones near the shelf edge with associated upwelling was seen in other seasons as well.

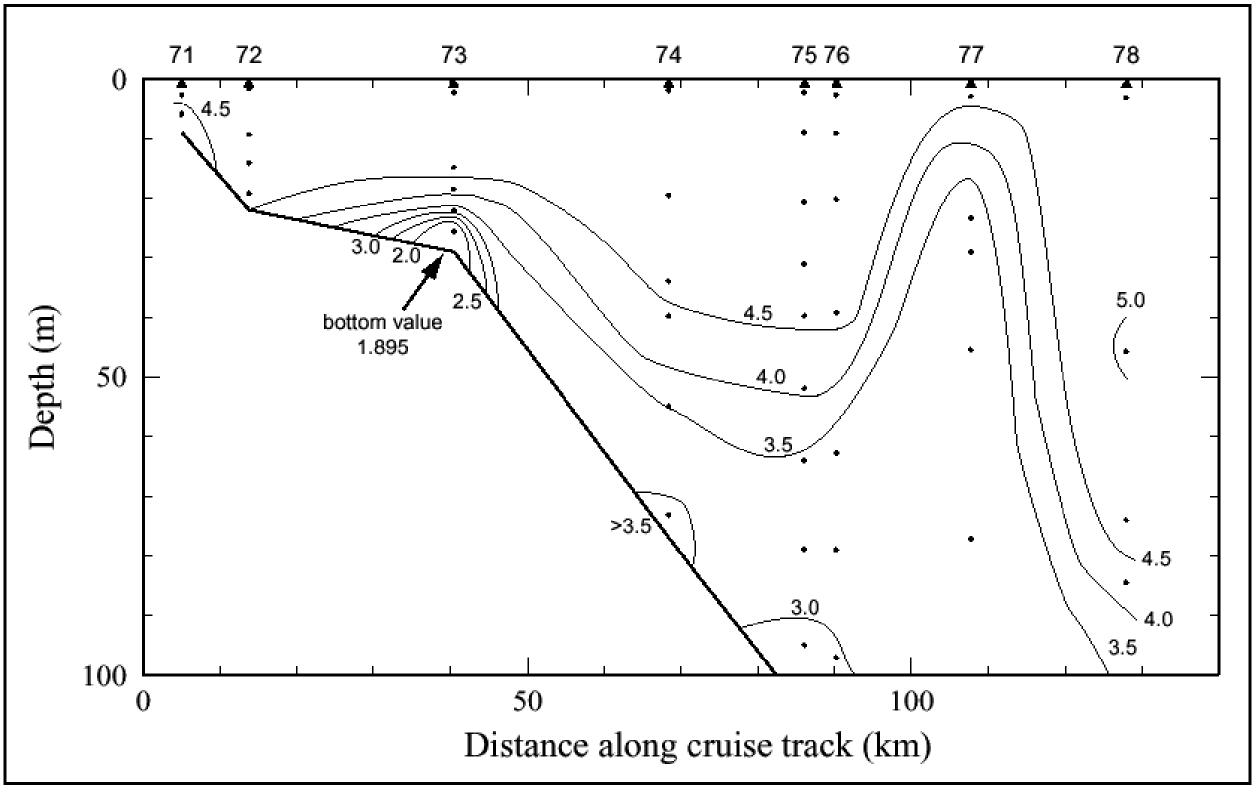

Figure 1H.8. Dissolved oxygen (mL·L -1) on line 4 of NEGOM cruise N3, 26 July - 6 August 1998.

FALL (NOVEMBER 1997 AND NOVEMBER 1998)

Western Inner Shelf

The near-surface circulation over the western inner shelf in fall was highly variable in direction and magnitude, most likely due to the frequent passage of cold fronts through the area (Figure 1H.9a). During both cruises, the average winds were directed approximately west to southwest over the western inner shelf. In each, the fall pattern of circulation included an elongated, but weak cyclone over the Mississippi-Alabama shelf. This pattern was strongest in 1998 (not shown). In fall, when river discharge is smaller than spring, the 3-m salinity concentrations were lowest immediately adjacent to the Mississippi River Delta (Figure 1H.9b). However, in contrast to the two summer cruises, east of the delta the salinity went from lower nearshore to higher offshore. The contours also approximately follow the isobaths, except near the Mississippi River Delta. The gradient was steeper in 1998 than in 1997, reflecting the higher river discharge in 1998. This difference also is reflected in the patterns and concentrations of 3-m nutrients. The 1998 conan order of magnitude or more off the delta than in 1997. In both years, localized high silicates occurred offshore of Pensacola and Choctawhatchee Bays. Nitrate and phosphate were low (generally less than 0.1 µM) over the western inner shelf except adjacent to the Mississippi River Delta in 1998. Chlorophyll *a*

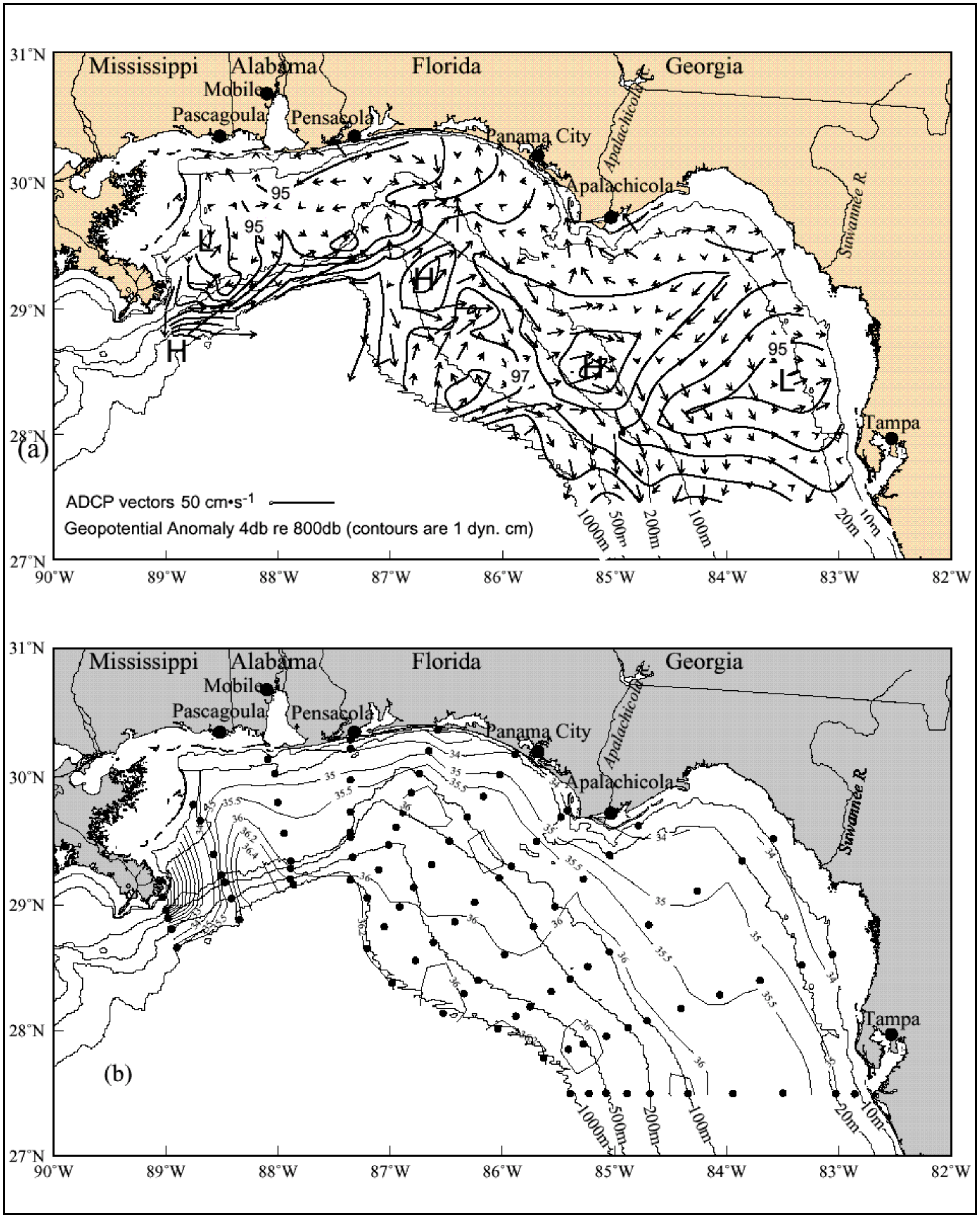

Figure 1H.9. Fall NEGOM Cruises (a) N1, 16-27 November 1997, gridded ADCP-measured currents at 10 and 12 m and geopotential anomaly (4db re 800db) and (b) N4, 13-24 November 1998, salinity at ~3.5 m.

concentrations were less than 500 ng•L^{-1} except adjacent to the delta. Bottom dissolved oxygen concentrations were high over the western inner shelf, as expected from vertical mixing induced by passage of cold fronts through the area in fall.

Eastern Inner Shelf

Geopotential anomalies over the eastern inner shelf in fall exhibited pairs of high and low features, where the dynamic range was approximately 5 dyn cm. In 1997, the low was centered near 28.5˚N, 83.5˚W and the high near 28.5˚N, 85˚W. The near-surface currents, however, do not indicate that these were well-developed circulation features (Figure 1H.9a). Rather, flows over the eastern inner shelf tended to bifurcate at about 29˚N, with flows directed northwestward north of that latitude and flows directed southward to the south of it. The north-south order of the high-low pair in 1998 was reversed from that of 1997, with the low centered at about 28.3˚N, 83.7˚W and the high at about 29˚N, 84˚W. No near-surface currents are available for this cruise. The 3-m salinities in both years are between 34 and 36, with lower values inshore (Figure 1H.9b). Nutrient values are low. Bottom dissolved oxygen concentrations are high, although the values in 1997 are generally higher than in 1998. The chlorophyll *a* patterns are somewhat different in the two years. The concentrations in 1998 are lower, ranging from <100 to ~400 ng•L^{-1}, compared to 1997, which ranges from about 200 to 3000 ng•L^{-1}. The highest values in 1998 were inshore just northwest of the Suwannee River; winds in this region during the cruise were toward the west. The highest values in 1997 were inshore south of the Suwannee River; winds during this cruise were directed to the south-southwest. Thus, these chlorophyll *a* patterns may reflect movement of Suwannee River water by the winds.

Outer Shelf/Upper Sloop

During both fall cruises, a weak anticyclonic eddy was located seaward of the western shelf edge, with lows in SSHA adjacent to the west Florida shelf. The currents over the outer shelf/upper slope indicate a response to the presence of these SSHA patterns. For example, associated with the anticyclone in 1997 are eastward currents over the outer shelf/upper slope just west of the delta and southward flow associated with the SSHA lows over the upper slope off Tampa (Figure 1H.9a). Except where influenced by the discharge from the Mississippi River in the west, property distributions in this region show patterns of low nutrients and chlorophyll *a* and salinities that are higher than those over the adjacent inner shelf.

SUMMARY

The preliminary results of the first six NEGOM-COHS cruises indicate a seasonal pattern to the circulation over the shelf. In spring, the wind field generally forces an eastward flowing coastal current over the inner shelf west of Cape San Blas. This transports nutrient-rich, fresh river water eastward along the coast. East of Cape San Blas there is no indication of an anticyclonic circulation in the Big Bend region; rather, there are indications of possible cyclonic flow. In contrast to the spring, there is no large alongshelf flow over the inner shelf in the fall season. Flows over the outer shelf were not strong either. This caused the effects of the discharge of the Mississippi and other rivers to be localized near the river mouths and offshore of the sounds, as apparent in property distributions. In summer, the major circulation feature seen on the NEGOM cruises was fresher water being drawn along the outer shelf in response to the presence of anticyclonic and cyclonic eddies over the slope adjacent to the shelf edge. In all seasons, the presence of such anticyclonic or cyclonic eddies adjacent to the shelf edge influenced the circulation, and hence the property distributions, over the outer shelf and upper slope.

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Dr. Matthew K. Howard is an Assistant Research Scientist in Oceanography at Texas A&M University. He has served as scientist on the LATEX A program and serves as a Principal Investigator on NEGOM-COHS and Deepwater. His research interests include coastal and blue-water oceanography, especially of the Gulf of Mexico, data quality control and data base management, near real-time data delivery systems, numerical models of ocean circulation,

circulation over steep topography, and computer visualization and Internet information delivery systems. He took his B.S. in physical oceanography from Humboldt State University and his Ph.D. in oceanography from Texas A&M University.

Professor Robert O. Reid is Distinguished Professor of Oceanography, Emeritus, at Texas A&M University. He has 48 years of service in teaching and research spanning the fields of physical oceanography, meteorology, and coastal engineering. He received his M.S. in oceanography from Scripps Institution of oceanography. He is a Principal Investigator for LATEX A, NEGOM-COHS, and Deepwater. His research interests, as reflected by over 80 publications, range from analytical and numerical studies of ocean circulation, storm surges, tide and tsunamis to surface waves dynamics, estuarine circulation, modeling of dense plumes, wave forces on structures, and stochastic modeling.

Mr. Ou Wang is a Graduate Assistant-Research in Oceanography at Texas A&M University. He received his degree from Ocean University of Qingdao, Qingdao, China, with graduate studies at the Second Institute of oceanography, State Oceanic Administration, Hangzhou, China. He presently is enrolled as a doctoral student in oceanography at Texas A&M University, where his research is focused on examination of pycnobathic effects over the shelf and slope using hydrographic and ADCP observations.

Dr. Joseph Yip is an Assistant Research Scientist in Oceanography at Texas A&M University. His research interests are continental shelf dynamics, coastal oceanic and atmospheric prediction system implementation, and data assimilation. He has developed and implemented an automated shelf circulation now/forecast system for the Texas-Louisiana shelf region for an oil spill prevention and response program sponsored by Texas General Land Office and is a scientist on NEGOM-COHS. He received his Ph.D. in oceanography at Texas A&M University.

LINKAGES BETWEEN BIOLOGICAL AND OCEANOGRAPHIC PROCESSES IN THE NORTHEASTERN GULF OF MEXICO

Dr. Frank Muller-Karger
Dr. Robert Weisberg
Dr. John Walsh
Mr. Busman Nababan
University of South Florida
Department of Marine Science

Dr. Fred Vukovich
Science Applications International Corporation

Dr. Robert Leoben
University of Colorado

INTRODUCTION

The continental shelf off the Florida Panhandle has unique fisheries and environmental characteristics that need to be studied in order to understand potential effects of OCS operations. There is a general lack of historical information on the oceanography of the region, which limits inferences that we may make on the linkages between physical and biological phenomena. For example, it is still unclear how features that operate over large scales, such as ocean circulation features like the Loop Current and its associated eddies, and meteorological phenomena, affect the oceanography of this shelf. Indeed, to build a solid infrastructure for designing OCS operations, the following questions need to be addressed:

- What are these connections between the NEGOM and the rest of the basin?
- What are the patterns of biological production?
- What are the processes controlling these patterns?
- What are the relevant space and time scales?

This presentation reviewed historical and concurrent Infrared, Radar-Altimetry, and Ocean Color satellite data, as well as selected *in-situ* information like drifting buoy trajectories, in an attempt to highlight linkages between various phenomena that affect the Northeastern Gulf of Mexico. A report describing preliminary results and processing techniques is available from the Minerals Management Service's Public Information Office (Report title: Northeastern Gulf of Mexico Physical Oceanography Program: Eddy Monitoring and Remote Sensing. By Muller-Karger, F. E., F. Vukovich, R. Leben, B. Nababan and D. Myhre. 1998.)

METHODS

We collect and process satellite time series data to identify and track major circulation features in the Gulf of Mexico. Specifically, we generate daily Advanced Very High Resolution Radiometer

(AVHRR) Sea Surface Temperature (SST) distribution fields, Topography Experiment (TOPEX) and European Remote Sensing satellite (ERS-1 and 2) radar altimetry Sea Surface Height (SSH) fields, and Coastal Zone Color Scanner (CZCS) and Sea-Viewing Wide-Field-of-View (SeaWiFS) ocean color-derived pigment concentrations. We hold the historical (1978-1986) CZCS data in archive. We collect and process the AVHRR and SeaWiFS data in real-time mode with an antenna installed in St. Petersburg, FL. The TOPEX and ERS data have been merged and interpolated at the University of Colorado to render one image per day for the study period. We merged AVHRR, altimetry and buoy drifter data by overlaying contours of the sea surface dynamic height in the Gulf of Mexico and NEGOM regions onto time-averaged sea surface temperature fields (day, week, month), and then overlaying individual or monthly-averaged drifter tracks or velocity vectors derived from these tracks. To obtain ground truth for the ocean color data, we participate in the MMS-sponsored NEGOM cruises conducted by Texas A&M University (TAMU).

Much of these data are accessible through our web site (*http://paria.marine.usf.edu*) or by contacting FMK (*carib@marine.usf.edu*).

DISCUSSION

Gulf of Mexico-Wide Connections

Seasonal Gulf-wide changes: Figure 1H.10 shows two boxes within the Gulf of Mexico from which we derived phytoplankton concentration and SST cycles using historical satellite data. We also derived SST cycles from the Comprehensive Ocean-Air Data Set (COADS) for comparison, and computed the mixed layer depth based on aggregation of all the hydrographic profile data available for the deep Gulf of Mexico from NOAA’s National Oceanographic Data Center (NODC). Figure 1H.11 shows the monthly means computed across years from these data (monthly “climatologies”).

The pigment and SST climatologies show cycles that are slightly out of phase. Pigment concentrations peak in December and January, and reach minima in June-August in the interior of the Gulf of Mexico. SST reaches minima in February-May, and maxima in August-September. Since there is sufficient light throughout the year to support growth of phytoplankton in the Gulf of Mexico throughout the year, the process that controls growth in the region is the depth of the mixed layer depth. Seasonal changes in the MLD lead to nutrient supply to surface, sun-lit waters in the winter time through convection driven by cooling and increased mixing action by frontal passages and strong winds. There are several phenomena that modify and extend the growth season in the GOM, specifically the outer front of the Loop Current and upwelling in the NEGOM.

The Loop Current: The AVHRR data provides substantial information on circulation patterns during the winter (October-May), when temperature gradients are strong. During summer (June-September), AVHRR data for the most part shows uniform sea surface temperature patterns over the NEGOM. Summer AVHRR data can provide some information on the position of the Loop Current after images are contrast-stretched. The ocean color data (CZCS and SeaWiFS) are an effective tool for tracing small scale as well as large scale circulation patterns in the GOM. These patterns are very clearly outlined during summer months by regional phytoplankton blooms and river plumes, and therefore the combination of AVHRR and CZCS/SeaWiFS is very robust for

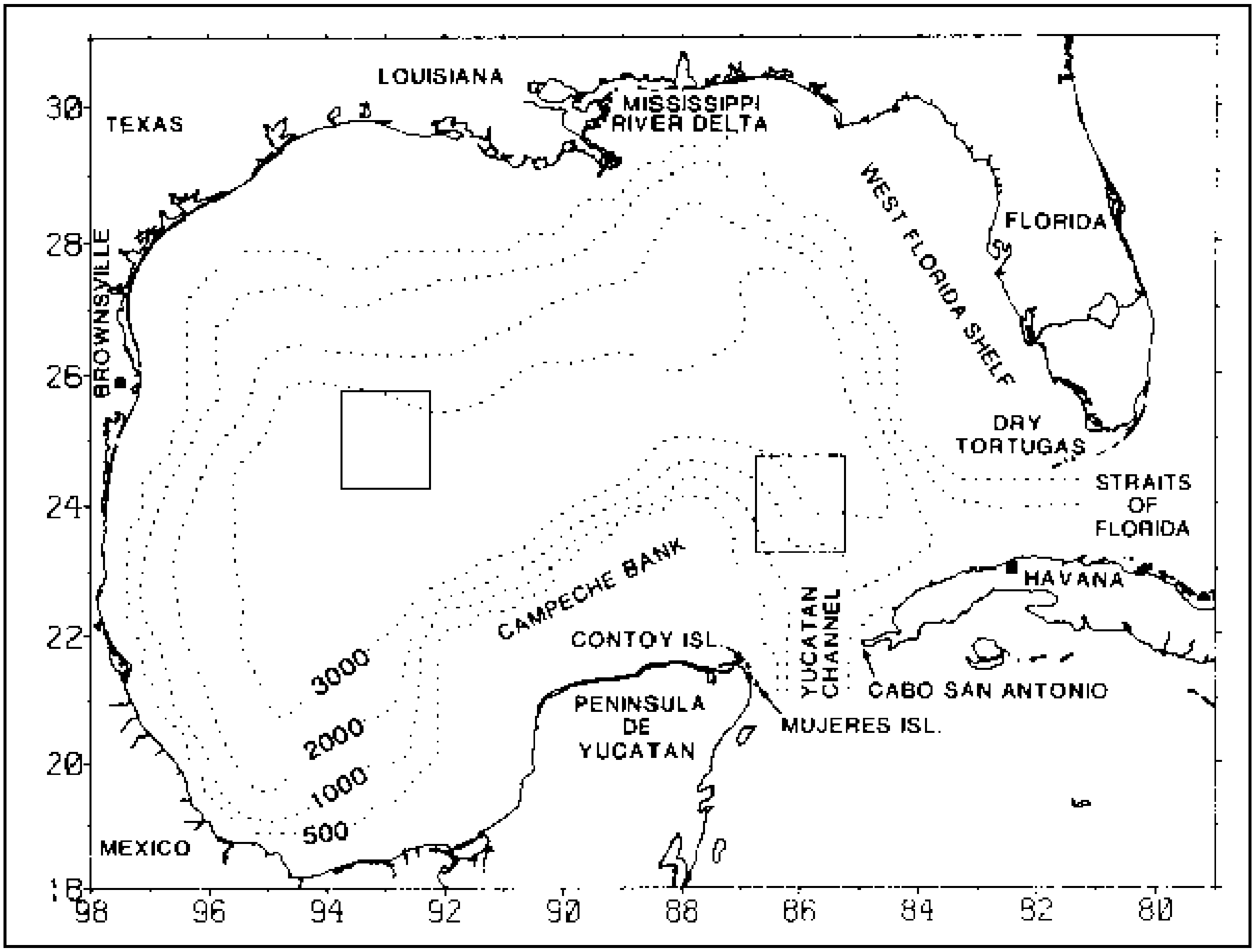


Figure 1H.10. Schematic of the Gulf of Mexico showing two boxes of 200x200 km^2 each for which series of pigment concentration and SST were derived.

outlining the position of the Loop Current, eddies, and various instability waves visible along fronts in the region. Upon merging the high resolution AVHRR sea surface temperature data (order 1 km pixels), or the high resolution ocean color data (order 1 km pixels), with the coarse resolution (order 100-200 km grid resolution) altimeter fields, we found extremely good correlation between warm areas and elevated dynamic heights, and cool areas and low dynamic heights. Both the individual drifter tracks and the monthly-mean velocities derived from these MMS-deployed drifters help in interpreting the direction of flow within specific features observed in the images.

The Loop Current provides several important linkages to the rest of the Gulf of Mexico. From a physical point of view, the important linkages revolve around the moderating effect that the Loop Current and its eddies have on temperatures far into the northern Gulf, on modification of water masses, and in the adjustment of the thermocline/nutricline depth by geostrophy. From a biological point of view, the Loop Current and its eddies are transport mechanisms for organisms originating in the Caribbean Sea or near Campeche Banks on the Yucatan Peninsula. While there has been much speculation about this transport mechanism, little is actually known about the types of organisms transported, rates, or impacts.

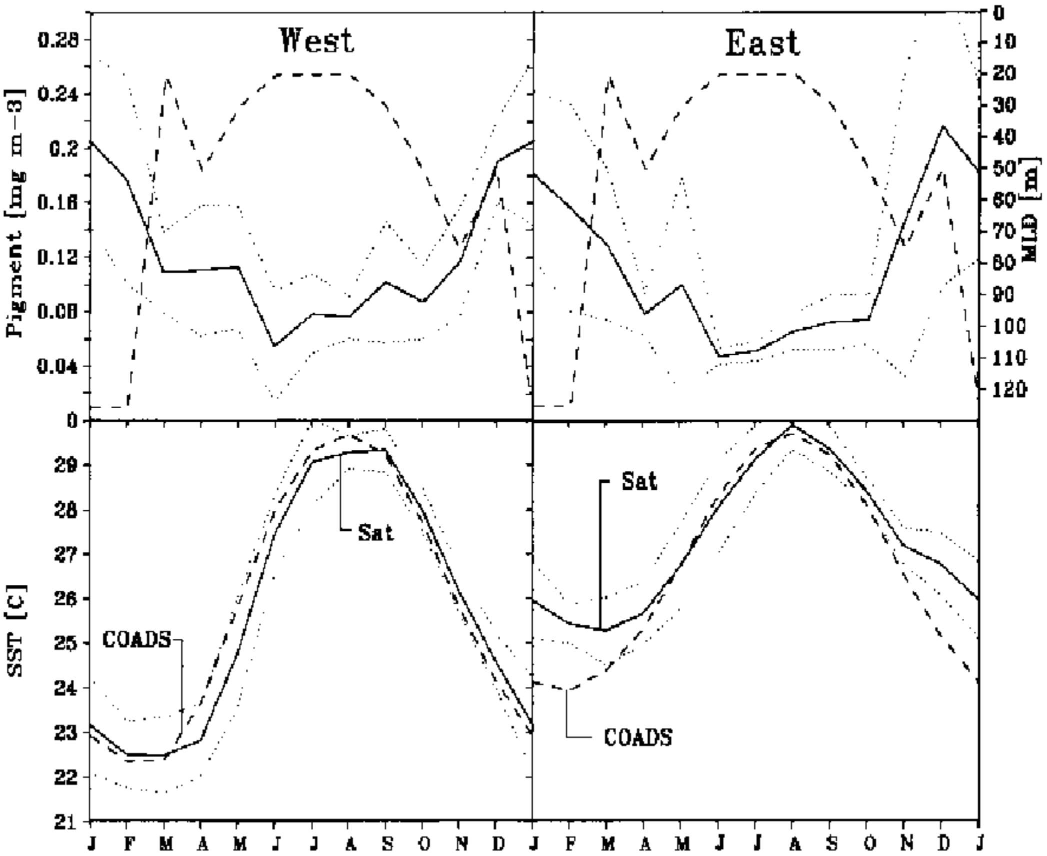


Figure 1H.11. Time series of pigment concentration (top, left axis), mixed layer depth (top, right axis), and sea surface concentration (bottom) for the two boxes shown in Figure 1H.10.

An interesting hypothesis posed by John Walsh (University of South Florida) links red tides along the Florida coasts to nitrogen-fixing blue-green algae (*Trichodesmium*) transported by the Loop Current and delivered into the NEGOM. Specifically, Florida coastal waters are enriched in dissolved phosphorus relative to nitrogen. *Trichodesmium* blooms seem to occur near the Florida coasts where rivers provide a source of dissolved iron, a necessary nutrient for these blue-green algae to grow. The hypothesis proposes that as these blooms decay, the dinoflagellates responsible for red tides off Florida (*Gymnodinium breve*) obtain the necessary nitrogen to grow and bloom, reaching red-tide proportions.

As the Loop Current flows by the Bank of Campeche on the Yucatan Peninsula, substantial upwelling is generated by interaction of the flow with the topography. This upwelling generates a strong cold front, which is maintained as the Loop Current separates from the continental mass off Yucatan. Ocean color satellite data show that this front contains elevated phytoplankton concentrations relative to adjacent waters, and that these plants are transported along the entire periphery of the Loop Current. Indeed, these blooms are carried toward the NEGOM and the West Florida Shelf, and as such can be delivered to these regions if surface waters are moved toward the coast by action of the wind. Eventually, these algae exit the Gulf of Mexico through Florida Strait.

The Loop Current and its eddies have important physical-oceanographic implications on circulation in the NEGOM. As the Loop Current extends far into the Northern Gulf, it periodically sheds an anticyclonic (clockwise-spinning) eddy. If the Loop Current or such an eddy move into the NEGOM, they generate substantial currents and upwelling along the shelf break in the NEGOM and off the West Florida Shelf.

The Northeastern Gulf of Mexico (NEGOM) and the West Florida Shelf: There are several important physical phenomena that make the NEGOM a unique location within the Gulf of Mexico. One is that this region receives most of the river discharge that is input to the Gulf of Mexico. It also has the widest shelf, which includes the De Soto Canyon off the Florida Panhandle. This is a deep canyon that serves as a conduit for deep Gulf of Mexico waters to the coastal zone of Florida and Alabama.

Ocean color satellite imagery show that the bulk of the Mississippi plume flows to the west of the delta, but both in spring (February-May) and in fall (August-October), substantial amounts of Mississippi water flow toward the east and southeast along the edge of the West Florida Shelf.

Significant upwelling events are observed every spring along the periphery of the NEGOM, specifically along the Florida Panhandle and Cape San Blas. This upwelling renders the NEGOM as the coldest and most biologically-productive region within the northern Gulf of Mexico for 3-5 months every spring.

The NEGOM upwelling plume is massive. It grows in February-March to the southeast, carrying substantial amounts of water, river water, and phytoplankton. The plume flows to the southeast following bathymetry and may reach as far south as the keys and wrap around the keys, delivering NEGOM water and materials to the Florida Strait. This plume was originally described by Gilbes *et al.* In 1996 (Gilbes, F., C. Tomas, J. J. Walsh, and F. E. Muller-Karger 1996. An episodic chlorophyll plume on the west Florida shelf. Continental Shelf Research. 16:9, 1,201-1,224.)

In January-March 1996, flow immediately to the east of the Mississippi delta seemed to be erratic or turbulent. Flow vectors derived from drifters showed either northward or southward components. However, flow in the eastern portion of the NEGOM and over the west Florida shelf was distinctly and strongly (> 10 cm/s) southward. Waters here are much colder (>5^0C) than Loop Current waters. The Loop Current was extended about half-way north into the GOM from the Yucatan Channel, and a cyclonic eddy sat between the northern extension of the Loop Current and the NEGOM shelf. In April 1996, drifter vectors over the shelf reversed, showing a slow (< 10 cm/s) drift to the north. However, along the shelf break of the West Florida shelf proper, current vectors remained strongly southward. The cyclone north of the LC drifted somewhat to the West in May but drifted back East over the summer. By August, currents over the shelf aligned themselves to flow northward at speeds exceeding 10 cm/s. In September, currents over the shelf were to the south again (~10 cm/s), and an eddy was shed from the Loop Current. The southward flow over the shelf intensified in October.

In November, while southward flow was observed over the shelf, northward flow was observed along the shelf break. In December 1996, southward flow prevailed over the West Florida shelf.

Unusual upwelling in May-July 1998 along the coasts of the Florida Panhandle in the northeastern Gulf of Mexico led to 3 C lower sea surface temperatures (SST) than is normal for these waters at this time of the year. Concurrently with the anomalous SST, substantial volumes of turbid Mississippi River water spread along the coast in the region. The upwelling and eastward dispersal of Mississippi water were associated with periodic eastward winds and a large anticyclone that migrated into the northeastern Gulf of Mexico. Wind reversals trapped the Mississippi water against the coast, which led to water column stability and submergence of coastal waters in which phytoplankton had been blooming vigorously during the bloom. This stability probably led to the anomalous hypoxia observed in bottom waters in this region during that time. As upwelling-favorable winds were re-established, and particularly during July 1998, the Mississippi plume was advected offshore and to the southeast along the West Florida Shelf.

The satellite data show that upwelling in the NEGOM is not at all unusual, but that interaction between shelf waters and a large anticlone, combined with upwelling-favorable winds, can enhance and prolong this phenomenon into the summer months.

Other, more intermittent upwelling can be observed off Pinellas and Manatee Counties (near the mouth of Tampa Bay).

CONCLUSIONS AND RECOMMENDATIONS

It would be impossible to interpret flow and linkages within the NEGOM and the rest of the Gulf of Mexico without the aid of remotely-sensed data. Satellite data complement hydrographic and drifter-track studies and provide a synoptic view within which these other data can be properly understood.

SST and Altimeter data are now widely available over the internet, including our web site at the University of South Florida (*http://paria.marine.usf.edu*). However, “fused” data (for example, new products generated by merging various satellite and/or field data) are not yet freely available. Also, the images need to be interpreted for identification of features, compositing (averaging) to minimize the obscuring effect of clouds, and ensuring accurate identification and quantification of phytoplankton blooms versus river plumes, since these latter ones are misclassified as blooms when using standard ocean color satellite-data processing algorithms. Such value-added products are not available except through investigations such as these outlined here. Further, SeaWiFS data remain proprietary.

However, NASA is about to launch the MODIS (Moderate Resolution Imaging Spectrometer) on EOS Terra in 2000, and the University of South Florida has implemented a unique real-time data capture system (an X-band antenna) with NASA support to collect the MODIS data.

With this infrastructure in place, the MMS needs to design and implement a circulation / linkages experiment. This experinet should focus on the following questions:

- What forces surface flow near the shelf break? (What drives spring-time up welling?)
- What is relative contribution to production of river vs. upwelling?
- What are water masses established by the passage of Hurricanes in the NEGOM?

The study needs to incorporates synoptic (space, time) remote sensing tools, a set of moorings for continuous *in-situ* time series, a ship-based program, concurrent surface and subsurface drifter deployments, and a numerical modeling component. The remote sensing program needs to incorporate the new MODIS data and develop a series of "fused" and interpreted products. The ship-based program needs to incorporate biological production, hydrography, and optical observations. The mooring program needs to incorporate a minimum of three mooring arrays arranged around DeSoto Canyon and along the Panhandle coast in order to properly characterize upwelling. and modeling components. This study should focus the ship-based studies around "transition" periods, namely spring and fall. On top of this infrastructure, which provides a robust basis of environmental information, specific biological oceanographic process studies can be designed that address critical issues on bottom and pelagic fish resources.

ACKNOWLEDGMENTS

This report was prepared under contract between the Minerals Management Service (MMS) and the University of South Florida, through an investigation entitled "Northeastern Gulf of Mexico Physical Oceanography Program: Eddy Monitoring and Remote Sensing," MMS contract number 1335-01-97-CA-30857.

SESSION 1J

A PROGRESSIVE PARTNERSHIP: MMS/GOMR AND MINORITY-SERVING COLLEGES AND UNIVERSITIES

Chair: Mr. Lynard Carter, Minerals Management Service
Co-Chair: Mr. Alvin Jones, Minerals Management Service

Date: December 2, 1999

Presentation	Author/Affiliation
Introduction	Mr. Lynard Carter Minerals Management Service
Supporting the MMS OCS Mission	Mr. Alvin L. Jones, Sr. Minerals Management Service
Geoscience at Elizabeth City State University: Past, Present and Future	Dr. Francisco San Juan, Jr. Elizabeth City State University
Earth Sciences in Academia: Student Successes and Faculty Achievements	Dr. Paul J. Croft Jackson State University
Engineering Sciences in Academia: Applications to Decision-Making	Dr. Irvin W. Osborne-Lee Dr. Milton R. Bryant Prairie View A&M University Dr. Juan J. Ferrada Oak Ridge National Laboratory
Partnering with MMS: Opportunities for Students	Ms. Gay Larré Ms. Eileen Swiler Minerals Management Service

INTRODUCTION

Mr. Lynard Carter
Minerals Management Service

Historically Black Colleges and Universities (HBCUs) are post secondary academic institutions founded before 1964 whose education mission has historically been the education of Black Americans. Located primarily in the Southeastern United States, there are now about 120 HBCUs, a mix of community and junior colleges, four-year colleges and universities, and public and private institutions.

HBCUs enroll fewer than 20% of African-American undergraduates but award one-third of all bachelor's degrees and a significant number of the advanced degrees earned by African-Americans.

The session focuses on channels of communication between the academic community and the staff of MMS GOM Region. Representatives from minority-serving institutions of higher learning will have the opportunity to introduce their prospective programs in social, natural, and physical sciences. The representatives will also have the chance to mention their accomplishments and their student successes.

Such programs and accomplishments can be valuable resources for the agency and its leaders in its efforts to increase diversity in the workforce and recruit the best people for the jobs.

We have distinguished professors from three Historically Black Colleges and Universities who will discuss topics in geoscience, earth science, and engineering science.

SUPPORTING THE MMS OCS MISSION

Mr. Alvin L. Jones, Sr.
Minerals Management Service

The Department of the Interior's Minerals Management Service (MMS) shoulders significant responsibilities in managing the natural and economic offshore resources of America. The MMS manages more than a billion acres and collects billions of dollars in mineral revenues annually.

The primary mission of the MMS is two-fold.

- MMS runs the federal government's program for managing minerals resources on the Outer Continental Shelf (OCS). The resources can be grouped into two categories: energy and non-energy. The energy minerals includes oil, gas, and sulfur. The non-energy minerals include sand shale, gravel, and gold.

- MMS's Royalty Management Program collects and distributes bonuses, rents, and royalties from companies that lease and produce minerals from federal lands, from both onshore and offshore, and from Indian lands to the amount of more than $54 billion dollars to date.

The Outer Continental Shelf Act and its amendments directed the Secretary of the Interior, through the MMS, to:

- Conserve the Nation's natural resources;
- Develop natural oil and gas resources in an orderly and timely manner;
- Meet the energy needs of the country;
- Protect the human, marine, and coastal environments; and
- Receive a fair and equitable return on the resources on the OCS.

Many disciplines are utilized to conduct this program. Occupational categories include:

- Petroleum Engineers
- Geologists
- Geophysicists
- Inspectors
- Physical Scientists
- Technicians
- Environmental Scientists
- Oceanographers
- Meteorologists
- Marine biologists
- Economists
- Mineral Leasing Specialists
- Archeologists
- Contract Specialists
- Paleontologists
- Computer Specialists
- Information Specialists
- Administrative Specialists
- Clerical Specialists

The total number of employees in the Gulf of Mexico Region is 535, which includes our district offices in Houma, Lafayette, Lake Charles, and New Orleans, Louisiana and Lake Jackson and Corpus Christi, Texas.

The colleges and universities that you represent and other colleges and universities may belong to associations such as:

- HBCU – Historically Black Colleges and Universities,
- HACU – Hispanic Association of Colleges and Universities,
- MIA – Minority Institute Alliance,
- Colleges for Women, and
- American Indian higher education Consortium

Collectively, they are also known as Historically Black and Minority-Serving Colleges and Universities (HBMSCUs).

The two-fold mission of the MMS, to manage the OCS resources safely and to collect and distribute bonuses, rents, and royalties is being supported by the MMSers from many public and private colleges and universities, including those that fall under the umbrella of the HBMSCUs. Many quality graduates from HBMSCUs are needed for the MMS to continue to perform its mission.

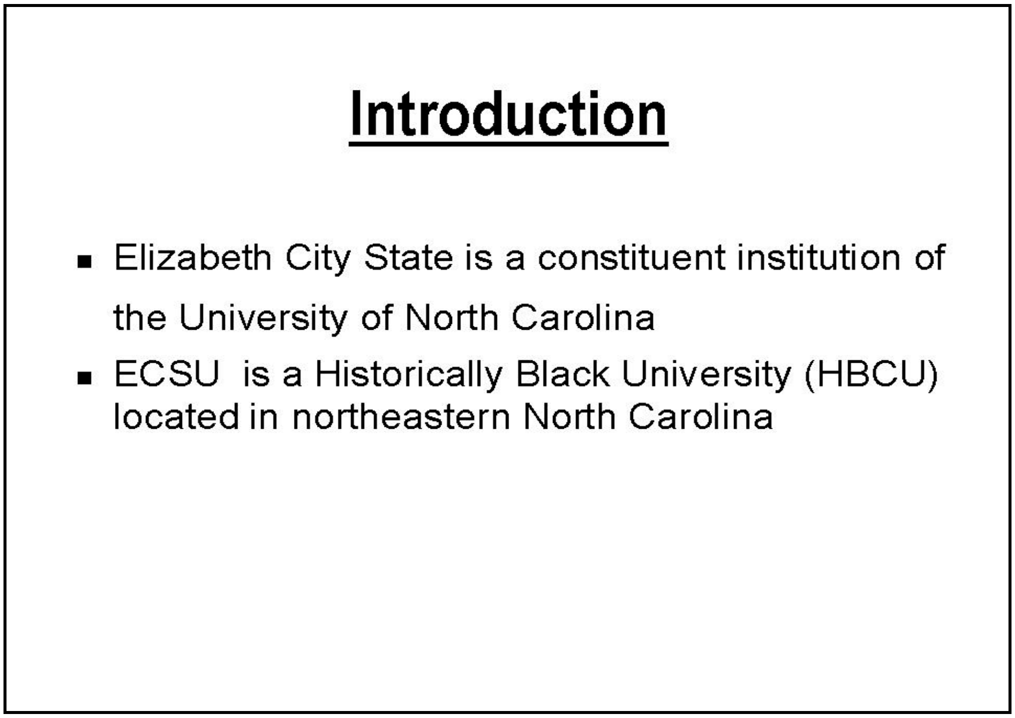
We are gathered here to receive reports from several distinguished educators and professionals pertaining to programs and particular aspects at their present college or university and from the MMS' Gulf of Mexico Region. We are going to receive reports about

- Specific ongoing programs or projects at HBMSCUs;
- A few graduates from HBMSCUs;
- Present and past student and faculty members; and
- Successes and types of programs at selective HCMSCUs.

The last portion of this session is dedicated to a panel discussion/open forum.

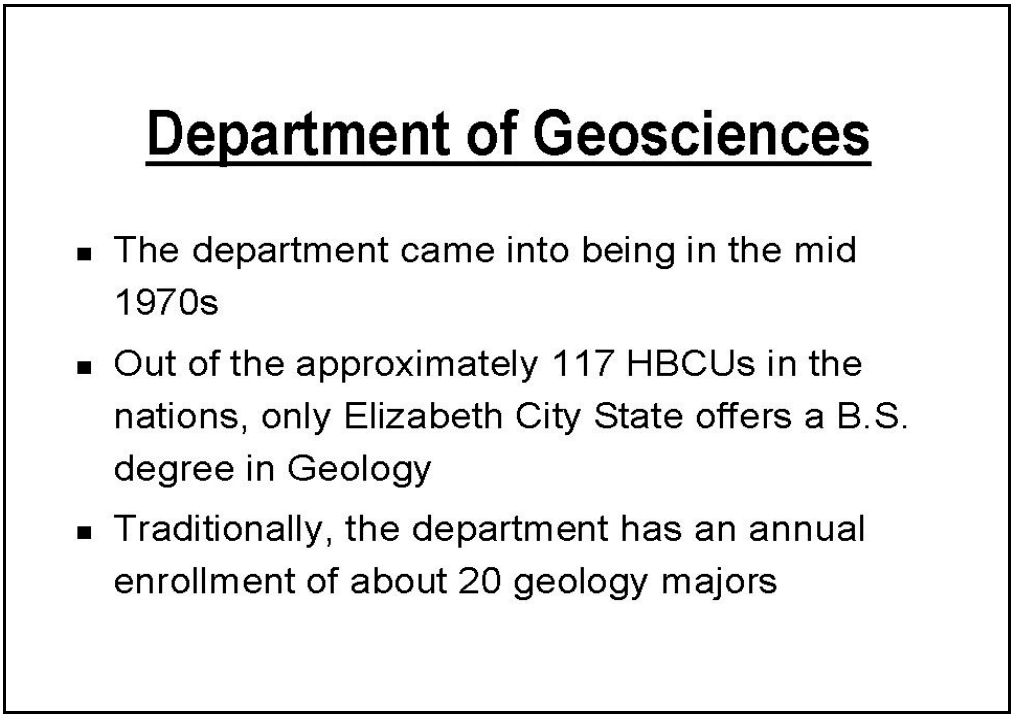
GEOSCIENCE AT ELIZABETH CITY STATE UNIVERSITY: PAST, PRESENT AND FUTURE

Dr. Francisco San Juan, Jr.
Elizabeth City State University



Introduction

- Elizabeth City State is a constituent institution of the University of North Carolina
- ECSU is a Historically Black University (HBCU) located in northeastern North Carolina



Department of Geosciences

- The department came into being in the mid 1970s
- Out of the approximately 117 HBCUs in the nations, only Elizabeth City State offers a B.S. degree in Geology
- Traditionally, the department has an annual enrollment of about 20 geology majors

Programs

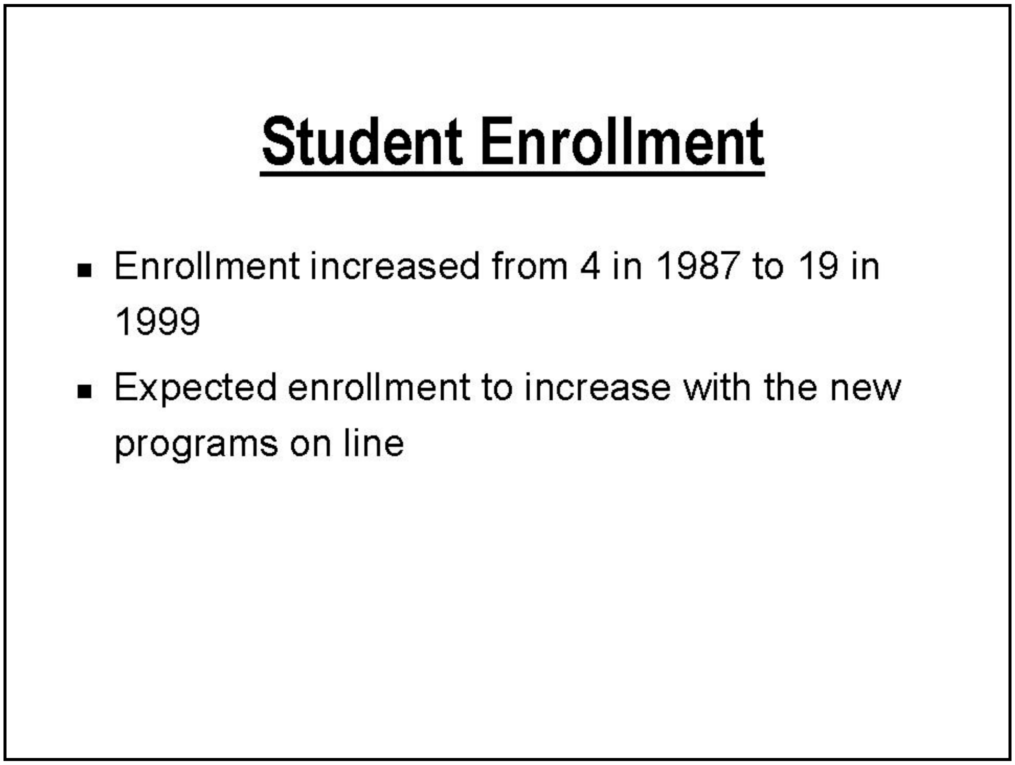
- Aside from the **Major in Geology**, the department is also offering minor programs in **Environmental Science** and **GIS/Remote Sensing**
- A proposal has been submitted to the General Administration of the University System for an undergraduate major program for **Marine Environmental Science**

Major in Geology

- The program curriculum is recognized by Federal Agencies and the University of North Carolina - General Administration

Field Programs

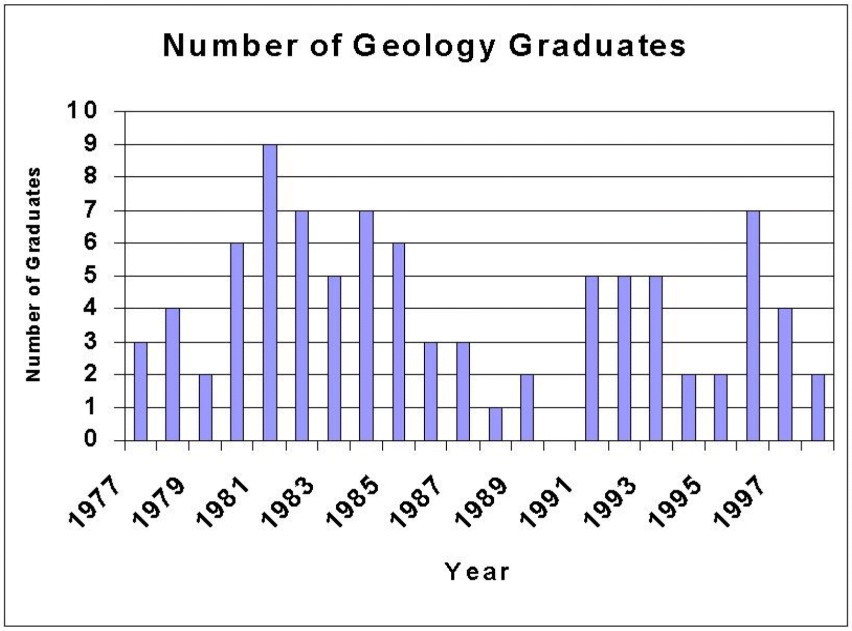
- Since 1987, ECSU has been part of the UNC System-wide Joint Field Program
- Juniors spend 6 weeks in New Mexico, Arizona, and Colorado
- At least one weekend field trip is organized every semester



Student Enrollment

- Enrollment increased from 4 in 1987 to 19 in 1999
- Expected enrollment to increase with the new programs on line

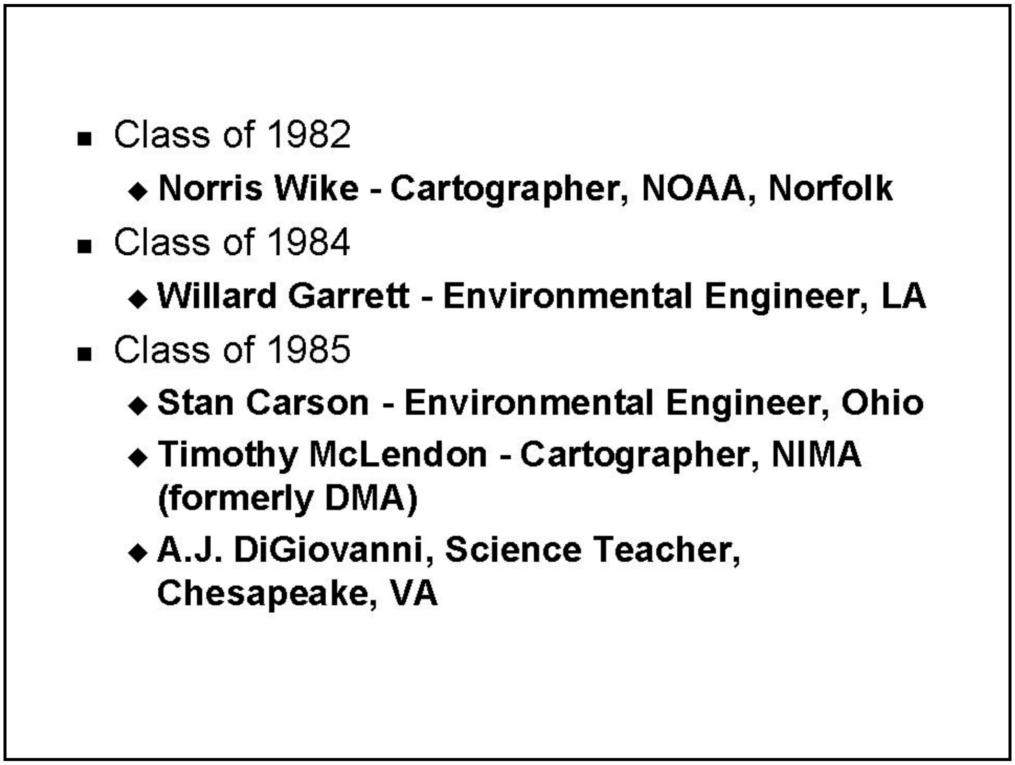
Graduates in Geology



Alumni Achievements

- Class of 1977
  - **Ronald Bowser - Section Chief, Petroleum Geologist, MMS, New Orleans**
  - **Ronald Davis - Environmental Engineer, EPA, Philadelphia**
- Class of 1978
  - **Katrina Burke - Cartographer, USGS, Reston**
  - **Alvin Jones - Physical Scientist, MMS, New Orleans**
  - **Darrell Collins - Historian, NPS, Wright Brothers National Monument**

- Class of 1980
    - **Randall Knight - Professional Geologists, Exxon**
    - **Mack Wiggins - Technical Supervisor, NC Dept of Natural Resources**
- Class of 1981
    - **Ricky Sharpe - Technical Engineer, Offshore Drilling, N.L. Industries**
    - **Marvin Mullen - Intergraph Corporation, AL**
    - **Elijah White - Domestic Production Supervisor, Exxon Production Research Co., Houston**



- Class of 1982
    - **Norris Wike - Cartographer, NOAA, Norfolk**
- Class of 1984
    - **Willard Garrett - Environmental Engineer, LA**
- Class of 1985
    - **Stan Carson - Environmental Engineer, Ohio**
    - **Timothy McLendon - Cartographer, NIMA (formerly DMA)**
    - **A.J. DiGiovanni, Science Teacher, Chesapeake, VA**

- Class of 1986
  - **Michael Bowser - Cartographer, NIMA**
- Class of 1987
  - **Chuck Overton - Cartographer, NIMA**
  - **Linda Stewart - Science & Math Teacher, Currituck, NC**
- Class of 1988
  - **Roxanne Hawkins Lamb - Cartographer, USGS, Reston**
- Class of 1989
  - **Eric McLendon - Cartographer, NIMA, Maryland**

- Class of 1990
  - **Patricia Gilmartin - Environmental Technician, Pasquotank County Health Department**
- Class of 1991
  - **John Taylor - USGS, Raleigh, NC**
  - **Donald Myrick - NPS, Miami**
- Class of 1992
  - **Pamela Phillips Hargett - Environmental Scientist, EPA, Philadelphia**
  - **James Weathers - NC Coastal Management, Elizabeth City**
  - **Corey Miller - Geologist, USFS**

- Class of 1995
  - **Vincent Thomas - Geologist, Exxon**
- Class of 1996
  - **Michael Johnson - Geologist, BLM, salt Lake City**
  - **Jason Powell - Geologist, BLM, Phoenix**
  - **Roger Spivey - DEHNR, Washington, NC**
  - **Dessalines McClure - Graduate School (MS in Geology), Univ. of Memphis**
- Class of 1997
  - **William Lewis - USGS in Atlanta**
- Class of 1998
  - **Sunday Shepard - Graduate School, MS in Geology, Univ. of Texas**

Program Enhancements

- Visiting instructors from federal agencies
- A seminar series with alumni and other professionals as speakers
- Student and faculty internships
- Joint program with UNC-Chapel Hill
- Student co-op programs
- Faculty enhancement as workshops, courses, research projects, including joint research programs with other universities
- Undergraduate research projects

- Student financial assistance from NABGG, AGI, and NAGT
- Student and faculty attendance in conferences, field trips, and workshops
- Faculty presentations:
    - **GSA Annual Meeting**
    - **NC Academy of Science**
    - **Global Warming International Conference**
    - **Virginia State University**

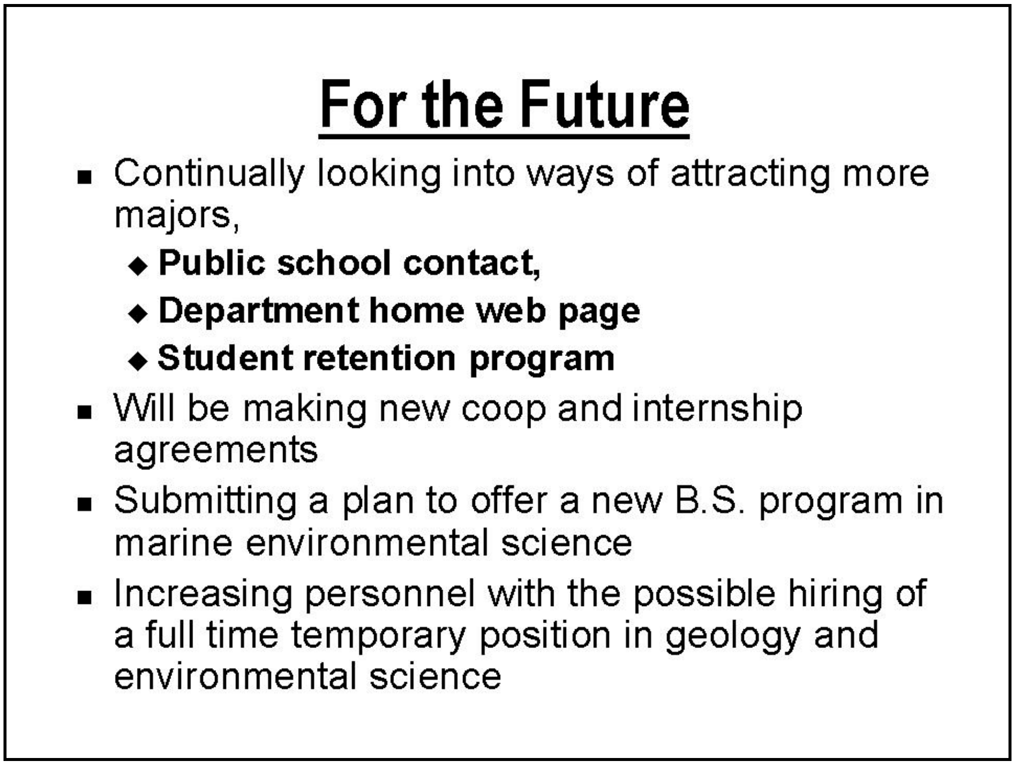
Funded Research

- Grants from the USGS and the NC Geological Survey on a joint research on placer/heavy mineral deposits
- Grant from the NC Water Resources Research Institute on isotope study of surface and ground waters
- Joint research program with UNC-Chapel Hill, funded by NSF
- NSF grant on curriculum development in GIS and Remote Sensing

- Ozone monitoring in northeastern North Carolina
- NASA grant on the impact of forest fires on global warming
- Funds for GIS, Remote Sensing, and petrographic and water quality lab equipment
- Funds for the construction of a boardwalk in the Dismal swamp for research and teaching
- Funds for undergraduate research

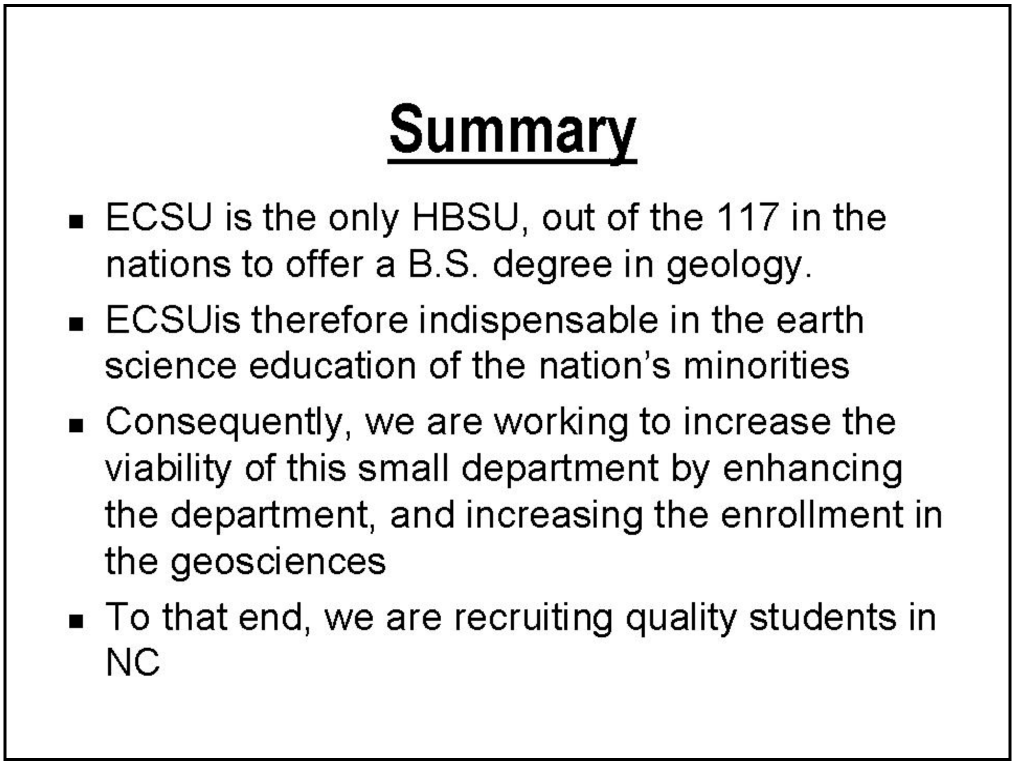
Faculty and Staff

- Four full-time faculty with terminal degrees, three in geology, one in geography
- Four part-time faculty with at least at least an M.S. degree or experience
- Will be hiring for the spring a full-time temporary person with a Ph.D. in geology to replace some of the part-time instructors
- A secretary
- A laboratory manager with a B.S. degree in geology



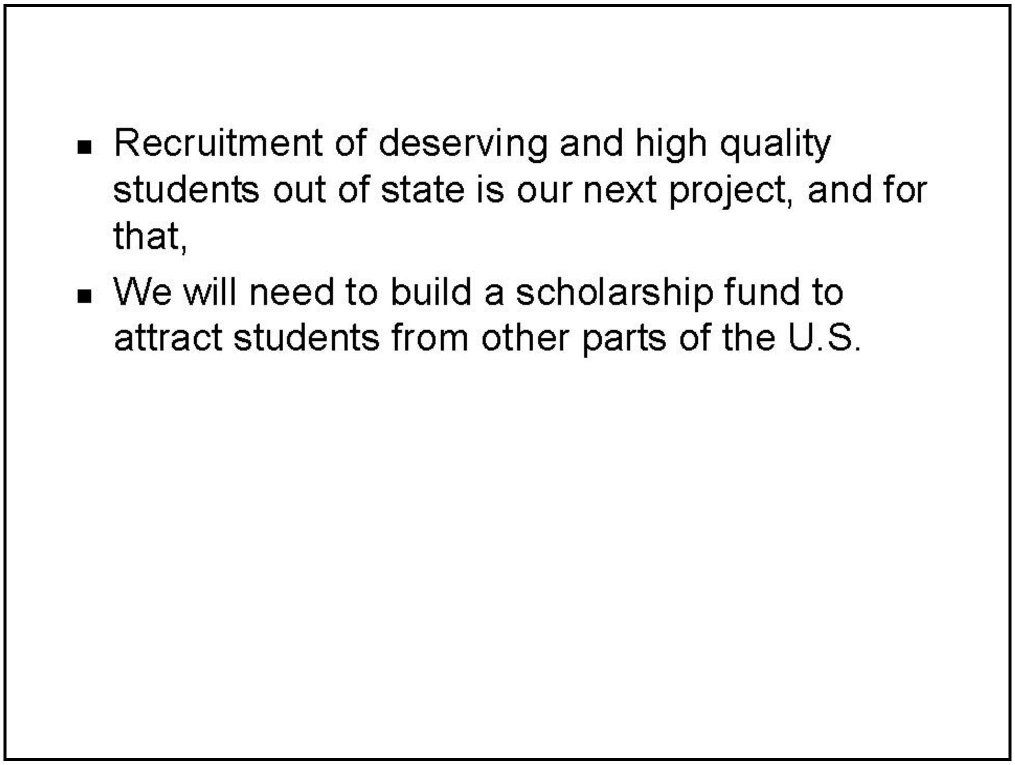
For the Future

- Continually looking into ways of attracting more majors,
  - **Public school contact,**
  - **Department home web page**
  - **Student retention program**
- Will be making new coop and internship agreements
- Submitting a plan to offer a new B.S. program in marine environmental science
- Increasing personnel with the possible hiring of a full time temporary position in geology and environmental science



Summary

- ECSU is the only HBSU, out of the 117 in the nations to offer a B.S. degree in geology.
- ECSUis therefore indispensable in the earth science education of the nation’s minorities
- Consequently, we are working to increase the viability of this small department by enhancing the department, and increasing the enrollment in the geosciences
- To that end, we are recruiting quality students in NC



- Recruitment of deserving and high quality students out of state is our next project, and for that,
- We will need to build a scholarship fund to attract students from other parts of the U.S.

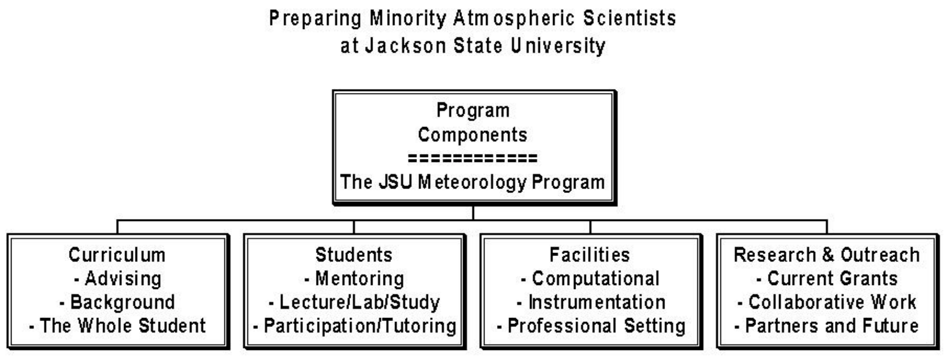
EARTH SCIENCES IN ACADEMIA: STUDENT SUCCESSES AND FACULTY ACHIEVEMENTS

Dr. Paul J. Croft
Jackson State University

History and Demographics

- Initiated 1975
- General Science
- NOAA support
- Association with NWS
- Teaching Mission
- Research Mission
- Current Enrollment
- Past Graduates
- Location: Jackson, MS
- JSU School of Science and Technology
- Urban University
- Only HBCU with B.S. Degree in Meteorology
- Research NASA, WES, AHPCRC, NSF, and others

Program Components



Preparing Minority Atmospheric Scientists
at Jackson State University

Program
Components
============
The JSU Meteorology Program

Curriculum
- Advising
- Background
- The Whole Student

Students
- Mentoring
- Lecture/Lab/Study
- Participation/Tutoring

Facilities
- Computational
- Instrumentation
- Professional Setting

Research & Outreach
- Current Grants
- Collaborative Work
- Partners and Future

The Curriculum

- Curriculum Revision as per AMS Bachelor’s Degree Statement
- Relevance to NWS and other employers
- Practical classroom & field experiences
- Research experiences during semester
- Summer Internships and Co-ops
- Development of Graduate Program

Students

- Meteorology Courses which build upon and make use of knowledge from required college courses, especially math
- Laboratory assignments requiring critical thinking and application of knowledge to new situations (and the “real-world”)
- Integration of multi-media environment and mentoring in and out of class

Facilities

- MCSR newly installed Cray 90
- JSU-AHPCRC SP2 being installed
- Upgrade of Weather Instrumentation
- Building and Campus Renovations
- Professional Development through Research, Service, Presentation, and Role-Playing Opportunities

Research

- Attendance and Presentation at Professional Conferences and Meetings
- Presentations to Peers, Faculty, and Public
- Research Support for Faculty Projects
- Co-authored publications on research
- Grants of approximately $ 2.5 Million in the Department

Research & Outreach

- MM5 now operational
- Collaborations
- UCAR/NCAR
- NWS COMET
- NWS JAN AMS
- NASA, WES, NSF, ONR, others...
- Informal Exchanges
- National Laboratories
- Local Schools
- Local TV Affiliates
- Teacher Workshops
- High School Programs
- Dissemination
- Web-site: http://santa.jsums.edu

The Future

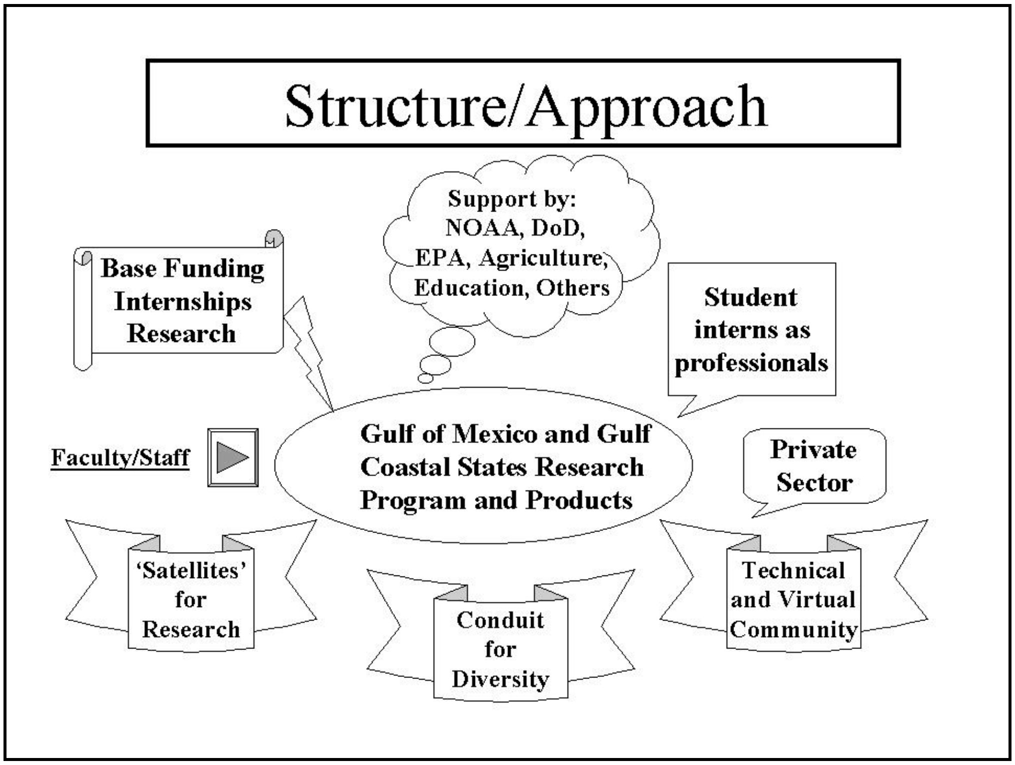
- Transition to Complete Pre-Professional Environment and Curriculum
- Complete Electronic Instruction and Professional Development
- JSU Meteorology Program as Institute for Gulf Coastal States and Gulf of Mexico Research and Education…the *VISION* ☞...

The JSU Meteorology Program – *A Vision for the Future*

- Gulf Coast States & Gulf of Mexico Focus
- Suite of Models (QG, MM5, GCM, etc.,)
- Satellite, Buoy, and other RS/GIS ingest
- Visualization and Applications:
  - **Weather Analysis and Forecasting**
  - **Tropical Cyclones and Convective Initiation**
  - **Pollutant Transport and Aerosol/Radiation**
  - **Severe and Winter Weather and others**

To Accomplish the Vision

- Network Reliability
- Recruitment
- Retention
- Commitment
- Resources
- Partnering
- Assistance
- Graduate Program
- Systems Administrator
- Program Secretary
- Post-docs, Research Assistants, Technician
- Publicity
- Students/Scholarships
- Data (**e.g., NOAAport**)
- Space and Lab Needs



Structure/Approach

Support by:
NOAA, DoD,
EPA, Agriculture,
Education, Others

Base Funding
Internships
Research

Student
interns as
professionals

Faculty/Staff ▶

Gulf of Mexico and Gulf
Coastal States Research
Program and Products

Private
Sector

'Satellites'
for
Research

Conduit
for
Diversity

Technical
and Virtual
Community

ENGINEERING SCIENCES IN ACADEMIA: APPLICATIONS TO DECISION-MAKING

Dr. Irvin W. Osborne-Lee
Dr. Milton R. Bryant
Prairie View A&M University

Dr. Juan J. Ferrada
Oak Ridge National Laboratory

INTRODUCTION

The rapid pace of advancing technology is yielding fruit of previously unexpected proportions. Regular space shuttle runs provide technical support to an increasingly space-based industry. A new space station is under construction and is soon to be a reality. New comprehension of the human genome and genetic manipulation techniques are producing medical advances with the result that people are living longer, at least in technologically advanced nations. And increased productivity in private industry has led to economic prosperity and a paradigm shift in the way that companies view their employees, especially in technical fields, resulting in few career-long commitments and more frequent down-sizing.

However, today's rapidly developing technologies, industrial products, and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. Under a mandate of national environmental laws and directives, the U.S. Environmental Protection Agency (EPA) strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life (Vigon *et al*. 1993).

Industrial processes rarely avoid secondary waste stream generation. Even waste management activities suffer from this seemingly inevitable technical situation. Hence, there is a critical need for good decision-making on the issues that pertain to the utilization of our existing technology and on questions of technological advances. In short, society needs people who can formulate, evaluate, and weight the alternatives and thus support good decision-making.

To evaluate technological alternatives properly, decision-makers must employ analysis methodologies that take into consideration as many components of the entire system as is possible. The ultimate goal is to make a calculated decision that maximizes benefits while minimizing adverse consequences. The increasingly technical nature of the systems we face means that engineers will ideally be involved in such decisions. The complexity of the issues involved in these decisions will require that methodical and tool-based approaches, combined with rational thinking will likely be needed as well.

TEACHING GOOD DECISION MAKING

To help promote good decision-making, Prairie View A&M University's College of Engineering initiated a course offering at the graduate level, anticipated to be most useful for its Master of Engineering Degree program. A part of an off-site program with an environmental focus, the course targets graduate degree seekers in industry—one of the primary decision-making sectors. The course combines current techniques and tools for decision analysis with contemporary case studies in the environmental subject area, largely drawn from many years of experience in supporting technical decisions.

Decision Analysis Methods

The course uses a very highly recognized textbook (Clemen 1996) to provide the decision analysis methodologies, along with support textbooks to provide different perspectives on various aspects of the decision-making process, including the following:

- Making Hard Decisions: An Introduction to Decision Analysis (Clemen 1996);
- A Practical Guide to Making Decisions (Hammond *et al.* 1999);
- Sources of Power: How People Make Decisions (Klein 1999);
- Facilitator's Guide to Participatory Decision Making (Kaner *et al.* 1996); and
- Decisions with Multiple Objectives: Preferences and Value Tradeoffs (Keeney and Raiffa 1993).

Decision Analysis Tools

There are many computerized tools for decision analysis, several of which are used in the course to expose students to a variety of alternative approaches to representing and modeling decision problems, including the following:

- Influence diagrams
- Decision trees (also known as event trees)
- Bayesian networks (also know as belief networks)
- Sensitivity analysis, and
- Uncertainty analysis

Course participants survey a range of tools, but focus on one or two of these for the formulation and solution of individualized decision problems.

Using Case Studies

Case studies play an essential role in teaching decision analysis. Relevant examples ranging from the simple to the complex are needed as vehicles by which to (1) understand the basic nature of decisions, (2) appreciate the characteristics of good decisions, and (3) develop the depth required to fathom complicated decision problems. Simple decisions examples and case studies are available in good textbooks (c.f. Clemen 1996). More complicated decision problems are best embodied in case studies, which should be both relevant and experience-rich. For these reasons, and to best suit our Masters of Engineering Program with an environmental focus, the case studies used in the course are based on the cumulative 20+ years experience of the instructors in environment-related decision support.

Practical Decision Support Experience Base

The focus of the remainder of this paper is on a methodology for engineering assessment with environmental applications. One particularly important area is that of enhanced waste treatment decision-making. The methodology was originally developed at Oak Ridge National Laboratory and has been a key factor in the development of treatment plans at ORNL facilities. The approach and tools are also particularly useful in enhancing the teaching of decision analysis at Prairie View A&M University (PVAMU) through practical methods and relevant case studies.

The methodology is based on an integrated systems analysis approach because of the diversity of alternatives to be studied, the complexity of system interactions, and the variability and uncertainty of constraints. Many possible combinations of treatment and disposal options exist, each of which results in different costs, schedules, quality of waste form, risk to workers and the public, acceptability, etc. This type of analysis must address all significant aspects of waste management from on-site treatment and transportation, to off-site treatment and disposal.

Ultimately, the objective of systems analysis is to provide technically sound basis for decisions leading mixed-waste treatment processes that are safe, technically feasible, environmentally sound, cost effective, and acceptable to regulators, governments, and the public. Our objective is not to develop and demonstrate treatment technology, but rather to estimate how existing and potential technologies might best be integrated and deployed. Additionally, our goal is to make the decision-making process involved in selecting technologies come alive in a meaningful way in the classroom.

SYSTEMS ANALYSIS-BASED DECISION METHODOLOGY PART 1 – APPROACH

The objectives of the system analysis methodology depend on the goal of the decision to be supported. In our particular experiences, the goals were centered on arriving at a preferred set of alternative scenarios for waste treatment. Other methods exist that can be used to obtain a preferred set, such as multivariate optimization. However, the use of defining alternative scenarios was chosen over multivariate optimization because of several important factors. A primary factor in this choice was the uncertainty in waste characteristics and treatability. Other factors were also important: (1) the importance of fuzzy variables, such as public acceptance of a given technology, (2) state equity issues in the final disposition of waste, and (3) technology maturity. Each of these factors makes formulation of an objective function difficult and makes the analysis more amenable to a scenario-based approach. Furthermore, the drivers behind this study did not require an optimal set of technologies, but rather a practicable set reflecting the primary objectives discussed above. The practical limitations of the real situations encountered are very instructive, providing an engaging context in which the need for decision methods and tools can be effectively illustrated.

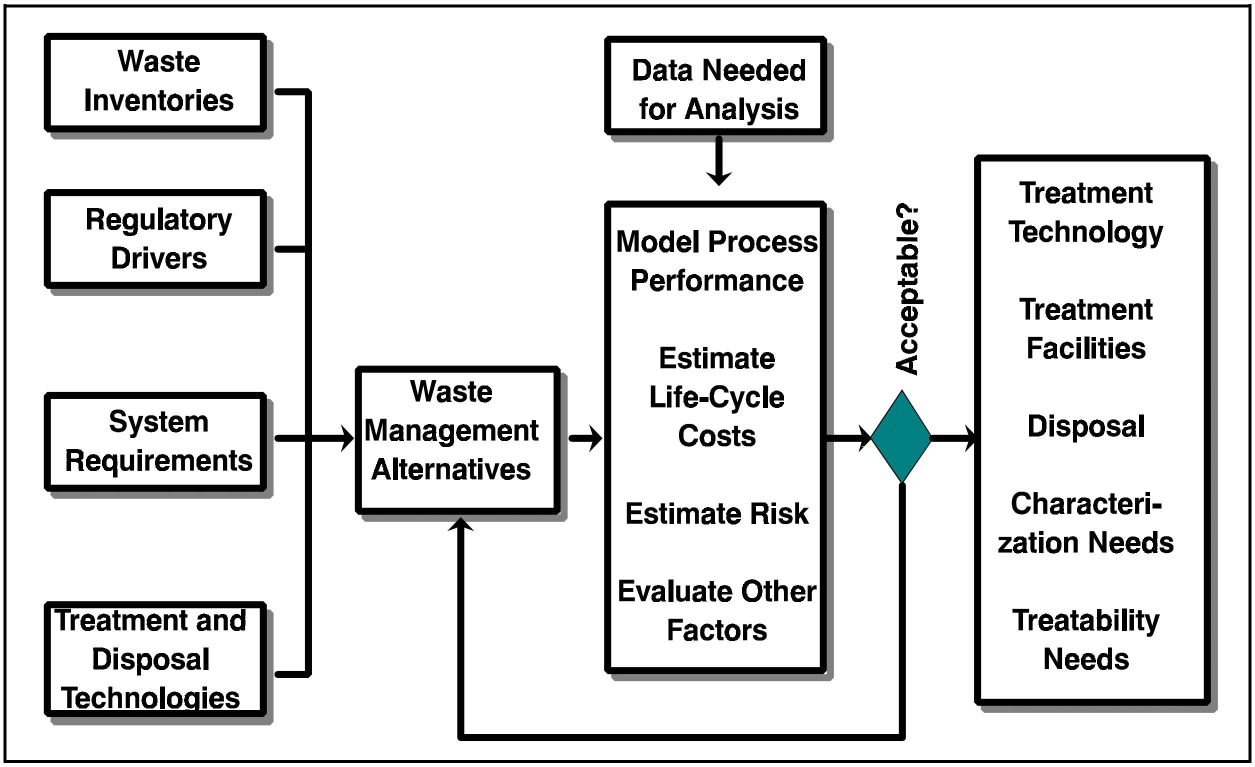


Figure 1J.1. Methodology for evaluation of waste management scenarios.

Scenario-Based Analysis

The scenarios for analysis are built by selecting a set of existing or projected waste streams that are then combined with appropriate treatment processes. The result should be acceptable discharges to the environment and waste forms that meet the waste acceptance criteria of feasible waste disposal sites. For transportation costs and risks to be evaluated, the distances between waste storage sites, treatment facility locations, and disposal sites must be included in the scenarios. Usually, only scenarios with common waste streams are compared with each other, although each scenario can be independently evaluated and scored. The methodology (Osborne-Lee *et al.* 1994) used to build scenarios in the studies performed included the steps outlined below (see Figure 1J.1).

(1) Assemble combinations of:
  - Waste category, quantity, and location;
  - Treatment types and location; and
  - Disposal site and its waste acceptance criteria.

(2) Screen for inappropriate combinations on basis of:
  - Inappropriate treatment for waste type, or
  - Inability to meet requirements to satisfy regulatory drivers.

(3) Use remaining combinations as scenarios for systems analysis comparison of
  - Cost,

- Safety (eg. risk), and
- Other performance metrics.

The first step in this systems analysis approach is to study the factors that will determine the possible waste treatment scenarios. The first of these factors is waste inventory. This includes the quantity of wastes to be processed; the physical form of the wastes (such as sludge, soil, metal, etc.), and the types of contaminants present in the wastes. The next factor to consider encompasses the regulatory drivers defining such requirements as the maximum contaminant level allowed in the processed waste, the time-constraints which dictate the schedule for treating the wastes, and the rules governing the disposal of treated wastes. The third factor includes the system requirements such as criticality concerns, safety, and transportation. These requirements must be considered in the treatment process design. The final factor consists of the treatment and disposal technologies. Once determined, the important factors must be analyzed in relation to each other to arrive at a set of potential waste treatment scenarios, each of which must satisfy the requirements just mentioned.

Definition of Scenario Components

Scenarios are assembled from a set of potential scenario components. Scenario components might include typical flow sheet elements such as storage for specific wastes and final products, transportation alternatives for the specific waste feeds and final products, candidate treatment processes, and final disposal options. A meaningful engineering assessment of such scenarios realistically requires the use of analytical tools to provide estimates of performance and other evaluation criteria, as well as life cycle costs and risks to the health of the worker, the public, and the environment. An element crucial to proper integration of all these components is a simulation environment wherein scenario components can be assembled, organized, and efficiently analyzed. The remainder of this section considers the various scenario components and their integration.

Prioritization of Treatment Technologies

Early prioritization can be used to reduce the number of technologies to be evaluated, thus enhance the cost effectiveness of the technology assessment. Typically, the basis for prioritization is found in the objectives and governing constraints for the decision to be made. For example, the decision may require a focus on limited number of primary treatment technologies that seem suitable for treating a particular type of waste. Before prioritization, the technologies considered in this study were screened based on specific criteria. For example, candidate technologies were limited to those that (1) were at the time under development by the Department of Energy (DOE), (2) were then commercially available, or (3) had already been applied to similar processing needs. Other criteria may include the following:

- Potential for compliance with the Resource Conservation and Recovery Act (RCRA) and other applicable regulations;
- Potential for limiting the liability of the DOE and the Oak Ridge Reservation (ORR) managing and operating contractor;
- Potential to accelerate the schedule for the development and demonstration of the technology and the treatment and final disposition of the waste,

- Opportunities to minimize life-cycle costs of mixed waste treatment, storage, and disposal,
- Opportunities to limit short-term and long-term risks associated with continued storage, treatment, and final disposition of the mixed wastes; and
- Potential to improve public acceptability of the mixed waste management plan.

Cost Analysis

Analysis of cost elements is an important consideration, whether in the private sector where profits are at stake or in the government sector where tax dollars are being used. The cost model (Feizollahi and Shropshire 1992) used as the basis for cost analysis in this study provided the following:

- Rough estimates of cost (versus a detailed cost estimation, which was not desired),
- A basis for relative comparisons between technology alternatives and scenarios,
- Consistency across technology alternatives and scenarios,
- Life cycle costs, and
- Information with which to calculate a cost-to-benefit ratio.

Life cycle costs included (1) research, development, demonstration, testing, and evaluation (RDT&E) costs, (2) facility construction costs, (3) operating and maintenance costs, (4) decontamination and decommissioning (D&D) costs, and (4) final disposal costs.

Risk Analysis

Risk evaluation is also an important part of the assessment as it is the most feasible and recognized framework for environmental protection. For the level of detail characteristic of this study, it was important that the risk estimates be useful for comparison of technologies and thus sensitive to differences in technology characteristics as well as stream constituent concentration levels. However, absolute values of risk were neither feasible nor required. Risk due to normal operations was the focus of the analysis, and accident risks were not considered.

The risk analysis model was developed using a unit risk factor approach in which site-specific impacts are determined based on the release of a unit quantity of a given contaminant. The result was a database of unit dose factors for a various compounds at the different sites of interest. Risk values for comparison are obtained simply as a product involving the unit dose as follows:

$$\text{Risk} = \text{unit dose factor} \times \text{release rate} \times \text{years of operation} \times \text{slope factor}$$

where the release rate characterizes process emissions, years is the years the process is in operation, and the slope factor is characteristic of the stream constituent giving rise to the health impact. During the flow sheet simulation, the risk module essentially scales up the risk contributions from each stream constituent. The result is a set of estimates of latent cancer fatalities and genetic defects from releases of radionuclides or chemical carcinogens, and toxic effects (acute and chronic) from chemical toxins. Risk estimates include impacts to workers onsite, the population offsite, and the maximally exposed individual.

Performance

Adequate performance by both the treatment process and the waste forms it produces are criteria of high importance. Performance decision criteria can include the following (Ferrada and Berry 1993):

- Waste treatment capacity
- Production rates
- Plant availability
- Plant maintainability
- Volume reduction
- Contaminant concentrations
- Secondary waste and effluent generation
- Waste-form activity
- Waste-form stability
- Waste-form contaminant release characteristics

In addition, the performance criteria should be quantitative and relevant to regulations and health, safety, and environmental (HS&E) goals.

Evaluation Criteria

This section addresses the problem of selecting mixed waste management technologies from a suite of alternatives. In general terms, once the scenarios that include specific technologies are obtained, a ranking procedure follows which indicates an order of preference by which the decision maker can establish his or her decision. Mixed waste management is a multi-criteria decision problem (Keeney and Raiffa 1993; Ferrada and Berry 1993; Ferrada 1990). Multi-criteria analysis is based on the premise that the outcomes of the various decision criteria need not necessarily be transformed into monetary units to arrive at a comprehensive comparison of different project outcomes. Other elements besides the traditional monetary evaluation methods, such as social cost-benefit analysis and cost-effectiveness analysis, must be taken into consideration—particularly when public concern is involved in the decision-making process.

Process Simulation

The process simulation model has several requisite characteristics and capabilities. For applications to waste management systems, the simulation or model must have the capacity for:

- Considering generation, storage, treatment, and disposal of mixed waste on the ORR
- Representing complex flow sheets in a simplified manner
- Being readily modifiable to add or remove process components
- Being easy to learn; easy to use
- Being able to provide material and energy balances with a paucity of detailed input
- Being able to provide information needed for cost and risk analyses and comparisons
- Providing for consistency across technologies
- Being able to address major waste types or groups

SYSTEMS ANALYSIS-BASED DECISION METHODOLOGY PART 2 – ORNL WASTE MANAGEMENT CASE STUDY

Our systems analysis approach has been applied several times to support technology selection decisions at ORNL. The various applications range from providing the technical basis for the selection of mixed waste treatment alternatives to analyzing individual innovative technologies. The integrating tool for these environmental studies (Ferrada *et al.* 1995; Ferrada *et al.* 1994) around the ORNL complex and other DOE sites in each case has been FLOW (Ferrada and Jackson 1992).

Selection of *In-Situ* or *Ex-Situ* Grouting

The objective of this project was to determine the best method for solidification of the ORNL gunite (building materials for liquid and sludge storage tanks) tanks sludges within a robust grout formulation. The system to be analyzed consisted of two scenarios (1) disposal in the existing gunite tanks by *in-situ* grouting and (2) removing the sludge from tanks and processing it through a grout plant located on site. The definition of "robust" in this situation is a low waste loading such that the grout can (1) handle the variability expected from the sludges of all the gunite tanks with minimal testing and (2) pass all testing using a dry blend previously derived from a grout formulation developed for a sludge.

The systems analysis of the proposed grouting of the gunite tanks determined comparative cost estimates for the two options considered in the study as well as performance of final grout considering disposal issues. The cost elements were estimated by analyzing previous solidification campaigns and by communications with potential vendors.

The systems analysis applied to this project integrated (1) waste stream characterization, (2) grouting processes, (3) radioactivity restrictions, (4) transportation, (5) storage, (6) waste acceptance criteria, (7) disposal site selection, and (8) cost estimation. Control elements to determine the correct formulation of the grout were needed as part of the system. This study involved a technical evaluation that established the range of contaminant release reduction, which experience suggested can be achieved by *in-situ* and *ex-situ* grouting of the materials stored in the ORNL gunite tanks. The evaluation includes a review of waste characterization data to confirm suitability of grout processing for the waste, the development of preliminary flow sheets, and estimation of the order of magnitude of cost for each option.

Option 1: Processing Tanks In-Situ: The evaluation of this option considers that the grout formulas are set to produce the minimum volume of waste product consistent with producing a waste form that meets the Nuclear Reactor Commission (NRC) performance requirements, waste acceptance criteria (WACs), and land-disposal restriction (LDR) criteria. At the same time, the analysis will determine if the final waste produced is below radioactive limits for low level radioactive waste. The *in-situ* grouting process suggested for the gunite tanks is based on the jet-grouting method. Experience based on treatability studies (Kauschinger 1996) shows that a multipoint injection (MPI) process has been effective in forming a homogeneous, low-conductivity monolith starting with heterogeneous, shallow-buried waste. One reservation about this technology is ensuring that the high-pressure injection jets will not damage the gunite tank walls.

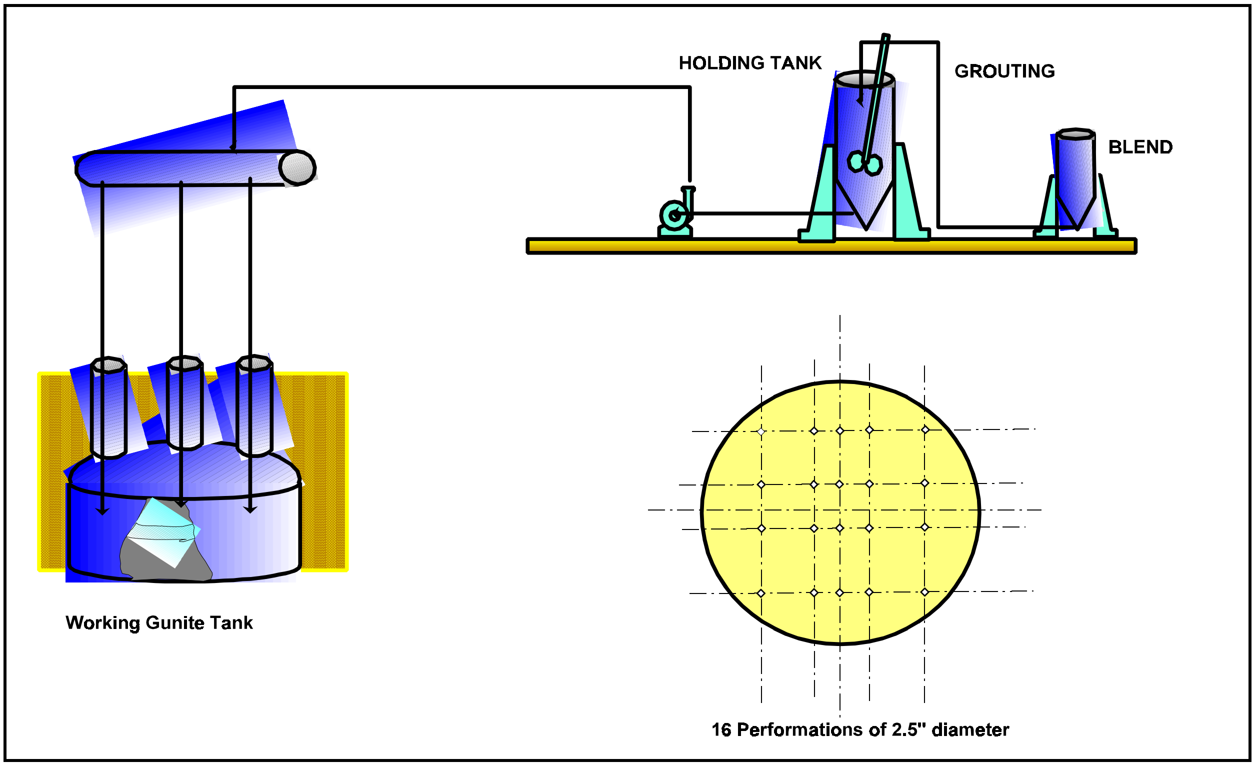


Figure 1J.2. *In-situ* process for grouting tank wastes (option 1).

The holding tank, the pump, the manifold, and the blender shown in Figure 1J.2 can be located at a large distance from the tank. The pipes and injection jets will remain inside the tanks. This feature will reduce the needs for decontamination after the grouting process has ended.

Option 2: Grouting Ex-Situ: This option assumes removing the sludge from the gunite tanks and processing it through a grout plant located on-site. Processing of the waste would be followed by containerizing the waste and transporting it to an interim storage facility before shipment to a disposal facility. The evaluation of this option considers that the grout is set to produce the minimum volume of waste product consistent with producing a waste form that meets Nuclear Regulatory Commission (NRC) performance requirements, Waste Isolation Pilot Plant (WIPP) WACs, and LDR criteria. At the same time, the analysis will determine whether the final waste produced is below radioactive content limits for low level radioactive waste.

The *ex-situ* grouting approach assumed for this study is based on the commercially proven, large steel liner, batch solidification system which has been successfully used over the past seven years at ORNL in four treatment campaigns called Liquid Waste Solidification Projects (LWSPs). During the LWSPs, more than 180,000 gallons of concentrated radioactive supernate have been solidified at ORNL MVSTs for ultimate disposal at the liquid low-level waste (LLLW) facilities at the Nevada Test Site (NTS). These monolithic grouted waste liners await final approval for shipment. The ex-situ process is illustrated in Figure 1J.3.

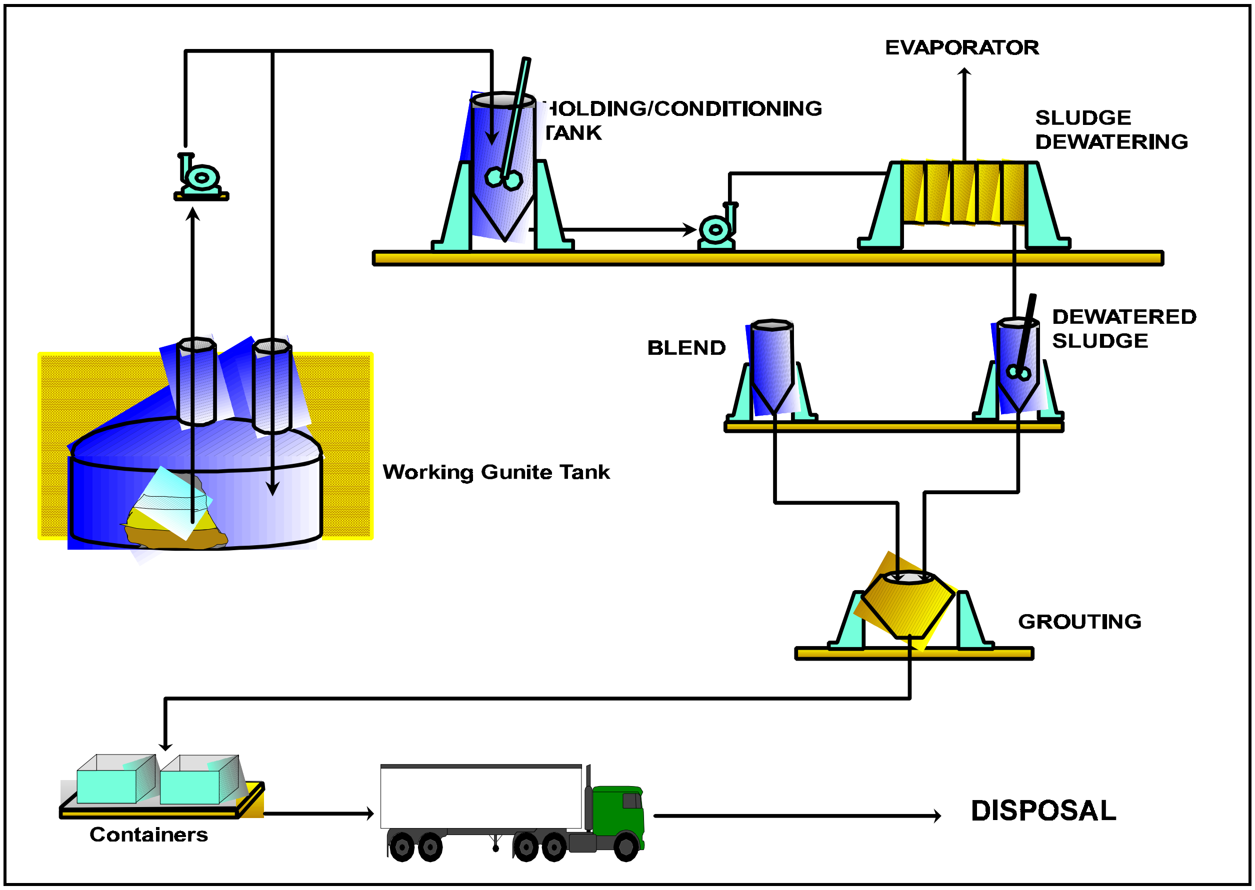


Figure 1J.3. *Ex-situ* process for grouting tank waste (option 2).

The process has proven reliable at ORNL for treating batches of waste similar to the GAAT supernate, while providing adequate shielding and containment to protect workers and the environment. Also, several commercial companies offer essentially the same treatment services so that a competitive basis for bidding can be established. Moreover, these same companies have broad experience in adapting the system to both different grout-waste formulations and different waste-packaging requirements, including transfer of the grouted waste from the mixing vessel to 55-gal drums.

Advantages and Disadvantages of Both Processes

For the *in-situ* process, it is recommended that pilot-plant-scale experiments be conducted to observe the behavior of the high-pressure stream against the wall of the tanks. Specifically, a correlation must be established between the closeness of the jet streams to the tank wall and the efficiency of mixing to produce an appropriate monolith. It is also desirable that the pilot-plant experiments study the grouting efficiency of systems. Work has been previously done with shallower open systems and has shown success.

The *ex-situ* grouting system provides several distinct advantages for timely and affordable implementation. The first advantage of this system is that it is the most mature and thoroughly demonstrated and proven radioactive liquid and sludge waste treatment system in the commercial nuclear power industry. Also, several commercial companies offer essentially the same treatment services so that a competitive basis for bidding can be established. The *ex-situ* operations must be housed in a special building for safety reasons. The equipment will be contaminated and further decontamination activities must be pursued after the process has ended.

Process Model Results

The results of this analysis have indicated that both the *in-situ* and *ex-situ* grouting systems are viable (shown in Tables 1J.1 and 1J.2). The *ex-situ* grouting process has the advantage of producing the grout with a better control of operations because the operations are completely visible on the surface. It also allows a simplified sampling mechanism. However, the cost of the *ex-situ* grouting process is always higher than the corresponding *in-situ* operations. Interim storage, transportation, and disposal costs are additional costs for the *ex-situ* options that are not present in the *in-situ* operations. Also, the potential for contamination and exposure is higher in the *ex-situ* grouting process. The *in-situ* operations uses piping and jet elements that will remain inside the tanks after the operations have finished, while the *ex-situ* operations require decontamination activities after the grouting has been finished. Pilot-scale demonstration is required to analyze the effect of pressure jet against the walls of the concrete tanks.

Table 1J.1. Cost estimates of *in-situ* grouting.

Costs, $\$10^3$	**Tank 1**	**Tank 2**	**Both Tanks, $K**
Operations	520	525	1,045
Transportation	0	0	0
Disposal	0	0	0
Total	520	525	1,045

Table 1J.2. Cost estimates of *ex-situ* grouting.

Costs, $K	**Tank 1, $K**	**Tank 2, $K**	**Both tanks, $K**
Fixed	574	575	1,149
Variable	37	269	306
Transportation	21	144	165
Disposal	6	44	50
Total	639	1,033	1,672

SUMMARY

In today’s rapidly changing business world where technological progress, environmental laws and regulations, public opinion, and cost-effective business practices can often conflict, it is necessary to have a method to evaluate how changes in your products or processes are going to effect the overall environment your company is operating. Often, it is discovered too late that a change made in operations to correct a problem causes new problems to appear elsewhere in the process or plant as a whole. A sound systems analysis methodology can help eliminate new and unanticipated problems from appearing.

The methodology presented has been developed and successfully applied in numerous waste management cases at ORNL and other U.S. Department of Energy sites. Though used mainly for waste management studies, the principles and the tools used in our approach to decision improvement can also be used for any type of systems analysis study. The tools developed are flexible and easy to use and are adaptable for most situations. The methodology encourages a team approach to selecting the various factors that must be applied in a systems analysis study with representatives of all the stakeholders represented. This initial buyoff on the criteria of the study has proven to increase acceptance of the results at the end, as has been shown by the studies at ORNL.

Finally, the methods and tools presented serve as experience-rich assets for the purpose of teaching. The case presented demonstrates the value of examples in which applications of decision analysis techniques and tools may be shown. The many decision gates reflecting the different levels of decisions that must be made to support a technology-based decision provide a very effective tool for engaging the student in challenges and complexities of real-life problems. Numerous other decision support examples exist (Osborne-Lee *et al.* 1994; Ferrada *et al.* 1995; Forsberg *et al.* 1995; Forsberg and Elam 1995; Ferrada and Forsberg 1996; Ferrada *et al.* 1996), providing a significant resource for on-going enrichment of decision analysis instruction at PVAMU for the future.

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Dr. Milton R. Bryant is Dean of the College of Engineering at Prairie View A&M University. He teaches probability and statistics and engineering operations research at the graduate level and has held many positions of responsibility, including Interim President. Dr. Bryant is a Distinguished Professor and holds a Ph.D. in industrial engineering from Texas A&M University.

Dr. Irvin W. Osborne-Lee is Head of the Chemical Engineering Department at Prairie View A&M University. He teaches decision analysis and engineering design courses. He has over ten years of experience in applying systems analysis, modeling, and decision analysis to support improved technical decision-making. Dr. Osborne-Lee is an Associate Professor and holds B.S., M.S., and Ph.D. degrees in chemical engineering from the University of Texas at Austin.

Dr. Juan J. Ferrada is a member of the development staff at Oak Ridge National Laboratory. He has expertise is decision analysis, systems analysis, and computer application development. He has led numerous projects to develop and apply enabling tools to support technical decisions for the U. S. Department of Energy and other government agencies. Dr. Ferrada has his Ph.D. from the University of Tennessee, Knoxville.

PARTNERING WITH MMS: OPPORTUNITIES FOR STUDENTS

Ms. Gay Larré
Ms. Eileen Swiler
Minerals Management Service

The MMS Gulf of Mexico Office of Resource Evaluation (RE) vigorously supports and enthusiastically participates in MMS Student Programs. These programs provide for permanent employment or conversion to permanent employment, temporary internships/partnerships, and temporary student curricula. Among those encouraged to apply for student positions are geoscience students, including those majoring in geology, micropaleontology, or geophysics (mathematics and physics); petroleum, mechanical, chemical, electrical, and civil engineering students; computer science majors and those studying other disciplines. Students are recruited through the MMS Personnel Office, college and university professors, other students employed by MMS, and the Internet.

The programs offer numerous benefits to both the students employed and MMS. Students are exposed to an office work-environment; they learn new skills and have an opportunity to apply these skills and their knowledge to practical problem-solving situations. These jobs enable students to set up good “networking” foundations for future employment. In addition, the students earn salaries and benefits. At the same time, MMS diversifies its work force with students eager to learn. These students bring to MMS the most recent scientific theories and knowledge of computer systems. These factors expose MMS employees to new ideas and keep their thinking young (fresh). Finally, MMS has an opportunity to pass on geoscientific and engineering “institutional memory” that may otherwise be lost.

RE follows the following student employee guidelines:

- Have work for the student to do—even the most enthusiastic student needs to know what is expected;
- Plan ahead—have a work plan before the student starts work—he or she may need special equipment, a PC, specific passwords, drafting table or access to a Sun Workstation;
- Make sure the student understands what he or she is assigned to do and why it is important that the work is done correctly;
- Work with the student to set up an acceptable work schedule—be flexible.

The Student Work Programs are beneficial to both students and MMS with each side learning and gaining insight from the other.

SESSION 2G

TOOLS TO ASSESS SPILL ENVIRONMENTAL RISK

Co-Chairs: Ms. Gail Rainey, Minerals Management Service
Dr. Donald Davis, Louisiana Oil Spill Coordinator's Office

Date: December 2, 1999

Presentation	Author/Affiliation
NOAA Oil Modeling Initiatives: Tools for Oil Spill Response and Planning	Mr. Charles B. Henry, Jr. National Oceanic and Atmospheric Administration
Louisiana's Oil Spill Program	Dr. Karolien Debusschere Deputy Coordinator Louisiana Oil Spill Coordinator's Office, Office of the Governor
Economic and Social Consequences of the Oil Spill in Lake Barre, Louisiana	Dr. Allan Pulsipher Mr. Richard Pincomb Center for Energy Studies Louisiana State University Dr. Deborah Tootle Department of Sociology Louisiana State University
Tools That Have Been Used Successfully During Real Spills: SMART	Mr. Charles B. Henry, Jr. National Oceanic and Atmospheric Administration
Entering the New Millennium: Electronic Contingency Plans	Mr. Jim LaFevers Union Pacific Resources

NOAA OIL MODELING INITIATIVES: TOOLS FOR OIL SPILL RESPONSE AND PLANNING

Mr. Charles B. Henry, Jr.
National Oceanic and Atmospheric Administration

The Outer Continental Shelf (OCS) energy resources have the potential for oil spills which threaten sensitive marine ecosystems. Accidental releases from oil production are not the only source of oil pollution. Each year, millions of gallons of oil are spilled into U.S. waters from both accidental spills and urban run-off. Oil spills can kill fish and birds, destroy fragile coastal habitats, and contaminate critical food chain links. Oil spills are equally destructive to a national economy heavily dependent upon a healthy coastal environment.

When oils spills occur, the National Oceanic and Atmospheric Administration (NOAA) provides scientific and technical support to the lead federal On-Scene Coordinator (FOSC) in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). For most marine spills, the FOSC is most often the United States Coast Guard (USCG) Captain of the Port (COTP). Managing NOAA's support is the Scientific Support Coordinator (SSC). The consultation provided by the NOAA SSC to the FOSC is directed toward the goal of developing the best course of action during a spill response. To that end, the SSC must quickly develop an understanding of the characteristics of the spilled oil (what got spilled?), spill trajectory (where is it going?), and environmental resources at risk (who gets hit?). These elements are critical in developing and implementing strategies that minimize and mitigate environmental injury (assessing what can be done?). Unfortunately, oil spills are unplanned and uncontrolled emergency events. As a result, uncertainty is an important element that must be incorporated into both spill modeling and spill response decision making.

The NOAA trajectory analysis team (located in Seattle, WA) provide the SSC information on a spill's projected movement and behavior. The trajectory team members work together to develop estimates that combine visual spill observations made from overflights or remote sensing platforms with computer model calculations that include observed, predicted, and statistical information on the on-scene weather and ocean currents. To aid in these assessments, NOAA has developed several spill response tools that, when properly utilized during the spill response, provide tactical information to the FOSC. Each of these spill tools has a modeling component, but the oil forecast is the result of both the model output and the experience of the trajectory team. With more than 20 years experience dealing with the uncertainty of spill response, the NOAA trajectory team has developed a finesse in handling difficult situations.

An unfortunate consequence of oil exploration, production, and transportation of Outer Continental Shelf (OCS) energy resources is the potential for oil spills which threaten sensitive marine ecosystems. Accidental releases from oil production are not the only source of oil pollution. Each year, millions of gallons of oil are spilled into U.S. waters from both accidental spills and urban run-off. Oil spills can kill fish and birds, destroy fragile coastal habitats, and contaminate critical food chain links. Oil spills are equally destructive to a national economy heavily dependent upon a healthy coastal environment.

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Since the late 1970's, NOAA;s workhorse trajectory model has been On-Scene Spill Model (OSSM). OSSM was first used during the 1979 IXTOC I well blowout in the Bay of Campeche, and the model has been used on several hundred actual spills since. Over the last two decades, the model has been continually "tweaked and improved" as technology and our understanding of oil transport processes evolved. One such advancement was the incorporation of "game theory" into how the model predictions are translated into useful spill information. The result was two types of spill trajectory information: the models "best guess" and a "minimum regret."

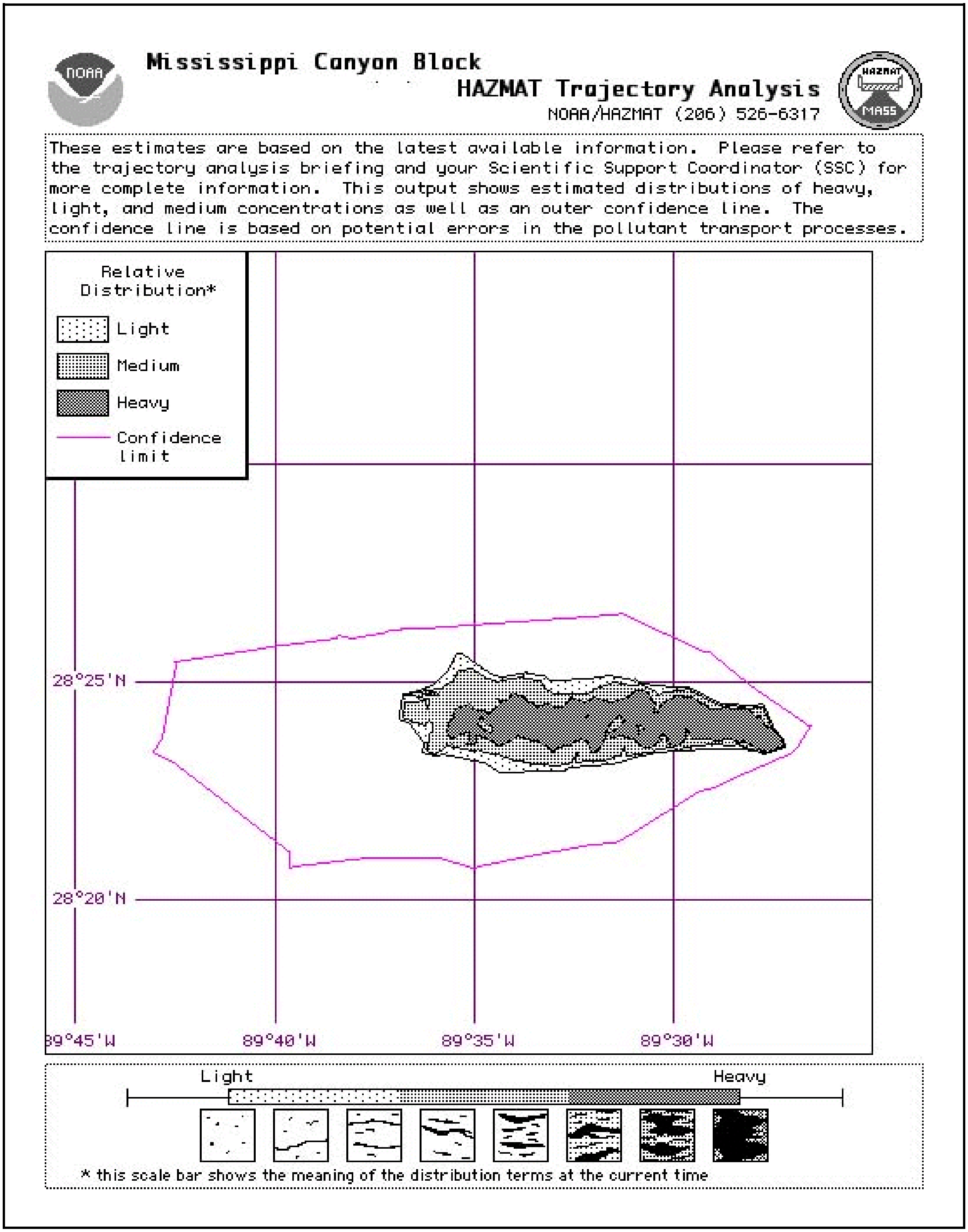
Game theory incorporates two strategies which are quite different, yet quite useful in developing spill response options. The two strategies are Max. Win! (or best guess) and Minimum Regret. Model trajectories based on best guess assume all of the environmental data and forecasts are correct (this is where the model thinks the oil will go). In the minimum regret approach, the uncertainty from possible errors in environmental data and forecasts result in an expanded trajectory area based on the estimates of uncertainty (this is where the oil could go). The minimum regret approach forces the spill responder to look not only at what habitat has the greatest potential to be impacted, but what habitat could, given the uncertainty, be at risk.

Clear consequences between the two concepts are readily apparent. For example, the model's best guess has all of the oil moving off-shore and away from any resources of concern because of the approach of a strong frontal passage. In contrast, the minimum regret output takes into account the possibility that the front will stall allowing oil to enter a sensitive bay and marsh. In this example, a max. win strategy would be to do nothing and hope that the forecast is accurate. If accurate, a proper response would have been made with the least amount of spill resources (cost) expended. Operating under a minimum regret strategy, you would boom the entrance to the small bay and associated tidal inlets, or possibly use dispersants to mitigate the surface oil pollution to protect potential impacts to sensitive areas. After years of responding to oil spills and the uncertainty inherent to spill response, the minimum regret approach is by far the best trajectory strategy. The approach only suffers when the uncertainty is so great that confidence interval (or lack of confidence line) is essential a large circle around the point of release. Our answer to critics is that we would rather tell the FOSC up front that, due to the uncertainty of environmental information, it is impossible for any model to predict with confidence where the oil will be the next day.

OSSM is an excellent trajectory model. OSSM provides confidence limits and scales surface oil concentrations (Figure 2G.1). The disadvantage to OSSM is that as a model it is only available through direct NOAA scientific support. In the past, this was an acceptable practice, but today the need for personnel computer models in the procession of oil spill contingency planners has resulted in the evolution of a new primary NOAA trajectory model. The new model can be operated in two basic modes: Planning Mode (standard mode) and Spill Response Mode (diagnostic mode). In the planning mode, the most representative environmental factors are modeled using mean values from past observations such as climatology data. In general, 10 years of recorded data are combined to make predictions. While standard output information provides a best guess for evaluating a possible spill two weeks or six months from the present, actual environmental conditions can be quite different from past recorded means. The diagnostic mode allows changes to the mean values which reflect actual observed and forecasted currents and weather. The new (Figure 2G.2) model has been named General NOAA Oil Modeling Environment (GNOME).

Another new oil spill response tool for both spill response and contingency planning is the updated Automated Data Inquiry for Oil Spills (ADIOS2). ADIOS is an oil weathering model. The updated ADIOS2 model allows for a better assessment of how uncertainty can effect oil weathering changes and possible cleanup strategies over time. ADIOS2 has evolved from the older ADIOS model with many improvements in the oil fate algorithms and an expanded number of processes which are modeled. The spill information modeled by ADIOS2 include the following oil properties and processes: density, viscosity, water fraction, benzene hazard, dispersion, evaporation, emulsification, spreading, beaching, in-situ burning, leak rate, skimming, and smoke plume.

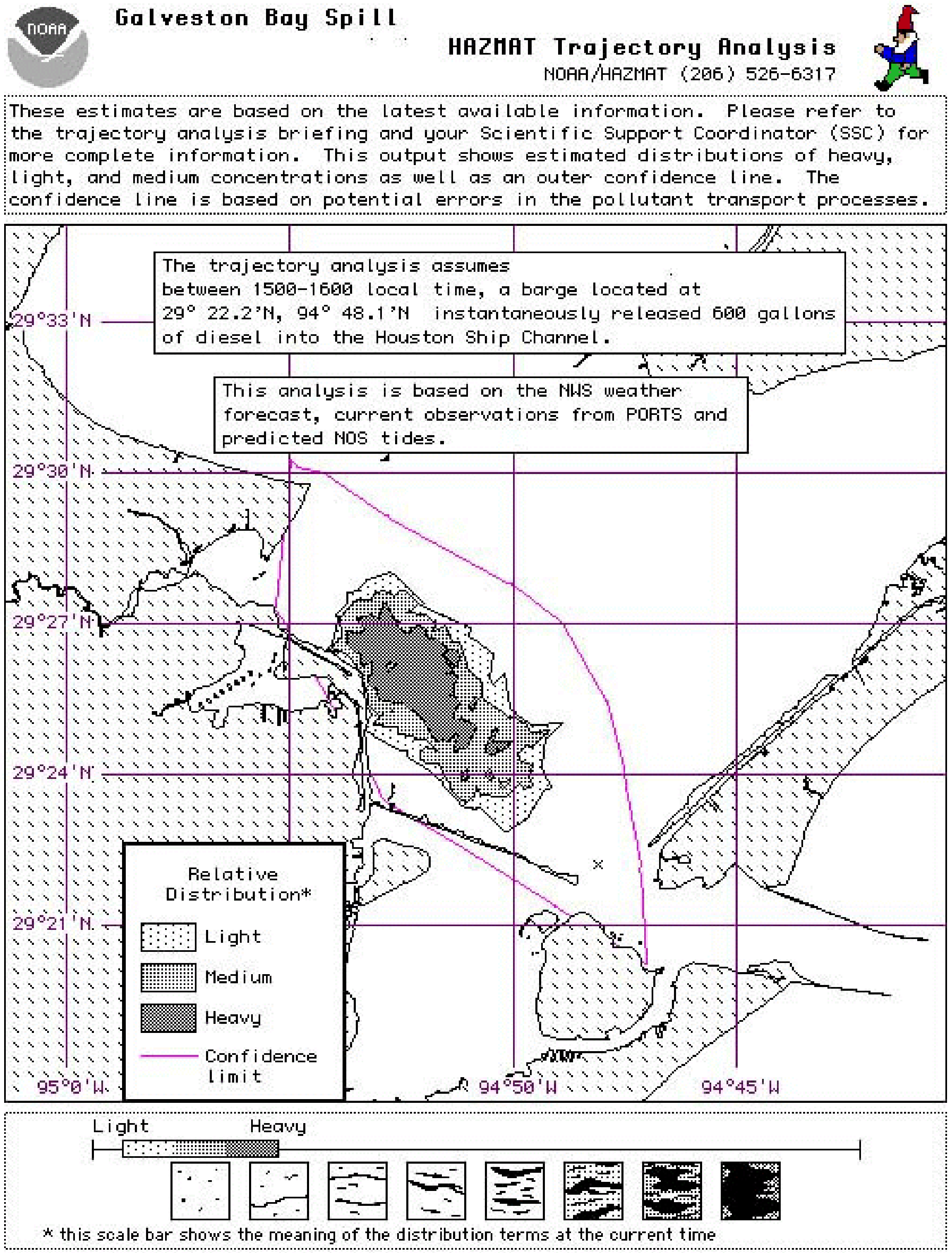
OSSM, GNOME, and ADIOS2 are just tools that help the spill responder develop an assessment of what got spilled, where will it go, and who gets hit. Models are only as accurate as our understanding of the processes, the characteristics of the oil, and environmental data inputted. Models that do not provide uncertainty information to the spill responder could easily result in false assessments based on a "best guess." Modeling that provides uncertainty information to the spill responder promotes a more comprehensive response plan (minimum regret). More information is available at the NOAA Office of Response and Restoration web site (*http://response.restoration.noaa.gov*).



These estimates are based on the latest available information. Please refer to the trajectory analysis briefing and your Scientific Support Coordinator (SSC) for more complete information. This output shows estimated distributions of heavy, light, and medium concentrations as well as an outer confidence line. The confidence line is based on potential errors in the pollutant transport processes.

* this scale bar shows the meaning of the distribution terms at the current time

Figure 2G.1 OSSM trajectory forecast map showing confidence limits and scaled surface oil concentrations for an offshore oil spill.



Galveston Bay Spill

HAZMAT Trajectory Analysis

NOAA/HAZMAT (206) 526-6317

These estimates are based on the latest available information. Please refer to the trajectory analysis briefing and your Scientific Support Coordinator (SSC) for more complete information. This output shows estimated distributions of heavy, light, and medium concentrations as well as an outer confidence line. The confidence line is based on potential errors in the pollutant transport processes.

The trajectory analysis assumes between 1500-1600 local time, a barge located at 29° 22.2'N, 94° 48.1'W instantaneously released 600 gallons of diesel into the Houston Ship Channel.

This analysis is based on the NWS weather forecast, current observations from PORTS and predicted NOS tides.

* this scale bar shows the meaning of the distribution terms at the current time

Figure 2G.2. GNOME trajectory map for a diesel release nearshore.

Response/Planning

SSCs provide critical scientific advice and coordination...

physical/chemical properties of oil and chemicals

- analysis of spill trajectory
- resource protection priorities
- use of different countermeasures
- assessments of shoreline impacts
- consequences of different cleanup strategies

Our Legislative Authority

- the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA, also known as the Superfund Act).
- the Superfund Amendments and Reauthorization Act of 1986 (SARA).
- the Oil Pollution Act of 1990.

These Acts are implemented through the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

Scientific Support Team

- AWAY
- HOME (WA)
  - Oceanographers
  - Biologist
  - Chemist
  - Others
- ADDITIONAL EXPERTS
  - Louisiana State University (LA)
  - Research Planning Inc., Columbia (SC)
  - GenWest Inc. (WA)

Models ???

- definition:
  - --a representation in miniature
  - --anything that serves as a pattern
  - --a person who poses for an artist
  - --one employed to put on articles of apparel and display them to customers
  - --serving as a model

(worthy of comparison-exemplary)

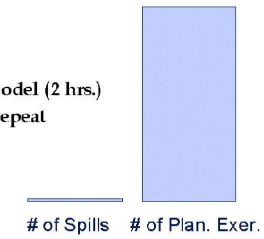
When to use models?

- Absence of real-time observations.
- To predict a future trend based on past performance current status.
  - Where could it go?
  - What is at risk?
  - What protection resources are needed?
- To evaluate our understanding of a process or system.

Models: Uses in spill Response

- Spill response:
  - tactical trajectories
  - verbal (30 min.)
  - computer generated model (2 hrs.)
  - make observations -- repeat

Planning



Have we ever been wrong?

- Information Input
  - Spill Data
  - Oceanography
  - Weather
  - Tides
  - Oil Type
- "We reserve the right to make mistakes, learn from our mistakes, and do a better job next time." (Galt)

Game Theory and
Spill Response Planning

- Strategy
  - Max. Win!
  - Minimum Regret
- Spill Trajectory Types
  - "Best Guess"
  - "Minimum Regret"

Spill Trajectory Types

- Best Guess - Spill trajectory that assumes all environmental data and forecasts are correct. *This is where we think the oil will go.*
- Min. Regret - Summary of uncertainty in spill trajectories from possible errors in environmental data and forecast. *This is where else the oil could go.*

Models

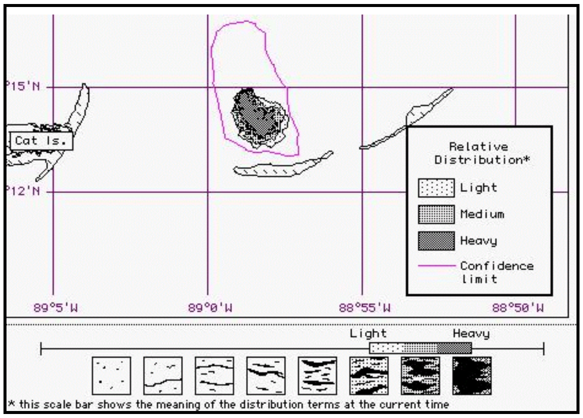
- Current NOAA Model Products:
  - OSSM - On-Scene Spill Model
  - CAMEO - Computer Aided Management of Emergency Operations
  - ADIOS (II)- Automated Data Inquiry for Oil Spills
  - GNOME - General NOAA Oil Modeling Environment
  - TAP - Trajectory Analysis Planner

OSSM

- Developed in the late 1970s
- First used during the IXTOC I well blowout (3 June 1979).
- Used hundreds of times to support actual spills.
- Tweaked and improved...
- Still the workhorse for NOAA HAZMAT

OSSM

- Tactical trajectory model
- Provides confidence limits
- Scales surface oil concentration
- Only available through the NOAA SSC



* this scale bar shows the meaning of the distribution terms at the current time

GNOME

General NOAA Oil Modeling Environment

- **Addresses the needs:**
  - Planning (Standard Mode)
    - "most representative movers"
    - MEAN VALUES
  - Spill Response (Diagnostic Mode)
    - requires additional input and expertise
    - MEAN VALUES COULD BE BAD

GNOME

- Splot Movers
  - wind
  - current
  - oil-type (weathering)
  - turbulence
- "Best Guess"
- Min. Regret

GNOME

- GOOD - FREE to Download
- BAD - Location files are only available for a few areas (three are planned for the Gulf of Mexico).
- UGLY - If the the demo fails...

Additional Information

- //response.restoration.noaa.gov
- no WWW
- no @
- just as shown above!
- gnonewizard@hazmat.noaa.gov

LOUISIANA’S OIL SPILL PROGRAM

Dr. Karolien Debusschere
Deputy Coordinator
Louisiana Oil Spill Coordinator’s Office, Office of the Governor

OVERVIEW

The Louisiana Oil Spill Prevention and Response Act of 1991 (OSPRA) created the Louisiana Oil Spill Coordinator’s Office (LOSCO) within the Office of the Governor to provide a centralized authority for all matters related to oil spill response and prevention. The Act designated LOSCO as the lead state agency for the prevention of and response to unauthorized discharges of oil in the state of Louisiana.

LOSCO’s primary function is to ensure effective coordination and representation of the state interests in all matters related to spill response and prevention. Our principal goals are to:

- Minimize unauthorized discharges of oil;
- Provide for an effective spill response;
- Compensate the public for damages to the state’s natural resources; and
- Assist the public through education, service and public outreach.

LOSCO has implemented several programs for carrying out its mission and achieving its goals.

PREVENTION

The objective of the Prevention Program is to prevent oil from impacting Louisiana’s resources. Planning, training, participation in drills and public awareness all serve to prevent oil spills from happening. LOSCO initiated the Abandoned Barge and Abandoned Facility Programs to directly enhance prevention.

The Abandoned Barge Program was initiated in 1993 and is aimed at minimizing the threat of an oil spill by locating and removing abandoned vessels that pose a high risk for unauthorized discharge of oil. Abandoned vessels and barges in Louisiana coastal waters were inventoried and given a priority ranking for removal. LOSCO established a partnership with the USCG and EPA by forming a cooperative effort known as the Joint Operating Procedures (JOP) Program to remove the abandoned vessels and eliminate the threat of a potential discharge.

In 1992, LOSCO began the statewide Abandoned Facility Program to locate and remove structures, pits, and wells which pose a high risk for unauthorized discharge of oil. All facilities, pits, sumps, or reservoirs in the coastal zone have been inventoried and evaluated to determine the sites that pose the highest risk to human health and safety, environment, and wildlife habitat through actual or potential discharge of oil. LOSCO established a partnership with the Office of Conservation in the

Louisiana Department of Natural Resources to plug the abandoned wells and eliminate the threat of a potential discharge.

RESPONSE

Even with the best Prevention Programs, accidents still happen. When prevention fails and oil is discharged into the environment, LOSCO activates the state's response procedures and makes every effort to minimize adverse impacts from the oil spills. The primary role of LOSCO during a spill incident is to provide a State-on-Scene Coordinator (SOSC) and ensure an effective, coordinated state response.

Preparing for a response requires constant planning, training, and exercising response procedures. These activities constitute the core of LOSCO's Response Program.

LOSCO adopted a State Contingency Plan for oil spills in 1995. The Louisiana State Oil Spill Contingency Plan defines the way the state of Louisiana will respond to actual or threatened unauthorized discharges of oil. The Plan, developed in cooperation with local, state, and federal agencies, addresses specific concerns of the state of Louisiana. The plan is reviewed and/or revised annually with the revisions being published in September of each year.

LOSCO initiated the Environmental Baseline Inventory Program in support of contingency planning for the State of Louisiana. The objective of the program is to compile the environmental and resource information needed for oil spill response. The statewide inventory incorporates data such as protected areas, sensitive environments, transportation, potential oil spill locations, ocean currents, historical hurricane tracks, remedial action facilities, spill locations, and many other features needed for oil spill response and contingency planning.

The effectiveness of a state response to an oil spill depends on the experience of response personnel, their knowledge of the environment and response technologies, and their exposure to current information related to these issues. LOSCO established the Oil Spill Response Management Training Program to improve Louisiana's readiness for responding to spills that threaten our valuable natural resources. The program, first of its kind in Louisiana, ensures the availability of trained government and industrial personnel to respond to oil spills, facilitates information exchange, and improves coordination between government agencies, spill response organizations, and industry personnel.

NATURAL RESOURCE DAMAGE ASSESSMENT

Natural Resource Damage Assessments are the mechanism through which the State of Louisiana can compensate the public for injuries to the state's natural resources resulting from oil spills. LOSCO is the lead agency for NRDA in the State of Louisiana and is responsible for coordinating NRDA issues for the state with the other state trustees and the federal trustees, as appropriate. NRDAs allow the trustees to restore, rehabilitate, replace, or acquire the equivalent of the injured natural resources, including interim losses. As of 1991, a total of nine NRDA cases have been initiated in the State of Louisiana.

LOSCO has been proactive in preplanning for NRDA by initiating the NRDA Regional Restoration Planning Program and Sampling and Analysis Program.

NRDA Regional Restoration Plans are being developed for the State of Louisiana. This interagency planning effort is being coordinated with the state and federal natural resource agencies, local governments, and special interest groups. NRDA Regional Restoration Plans will be based upon the principles of region-based watersheds/basins/and sub-basins. They will identify restoration projects throughout the state that can be implemented to compensate the public for injuries to natural resources resulting from oil spills. This will allow the trustees to achieve restoration of injured resources at a much faster rate than having to develop restoration projects on a case-by-case basis.

The Sampling and Analysis Program is aimed at supporting NRDA activities by establishing baseline hydrocarbon conditions in the environment. Sediment samples are consistently collected at predefined monitoring points over a wide geographic area and analyzed for petroleum hydrocarbons. The data are then compiled in a GIS database for use in damage assessments.

PUBLIC OUTREACH

Public Outreach is one of LOSCO’s many activities. We have a responsibility to the public for ensuring that their needs are met. The Oil Spill Awareness Program is the Program through which LOSCO conducts its numerous public outreach activities.

The Oil Spill Awareness Program is aimed at establishing partnerships with all stakeholders. Ongoing activities include development of educational materials, training, public meetings, joint planning, symposiums, and participation in drills and other training exercises.

Some examples of public awareness activities sponsored through LOSCO’s Applied Oil Spill Research and Development Program include: (1) the Oil Spill Awareness Through Geoscience Education (OSAGE) CD-ROM aimed at educating middle and senior high school students about earth sciences and the oil and gas industry; (2) the Small Spills Add Up: Recycle Used Engine Oil Protect Your Fisheries Resources poster promoting recycling of waste oil; and (3) training courses for the Louisiana Oil Spill Contingency map CD-ROM aimed at increasing awareness regarding the state’s resources that are at risk from oil spills.

RESEARCH AND DEVELOPMENT

Oil spill planning and response technologies are continuously evolving. LOSCO’s Applied Oil Spill Research and Development Program is at the forefront of that process. LOSCO endeavors to improve the way we do business in the oil spill response community. The program is aimed at improving spill prevention and response effectiveness by conducting risk assessments, developing innovative recovery and cleanup methods, providing training, and transferring research and development results to the spill response community and the public as a whole.

Since the fall of 1993, the OSRADP has funded 32 projects. Many of the projects have focused on increasing our knowledge of recovery and cleanup methods, including: In-Situ Burning (6 projects), Fate and Effect of Oil in Louisiana Environments (7 projects), Bioremediation (4 projects), Phytoremediation (5 projects), Composting (1 project), Chemical Cleaners (2 projects), Dispersants (1 project), Sorbents (3 projects), and Solidifiers (1 project). In the area of improving environmental risk assessment, several OSRADP projects have contributed to oil spill risk assessments in the Mississippi River and the acquisition and distribution of real-time wave and current information in the Gulf of Mexico, potential spill locations and the location of sensitive natural resources.

A unique component of the OSRADP is the "Spill-of-Opportunity" Program. Through the "Spill-of-Opportunity" Program, the OSRADP makes available $25,000 a year to apply and evaluate new and/or experimental technology to enhance the recovery of spilled oil or to test experimental cleanup techniques in a field situation. To date, these funds have been used in support of three projects: (1) Application of Microtox^{TM} assay to establish and evaluate the efficacy of in-situ burning of oiled marshes (Rockefeller Refuge), (2) Oil spill in Lake Barre: economic and social consequences, and (3) Potential for enhanced anaerobic BTEX degradation at the Blind River spill.

Dr. Debusschere is the Deputy Coordinator of the Louisiana Oil Spill Coordinator's Office, Office of the Governor. She obtained her B.S. in geography from the University of Ghent, Belgium and her Ph.D. in geomorphology from Louisiana State University, Baton Rouge. Dr. Debusschere has over 10 years of experience in oil spill response, planning, and resource management.

ECONOMIC AND SOCIAL CONSEQUENCES OF THE OIL SPILL IN LAKE BARRE, LOUISIANA

Dr. Allan Pulsipher
Mr. Richard Pincomb
Center for Energy Studies
Louisiana State University

Dr. Deborah Tootle
Department of Sociology
Louisiana State University

INTRODUCTION

This is a “spill-of-opportunity” study of the social and economic consequences of a 5,000 barrel oil spill that occurred in the saltwater Lake Barre, off the coast of Louisiana, in May 1997. Figure 2G.3 shows that while the spill was not in Federal OCS waters, its nearshore nature makes it worthy of investigation. The study was conducted with grants from the Louisiana Applied Oil Spill Research

Figure 2G.3. Location of Lake Barre.

and Development Program and the U.S. Department of the Interior's Minerals Management Service. The spill resulted from the rupture of a 16-inch pipeline bringing 170,000 barrels of oil per day to shore from offshore facilities. The response was prompt. The operator, Texaco Pipeline, shut-down the line within ten minutes of the drop in pipeline pressure. Satellite imaging was used to determine the location of a slick seven miles long and two miles wide, and work crews were dispatched. By the following morning, people and equipment had been mobilized and were on the site. Winds from the southeast pushed the spill into coastal marshes. About half of the 5,000 barrels of oil spilled eventually was recovered.

DISCUSSION

The research team interviewed officials from Texaco, the subcontractors hired by Texaco for the cleanup effort, governmental officials, business owners and operators, and other residents in the area most directly affected by the spill and analyzed a detailed statement furnished by Texaco of approximately $9.8 million expended in the cleanup operation. Table 2G.1 shows how the $9.8 million was distributed within and outside of the spill area. In addition, the team examined the Incident Action Plans, which describe, among other things, the number of workers and types of materials being used at the spill site on a daily basis.

The short-term social and economic consequences of the oil spill were modest, as measured either with the available data on cleanup expenditures and the number of people employed or as reflected in the interviews conducted with the business, public officials, and residents in the area. There were

Table 2G.1. Estimated expenditures to recipients within and outside the "spill area."

Location Recipient-Disposition	**Within Spill Area**	**Outside Spill Area**	**Total Expenditures**
Cenac-Manpower	$2,271,748		$2,271,748
Cenac-Service and Supplies	487,918	$975,837	1,463,755
Cenac-Subcontractors		3,583,273	3,583,273
Businesses in Terrebonne Parish	522,865		522,865
Businesses in Lafourche Parish	88,519		88,519
Businesses in St. Mary Parish	100,628		100,628
Businesses in other areas		1,737,622	1,737,622
Payments to individuals	53,263		53,263
Totals	$3,524,941	$6,296,732	$9,821,673

concerns in the area about negative economic and social consequences in the longer term if fishing, shrimping, or oystering were to suffer, or were to be perceived as having suffered, because of the spill. However, there is no persuasive evidence at this time either to support or to refute such concerns. State officials and cleanup professionals involved in the spill characterized the response to the spill as quick and well organized and do not anticipate serious long-term damage to the area. However, owners of oyster leases are suing for alleged damage to oyster beds.

There are three explanations for the limited nature of the short-term economic and social consequences of the spill.

- First, the oil spill cleanup industry along the Gulf Coast operates as a flexible, adaptive coalition when dealing with large spills. A lead subcontractor is designated–usually by geographic proximity. The lead subcontractor then contacts other cleanup firms, many of whom they have worked with during past spills. Pricing of cleanup services is on a day-rate basis, with rates uniform among firms. This system provides experienced and trained workers to deal with spills in a very short period of time; however, few new workers are hired locally. New expenditures, thus, are limited to lodging and meals–neither of which has high expenditure “multipliers,” especially when they are recognized as temporary.

- Second, the relatively short duration of cleanup activities limits the short-term economic and social impact of cleanup expenditures. The number of individuals working on the Lake Barre spill peaked at about 300 in the first ten days of the cleanup as shown in Figure 2G.4. Then employment fell to and averaged about 125 for the next 10 days, and then fell again, averaging about 25 for the rest of the cleanup. Thus, the secondary lodging and eating/drinking expenditures also were of limited duration.

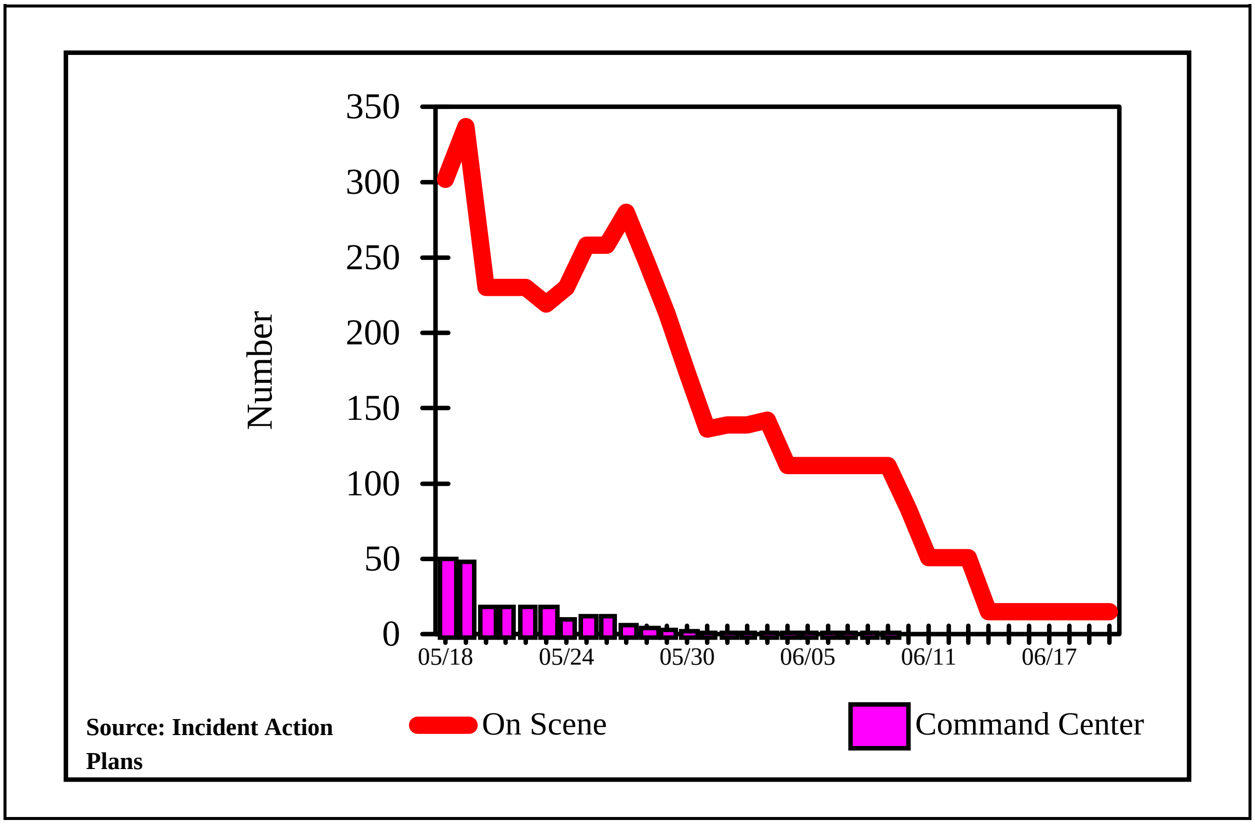
- Third, this spill site was geographically isolated, and most recreational and commercial coastal/ocean users were able to avoid the spill site at modest, if any, additional cost.

This pattern of a short and limited social and economic impact and disruption was confirmed by the responses during interviews with individuals in the local area:

- 20% of those contacted for interviews were unaware that a spill had occurred. This finding is surprising since the individuals contacted were either owner/operators of businesses, civic leaders or local officials. If the spill had resulted in major economic or social problems or dislocations, it seems doubtful that one out of five members of the economic, political, and social leadership would be unaware that a spill had taken place.

- 30% of the community leaders or civic officials who were aware of the spill and were interviewed did not believe the spill had any impact on their community, and 57% of the business owners or operators said the spill had no effect on their business.

- 25% of the civic leaders were afraid the spill would have a negative impact on their community, and 11% of the business owners and operators expected a negative effect on business as a consequence of long-run damage to fishing, shrimping, or oystering in the area.



Source: Incident Action Plans

Figure 2G.4. Employment profile: manpower at the scene and at command center 18 May - 20 June 1997.

- 22% of the civic officials and leaders responded that the spill had a positive impact due to expenditures by cleanup crews, and another 16% also thought the spill had a positive impact due to increased restaurant and lodging sales.

- 25% of the business sector respondents said associated spending had increased revenues of their businesses.

- 2% of the community leaders cited traffic congestion as a negative impact, and five percent were unsure if there were impacts or had no opinion.

SUMMARY AND CONCLUSION

To summarize, the oil spill cleanup industry on the Gulf Coast operates more as a cooperative coalition than as a group of competing firms. This structure is a result of the driving imperative of the oil spill cleanup industry–to be able to respond immediately to an unexpected and ill-defined event with hundreds of skilled and experienced workers who need large amounts of specialized equipment to do their jobs. Although this structure is a rational and efficient adaptation to the imperative it reflects, it also limits any positive, short-term, economic impact in the spill area from the cleanup activities.

Negative social and economic consequences of an oil spill also appear to be limited. Based upon information from the interviews with community officials and business operators in the spill region, short-term effects of this spill appear to have been very limited. Longer-term effects are difficult to characterize and evaluate so soon after the spill occurred. The preponderance of those interviewed believed there would be no negative effects from the spill, but a significant minority said they were worried that longer-term effects might yet manifest themselves.

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Deborah Tootle is an Assistant Professor with the Population Data Center at Louisiana State University. She earned her Ph.D. in sociology from the University of Georgia, her M.A. from Tulane University, and her B.S. from LSU. Her areas of specialization include rural labor markets and the sociology of work and labor.

Richard Pincomb is a Research Associate at the Center for Energy Studies. He has an M.L.I.S. and a B.S. from LSU and an M.E. in petroleum engineering from Tulane University.

TOOLS THAT HAVE BEEN USED SUCCESSFULLY DURING REAL SPILLS: SMART

Mr. Charles B. Henry, Jr.
National Oceanic and Atmospheric Administration

Special Monitoring of Applied Response Technologies (SMART) is a joint U.S. Coast Guard, Environmental Protection Agency (EPA), Center for Disease Control (CDC), and National Oceanic and Atmospheric Administration (NOAA) response program for monitoring in-situ burning and dispersant operations. SMART relies on small, highly mobile teams that collect real-time data using portable, rugged, and easy to use instruments. The information collected is reported directly to the Unified Command for operational consideration. SMART answers operational response questions related to dispersants effectiveness and if sensitive areas are being exposed to smoke particulates above the authorized concentration. With feedback information from the SMART field teams, the response managers can make informed decision as to the continued use of dispersants and in-situ burning. Implementation of the SMART program during actual oil spills in the Gulf of Mexico is tasked to the USCG Strike Gulf Team. The NOAA Scientific Support Coordinator (SSC) is a vital link in the process. The SMART program has been successfully demonstrated during field test and used during actual real spills in the marine environment.

Dispersants and in-situ burning are very different response technologies. The monitoring technologies for each are clearly different with different monitoring end-points. Dispersants are applied to oil slicks to enhance the transfer of oil from the water surface into the water column. SMART monitoring for dispersants is designed to assess if the chemical dispersants are actually working. To accomplish this goal, SMART uses a tiered approach that includes aerial observation (Tier 1) and real-time, on-water analytical monitoring using a flow-through fluorometer system and a vessel of opportunity (Tier 2). Fluorometry monitoring is a highly reliable and sensitive analytical technique. Yet, when applied to dispersed-oil monitoring, there are inherent weaknesses related to estimating actual, or true, dispersed oil concentration (Henry *et al.* 1999). Despite potential weaknesses, fluorometry has been an effective monitoring tool for dispersed oil (Page *et al.* 1983, Green *et al.* 1983, Lunel *et al.* 1997) and performed well during an actual spill deployment (Henry 1998). SMART monitoring can also be expanded to collect scientific data to advance scientific understanding of dispersant plume transport (Tier 3).

In-situ burning is method by which oil is burned as a removal technique. One concern with in-situ burning is the exposure to downwind populations (human and animal). The level of concern adapted for in-situ burn operations is 150 micrograms/cubic meter of particulates smaller than 10 micrograms in diameter (PM-10) averaged over a one-hour period. Modeling is generally conducted prior to burning to assess risk to population centers. If a risk is identified by modeling, it is doubtful that burning would be considered. When SMART is deployed during an in-situ burn, the monitoring teams are located at areas of concern. The field monitoring team is deployed to validate the modeling predictions. SMART uses fully portable, real-time PM-10 meters. If during an offshore in-situ burn, the observed PM-10 values were to exceed the standard, the burns could be halted. During the response to the grounded freighter New Carissa, a decision was made to explode the fuel tanks and burn the oil abroad ship to minimize the risk to the coastal environment. During this operation, SMART was successfully deployed (Henry 1999). No significant smoke impacts were detected by the monitoring teams at populations centers near the burn.

SMART monitoring is designed to be highly practical, and that is one key to its successful use during actual spills. Research investigation and actual deployment has shown that the SMART protocols meet the mission requirements. The SMART guidelines can be download at www.uscg.mil/vrp/smart.pdf. Additional information on SMART can be found on-line at *http://response.restoration.noaa.gov*.

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Page, D.S., J.C. Foster, J.R. Hotham, E. Pendergast, S. Hebert, L. Gonzalez, E.S. Gilfillan, S.A. Hanson, R.P. Gerber, and D. Vallas. 1983. Long-term fate of dispersed and undispersed crude oil in two nearshore test spills. *In* Proceedings of the 1983 IOSC, p. 479-482.

SMART (a.k.a. SROMP)

- Scientific Monitoring of Applied Response Technologies

- Mission Statement
- To provide a monitoring protocol for rapid collection of real-time, scientifically-based information, to assist the Unified Command with decision making during *in-situ* burning and dispersant application.

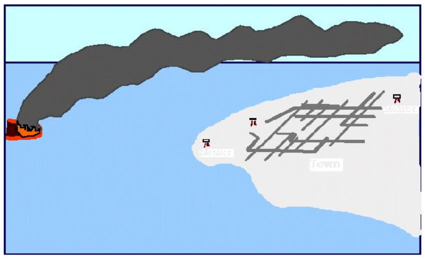
- OPERATIONAL MONITORING PROTOCOL

Operational Monitoring Objectives

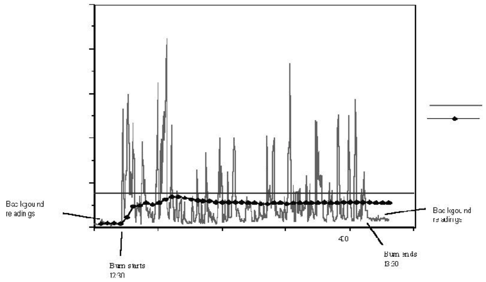
- *In-Situ* Burning: Ensure Public Safety

- Dispersants:
- Primary- Efficacy (Proof of Action)
- Secondary- Transport and Exposure

SMART: *In-Situ* Burning



Actual Monitoring Data



Actual Events

- Rockefeller Refuge, LA *In-Situ* Burn (1995)

- New Carissa Incident (1999)

- Others

SMART Basics

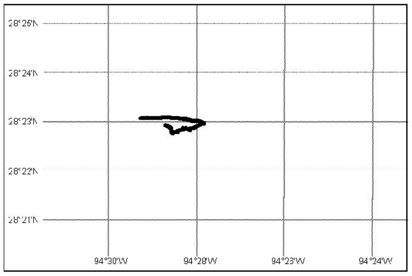
- USCG Strike Teams
- (NOAA, EPA)
- Vessel of Opportunity
- Flow Through Fluorometer
- Continuous Monitoring
- Target Transects:
  - Background
  - Preapplication
  - Dispersed Oil Plume

Case Study: HIPS Incident

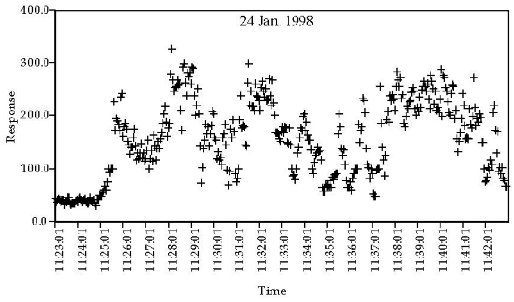
- **Date: 23 Jan., 1998**
- **Oil: Crude**
- **Volume: Unknown**
- **Location: >50 mi. off Galveston, Texas**
- **Disp.: Corexit 9527**
- **Application: Aerial DC-3 and DC-4**

- **SROMP "SUCCESSFULLY" DEPLOYED**

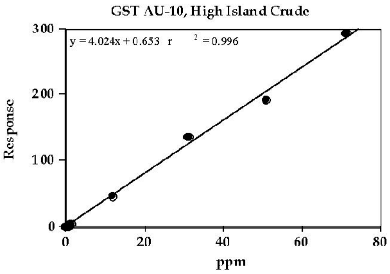
Flight Log and SROMP Position Log



SROMP Results: HIPS



Fluorometer Calibration

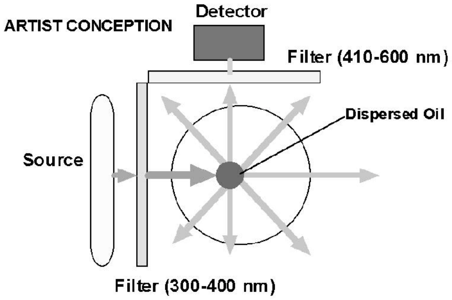


SROMP -- SMART

- Tiered Approach

- I Visual
- II On-Water Fluorometry
- III Advanced On-Water

Basic Fluorometry



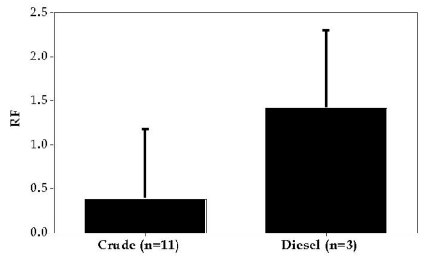
Factors Which Effect Fluorescence

- Dispersed Oil*
  - Oil Composition
  - Dissolved vs. Bulk
  - Droplette Size
  - Weathering
- Temperature
- Salinity
- pH
- Dissolved Oxygen
- CONVERGENCE ZONES

Background Waters

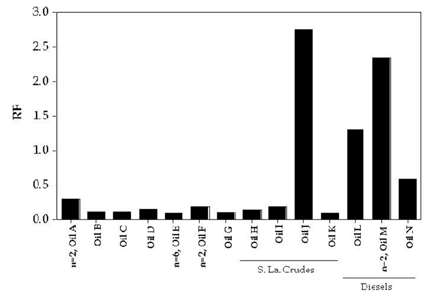
Source	71° F	111° F	41° F
DI* (LSU)	-0.40	-0.60	0.56
Orca Bay, PWS, AK	0.75	0.84	2.19
Pacific Ocean (Hi)	2.57	2.56	4.13
Pacific Ocean (CA)	4.89	4.27	6.54
Blank Vial (Room Air)	5.67	na	na
Tap Water (AL)	14.30	13.50	17.10
Kenai Pond, AK	21.10	18.80	27.60
Atlantic Ocean (FL)	28.60	24.80	30.60
Atchafalya River, LA	107.00	93.20	115.00
University Lake, LA	120.00	104.00	129.00

Relative Response Factors

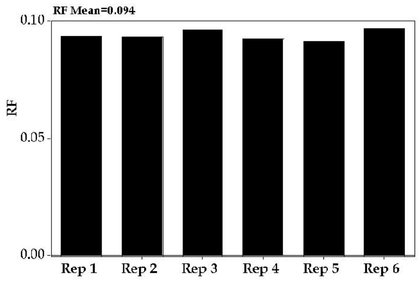


RF=Conc./Detector Value

Relative Response Factors



Reproducibility: RRFs

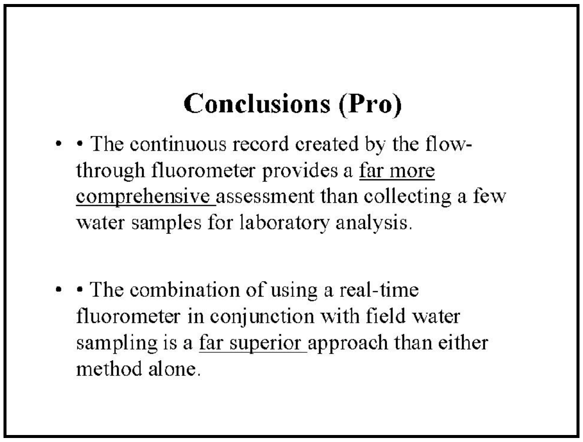


Conclusions (Con)

- Dispersed oil concentrations, as measured by real-time fluorometer readings, may or may not <u>directly</u> compare to standard laboratory values.

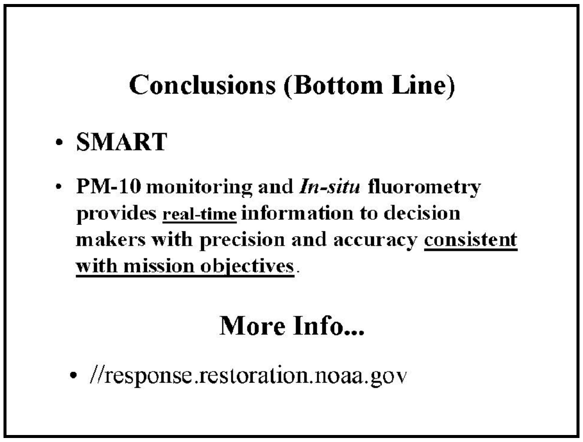
- ALL ANALYTICAL DATA IS METHOD DEPENDENT

- Matrix changes may have a significant effect on detector response.



Conclusions (Pro)

- • The continuous record created by the flow-through fluorometer provides a far more comprehensive assessment than collecting a few water samples for laboratory analysis.
- • The combination of using a real-time fluorometer in conjunction with field water sampling is a far superior approach than either method alone.



Conclusions (Bottom Line)

- **SMART**
- **PM-10 monitoring and *In-situ* fluorometry provides real-time information to decision makers with precision and accuracy consistent with mission objectives**.

More Info...

- //response.restoration.noaa.gov

ENTERING THE NEW MILLENNIUM: ELECTRONIC CONTINGENCY PLANS

Mr. Jim LaFevers
Union Pacific Resources

Union Pacific Resources (UPR) completed a large offshore purchase in June 1998. The acquisition increased UPR offshore operations four-fold and placed UPR within the top 20 producers in the Gulf of Mexico.

Many challenges presented themselves to UPR as a result of the acquisition, among them the need to consolidate both firms' Regional Oil Spill Response Plans (ROSRP's) and Spill Management Team (SMT's) manuals.

The acquisition afforded a prime opportunity for UPR to accomplish several goals regarding the plans:

- The desire to convert to an Incident Command System (ICS) format complete with National Interagency Incident Management System (NIIMS) forms and procedures.

- The development of a "performance-based, best practices" manual, which would satisfy statutory requirements, but more importantly allow for a clear, easy to follow outline that response team members could follow during a crisis.

- The development of a plan that would provide for a quick and effective response, communicate information rapidly—both internally and externally, identify safety and environmental concerns, track and control costs, and contain additional information that would aid in making quick appropriate decisions during a response effort.

UPR realized employees needed to have one contingency plan that was easy to understand and use, rather than several plans that were formatted differently. In addition, the need to incorporate additional information not required would assist operations personnel not only in responding to spills, but also during emergency evacuations as a result of fire, explosions, or hurricanes. The ROSRP would also serve as an offshore field operations guide.

As a result of the aforementioned needs and challenges, UPR developed an ROSRP that accomplishes all of the criteria set forth by jurisdictional agencies, the firm, and its employees. The plan has also been created in an interactive electronic version and placed on the company's Intranet for easy maintenance and access by all employees.

The ROSRP has many unique features that far exceed regulatory requirements and has set the standard for the future. The digitized version allows for speedy communication from remote sites offshore to be transmitted to the corporate office and then on to jurisdictional agencies such as the Minerals Management Service and the United States Coast Guard via e-mail, fax, or phone. Other key features of the plan are the visual graphics which include actual photographs of every offshore facility; field layout diagrams reflecting platform and interconnecting pipeline locations within a specific area; emergency notification numbers; medic, helicopter and boat locations; nearest oil spill equipment locations; equipment staging areas; driving directions and much more. The “area graphics” contain a tremendous amount of data and place the information at the fingertips of spill team members, management, and agency personnel.

The ROSRP also contains graphics of five oil spill equipment staging areas located along the coast of Louisiana. The staging area graphics contain the following:

- aerial and ground photographs
- pre-identified clean staging areas
- administrative, rehabilitation, and decontamination work areas
- complete listing of appropriate telephone numbers for emergency contacts, such as local hospital, fire, and police stations
- driving directions and map from nearest regional airport
- facilities available onsite such as water, sewer, electrical and administrative
- recommended equipment to further support administrative and emergency response actions
- description of the size and capability of the staging area

The graphics are designed in such a manner that response team members can initiate an emergency response utilizing the area and staging graphics. Jurisdictional agencies and executive management will be able to “see” what is occurring and where, immediately upon notification of an offshore spill or other emergency response.

The ROSRP also includes features to aid personnel in navigating the plan. A table of contents is displayed that continually allows users to know where within the document they are at all times. In addition, a secondary navigational system was developed to aid new employees or personnel with little or no spill management training. This enhanced navigational system includes user-friendly prompts to help guide the user to the appropriate section of the manual, i.e. “Are you reporting a spill?”

The ROSRP also contains a rainbow color scheme that allows the user or onlooker to readily identify at what stage of response certain personnel may be working. The spectrum of colors indicate the urgency of the response mode with red being reflective of “initiating a response” to purple for “debriefing and post-incident review.” All sections of the contingency plan are color-coded and the electronic version incorporates the color schemes by having them serve as backdrops to the computer monitor.

To further enhance the plan, a forms navigator is available that consolidates all of the ICS and NIIMS forms in one area. The forms can be accessed alphabetically or by SMT position. In addition, UPR built into the electronic version the ability to link to various Internet web sites in which vital data can be imported or exported. Access to the National Hurricane Center, United States Coast Guard, Marine Safety and Environmental Division, Minerals Management Service and the National Oceanic and Atmosphere Administration are just a few. The ability to link to internal Intranet sites has been incorporated. One for example, is access to offshore production volumes. In the event of a spill, evacuation, vessel collision, or other crisis, production volumes affected can be readily identified and made available to agencies or various internal departments within the company.

The ROSRP also serves as a base plan to help standardize emergency response outside of the Gulf of Mexico. The basic format can be retained and the visual graphics tailored specifically to UPR's domestic, international, and Canadian onshore operations. By standardizing the company's response procedures, each regional area can receive consistent spill management training. Table-top or unannounced spill drill exercises can be routinely implemented, and the appropriate documentation and record keeping can be tracked and maintained. Spill management team members in one regional area can be relocated or called into another area to assist in crisis management more readily and easily due to the standard format. An employee from one region can quickly assist another team and by using the graphics, learn the unfamiliar area quickly. This also ensures all response procedures throughout the firm are conducted with corporate consistency.

The ROSRP developed by UPR has been considered by many as "pioneering." UPR is the first firm operating in the Gulf of Mexico to take a contingency plan to such a level and to provide the plan in electronic format to the Minerals Management Service while simultaneously meeting the needs and concerns of its employees, agencies, media, and general public as we begin to enter the new millennium.

Jim LaFevers is employed by Union Pacific Resources in Fort Worth, Texas. He serves as the firm's Regulatory and Environmental Advisor for the Gulf of Mexico region. In addition, Jim is responsible for contingency planning and emergency response training throughout the company, both offshore and onshore. He has held various regulatory and environmental positions with other firms throughout his twenty years in the industry and has extensive federal, state, and municipal regulatory and environmental experience as well as a strong background in contingency planning and emergency response.

SESSION 2H

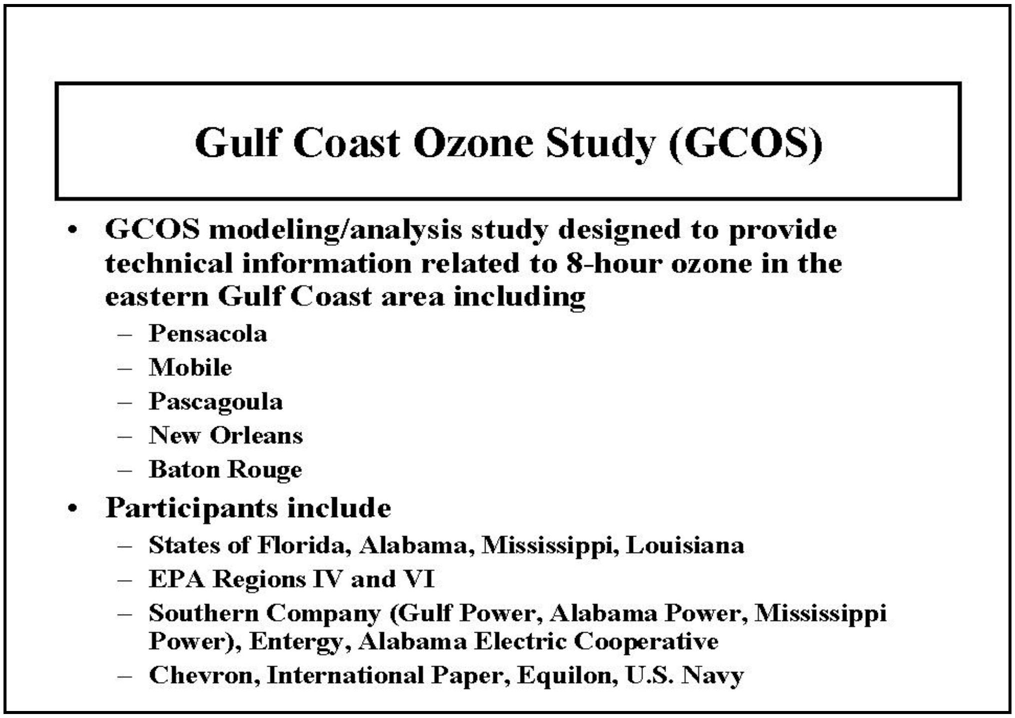
AIR QUALITY

Chair:	Ms. Terry Scholten, Minerals Management Service
Co-Chair:	Dr. Chester Huang, Minerals Management Service
Date:	December 2, 1999

Presentation	Author/Affiliation
Gulf Coast Ozone Study	Mr. James McGee Louisiana Department of Environmental Quality
Northeast Gulf of Mexico Ozone Scoping Study	Dr. Stephen D. Ziman Chevron Research and Technology Company
The Texas Air Quality Study (TexAQS-2000)	Dr. David Allen Center for Energy and Environmental Resources Houston, Texas Dr. Jim Price Texas Natural Resource Conservation Commission Houston, Texas
Breton Aerometric Monitoring Program (BAMP) Phase II	Mr. Brian E. Shannon ARCO Technology & Operations Services
Boundary Layer Study in the Western and Central Gulf of Mexico	Dr. Paul T. Roberts Mr. Clinton P. MacDonald Mr. Timothy S. Dye Sonoma Technology, Inc. Dr. Steven R. Hanna Consulting Meteorologist
Status of the Ozone and PM2.5 National Ambient Air Quality Standards	Dr. Dirk Herkhof Minerals Management Service

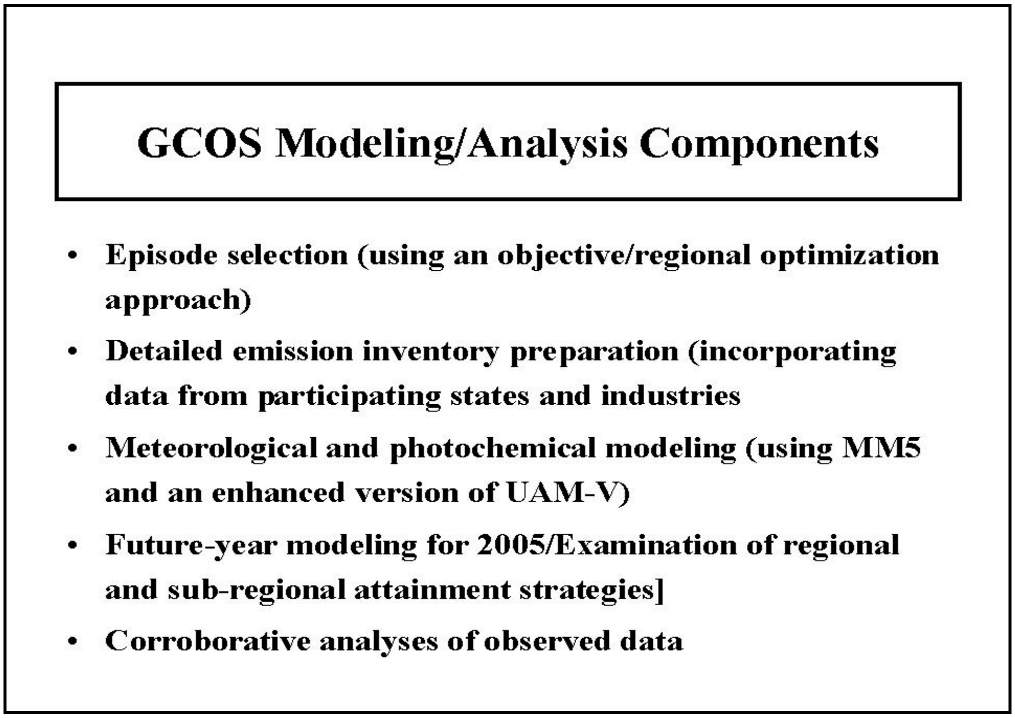
GULF COAST OZONE STUDY

Mr. James McGee
Louisiana Department of Environmental Quality



Gulf Coast Ozone Study (GCOS)

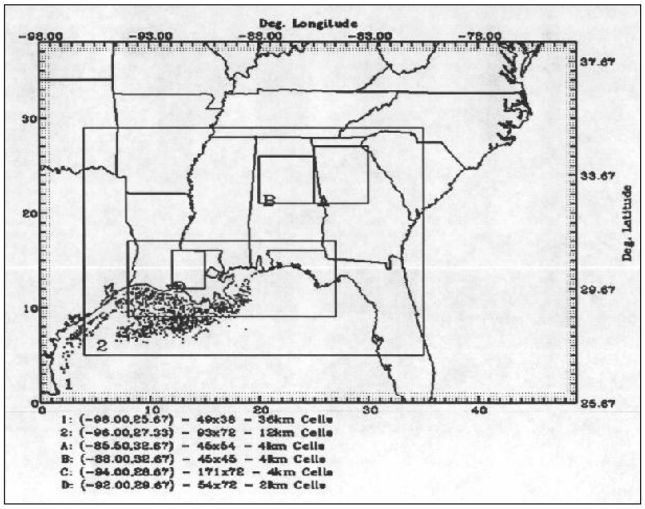
- **GCOS modeling/analysis study designed to provide technical information related to 8-hour ozone in the eastern Gulf Coast area including**
  - **Pensacola**
  - **Mobile**
  - **Pascagoula**
  - **New Orleans**
  - **Baton Rouge**
- **Participants include**
  - **States of Florida, Alabama, Mississippi, Louisiana**
  - **EPA Regions IV and VI**
  - **Southern Company (Gulf Power, Alabama Power, Mississippi Power), Entergy, Alabama Electric Cooperative**
  - **Chevron, International Paper, Equilon, U.S. Navy**



GCOS Modeling/Analysis Components

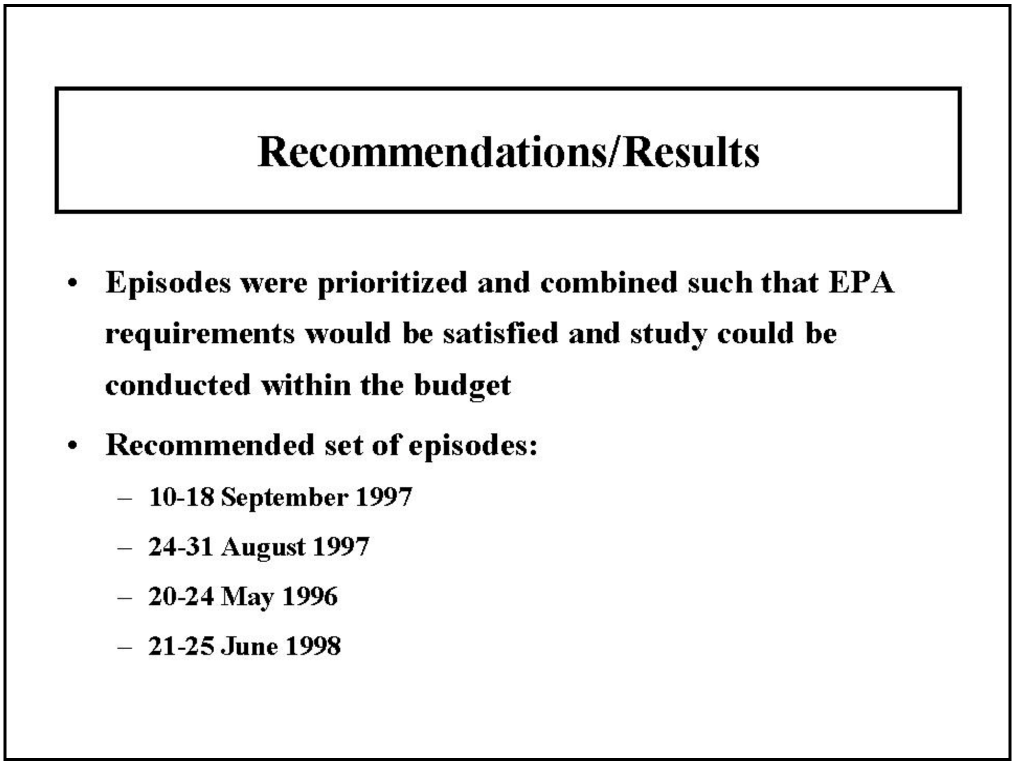
- **Episode selection (using an objective/regional optimization approach)**
- **Detailed emission inventory preparation (incorporating data from participating states and industries**
- **Meteorological and photochemical modeling (using MM5 and an enhanced version of UAM-V)**
- **Future-year modeling for 2005/Examination of regional and sub-regional attainment strategies]**
- **Corroborative analyses of observed data**

Gulf Coast Ozone Study UAM-V Modeling Domain



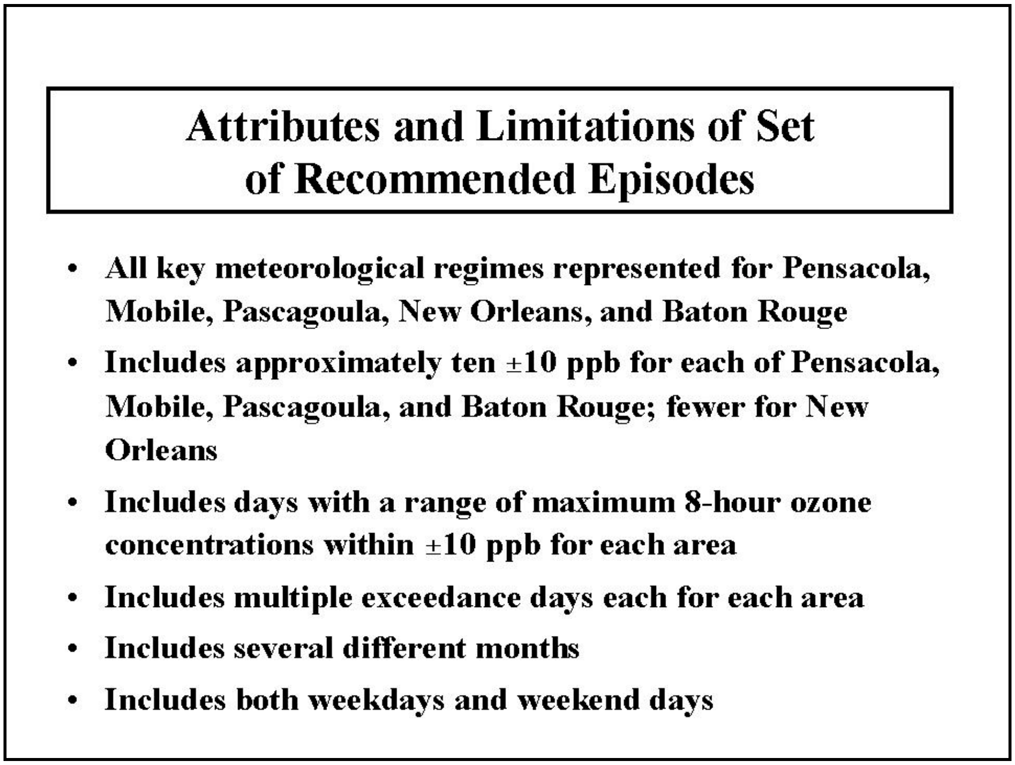
Gulf Coast Ozone Study
UAM-V Modeling Domain

- **Classification of days using Classification and Regression Tree (CART) analysis**
  - **groups exceedance and (non-exceedance days) according to meteorological and air quality characteristics**
  - **provides information on frequency of occurrence of exceedance regimes**
- **Integrated application of objective episode selection procedures (similar to those used for SAMI)**
  - **each area separately (Pensacola, Mobile, Pascagoula, New Orleans, Baton Rouge)**
- **Analysis with respect to key considerations (following EPA guidance)**
  - **representativeness and range of meteorological conditions**
  - **proximity to the design value**
  - **number of primary episode days (10 for 8-hour ozone)**
  - **data availability, spatial/temporal concentration patterns, etc.**



Recommendations/Results

- Episodes were prioritized and combined such that EPA requirements would be satisfied and study could be conducted within the budget
- Recommended set of episodes:
  - 10-18 September 1997
  - 24-31 August 1997
  - 20-24 May 1996
  - 21-25 June 1998



Attributes and Limitations of Set of Recommended Episodes

- All key meteorological regimes represented for Pensacola, Mobile, Pascagoula, New Orleans, and Baton Rouge
- Includes approximately ten ±10 ppb for each of Pensacola, Mobile, Pascagoula, and Baton Rouge; fewer for New Orleans
- Includes days with a range of maximum 8-hour ozone concentrations within ±10 ppb for each area
- Includes multiple exceedance days each for each area
- Includes several different months
- Includes both weekdays and weekend days

Preparation of the Base-Case Emissions Inventory for the 10-18 September 1997 Simulation Period

- Emission inventory components include
  - point source
  - areas source (includes non-road emissions)
  - motor vehicle
  - biogenic
- EPA 1996 National Emissions Trends (NET) Inventory
- Updated state-specific information
- Processed for input to UAM-V using the EPA Emissions Preprocessing Systems (EPS2.5)
- Summaries and plots provided to GCOS participants for review
- Refinements/further updates incorporated

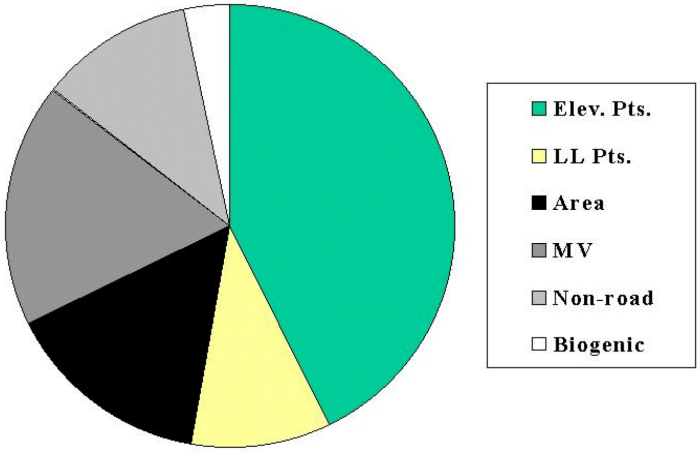
Base-Case Emissions Data

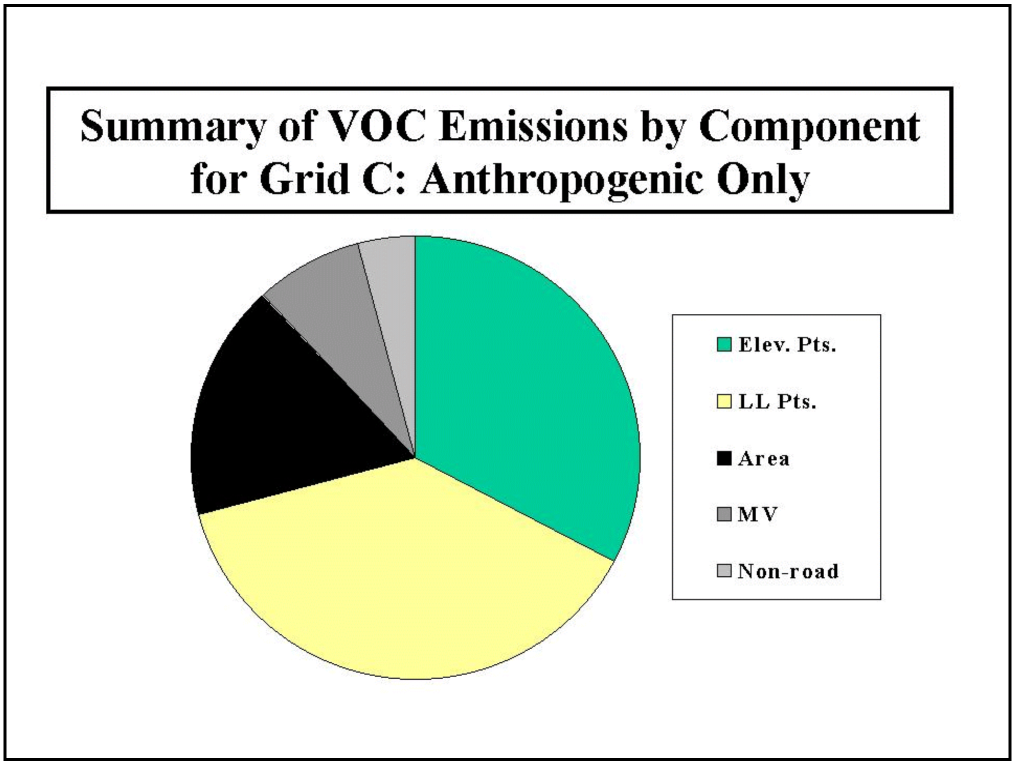
- Point sources
  - 1996 NET inventory
  - updated information from FL, AL, MS, and LA
  - facility-/episode-specific information from Southern Co., Entergy, DuPont
- Area sources
  - 1996 NET inventory
  - updated emissions for Baton Rouge (LA), Jefferson and Shelby Counties (AL)
- Motor vehicles
  - 1997 VMT estimates for FL, AL, MS, and LA
  - 1996 NET VMT estimates for other states
  - new daily/weekly profile
  - MOBILE5b

Base-Case Emissions Data

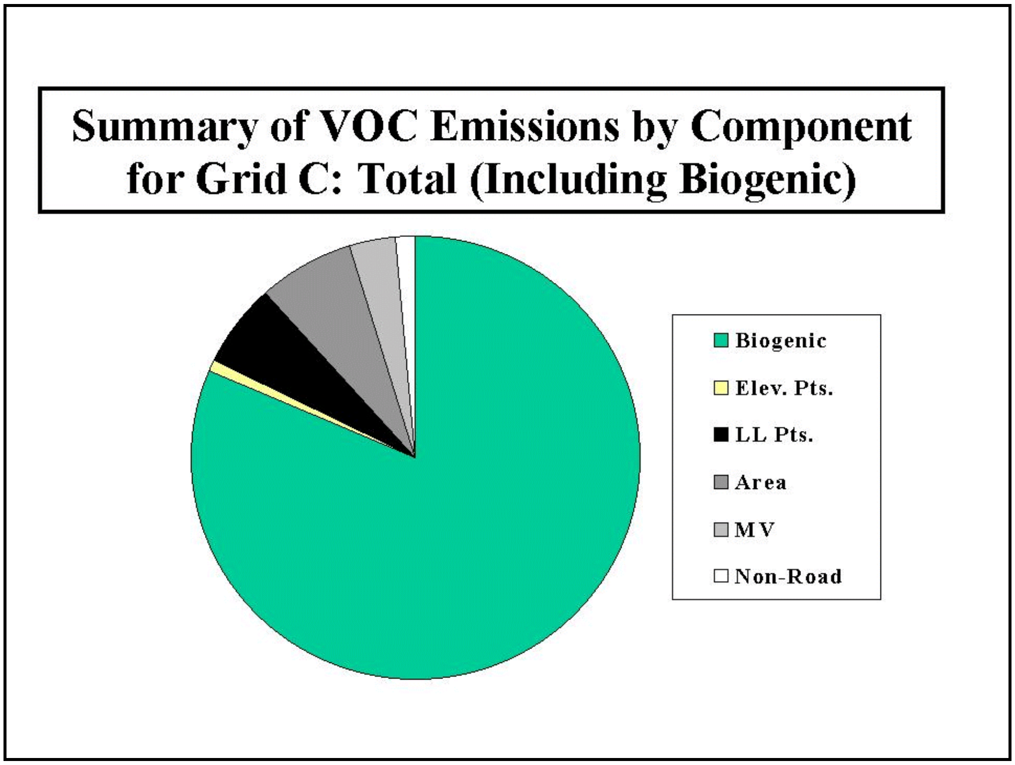
- **Non-road emissions**
  - **1996 NET inventory**
  - **EPA non-road model**
- **Biogenic sources**
  - **EPA Biogenic Emissions Information System (BEIS-2)**
- **Offshore sources**
  - **1993 MMS inventory**

Summary of NO_x Emissions by Component for Grid C





Summary of VOC Emissions by Component for Grid C: Anthropogenic Only



Summary of VOC Emissions by Component for Grid C: Total (Including Biogenic)

Use of the UAM-V Plume-in-Grid Treatment

- Provide a more realistic treatment of emissions from elevated point sources
- Applied for major NO_x point sources within the GCOS domain
- Sources selected according to emission rate and location
  - for Grid C, the cutoff is 5tpd (facility total) or 1 tpd (individual source)
  - for all other grids, the cutoff is 10tpd (facility total) or 2 tpd (individual source)
- Based on these criteria, the P-I-G treatment was applied for
  - 668 sources
  - 74% of elevated NO_x emissions

Meteorological Inputs Required by UAM-V

- Hourly, gridded, 3-dimensional fields:
  - wind (horizontal components)
  - temperature
  - water vapor concentration
  - vertical exchange coefficient (K_v)
  - pressure
  - cloud cover (optional)
- Hourly, gridded, 2-dimensional fields:
  - rainfall rate (optional)
- For GCOS, the UAM-V was modified to accept directly all meteorological inputs for all nested grids (previous versions of the model used interpolation for all but winds and K_vs)
- All inputs for GCOS were derived from the MM5 output

MM5 Options/Features Selected for this Application

- One-way nested grids
- Four-dimensional data assimilation
  - wind, temperature, humidity
  - 3-D analysis nudging
- High resolution planetary-boundary-layer parameterization scheme (MRF)
- Kain/Fritsch convective parameterization scheme (12 km resolution and coarser grids)
- Stable precipitation
- Time steps ranging from 12 seconds (Grids A,B and C) to three minutes (Grid 0)

Evaluation of MM5

- Graphical and statistical analysis
  - Wind fields with observations overplotted
  - Time-series of surface temperature
  - Statistics comparing simulated & observed wind speed, wind direction, temperature, & moisture values
- Findings
  - Synoptic-scale features (low pressure system & associated fronts) well represented
  - Regional-scale airflow patterns (including wind speeds & directions) well represented
  - Surface winds do not always match observed data
  - Surface temperatures show some over and underestimation—but surprisingly good representation of diurnal profile
  - Gulf breeze appears on nearly all simulation days (11th - 18th); consistent with surface observations
  - Mostly clear skies over Grid C; clouds may be overestimated on 14 September
  - Rainfall during early simulation period along front & consistent with observations

UAM-V 1.30

- Process and analysis capabilities
- Updated chemical mechanism (including treatment of toxic species)
- Improved treatment of deposition
- Expanded nested-grid capabilities
- Additional coordinated system options (e.g., Lambert conformal)
- Optional use of the “standard: or “fast” solver integration methods
- Other enhancements related to input/output options (e.g., linking MM5 to UAM-V)

Diagnostic Analysis

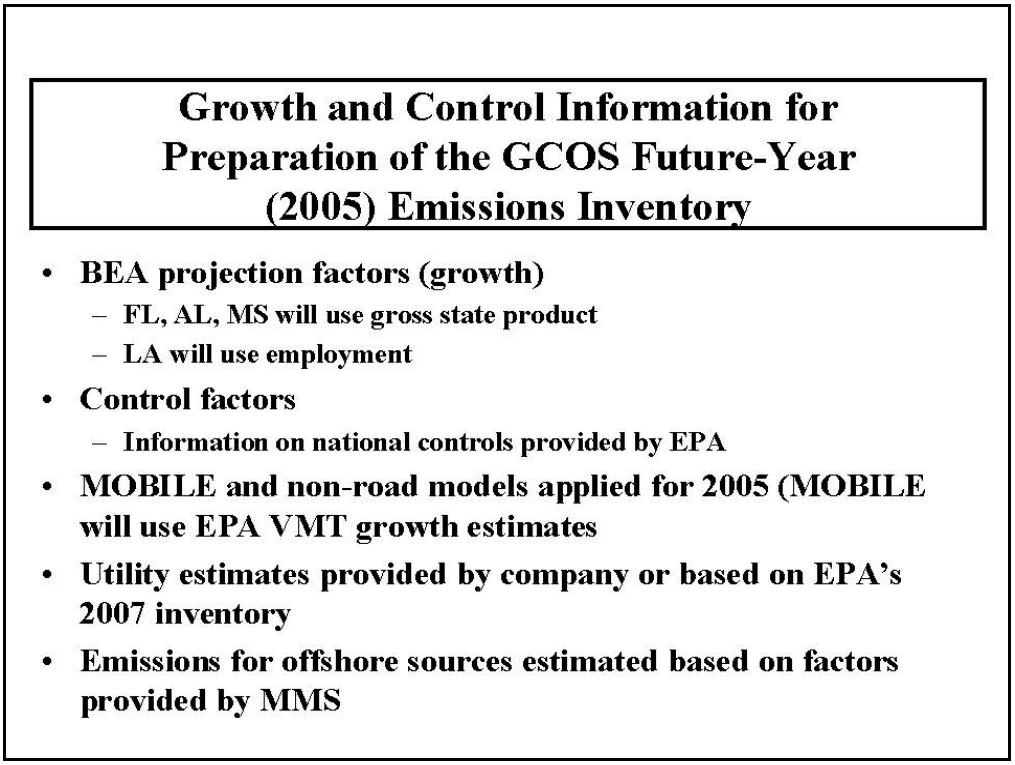
- Objective is to identify and correct errors, examine the effects of uncertainties on the modeling results, and test alternate assumptions
- Issues examined
  - assumptions in postprocessing the meteorological fields
  - vertical resolution of UAM-V
  - deposition effects
  - boundary conditions
  - cloud cover and rainfall-rate input fields
  - wind speed bias

Summary of Model Performance for the 10 - 18 September 1997 Episode

- Domain-wide concentration levels (full domain, including Grid C) are well represented in the simulation
- Model performance varies throughout the domain and simulation period
- Diagnostic analysis has shown that results are not overly sensitive to vertical structure, cloud-cover and rainfall amounts, uncertainty in biogenic emissions, or boundary conditions (for the outermost domain)
- Issues concerning overestimation of ozone in Louisiana, over-estimation of nighttime ozone concentrations, and specification of vertical exchange coefficients have been addressed/resolved
- Some underestimation of ozone along the coast on several of the key episode days

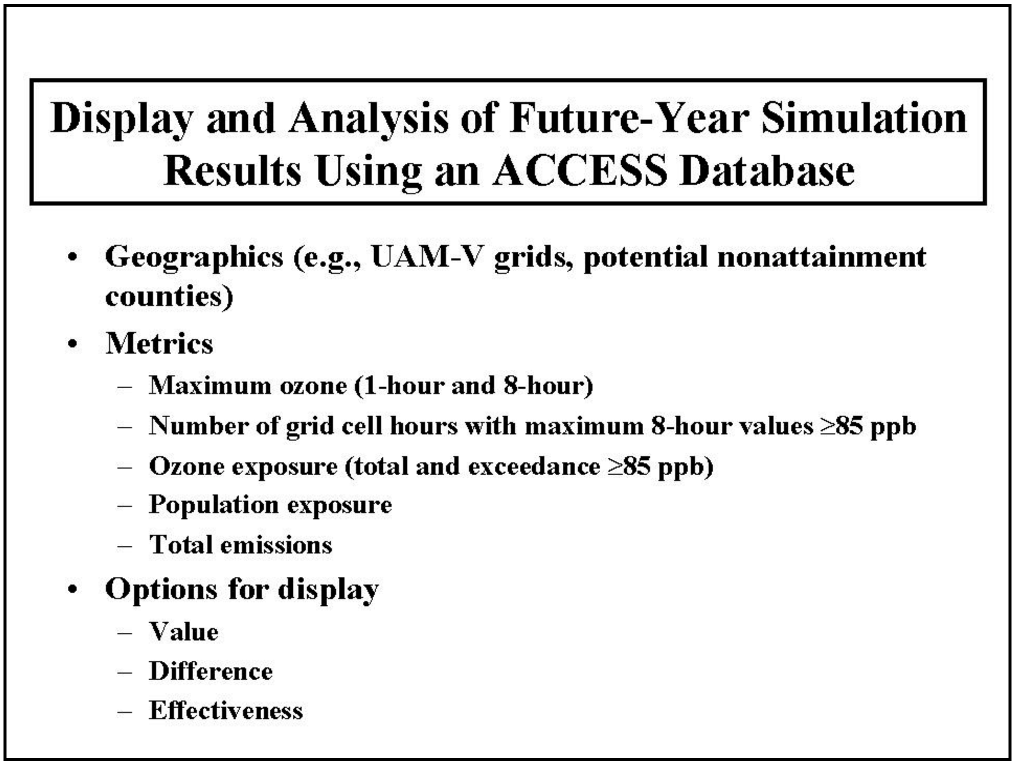
Future-Year Modeling

- Projection of emissions to 2005
- Emission-sensitivity simulations
  - "across-the-board" emission reductions by pollutant or source category
  - geographically based emission reductions
- Control-strategy simulations
- Application of the EPA 8-hour ozone attainment demonstration procedures



Growth and Control Information for Preparation of the GCOS Future-Year (2005) Emissions Inventory

- BEA projection factors (growth)
  - FL, AL, MS will use gross state product
  - LA will use employment
- Control factors
  - Information on national controls provided by EPA
- MOBILE and non-road models applied for 2005 (MOBILE will use EPA VMT growth estimates
- Utility estimates provided by company or based on EPA’s 2007 inventory
- Emissions for offshore sources estimated based on factors provided by MMS



Display and Analysis of Future-Year Simulation Results Using an ACCESS Database

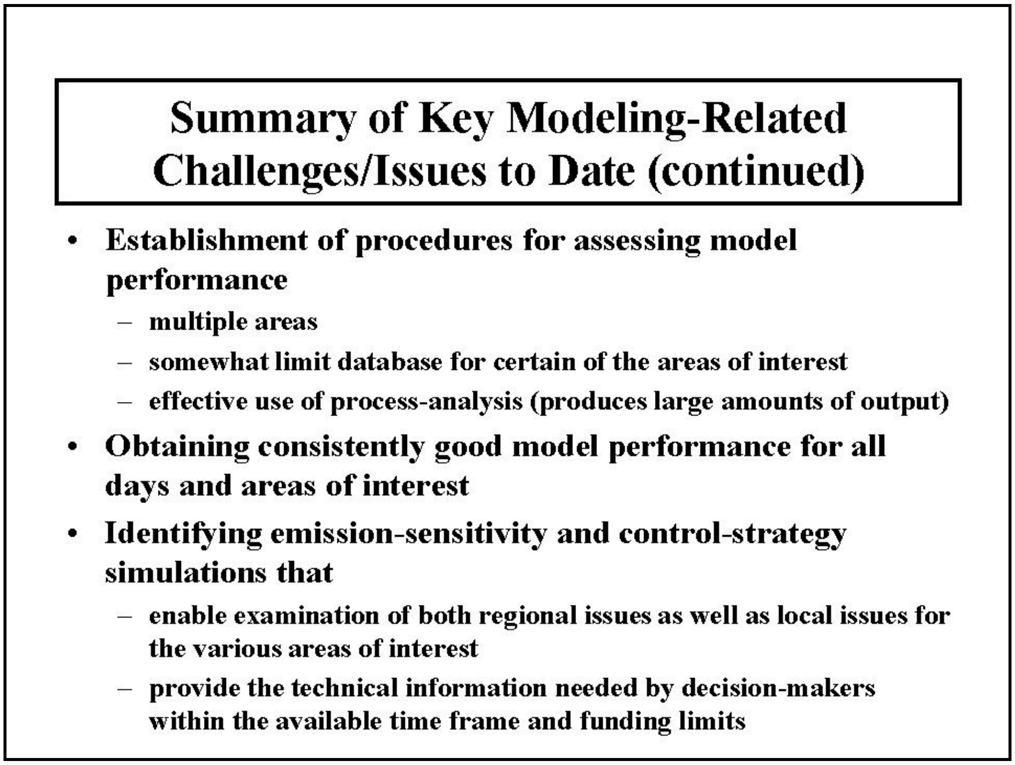
- Geographics (e.g., UAM-V grids, potential nonattainment counties)
- Metrics
  - Maximum ozone (1-hour and 8-hour)
  - Number of grid cell hours with maximum 8-hour values ≥85 ppb
  - Ozone exposure (total and exceedance ≥85 ppb)
  - Population exposure
  - Total emissions
- Options for display
  - Value
  - Difference
  - Effectiveness

Distribution/Review of Results

- GCOS Web Site
- Interactive (ACCESS) database
- Bi-weekly conference calls
- Bi-monthly (or so) project meetings

Summary of Key Modeling-Related Challenges/Issues to Date

- Identifying an optimal set of modeling episodes considering
  - multiple areas
  - representative meteorological conditions and ozone concentrations
  - other criteria provided in the EPA guidance (e.g., number of days)
  - costs/schedule constraints
- Obtaining consistent/quality assured emissions data for the regional-scale modeling domain
- Development of appropriate MM5 application procedures for
  - simulation of the gulf breeze dynamics
  - calculation of vertical exchange coefficients that are compatible with UAM-V
  - accurate depiction of the local airflow patterns (wind speeds and directions)
  - linking MM5 and UAM-V



Summary of Key Modeling-Related Challenges/Issues to Date (continued)

- **Establishment of procedures for assessing model performance**
  - **multiple areas**
  - **somewhat limit database for certain of the areas of interest**
  - **effective use of process-analysis (produces large amounts of output)**
- **Obtaining consistently good model performance for all days and areas of interest**
- **Identifying emission-sensitivity and control-strategy simulations that**
  - **enable examination of both regional issues as well as local issues for the various areas of interest**
  - **provide the technical information needed by decision-makers within the available time frame and funding limits**

James Magee has worked for the Louisiana Department of Environmental Quality for the past eleven years. His main responsibility has been the application of the Urban Airshed Model to the Baton Rouge ozone non-attainment area for the Louisiana State Implementation Plan. He has also served on several technical committees concerning ozone airshed modeling applications, including the Gulf Coast Ozone Study. Mr. Magee received his B.S. in chemical engineering from the University of Louisiana at Lafayette.

NORTHEAST GULF OF MEXICO OZONE SCOPING STUDY

Dr. Stephen D. Ziman
Chevron Research and Technology Company

INTRODUCTION

In 1997, the EPA adopted a new eight-hour ozone standard. Compliance with that standard requires that the fourth highest eight-hour average concentration averaged over three years be less than 85 ppb. The states of Mississippi, Alabama, and Florida recognized that some of the coastal counties within their states would potentially be out of compliance with the new standard. Compliance is to be based on 1997-1999 ambient ozone measurements. In late 1998, in conjunction with the Southern Company, these states agreed to carry out the Gulf Coast Ozone Study (GCOS), a photochemical modeling effort to determine what reductions would be necessary to come into compliance. A workplan was developed, and a contractor was selected to carry out the modeling. In early 1999, this consortium invited other interested parties to participate at the technical level or at the policy level with respect to the study. These parties included the state of Louisiana and representatives of the oil/gas and chemical industries, among others. Even though the eight-hour standard is not being enforced due to litigation, the study is proceeding on its original schedule, with completion in 2000. The GCOS is being described by a paper and presentation at this information transfer meeting.

The GCOS has as its main goal development and application of the Urban Airshed Model V for up to four ozone episodes in the coastal region of the three states. However, some of the participants had and still have concern about the adequacy of the program because of lack of available data for modeling and model evaluation. In response to these concerns, the Louisiana-Mid Continent Oil and Gas Association hired Sonoma Technology Inc. to prepare a scoping study to characterize what is known about ozone formation in the four-state coastal area. This paper presents the preliminary findings of the scoping study to date. It also presents preliminary recommendations as to how to improve the GCOS study through collection of additional data in 2000 or 2001.

OBJECTIVES OF SCOPING STUDY

The objectives of this study are two-fold. The first objective is the development of a conceptual model that describes the processes that lead to exceedances of the eight-hour ozone standard. This will be done by analysis of existing data to summarize air quality and meteorological characteristics associated with eight-hour ozone episodes in the four state coastal region. Available emissions inventory data will be analyzed to relate the temporal and spatial character of the inventory to high ozone concentrations. As part of this effort, gaps in our understanding will be identified.

The second objective is built on the above findings and will lead to the development of a set of recommendations for additional aerometric monitoring that could help to enhance the existing data base with respect to both model performance and application and additional data analysis. One set of recommendations will be presented for improvements in routine monitoring for ozone and precursor measurements and surface and aloft meteorological measurements. A second set will provide a preliminary design for an intensive data collection field program in either 2000 or 2001, which could be done concurrently with the Breton Aerometric Monitoring Program (also being described at this information transfer meeting). This design will be done for two levels of effort, and costs estimates for each will be presented in the report. The design could provide the basis by which to start development of a more detailed design for a field program.

PRELIMINARY FINDINGS

Ambient Air Quality Characterization of Ozone and its Precursors

Ozone: Using the EPA Aerometric Information Retrieval System (AIRS), hourly ozone data were obtained for all monitors in the three-state GCOS area, along with data from Georgia, Arkansas, and Louisiana. Ten monitoring sites were identified in the coastal counties (including four sites in Louisiana) that had a continuous record of valid data from 1993 through 1998 for the months of April through October. A comparison of the number of eight-hour and one-hour exceedances per year was done. What is striking is that there are significantly more exceedances in 1998, with or without the Louisiana data (44 without Louisiana data as compared to 23 in 1997 and 15 in 1994), than in any other prior year. However, additional analysis is being done to look at a longer data record for these sites if possible, as five years of data do not represent a robust data set. Additional analyses indicate that for the ten coastal monitoring sites, the eight-hour exceedances are highest in May, August and September with 40 to 45 exceedances in each of those months. June has the least number of exceedances (13) and July has 27. Unlike some other areas of the country in which the highest ozone concentrations occur on a weekend, the highest exceedances for the ten coastal monitors occur in midweek, with Wednesday being slightly higher than Tuesday. In terms of duration of the episodes at these ten sites between 1993 and 1998, the majority were single-day episodes (29 of 41). Nine episodes lasted between two and three days, and three episodes were four days or more.

Volatile Organic Compounds: Within the coastal region, there is only hydrocarbon data from one site, Kenner, in Louisiana. There is very limited hydrocarbon data in the large domain from sites around Birmingham. From AIRS, the three sites in Alabama (Pinson, Breaden Farm, and Tarrant City) along with the one site in Louisiana had three-hour (0500-0800 ST or 0600-0900 ST) speciated data for the summer months between 1993 and 1996. Two of these sites are rural, and two are suburban sites. None of the Alabama sites are co-located with ozone monitors. While the concentrations were higher at the suburban sites, all sites showed that mobile source emissions had a large influence on the sites. Moreover, for the rural sites, the biogenic species isoprene and the pinenes were abundant. Considering that biogenics emissions usually reach their peak concentrations later in the day, this is a good indication of the large influence of biogenic emissions on the total VOC contribution. While the data from these sites does allow one to draw the above conclusions, there are limitations in the data with respect to accuracy, precision, and detection limits, as well as the fact that the total of non-methane hydrocarbons was not reported. Thus, the amount and composition of other species could not be assessed.

Other Ambient Measurements: A search of the AIRS database revealed that only one year of NO_x data for a single monitor was found. Consequently, there is no way to assess the VOC/ NO_x ratios, or to perform any observational modeling-both of which could provide some indication as to whether a monitor location was VOC or NO_x limited with respect to ozone formation. CO, which could be used in conjunction with the VOC data to provide a better estimate of mobile sources, was not available

Data Gaps: The analyses in this scoping study have lead to the identification of the following gaps in data that hamper our ability to better understand the formation and transport of ozone. These data gaps are:

- Ozone Measurements
  - Aloft data are not available.
  - Ozone sites in Florida are sparse.
  - Ozone sites between the coast and the outer domain are sparse.
- VOC Measurements
  - VOC measurements during the day are not available. Measurements throughout the day are needed to better understand the diurnal behavior of biogenic and anthropogenic emissions, transport, and the possible effect of the gulf breeze.
  - Where should measurements be made? Boundary sites (for modeling), coastal sites (for effects of meteorology), and urban sites (for E.I. evaluation, VOC/NO_x ratio analysis).
  - VOC and NO_x measurements are needed at peak ozone sites to help evaluate VOC or NO_x controls.
- Nitrogen Oxides Measurements
  - NO_x or NO_y monitors are needed at representative source and receptor sites in the domain. For example, nitrogen oxide measurements should be added to several existing ozone sites and to any VOC sites to assess air mass aging (transport) and VOC/NO_x control strategies.
  - NO/NO_x (or NO_y) measurements are needed at source and receptor ozone sites in order to evaluate possible titration (source sites) and transport/control assessment (receptor sites).
- Modeling/Analysis Issues
  - Ozone and precursor measurements are needed at top and side boundaries for model input and evaluation. Model results are strongly affected by boundary conditions.

The EPA National Emissions Trends (EPA-NET) inventory for 1996, the most recent year available, was used to assess the emissions inventory for the region. The inventory is a countywide annual average inventory that provides estimates of VOC and NO_x for the four major source categories, point, area, mobile and biogenic. To get higher resolution for point sources, the EPA AIRS Facility Subsystem (EPA-AFS) was used. Offshore emissions were derived from the 1993 Gulf of Mexico Air Quality Study. The emissions are broken out into the different domains shown in Figure 2H.1.

For purposes of this scoping study, the annual average inventory was used to disaggregate the emissions into three components: counties along the Gulf Coast—coastal counties, these coastal counties and those slightly inland-small domain, and a region that extends north to encompass Atlanta and west to Shreveport—the large domain. This is shown in Figure 2H.1, above, which also shows the population on a county level. Table 2H.1 provides the estimated emissions for these domains as well as for offshore sources.

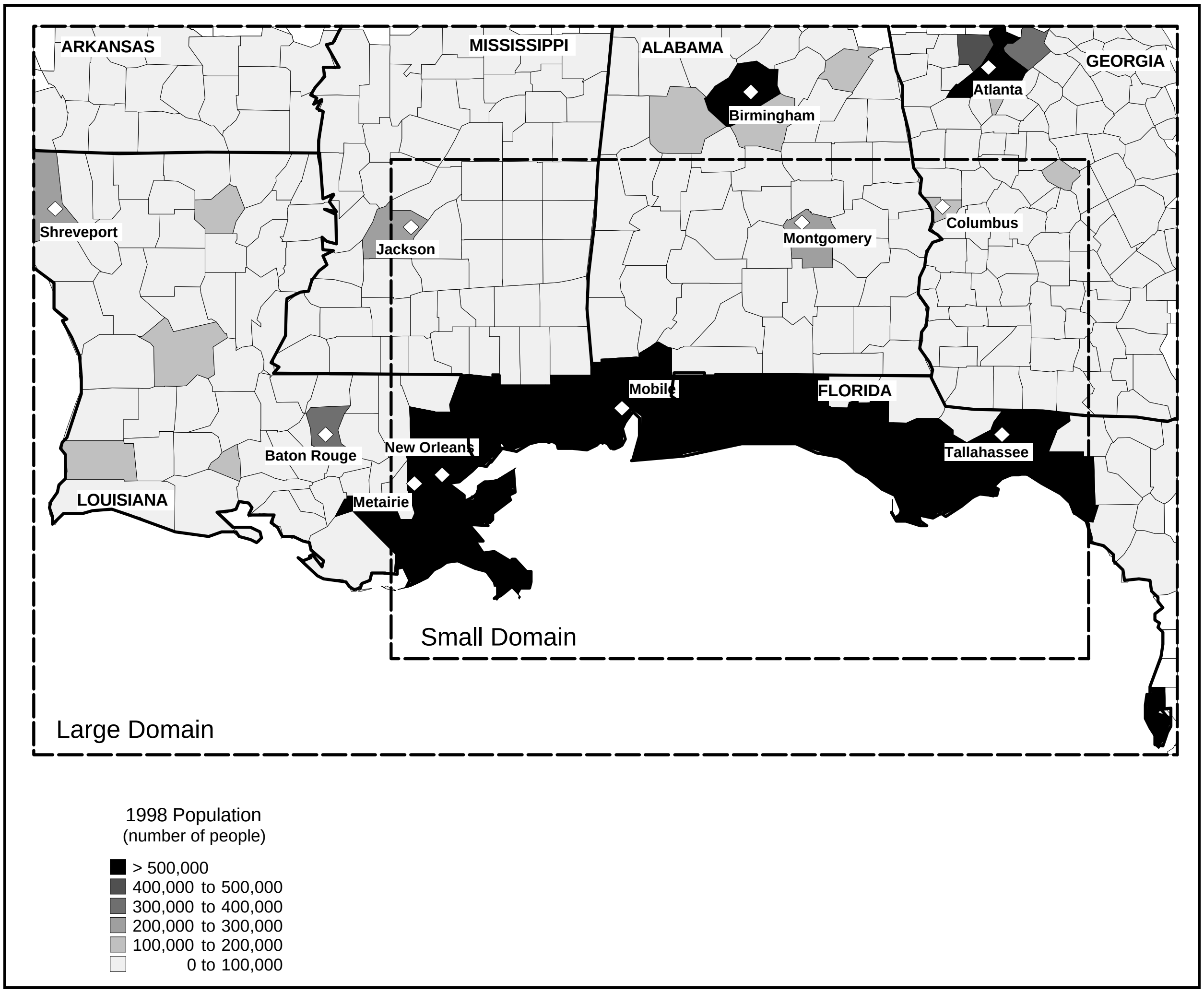


Figure 2H.1. Gulf Coast Study domains, with population.

Table 2H.1. Total anthropogenic VOC and NO_x emissions for the large, small, northeastern, and coastal counties as well as the offshore oil platforms in the Gulf coast region.

Domain	VOC (tons/year)	NO_x (tons/year)
Large Domain	1,620,040	2,192,339
Small Domain	669,207	843,187
Northeastern AL and GA	502,475	683,212
Coastal Counties	298,766	423,494
Coastal Counties Offshore	8,748	27,755

The estimated annual emissions contributions from each source category of VOC emissions are shown in Table 2H.2, both in tons/year and (percent of total).

Table 2H.2. Annual (tons/year) and percent VOC emissions.

Domain	Point	Area	Mobile	Biogenic
Large	210605 (13%*)	907222 (56%*)	502212 (31%*)	Not calculate
Small	86351 (3%)	371973 (12%)	185986 (6%)	2416026 (79%)
Coastal	32864 (4%)	179259 (23%)	86642 (11%)	484191 (62%)

These percentages reflect anthropogenic emissions only.

The estimated annual emissions contributions for each anthropogenic source category of NO_x emissions are given in Table 2H.3, both in tons/year and (percent of total). Biogenic NO_x emissions are not significant.

Table 2H.3. Annual (tons/year) and percent NO_x emissions.

Domain	Point	Area	Mobile
Large	876935 (40%)	701548 (32%)	613854 (28%)
Small	334774 (40%)	284557 (34%)	217603 (26%)
Coastal	186337 (44%)	143987 (34%)	93168 (22%)

Area sources represent a major potion of the both the VOC and NO_x anthropogenic inventory. This category can be broken out further to provide more information. Four sub-categories can be identified. These are off-road mobile, chemical manufacturing, petroleum refining and other. The break out by percentage of the total area source inventory is given in Table 2H.4.

Table 2H.4. Percentage of area emissions VOC and NO_x broken out in sub categories relative to all sources of anthropogenic emissions (per Table 2H.1).

Domain	Off-road mobile	Chemical	Pet. Refining	Other
Small VOC	14%	3%	3%	39%
Small NO_x	20%	-	-	14%
Coastal VOC	17%	5%	7%	31%
Coastal NO_x	21%	-	-	13%

There are few notable things with the emissions. With respect to anthropogenic emissions only, on-road mobile sources make up about 30% of both the VOC and NO_x inventory for all three onshore areas. Moreover, when the area source emissions are broken out, the combination of both on-road and off-road emissions are a significant amount of total emissions, amounting to about 45% of the VOCs and 50% of the NO_x for the small and coastal domains. All of these emissions are emitted at the surface.

The above estimates for mobile sources have been estimated with the EPA Mobile 5 emissions model. However, recently, the California Air Resources Board released an updated version of its mobile source emissions model, EMFAC 2000. EMFAC is similar to Mobile, and the new version of EMFAC estimates that on-road mobile source VOC emissions have been underestimated by about a factor of 2, while on-road mobile NO_x emissions have been underestimated by a factor of about 1.2. It is expected that when EPA releases its newest version of Mobile, version 6, that a similar change will be evident as compared to Mobile 5. To put this in perspective, a rough estimate was made of how the changes in EMFAC 2000 would affect the total VOC and NO_x emissions for the Coastal Counties. This adjustment to account for the additional on-road mobile source emissions is shown in Table 2H.5.

Table 2H.5. Coastal counties original and adjusted annual tons/year VOC and NO_x emissions and percent of total emissions.

Emissions	Anthropogenic	Biogenic
Original VOC	296762 (38%)	484191 (62%)
Adjusted VOC	395383 (45%)	483247 (55%)
Original NO_x	425008 (99%)	4293 (1%)
Adjusted NO_x	501263 (99%)	5063 (1%)

The potential differences in mobile emissions and overall anthropogenic emissions are very significant and have major implications with respect to evaluation of the base case simulations for the episodes being modeled in the GCOS effort.

While the above information is based on the best available emissions, there are some caveats with regard to the uncertainties in the emissions estimates. The 1996 EPA NET inventory was developed to provide easy access to summary-level emissions estimates based on EPA's National Emission Trends database. The emissions estimates contained in the NET inventory are generated using methodologies developed by the EPA, and are updated on a regular basis. The NET is compiled using emissions data provided by state agencies when available. In the absence of local data, default methodologies are used to develop emissions estimates. What this implies is that for regions where air-quality modeling and planning are customary, NET emissions estimates are likely to be fairly accurate. There is no existing documentation discussing the uncertainty of the emissions estimates contained in the NET. However, the accuracy of the inventory is only as reliable as the underlying data used to generate the emissions estimates. The 1996 NET inventory is currently being updated to include more local data and a new version of the inventory will be released on 15 November 1999. Moreover, as noted above, based on the EMFAC 2000 mobile source emissions model, it is expected that the new Mobile 6 model will show large increases in estimates of VOC emissions for on-road mobile sources, along with increases in NO_x emissions.

The AFS point source data are produced from a monthly extract of EPA's air pollution database, AIRS. The extract contains the best information available to EPA from state agencies; however, data values may be missing because of incomplete reporting, and some values may be subsequently changed due to quality assurance activities. The AFS data do not include all point sources that are subject to EPA regulations governing air pollutant emissions. The AFS includes about 10,000 sources for which state environmental agencies have compiled air pollutant emissions inventories and stored that information in the AIRS database.

It is difficult to estimate the absolute uncertainty in emissions estimates without performing a bottom-up evaluation of the data. One way to assess emissions estimates is to obtain consensus among several sources of emissions data. However, multiple sources of emissions data are rarely available. In the absence of multiple data sources, emissions estimates can be evaluated (on a relative basis) using demographic parameters and common sense evaluation. Neither of these techniques can estimate uncertainties in the absolute mass of emissions estimates; however, these techniques are useful for identifying potential errors in emissions estimates for individual source categories.

In terms of work that should be done with improvement to the emissions inventory, the following are suggested:

- All emissions source categories should be re-evaluated when the latest version of the 1996 EPA NET inventory and the Mobile 6 model are released.

- A bottom-up evaluation of area and mobile sources should be performed since these categories are the main contributors to emissions in the Gulf Coast region. Special attention should be focused on area sources since they constitute an unusually high percentage of the total emissions compared to other regions of the country.

- Biogenic emissions contributions to VOC and NO_x should be investigated.

- Prior to photochemical modeling, is recommended that an emission inventory be developed and/or compiled using the most current and representative data available.

- The inventory should be spatially and temporally resolved for use in photochemical modeling.

- To insure that the emissions data is of the highest possible quality, a bottom-up evaluation of the major source categories should be performed followed by a top-down evaluation.

- Based on the results of the bottom-up and top-down evaluations, areas of the inventory that appear to be suspect should be examined and improved.

Meteorology Associated with High Ozone Concentrations

Analyses of available meteorological data have not yet been completed. Thess data are very limited in that there are few surface wind sites throughout the area, and the quality of the existing data is unknown. There are no continuous upper-air meteorological sites in the coastal area or the region. Twice-a-day soundings are available from two sites, Slidell and Tallahassee. Neither can really be considered representative of the coastal area in Mississippi, Alabama, or Florida, nor are they representative of daytime meteorology.

Preliminary analyses suggest that a majority of days in which ozone exceedances occur are associated with a high-pressure system over the region. This type of condition is usually associated with light winds and suggests that local emissions can be the major contributor to ozone exceedances in the coastal region. A land/sea breeze flow pattern can occur along the coast under these conditions, which can result in recirculation of onshore pollutants. With limited information, the meteorology can be characterized as follows:

Synoptic Characteristics:

- Eight-hr exceedances have occurred under all types of classifications but were more likely to occur under ones that produce a weak local pressure gradient, light winds, stagnation, high surface temperatures, and strong temperature inversions.

- Exceedance days most frequently occurred under No Gradient (NG), Gulf High (GH), and Eastern Continental High (ECH) conditions.

- More site exceedances occurred on days in which conditions were NG, GH, or ECH.

High Ozone Characteristics:

- Re-circulation of air from land breeze/sea breeze feature is key at most sites.

- Port Bienville: significant transport from New Orleans, LA (from the southwest) and Mobile, AL and other regional sources (from the northeast).

- Pascagoula: significant transport from Mobile, AL, and some transport from New Orleans, LA and other regional sources.

- Chickasaw (Mobile, AL): significant local ozone production and some transport from regional sources to the southwest, northwest, and northeast.

- Axis (north of Mobile, AL): only one exceedance in six-year period; site is likely titrated as seen in diurnal ozone profiles.

- Pensacola NAS: significant transport from Mobile, AL, significant local ozone production, and some transport from New Orleans, LA (from the southwest) and from other regional sources (from the north).

- Pensacola Ellyson (north side of Pensacola): significant transport from Mobile and many fewer exceedances.

But without any measurements, there is no information on the depth of the mixed layer and the distance offshore that the land breeze travels before flow reversal. The lack of both surface and continuous aloft data are all major gaps. These gaps limit our ability to further describe the influence of meteorology on ozone formation or to provide data to evaluate the meteorological model used to provide windfields to the UAM-V. This limitation, along with the others described above, do not allow us to provide a detailed conceptual description of ozone formation in the coastal area yet.

Ramification of Findings With Respect to the Gulf Coast Ozone Study

The above assessments raise some major issues about the ongoing modeling now being carried out under the Gulf Coast Ozone Study. In terms of availability of ambient ozone and precursors data, the following are important concerns:

- There is no aloft air quality data to set initial or boundary conditions for modeling.

- Surface boundary and initial conditions are limited to a few ozone monitors.

- Lack of ambient VOC and NO_x measurements do not allow for evaluation of the UAM-V with respect to predicted VOC and NO_x concentrations, nor does this allow for non-modeling analyses for corroboration of modeling results.

- There are limited surface winds and no continuous winds aloft that can be used for data assimilation or for evaluation of the prognostic meteorological model, especially the land/sea breeze.

- Underestimation of on-road mobile will further complicate model performance evaluation and, if not addressed, will induce compensating errors in the base case as well as future case projections.

If the above issues can not be addressed in the present modeling (which in the case of aerometric data is true), confidence in the modeling results, especially in assessment of alternative reductions to reduce ozone, is undermined.

Recommendations for Aerometric/Emissions Data Collection in the Northeast Gulf of Mexico States

The ramifications of modeling with very limited data would suggest that consideration be given to collection of aerometric data in 2000 or 2001 to carry out new modeling simulations with an improved data set. EPA's emissions inventory will be updated by that time, including Mobile 6. In addition, the Breton Aerometric Monitoring Program will have started continuous surface and aloft meteorological measurements along with ozone and NO_y measurements at three locations in the central GOM, along with one location on the mainland near Dauphin Island. This program will start in April 2000 and go for one year. Though no discussions have been entertained yet, extension of the Breton measurements through the summer 2001 ozone season is possible since the equipment is already deployed. With these things in mind, there are preliminary recommendations for alternative monitoring networks. While past studies have used the intensive monitoring network approach, it is not clear that this approach has a high probability of success in characterizing an episode. This is because the majority of the episodes are single-day exceedances. Forecasting for such episodes to mobilize the equipment, such as aircraft, is difficult. Consequently, two different recommendations are made.

Routine Monitoring Recommendations: Final recommendations have not yet been prepared. These will be available in the final report from Sonoma Technology. However, given the lack of both ambient air-quality data and surface and aloft meteorology, states within the small domain should consider deployment of additional ozone monitors to provide rural and boundary concentrations. High sensitivity NO_y measurements should be co-located with existing and new ozone monitors. A few well located continuous VOC measurement platforms should be considered, or perhaps canister measurements for selected times. Speciation will allow information to assess the emissions inventory estimates as well as provide for inputs to modeling and model evaluation.

Intensive Field Program Recommendations: The recommendations have not been finalized yet and will be contained in the final report.

ACKNOWLEDGMENTS

The author would like to acknowledge Sonoma Technology, particularly Hilary Main, Craig Anderson and Paul Roberts. Material for this paper was taken from the draft report. However, the author takes full responsibility for the paper itself.

THE TEXAS AIR QUALITY STUDY (TexAQS-2000)

Dr. David Allen
Center for Energy and Environmental Resources
Houston, Texas

Dr. Jim Price
Texas Natural Resource Conservation Commission
Houston, Texas

SUMMARY

The largest air-quality field study ever undertaken in the State of Texas currently advanced planning stage. The plans call for a 6-8 week period of intensive sampling of gaseous, particulate and hazardous air pollutants during August and September of 2000. Measurements will be made at ground stations and from multiple aircraft throughout the eastern half of the state, with a particular focus on the Gulf Coast of southeastern Texas. The study is designed to improve our understanding of the chemical and physical processes that control air pollutant formation and transport along the Gulf Coast. The study will also provide an extensive set of data that can be used in assessing the health effects of air pollutants.

BACKGROUND

The State of Texas faces challenging air-quality problems. Some of the most pressing challenges involve meeting the National Ambient Air Quality Standards (NAAQS) for ozone and meeting standards related to fine particulate matter and regional haze. Developing cost-effective approaches for addressing these air-quality challenges requires a substantial body of information on emission sources, the fate of the emissions, and potential control strategies. The State of Texas, through the efforts of the Texas Natural Resource Conservation Commission and related agencies, has worked aggressively to develop scientifically sound air-quality management strategies. While much of the information necessary for developing air-quality improvement strategies has been collected, key information gaps exist.

Because so many features of the atmosphere are interdependent, coordinated air-quality field studies are one of the most powerful tools available for addressing air-quality information gaps. Coordinated studies involving numerous investigators simultaneously probing the composition and movement of the atmosphere provide much more information than single investigators working in isolation, probing a single feature of the atmosphere at a time. The last coordinated field study of air quality in Texas was performed in 1993. Since then, the tools available to probe the composition and movement of the atmosphere have improved substantially; thus, many questions that could not be addressed in 1993, can now be answered. In addition, there has been a growing recognition that air pollutants can be transported over very long distances; the air-quality study planned for 2000 (TexAQS 2000) will examine long-range transport of air pollutants in far more detail than the 1993 study. Finally, the State of Texas is in the process of defining regional approaches to air quality;

TexAQS 2000 will help ensure that the policies can be based on a sound scientific understanding of the formation, transport, and fate of air pollutants.

GOALS OF THE STUDY

The major scientific objectives of TexAQS 2000 are to

- Characterize ozone and particulate matter formation in extended metropolitan areas;
- Understand day-night cycles in chemistry and meteorology (especially nigh-time chemistry);
- Characterize meteorological effects on ozone and particulate matter formation (especially near surface phenomena and marine interactions);
- Characterize the composition, and spatial and temporal variability in particulate matter;
- Collect time-series data on air pollutants that can be used in assessing the relationships between air pollutants and health effects;
- Improve inventories of emissions (especially biogenics, particulate matter, and selected reactive compounds);
- Assemble all of the improved scientific understanding of air pollutant physics and chemistry into air-quality models; these models can then be used by regulatory agencies and interested parties in developing and commenting on proposed regulations.

PARTICIPANTS IN THE STUDY

TexAQS 2000 will involve researchers from Texas, experienced in air-quality field programs, and researchers from throughout the country, who will bring specialized equipment not currently available in the state. The home institutions of the participating scientists include Brookhaven National Laboratories, the National Oceanographic and Atmospheric Administration (NOAA), numerous Texas universities (the University of Texas, Texas A&M, Rice University, Baylor University, Lamar University, and Texas Technological University) and the Texas Natural Resource Conservation Commission.

Planning meetings have included representatives from local, state and federal government agencies, environmental groups, private industry, and industrial trade organizations.

THE PATH FORWARD

Final study plans will be formulated during the summer and fall of 1999. Input and queries for more information are welcome. Information requests can be addressed to:

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Henry Beckman Professor in Chemical Engineering and
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or

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12118 Park 35 Circle, Building E
Austin, Texas 78753
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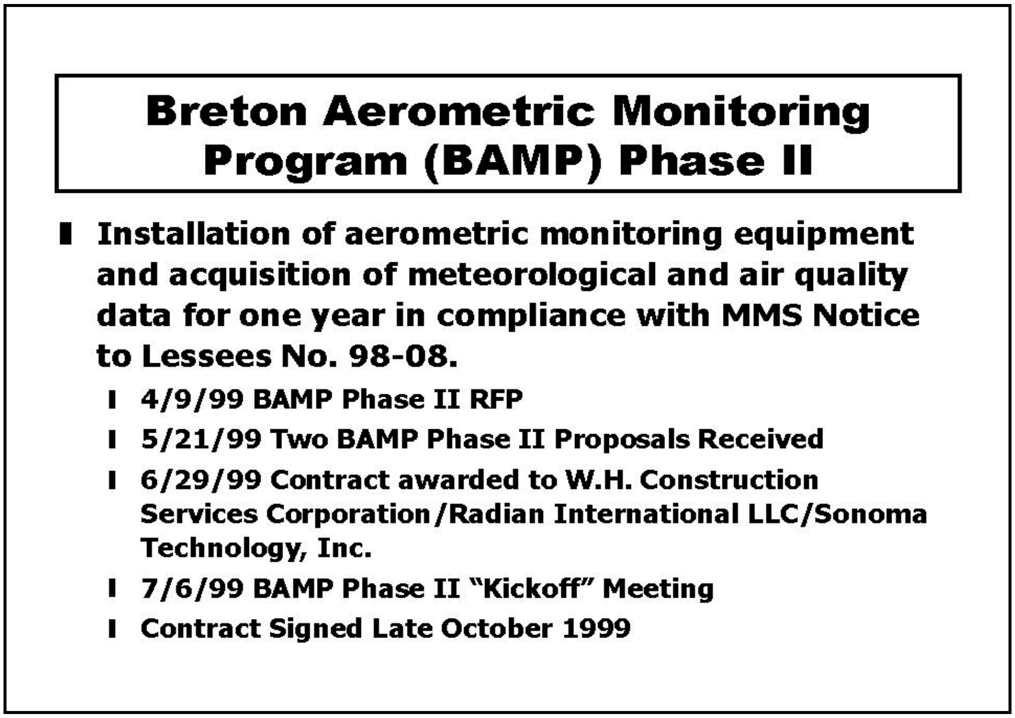
(512)239-1500 (fax)

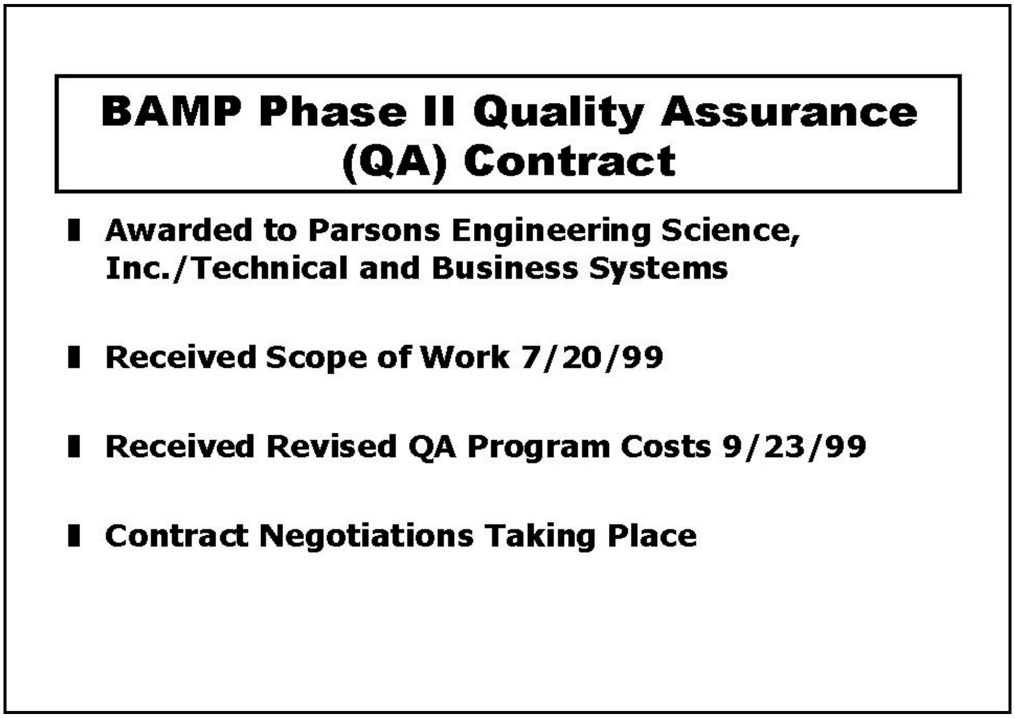
BRETON AEROMETRIC MONITORING PROGRAM (BAMP) PHASE II

Mr. Brian E. Shannon
ARCO Technology & Operations Services



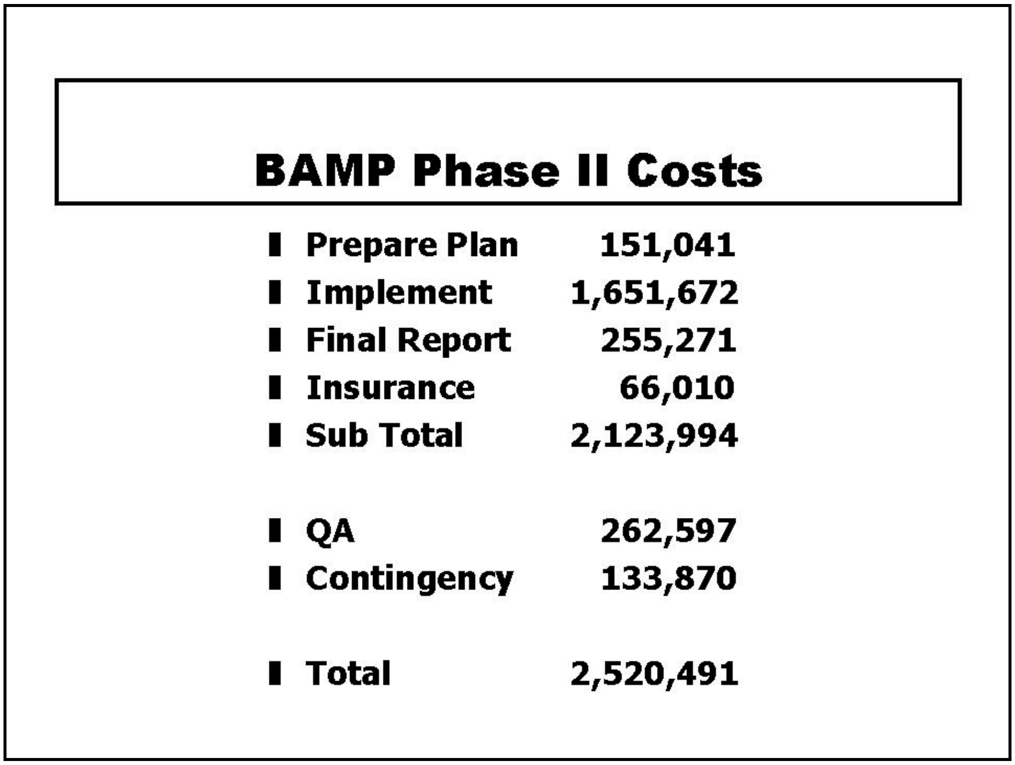
Breton Aerometric Monitoring Program (BAMP) Phase II

- Installation of aerometric monitoring equipment and acquisition of meteorological and air quality data for one year in compliance with MMS Notice to Lessees No. 98-08.
  - 4/9/99 BAMP Phase II RFP
  - 5/21/99 Two BAMP Phase II Proposals Received
  - 6/29/99 Contract awarded to W.H. Construction Services Corporation/Radian International LLC/Sonoma Technology, Inc.
  - 7/6/99 BAMP Phase II "Kickoff" Meeting
  - Contract Signed Late October 1999



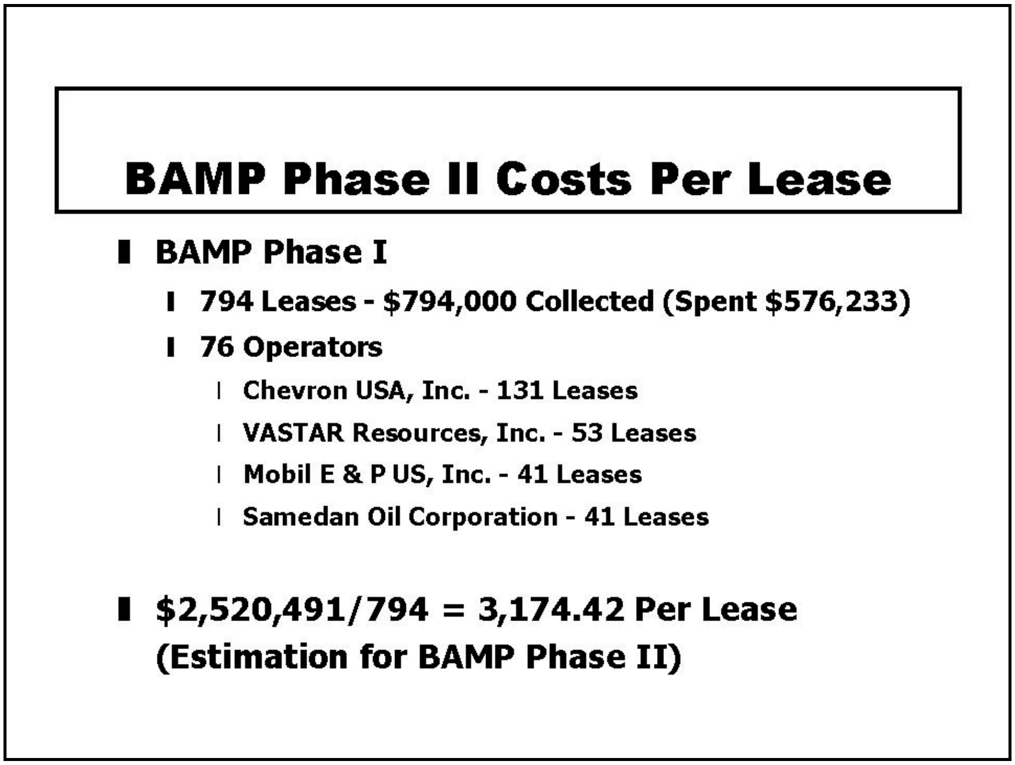
BAMP Phase II Quality Assurance (QA) Contract

- Awarded to Parsons Engineering Science, Inc./Technical and Business Systems
- Received Scope of Work 7/20/99
- Received Revised QA Program Costs 9/23/99
- Contract Negotiations Taking Place



BAMP Phase II Costs

Prepare Plan	151,041
Implement	1,651,672
Final Report	255,271
Insurance	66,010
Sub Total	2,123,994
QA	262,597
Contingency	133,870
Total	2,520,491



BAMP Phase II Costs Per Lease

- BAMP Phase I
  - 794 Leases - $794,000 Collected (Spent $576,233)
  - 76 Operators
    - Chevron USA, Inc. - 131 Leases
    - VASTAR Resources, Inc. - 53 Leases
    - Mobil E & P US, Inc. - 41 Leases
    - Samedan Oil Corporation - 41 Leases

- $2,520,491/794 = 3,174.42 Per Lease (Estimation for BAMP Phase II)

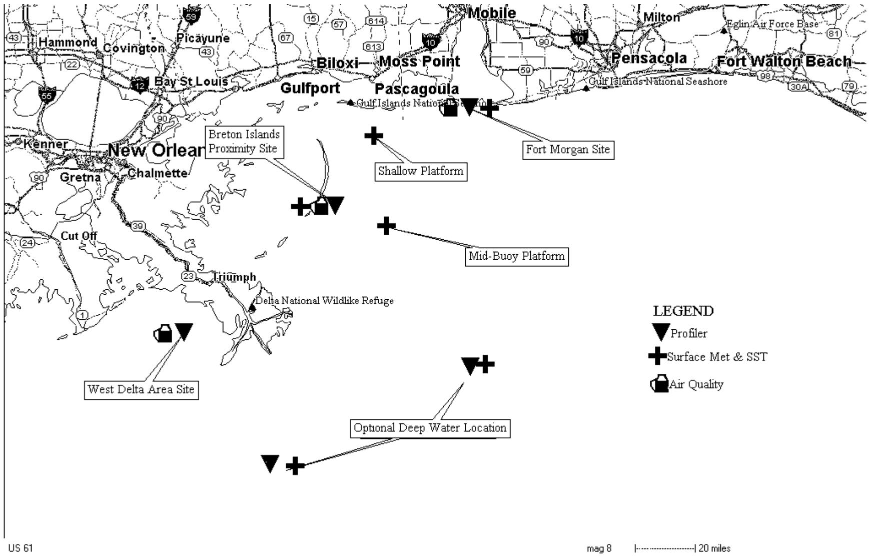
BAMP Phase II Time Schedule

- MMS NTL No. 99-G14 Production Activities Information Collection and Reporting (Breton National Wildlife Refuge/Wilderness Area) requires BAMP Phase II to commence 1/1/00 and run until 12/31/00.
- Current BAMP Phase II Project Schedule has data collection starting between 3/31/00 - 4/24/00.
- Virgil Harris and Dick Gloger meet with Chris Oynes 11/2/99 to explain project delay.

BAMP Phase II Proposed Locations

- Breton Island Vicinity - Chandeleur Block 29
- Shallow Water - Mobile Block 990
- Mid-Buoy - Main Pass Block 162
- Deep Water - Mississippi Canyon Block 809
- West Delta - West Delta Block 31 or 74
- Dauphin Island

BAMP Phase II Proposed Locations



BAMP Phase II Instrumentation

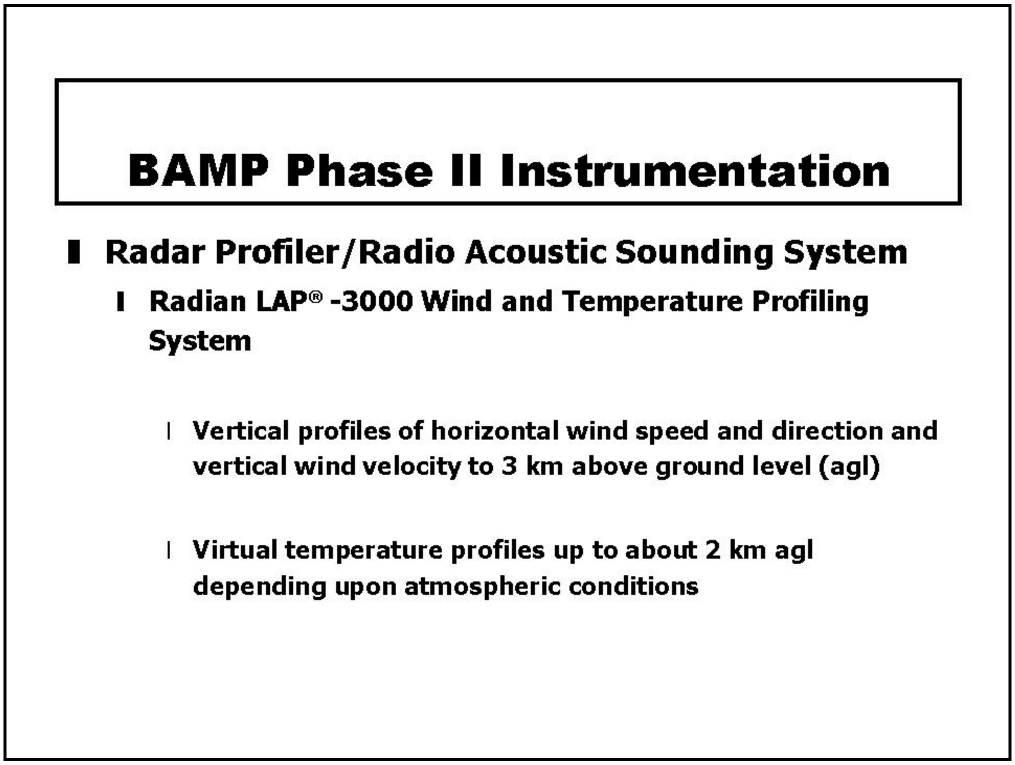
- **Air Quality Monitors**
  - **Thermo Environmental Instruments, Inc. (TEI) Model 42C NO_y Monitor**
  - **Advanced Pollution Instrumentation (API) Model 100A SO_2 Monitor**
  - **API Model 400 Ozone Monitor**
  - **API Model 701 Zero Grade Air Generator**
  - **Microprocessor-based automatic dynamic calibration system capable of performing zero, precision, span and multipoint calibration checks on all gas analyzers**

BAMP Phase II Instrumentation

- Surface Meteorological Equipment
  - Wind Sensor - Met One Instruments Model 012 Vertical Wind Velocity Sensor
  - Air Temperature Sensor - Met One Instruments Model 062 Air Temperature Sensor
  - Relative Humidity Sensor - Met One Instruments Model 083C Relative Humidity Sensor mounted in a Met One Model 077 Radiation Shield
  - Barometric Pressure Sensor - Met One Instruments Model 090D Barometric Pressure Sensor
  - Solar Radiation Sensor - Met One Model 096 pyranometer

BAMP Phase II Instrumentation

- Surface Meteorological Equipment (con't)
  - Precipitation Gauge - Met One Model 370 rain gauge
  - Sea Surface Temperature Sensor - Everest Interscience, Inc. Model 4000.4GL Infrared Temperature Transducer
- GOES Data Collection Platform - Campbell Scientific TGT1 GOES uplink transmitter for all SM/SST data
- Data Logger - Campbell Scientific CR10X measurement and control module



BAMP Phase II Instrumentation

- **Radar Profiler/Radio Acoustic Sounding System**
  - **Radian LAP® -3000 Wind and Temperature Profiling System**
    - **Vertical profiles of horizontal wind speed and direction and vertical wind velocity to 3 km above ground level (agl)**
    - **Virtual temperature profiles up to about 2 km agl depending upon atmospheric conditions**

BOUNDARY LAYER STUDY IN THE WESTERN AND CENTRAL GULF OF MEXICO

Dr. Paul T. Roberts
Mr. Clinton P. MacDonald
Mr. Timothy S. Dye
Sonoma Technology, Inc.

Dr. Steven R. Hanna
Consulting Meteorologist

This four-year project began in late-1998. The study plan was approved in 1999 and technical work has begun. This paper presents a summary of the plan for the project, plus several examples of preliminary data analysis results. Further updates on the project will occur at future ITM meetings.

PROJECT OBJECTIVES

The purpose of this study is to provide the MMS with a description and analysis of the atmospheric boundary layer and how its structure influences the dispersion and transport of pollutants in the western and central Gulf of Mexico (GOM). The results of this study will be used by the MMS to support techniques for evaluating the effects of oil and gas exploration, development, and production activities in the Outer Continental Shelf (OCS) on air quality over coastal areas. In summary, specific activities to be performed include the following:

Initiate the study and perform detailed planning for the study.
Collect data into a common database.
Perform characterization and analysis of the atmospheric boundary-layer structure.
Perform transport and dispersion analyses.
Prepare synthesis reports and a database.
To complete this study we will conduct a number of technical tasks:

- Produce a data inventory for synthesizing the characteristics of the Atmospheric Boundary Layer (ABL) and its dispersion properties in the western and central GOM, based on 1998 to 2001 observations and modeling results.

- Evaluate annual, seasonal, and diurnal variations in the ABL’s structure.

- Describe the processes governing variations in the ABL’s structure.

- Evaluate transport and mixing characteristics that govern pollutant dispersion over diurnal and multi-day scales.

- Provide conceptual model summary of processes that influence the ABL’s structure and variability and pollutant transport and dispersion.

KEY TECHNICAL ISSUES

- A complete and quality-assured data set. If the data set is incomplete, or if individual values are in error, then the analysis results obtained using the data set might be in error, or more uncertain than otherwise.

- Data that are quality assured at Level 1 (consistent with physical constraints and other measurements at the same site by the same monitor).

- Data that are quality assured at Level 2 (consistent with measurements collected at other sites, and with other methods).

- Data representativeness (of the ABL, of the region where the data were collected, of the important ABL processes).

- Control of data management activities.

- Database accessibility (ease of access to quality-controlled data, to statistical summaries of the data, and to derived ABL parameters).

- How to use data to characterize ABL.

- Understanding of ABL processes, especially over water and coastal areas.

- Understanding of transport and dispersion processes, including the uses and limitations of models

There has always been great uncertainty concerning the vertical and horizontal variability of the atmospheric boundary layer in the GOM. For example, the depth of the boundary layer and its vertical stability and wind and turbulence structure can vary greatly in OCS zones due to horizontal variations in sea surface temperature and the overlying air mass. We are fortunate that the MMS now has available the following new boundary layer observations in the GOM— two meteorological stations collecting observations of the atmospheric boundary layer for three years (1998-2001) by using 915 MHz radar wind profilers (RWP), 2 KHz Radio Acoustic Sounding Systems (RASS), and surface meteorology units. The profilers measure winds and virtual temperatures between the surface and heights of a few kilometers, and the surface stations measure sea surface temperature as well as wind speed, wind direction, air temperature, and mixing ratio. In addition, The Breton Aerometric Monitoring Program (BAMP) will be installing and operating three additional sites offshore plus one shoreline site with RWP/RASS and surface meteorological monitors. The BAMP sites will operate for one year, beginning about April 2000.

The two most important meteorological parameters for use in transport and dispersion models are wind velocity and vertical stability. These parameters are needed over the full depth of the overwater boundary layer (i.e., up to heights of 1 or 2 kilometers), to better account for variations in transport speed, transport direction, turbulent dispersion, and stability over the depth of the pollutant plume.

Over travel times of several hours to a few days, or travel distances of several kilometers to a few hundred kilometers, such pollutant plumes can disperse upwards to the top of the boundary layer, can shear off in several directions, and can be subjected to layering during the transition and nighttime hours. The previous practice of using estimates of stability based on the difference between sea surface and air temperature and single wind speed observations was often unsatisfactory.

The new data will be analyzed to investigate the following technical issues:

- The overwater surface energy balance will be studied using the near-surface observations for both steady-state horizontally-homogeneous conditions and for conditions variable in time and space. A climatology of latent heat versus sensible heat fluxes will be developed for both situations, and parameterizations will be developed for use in situations when only degraded data are available.

- Given the surface energy balance components, the vertical profiles of wind and temperature will be studied to develop climatologies and parameterizations. In particular, it is desirable to be able to estimate the full vertical profiles of wind and temperature based only on near-surface measurements of air-water temperature differences and wind speeds.

- The extensive vertical temperature profiles will be studied to estimate the mixing depths and prepare empirical formulas to parameterize these observations.

- The frequency of occurrence of very stable conditions near the surface and in layers aloft will be investigated due to the importance of these layers for defining worst-case conditions for the dispersion of air pollutants.

- The horizontal spatial variability of wind speed and direction will be studied to identify the fraction of time that wind directions and speeds persist over several hours in the GOM, thus causing direct straight-line transport of pollutants toward receptors on the shoreline.

- Vertical profiles of wind and temperature in the near-surface layer (i.e., heights below about 50 m) will be plotted and analyzed to derive surface roughness length relations and to estimate the scaling velocity (u*) and scaling temperature (T*). These scaling parameters are directly related to surface momentum and heat fluxes. Since turbulent velocities (important to dispersion) are directly proportional to u*, it should be possible to derive improved parameterizations for the dispersion coefficients s_y and s_z. Perhaps the single most important technical issue for understanding over-water air quality dispersion is the ability to properly assess the mixing depth.

Using the data collected by the radar wind profilers, hourly mixing depth estimates can be estimated from a combination of the refractive index structure parameter (C_n^2), RASS virtual temperature profiles, and surface measurements. Radar profiler mixing depth estimates have been demonstrated to relate well to other fundamental mixing depth estimation techniques using rawinsonde temperature profiles and aircraft data.

Estimating hourly mixing depths from profiler/RASS data is relatively straightforward. Using a technique developed by STI, we will estimate mixing depths from the profiler's reflectivity measurements and RASS's virtual temperature profiles. The refractive index structure parameter (C_n^2) is computed from the profiler's reflectivity measurements. Maximum values of C_n^2 have been theoretically and observationally linked to the top of the mixed layer. RASS virtual temperature profiles coupled with surface virtual temperature measurements can estimate the height of the mixed layer by using stability analysis.

Figures 2H.1 and 2H.2 show examples of mixing depths estimated using RASS virtual temperature and surface temperature data, and using RWP Cn2 data. Diurnal variations ranging from about 300 m msl to about 1,000 m msl are evident in these examples. We will be performing similar estimates for long periods of time and compiling statistics on the mixing depth.

Conceptual Model Development

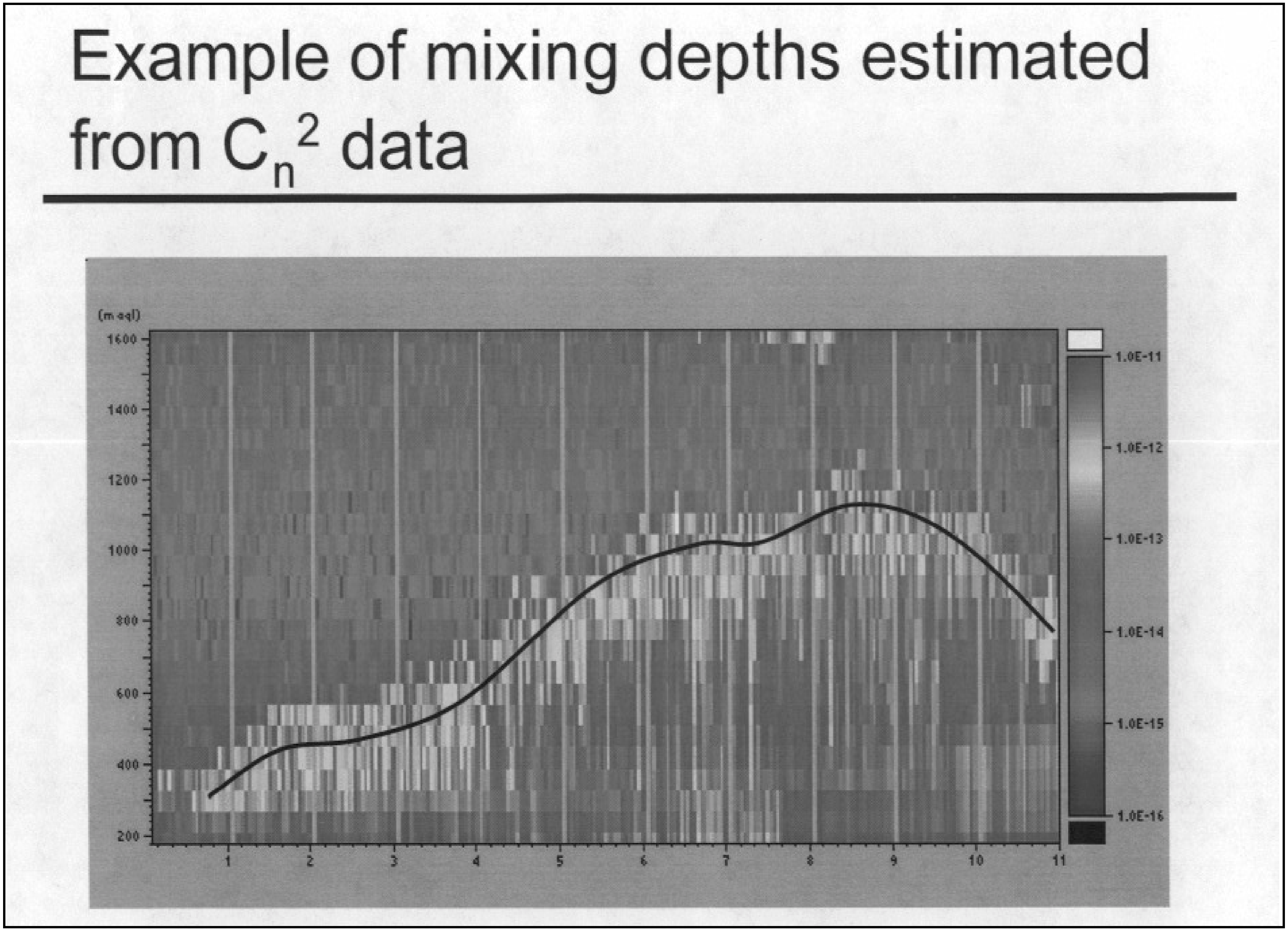
We will develop a conceptual model of ABL characteristics and variability (as part of Task 3) and of pollutant transport and dispersion (as part of Task 4) in the offshore and coastal environment of the western and central GOM. The conceptual model will describe and illustrate the major meteorological phenomena which control the ABL structure and variability (Task 3) and which control pollutant transport and dispersion (Task 4). The purpose of developing a conceptual model is to summarize the current state of knowledge, to provide a basis for testing and evaluating specific hypotheses, to focus continuing analysis efforts on the most important issues, and to identify those processes which must be represented in models.

Note the following regarding conceptual models:

- The controlling processes may differ spatially, and by month, season, and weather pattern.
- The scale of controlling processes vary from synoptic to local.
- The type of controlling processes include synoptic, geographic (e.g., coastline), and thermal.

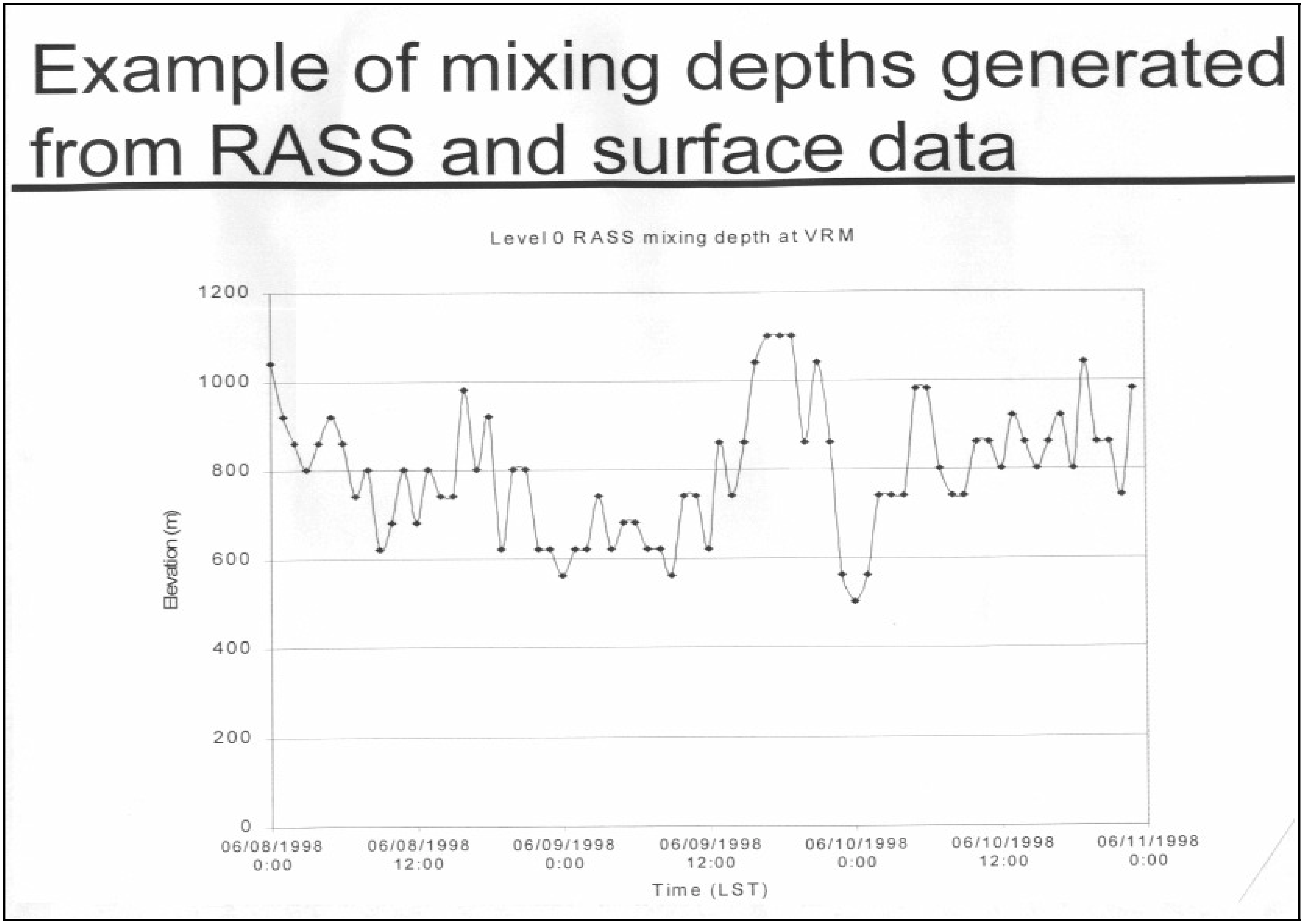
Example processes to be considered for inclusion in a conceptual model include the following:

- Synoptic weather patterns, including fronts and high/low pressure systems.
- High-pressure induced subsidence (warming).
- Air mass advection.
- Thermal ocean/atmospheric interactions.
- Land/sea breeze processes (especially for distinct shorelines).
- Diffuse shoreline in central Louisiana.



Example of mixing depths estimated from C_n^2 data

Figure 2H.3. Time-height cross section of C_n^2 at South Marsh Island profiler on 11 February 1998 between 0000 and 1100 CST.



Example of mixing depths generated from RASS and surface data

Figure 2H.2. Time-height cross section of mixing depths generated from RASS and surface data at VRM from 8 June 1998 through 10 June 1998.

TASK 1: STUDY INITIATION

- Establish a Scientific Review Board (SRB). The SRB members will inspect the progress and the scientific validity of the study and its deliverables, including reviewing the study plan, interim synthesis report, and final synthesis report.

- Prepare and distribute a draft study plan summarizing how we will perform the study tasks and meet the study objectives, review the study plan, and revise the study plan based on comments received.

TASK 2: DATA COLLECTION AND INVENTORY

Database

- A Microsoft Access database will be used to archive the data for this project.

- The database will allow output of data into several different types of formats, including ASCII, comma-separated-value (CSV), and space-delimited, which are capable of being imported into other programs (e.g., ARC/INFO, Excel).

The database will store

- Metadata: to describe the content, quality, condition, and other characteristics of data that help users locate and understand the data.

- Observations and calculated fields: measurements from surface and upper-air sensors, as well as calculated fields generated as part of Task 3.

- Three-dimensional fields: contain a reference to the model analysis fields. Storing the actual model output in an Access database is inefficient due to the large amount of data; however, the database will manage the inventory for the model output fields.

To efficiently monitor and track the contents of the database, automated reporting will be used to generate data availability and data validation levels reports.

Graphical user interface (GUI) will allow for quick and efficient display and analysis of the database. Several display types are available:

- Time-series

- Spatial plots

- Statistical summary

- Trajectory plots

- Cross section plot

- Output options will allow the users to save displays as files, graphics, or animations.

- Creation of the database will be done on a routine basis (e.g., every quarter). Prior to entry into the database, data will undergo format conversion; standardization of the units, time zones, and time conventions; and Level 1 and Level 2 data validation.

TASK 3: ANALYSIS OF THE ABL STRUCTURE

Objectives

- Characterize the ABL

- Evaluate annual, seasonal, and diurnal variations in ABL structure

- Describe processes that influence ABL structure and variations

Approach

- Describe ABL using measurements

- Describe ABL using vertically averaged variables and bulk theory

- Perform statistical and time-series analyses

- Perform correlations and propose simple relationships using only surface observations

- Describe processes

- Important tool is the Toga COARE algorithm.

Plusses and Minuses of Available Data:

- Plusses:

  1. Continuous records over three years from two MMS profiler stations, with wind and temperature data (at about 60m resolution) extending from about 150 m to about 4 km.

  2. Near-surface data from platforms and buoys over the three-year period.

  3. Archived ETA NWP model outputs available for the same time period.

  4. Many on-shore data also available.

- Minuses:

  1. No fast response flux data (e.g., <w’T’>).
  2. Wind and temperature measurement at only one height in the lowest 100 m.
  3. Insufficient coverage to resolve sea/land breezes, TIBLs, and other local phenomena.

We identified 10 different synoptic weather patterns that influence large-scale flows in the northeastern Gulf (STI work for the NE Gulf Meteorological Study, ongoing, report due out later in 1998). Once several of these patterns are slightly modified to focus on the western and central Gulf, these patterns can be used to classify days during the study period (June 1998 through May 2001). The frequency of these patterns will vary by season. Several of these synoptic classifications show features which dominate winds and transport patterns in the area of interest. Other patterns show more neutral gradients in the offshore and coastal areas of interest, and thus local characteristics would likely dominate flows and transport. The synoptic features also likely influence stability in the regions, and thus strongly influence mixing heights and dispersion characteristics. As part of this task, we will modify the classifications for the western and central GOM, and will classify every day in the three-year period; these classifications will be used in other analyses in both Tasks 3 and 4.

Figure 2H.4, 2H.5 and 2H.6 show example time-series data used by Toga COARE and example COARE output for heat flux and various lengths and frictional velocity. Even in these limited examples, it can be seen that heat flux and roughness length can depend strongly on small humidity and temperature changes, for example. We will perform these types of calculations for longer time periods and compile statistics of these boundary-layer characteristics.

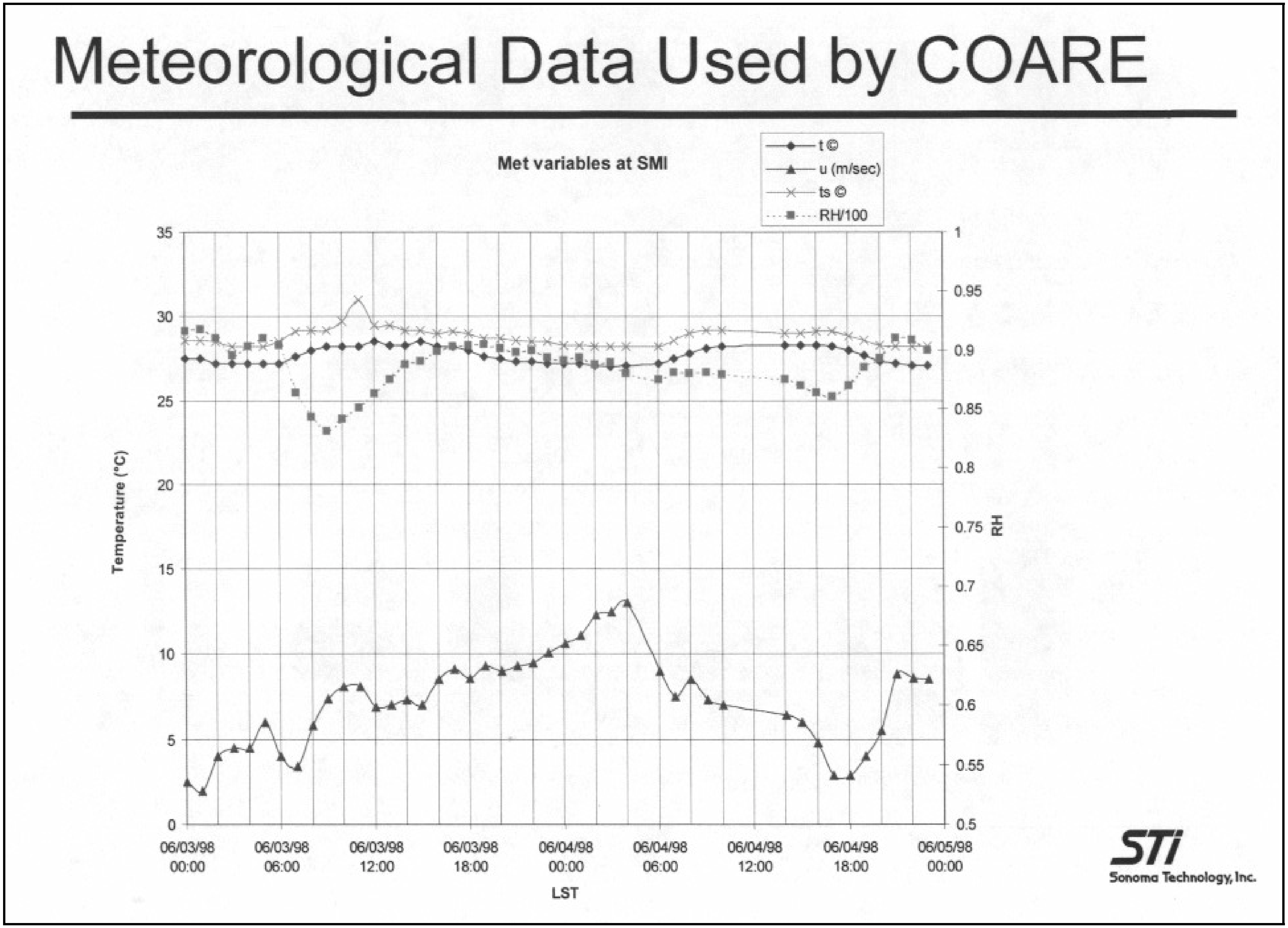
TASK 4: DISPERSION ANALYSIS

Objectives

- Characterize the dispersion properties of the ABL.
- Evaluate transport and mixing characteristics of ABL that govern pollutant dispersion.
- Include diurnal and multi-day scales.
- Describe processes that influence ABL transport and dispersion.

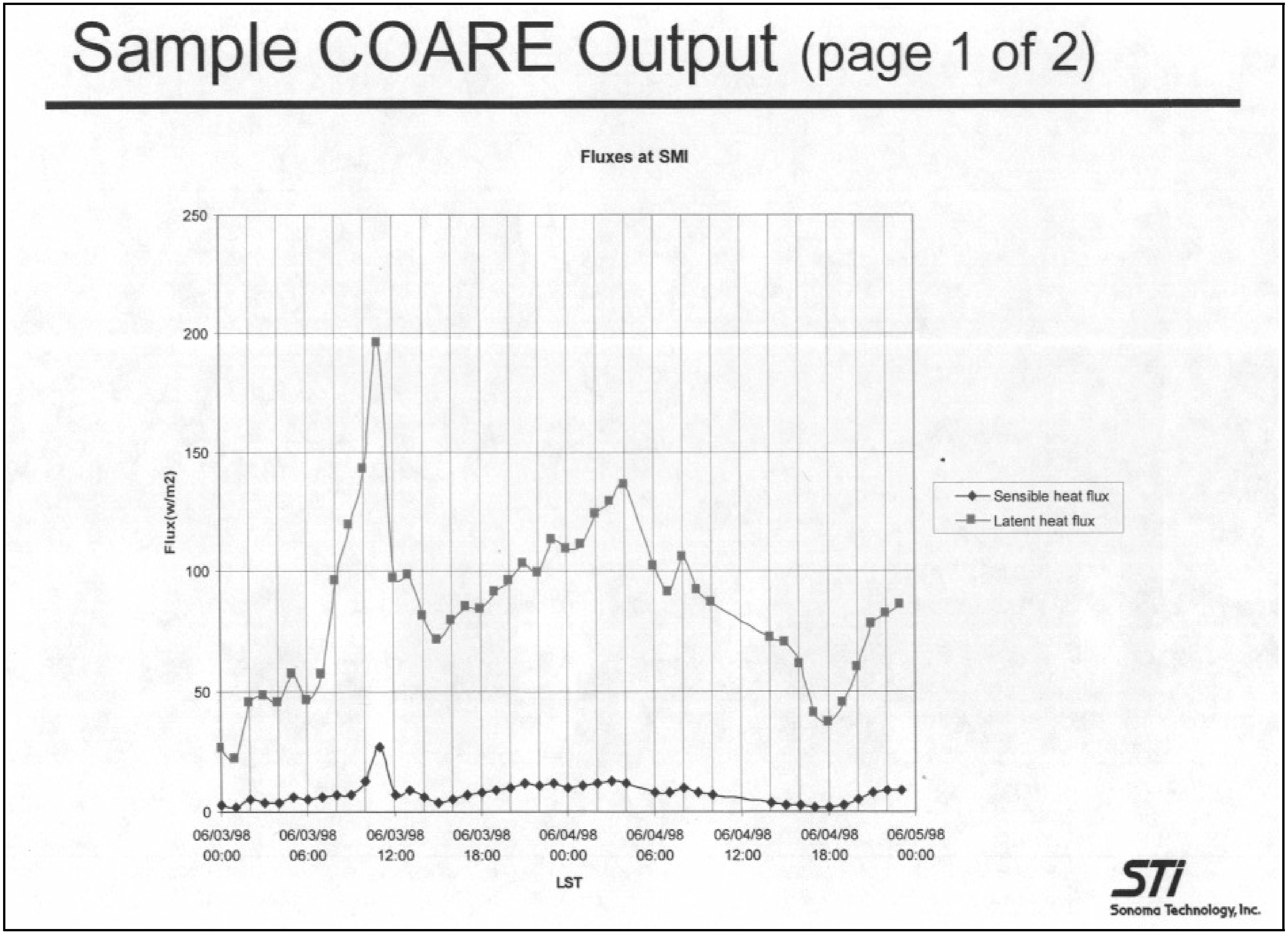
Overall Technical Approach

- Describe transport and mixing fields using statistical analyses.
- Describe processes that influence transport and mixing (conceptual model).



Meteorological Data Used by COARE

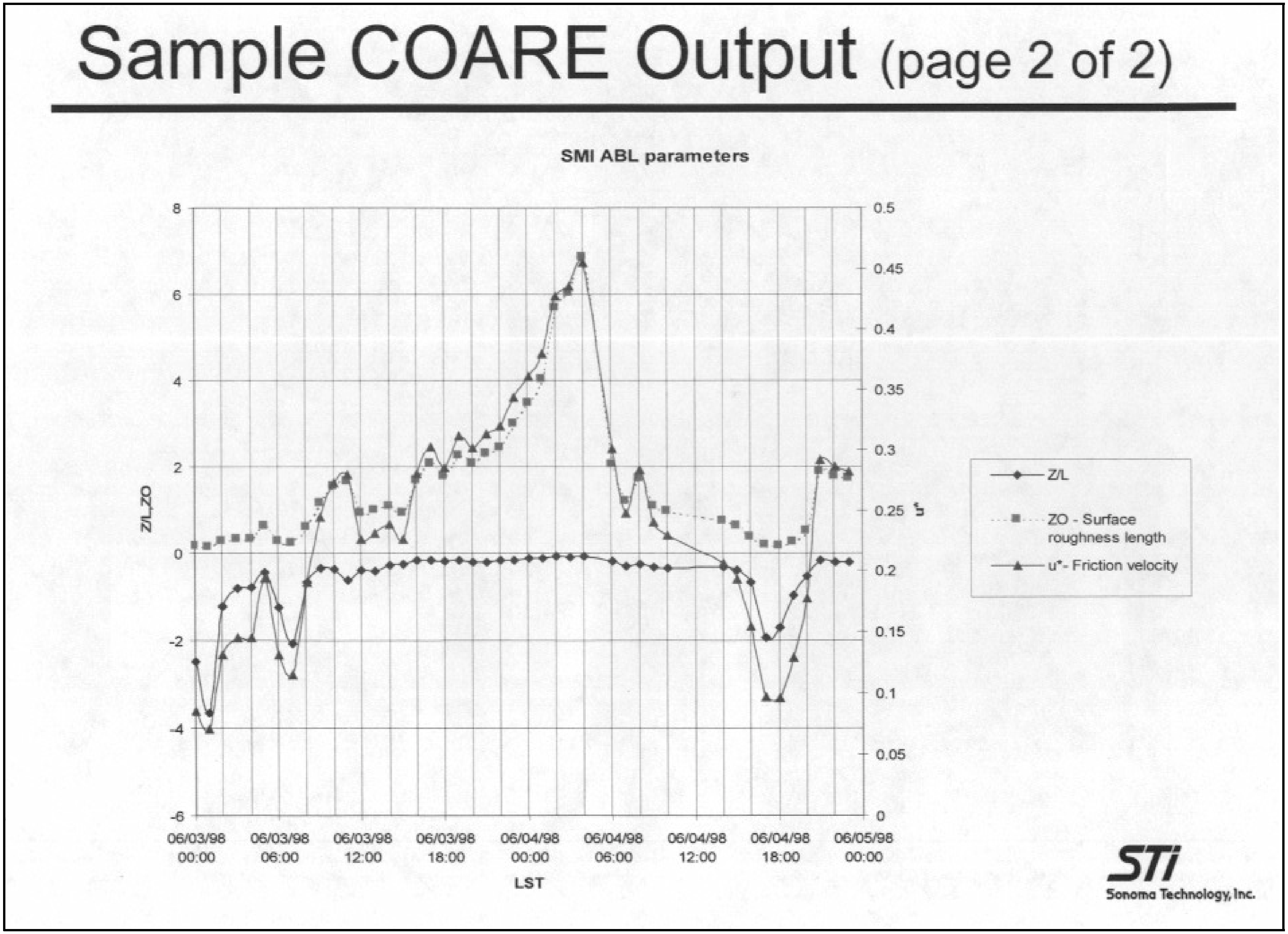
Figure 2H.4. Example of time-series meteorological data.



Sample COARE Output (page 1 of 2)

Sonoma Technology, Inc.

Figure 2H.5. Example 1 of COARE output.



Sample COARE Output (page 2 of 2)

STI
Sonoma Technology, Inc.

Figure 2H.6. Example 2 of COARE output.

- Identify limitations of using homogeneous and equilibrium conditions.
- Recommend improvements to models & observations.

Technical Details of Approach

- Compare observed transport winds with Eta winds. This will occur at location and times when both the observed and Eta winds exist. If differences occur, then we will look into the potential causes.
- Select periods of interest, ensuring representation from various seasons and met classifications (about 1 month/season).
- Generate wind and mixing ht. fields with diagnostic model (we will likely use CALMET, but we will evaluate various alternatives before proceeding).
- Perform statistical analysis (e.g. averages, perturbations, and cycles) of transport wind, mixing ht., and vertical diffusivity fields.
- Separate the results into several regions, such as offshore, near shore, coastal, and onshore.
- Summarize statistical results and perform a few case studies to investigate similarities and differences among seasons and classifications.
- ID controlling processes by weather classification and season.
- Perform detailed analysis for selected cases.
- Illustrate controlling processes with examples.

A schedule for the project is shown in Figure 2H.7.

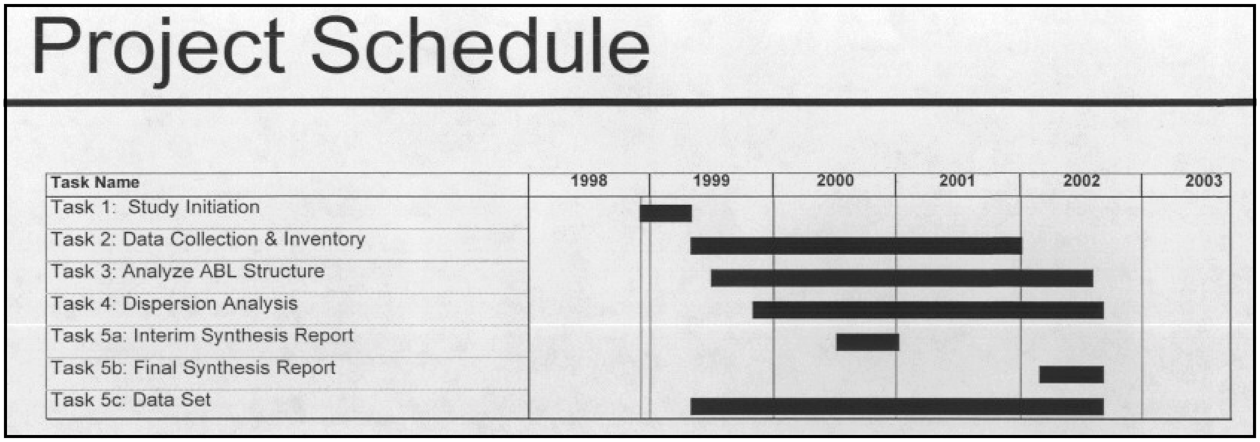


Figure 2H.7. Example of a project schedule.

Dr. Paul T. Roberts, STI Vice President, designs and manages air-quality field, data management, and data analysis projects. Most of these projects have involved the use of field data and analysis methods to understand important meteorological and air-quality phenomena, and to develop, apply, and evaluate meteorological and photochemical model. Specific projects during which boundary-layer processes over water and shoreline environments were important components include the MMS-sponsored Gulf of Mexico Air Quality Study (southeast Texas and Louisiana and offshore), the Southern California Air Quality Study (SCAQS) and several subsequent data analysis efforts in and around the South Coast Air Basin (SoCAB), the Lake Michigan Ozone Study, and the NARSTO-Northeast Air Quality Study (covering Virginia to Maine, including offshore).

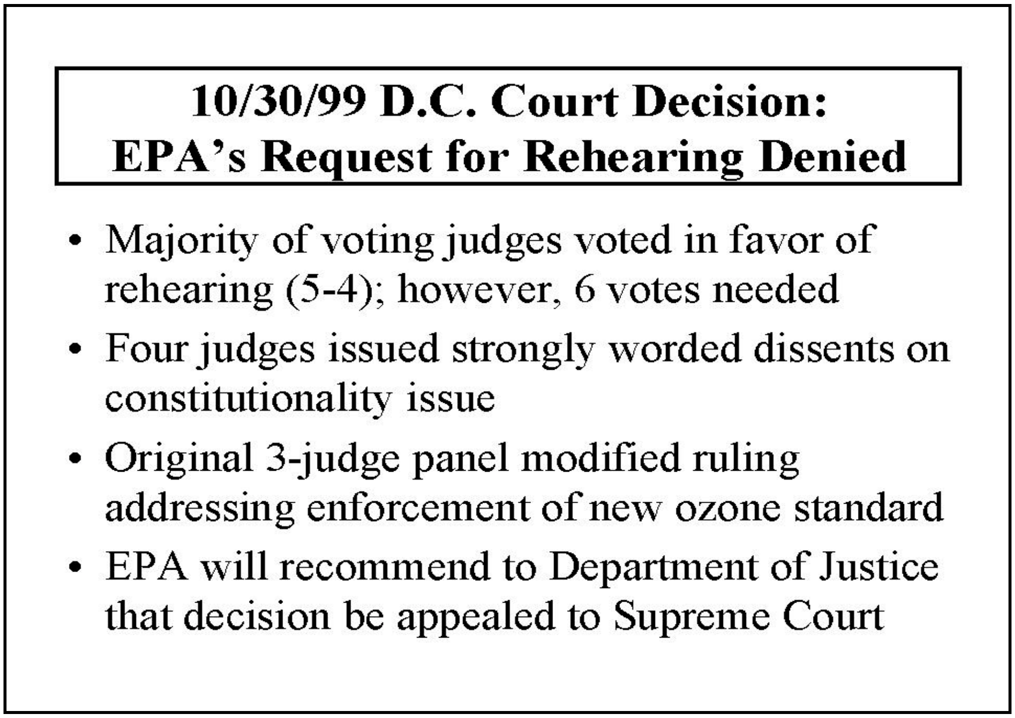
Mr. Clinton P. MacDonald, a Senior Meteorological Analysis at STI, has performed meteorological and air-quality data analyses in coastal and inland environments throughout the U.S. He has made extensive use of radar wind profiler and RASS virtual temperature upper-air meteorological data to understand the phenomena occurring in the atmospheric boundary layer. Mr. MacDonald has developed and implemented several computer software tools to process and interpret upper-air and surface meteorological data.

Mr. Timothy S. Dye, STI's Manager of Meteorological Programs, has operated, quality controlled, and analyzed radar wind profiler wind and temperature data for over 11 years. Mr. Dye has extensively used these upper-air data to conduct analyses of pollutant formation, transport, and dispersion. He developed algorithms to estimate mixing height from radar profiler reflectivity and temperature data and has used this technique to understand marine and overland boundary layer structure and evolution in such programs as the Lake Michigan Ozone Study, the Gulf of Mexico Air Quality Study, and the NARSTO-Northeast Air Quality Study. Mr. Dye is co-author of the new EPA guidelines for collecting, quality controlling, and managing the upper-air data from radar profiler/RASS, sodar, and rawinsonde systems and has designed several methods for conducting Level 2 data validation of upper-air data.

Dr. Steven R. Hanna is a specialist in atmospheric turbulence and dispersion, in the analysis of meteorological and aerometric data, and in the development, evaluation, and application of air-quality models. He is an AMS Certified Consulting Meteorologist with over 30 years of experience. He has led several research and development projects involving, for example, the statistical evaluations of hazardous gas dispersion models and regional ozone models; the development of models for the dispersion of emissions from tall power plant stacks and from offshore oil platforms; and the analysis of data from large regional field experiments in the Santa Barbara area, in the Lake Michigan region, in the Gulf of Mexico, and in the northeastern United States. He led the development of the OCD Model. From 1988-1997, Dr. Hanna was Chief Editor of the *Journal of Applied Meteorology*, and has published over 100 articles in peer-reviewed journals, six chapters in books, and four books in which he is the primary author.

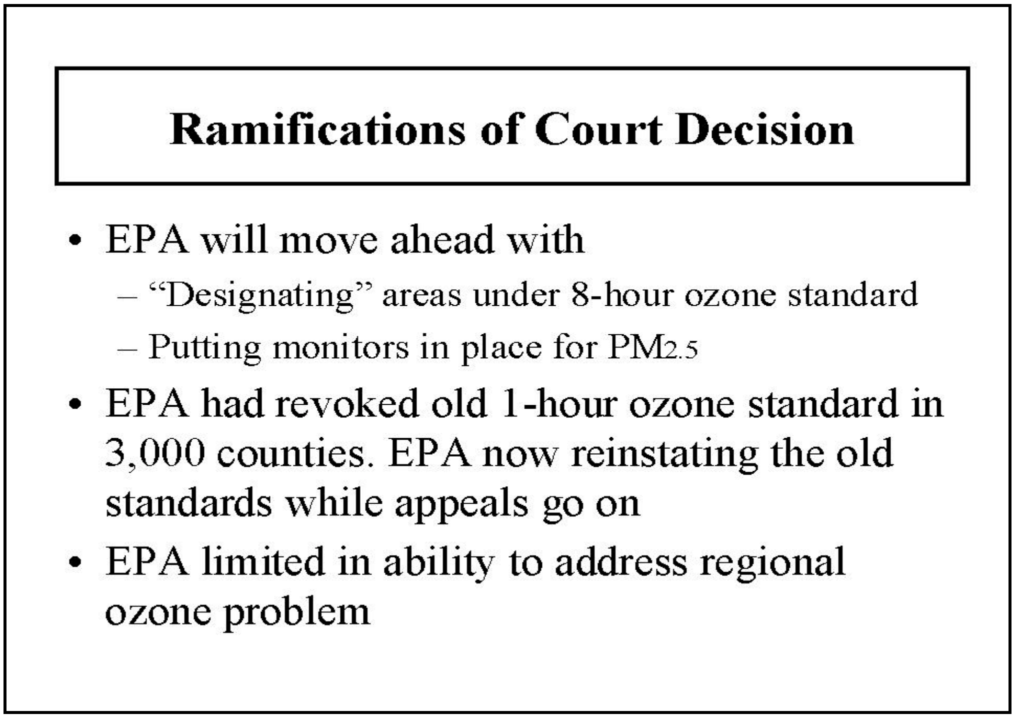
STATUS OF THE OZONE AND PM2.5 NATIONAL AMBIENT AIR QUALITY STANDARDS

Dr. Dirk Herkhof
Minerals Management Service



10/30/99 D.C. Court Decision: EPA's Request for Rehearing Denied

- Majority of voting judges voted in favor of rehearing (5-4); however, 6 votes needed
- Four judges issued strongly worded dissents on constitutionality issue
- Original 3-judge panel modified ruling addressing enforcement of new ozone standard
- EPA will recommend to Department of Justice that decision be appealed to Supreme Court



Ramifications of Court Decision

- EPA will move ahead with
  - "Designating" areas under 8-hour ozone standard
  - Putting monitors in place for $PM_{2.5}$
- EPA had revoked old 1-hour ozone standard in 3,000 counties. EPA now reinstating the old standards while appeals go on
- EPA limited in ability to address regional ozone problem

The D.C. Circuit Court of Appeals Decision

- Two of three judges found an unconstitutional delegation of legislative powers
- All ozone and PM standards remanded to EPA
- Rejected various procedural and cost consideration claims
- In the meantime:
  - – $PM_{2.5}$ and new ozone standards remain "on the books"
  - – Revised PM_{10} coarse standards "vacated"
  - – Old (more stringent) PM_{10} standards remain in effect
  - – Cannot implement new ozone standards

Was It Insufficient Science?

- Unanimous opinion on fine particles:
  - – "The growing empirical evidence demonstrating a relationship between find particle pollution and adverse health effects amply justifies establishment of new line particle standards."
- Unanimous opinion on coarse particles:
  - – "We find ample support for EPA's decision to regulate coarse particulate pollution above the 1987 levels."

Practical Import for $PM_{2.5}$/PM_{10}

- EPA has appealed these decisions with the full DC Circuit Court
- Unclear how significant this decision would be for implementation in any case
  - Greatly expanded monitoring program being put into place nationwide and collecting data
  - Major research effect continues space (NAS support)
  - Review of the scientific criteria and standards on track for 2002
- Need to consider new coarse indicator ($PM_{10-2.5}$)

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.