

STUDY TITLE: Effects of Oil and Gas Exploration and Development at Selected Continental Slope Sites in the Gulf of Mexico

REPORT TITLE: Effects of Oil and Gas Exploration and Development at Selected Continental Slope Sites in the Gulf of Mexico, Volume I: Executive Summary, Volume II: Technical Report, and Volume III: Appendices

CONTRACT NUMBER: 1435-01-00-CT-31034

SPONSORING OCS REGION: Gulf of Mexico

APPLICABLE PLANNING AREAS: Central Gulf of Mexico, Western Gulf of Mexico

FISCAL YEARS OF PROJECT FUNDING: 2000; 2001; 2002; 2003; 2004; 2005; 2006

COMPLETION DATE OF REPORT: September 2006

COSTS: FY 2000: \$59,190; FY 2001: \$2,180,912; FY 2002: \$871,343; FY 2003: \$370,240; FY 2004: \$147,421; FY 2005: \$141,438; FY 2006: \$81,905; **CUMULATIVE PROJECT COST:** \$3,852,449

PROJECT MANAGER: D. Gettleson

AFFILIATION: Continental Shelf Associates, Inc.

ADDRESS: 759 Parkway Street, Jupiter, FL 33477

PRINCIPAL INVESTIGATORS : N. Phillips; A. Hart; H. Roberts; I. Williams; J. Blake; D. Rhoads; P. Neubert; R. Diaz; J. Trefry; R. Trocine; R. Rember; M. McElvaine; T. McDonald; J. Brooks; P. LaRock; Barry A. Vittor & Associates, Inc.; R. Carney; C. Gregg; D. Foltz; J. Fleeger; R. Kropp; J. Neff

KEY WORDS: Central Gulf; Western Gulf; deepwater; benthic ecology; impacts; monitoring; drilling fluids; cuttings; synthetic based fluids; geophysical surveys; side-scan sonar; sediment grain size; sediment profile imaging; redox potential; trace metals; hydrocarbons; microbes; meiofauna; macroinfauna; megafauna; photography; image analysis; copepod genetics; toxicology; risk assessment.

BACKGROUND: Drilling activities on the northern Gulf of Mexico continental slope have increased dramatically in the last decade. However, there have been few environmental studies of benthic impacts at deepwater drill sites in the Gulf of Mexico. Because of environmental and technological differences, the applicability of previous impact studies done on the continental shelf is uncertain. The findings from this study will assist the MMS in conducting environmental analyses, as well as in developing mitigative measures and regulations specifically tailored to deepwater operations.

OBJECTIVES: The objectives of this study were to assess the physical, chemical, and biological impacts of oil and gas development at selected exploration and development wellsites on the Gulf of Mexico continental slope. Specific objectives were to document (1) drilling mud and cuttings accumulations; (2) physical modification/disturbance of the seabed due to anchors and mooring systems; (3) debris accumulations; (4) physical/chemical modification of sediments; and (5) effects on benthic organisms.

DESCRIPTION: Four study sites were selected on the northern Gulf of Mexico continental slope. Viosca Knoll (VK) 916 was an exploration site sampled before and after drilling of a single exploration well. Garden Banks (GB) 516 was an exploration/development site that was sampled once after exploration drilling and again after several development wells were drilled. GB 602 and Mississippi Canyon (MC) 292 were post-development sites sampled once after several exploration and development wells had been drilled. Each location consisted of a near-field site (500-m radius) and six far-field sites located 10 to 25 km away. Three geophysical cruises and three chemical/biological cruises were conducted between October 2000 and August 2002. The geophysical cruises included site mapping using bathymetry, side-scan sonar, and subbottom profiling. The chemical/biological surveys included box coring, sediment profile imaging, seafloor photographs, and baited traps (for tissue samples).

SIGNIFICANT CONCLUSIONS: Physical, chemical, and biological impacts of drilling activities were detected at all four sites. Anchor scars were observed within about 3 km of wellsites, with individual scars ranging in length from less than 100 m to over 3 km. At all four sites, there were side-scan sonar contacts identified as debris. Cuttings and drilling fluid accumulations were evident mainly within the 500-m radius near-field zone at all four sites, though there was geophysical and chemical evidence for deposits extending beyond this area. Impacts noted within the near-field zone included elevated barium, synthetic based fluid (SBF), and total organic carbon (TOC) concentrations, low sediment oxygen levels, presence of microbial mats, and altered densities of meiofauna, macroinfauna, and megafauna. Within the near-field zone, impacts were patchy, with some stations showing conditions similar to those at the far-field sites. Impacts generally were less extensive and less severe at post-exploration sites than at post-development sites. The severity of discharge-related impacts varied depending on the volume of SBF cuttings discharged and the time elapsed since drilling was completed.

STUDY RESULTS: Geophysical and chemical measurements indicated that a layer of SBF cuttings and muds several centimeters thick was deposited within the near-field sites. Geophysically mapped cuttings zones ranged from 13 to 109 ha in area, with larger zones observed at post-development sites.

Concentrations of drilling fluid tracers (barium and SBF) were elevated by several orders of magnitude within near-field sites. Mean sediment concentrations of barium and SBF were positively correlated with estimated discharge volumes of SBF cuttings. Areas of SBF cuttings deposition were associated with elevated TOC and anoxic conditions, including low dissolved oxygen, negative Eh, and shallow depth of the

oxidized layer. Sites with larger volumes of SBF cuttings discharges and higher mean sediment SBF concentrations had the greatest reduction in mean sediment oxygen levels.

Sediment profile imaging indicated that the near-field sites had patchy zones of disturbed benthic communities, including azoic areas, microbial mats, zones dominated by pioneering stage assemblages, and areas where surface-dwelling species were selectively lost. Macroinfaunal and meiofaunal densities and microbial biomass generally were higher near drilling, although some faunal groups were less abundant in the near-field (amphipods, ostracods). Among megafauna, increased fish densities and reduced ophiuroid densities were noted in the near-field of two sites (VK 916 and GB 516).

Generally, meiofaunal densities in the near-field were not consistently correlated with drilling indicators (barium and SBF) or other sediment variables (TOC and grain size fractions). A genetic study of the harpacticoid copepod *Bathycletopsyllus* sp. was conducted with samples from GB 602 and MC 292. This species was absent from far-field sites but present in large numbers at the two near-field sites. Within the near-field, abundances were positively correlated with sediment SBF concentrations up to about 2,500 $\mu\text{g/g}$. Low genetic diversity was observed in near-field *Bathycletopsyllus* sp. populations, a result consistent with expansion from a small population size.

Polychaete and gastropod densities in the near-field were positively correlated with drilling indicators (barium and SBF). Some near-field stations with barium concentrations higher than about 10,000 $\mu\text{g/g}$ and/or SBF concentrations greater than about 1,000 $\mu\text{g/g}$ had elevated polychaete densities. A few near-field stations at GB 516 and GB 602 had very high gastropod densities, which were associated with barium concentrations of 55,000 $\mu\text{g/g}$ or higher and SBF concentrations of 4,500 $\mu\text{g/g}$ or higher.

Amphipod densities in the near-field were negatively correlated with drilling indicators (barium and SBF). Generally, near-field stations with barium concentrations higher than about 10,000 $\mu\text{g/g}$ and/or SBF concentrations greater than about 1,000 $\mu\text{g/g}$ had low amphipod densities. Separately, acute toxicity tests with near-field and far-field sediments from MC 292 and GB 602 showed that mean amphipod survival was significantly lower in sediments from near-field stations than in sediments from far-field stations. Amphipod survival in the toxicity tests was negatively correlated with drilling indicators. SBF chemicals in sediments may adversely affect benthic communities by direct toxicity or by organic enrichment and associated development of sediment hypoxia caused by microbial degradation of the organic chemicals.

Detailed taxonomic analysis of a subset of the macroinfaunal samples showed some stations near drilling had lower diversity, lower evenness, and lower richness indices compared with stations away from drilling. Species composition varied in relation to both geographic location and drilling impacts. Station/cruise groups most likely affected by

drilling were dominated by high abundances of one or a few deposit-feeding species, including known pollution indicators.

Impacts attributable to SBF cuttings such as elevated TOC, poor redox conditions, and associated biological changes were least severe at MC 292, where the smallest quantities of SBF cuttings were discharged. However, the time elapsed since drilling also was longer at this site (about 2 years) than at the other three sites (5 to 14 months), and the less severe impacts may reflect recovery of this site over time.

Observations from the study sites and adjacent lease blocks suggest that geophysically detectable mud/cuttings deposits may persist for 5 years or more and anchor scars may persist for 14 years or more. Because no chemical or biological sampling was done in adjacent blocks, it is not known if the mapped mud/cuttings from older wells are associated with persistent elevations in barium, anoxic conditions, or altered benthic communities.

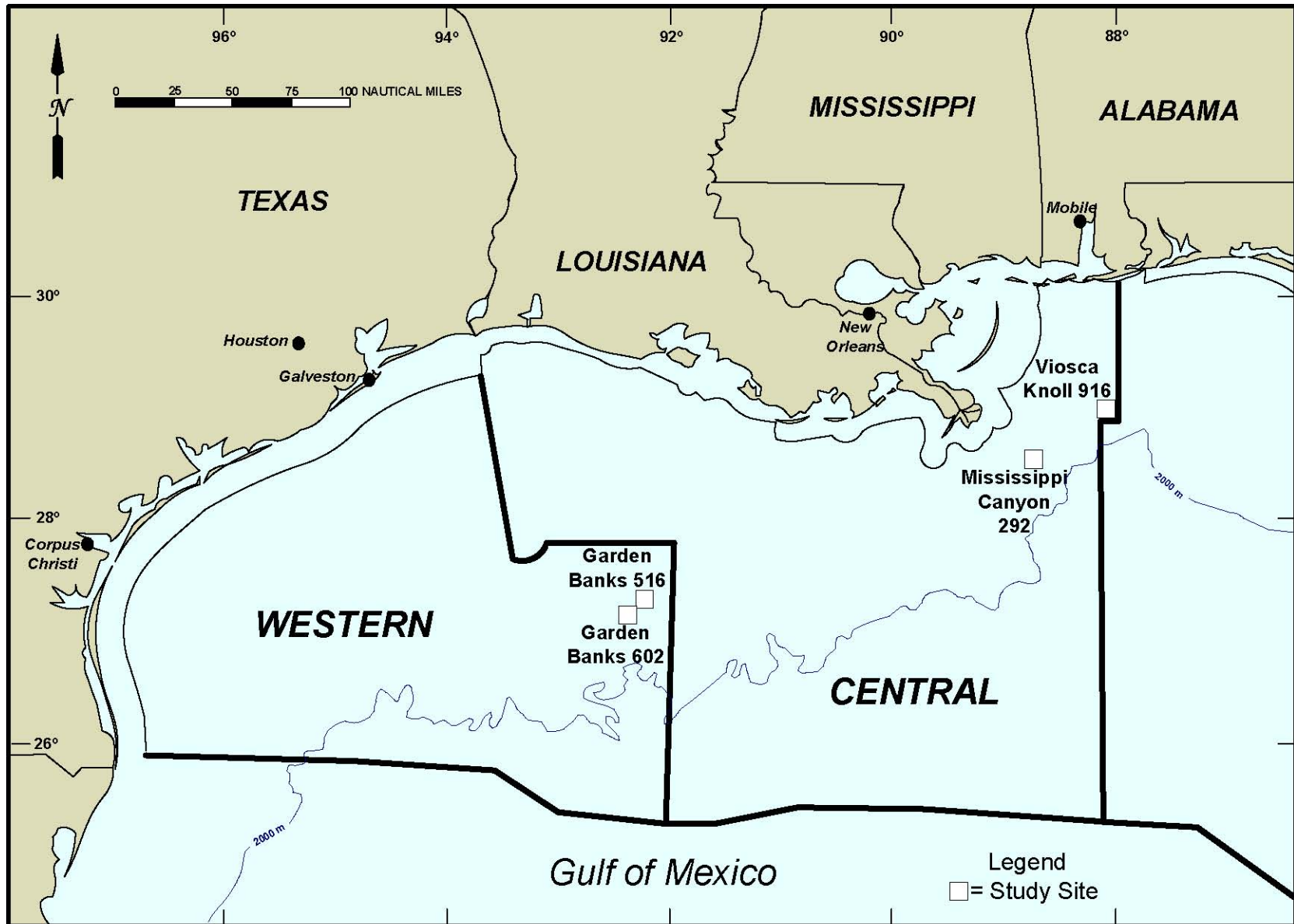
STUDY PRODUCTS: Continental Shelf Associates, Inc. 2006. Effects of Oil and Gas Exploration and Development at Selected Continental Slope Sites in the Gulf of Mexico. Volume I: Executive Summary, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2006-044. 51 pp.

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*P.I.'s affiliation may be different than that listed for Project Managers.



STUDY AREA FOR "DEEPWATER PROGRAM: EFFECTS OF OIL AND GAS EXPLORATION AND DEVELOPMENT AT SELECTED CONTINENTAL SLOPE SITES IN THE GULF OF MEXICO."