MMS OCEAN SCIENCE
VOLUME 1 ISSUE 2
MARCH/APRIL 2004
THE SCIENCE & TECHNOLOGY JOURNAL OF THE MINERALS MANAGEMENT SERVICE

Giant Tools for Exploring the Deep

Moving Into Deepwater

Deepwater Communities

Na Kika – Challenge & Innovation

Artificial Deepwater Reefs

MARCH/APRIL 2004
Volume 1 Issue 2

MMS OCEAN SCIENCE is published bi-monthly by the Minerals Management Service to communicate recent ocean science and technological information and issues of interest related to offshore mineral recovery, ocean stewardship, and mineral revenues.

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ABOUT THE COVER

Top: The drillship *Discoverer Deep Seas. Photo courtesy of Transocean.*

Bottom: An Autonomous Underwater Vehicle (AUV) used for exploring the seafloor. *Photo courtesy of C&C Technologies.*

All photos courtesy of Minerals Management Service unless otherwise noted.

Publication services provided by Schatz Publishing Group

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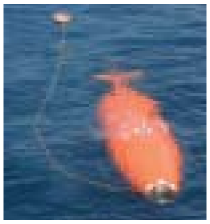
DRILLSHIPS GIANT TOOLS FOR EXPLORING THE DEEP

Left: Artist rendition of a drillship showing the riser and connection to the blowout preventer at the seafloor. Below left: Autonomous underwater vehicle used to explore the seafloor. Photo courtesy of C&C Technologies. Below right: Deepwater blowout preventer (BOP). Below: Remotely operated vehicle used for installing BOPs and repairing equipment at depth.



As exploration activities extend farther into the deepwater Gulf of Mexico, industry is finding new technologies to reach the oil and gas resources lying beneath the ocean floor. The most impressive of these new technologies are the giants of the sea – deepwater drillships.

In November 2003, ChevronTexaco, using Transocean's *Discoverer Deep Seas* drillship, set a new world water-depth record for drilling in 10,011 feet of water. How deep is that? Imagine stacking the world's nine tallest buildings top to bottom from the Petronas Tower to the Empire State Building. You would still be over 500 feet short of the record.

The *Discoverer Deep Seas* is a drillship of amazing complexity; it is almost as tall as the length of a football field and nearly as long as three fields placed end zone to end zone. This massive drillship is constructed with more than 75 million pounds of steel…equal to the weight of over 1,300 empty flatbed railcars!

To drill in the deepwater Gulf successfully, the ship must use special tools that allow safe drilling despite strong currents, high water pressure, and cold temperatures.

Among the vital equipment on any drill rig is a blowout preventer (BOP), which secures the well in case of a blowout and serves as a method to relieve well pressure. The BOPs are rated according to the depth of water they can withstand and the amount of pressure they can hold back (typically 10,000 to 15,000 pounds per square inch). For deepwater drilling, the BOP attaches to the wellhead on the seafloor and is computer controlled through cables run from the surface. The BOPs may be as tall as 45 feet and weigh as much as 640,000 pounds.

The drilling riser provides a way for drilling fluids and cuttings to return from the wellhead to the surface. The riser is constructed of 75-foot lengths of 21-inch diameter pipe. The risers connect the drilling ship itself to the BOP which, in turn, is attached to the wellhead.

Drilling mud is used to lubricate the drill bit, to keep the formation fluids from entering the wellbore, and to circulate out cuttings to the surface. The weight of the mud has to be sufficient to keep formation fluids from entering the wellbore but not so heavy that the rock fractures and the circulation is lost.

A riser tensioner system consisting of giant hydraulic cylinders is used to help support the weight of the drilling riser, the drilling fluid it holds, and the BOP.

Drilling in deepwater is never easy, and the deeper you drill, the more difficult it becomes. The potential risks include oil spills, worker accidents, and effects on the surrounding environment. These giant drillships are helping to minimize or eliminate the risks by using innovative new safety and exploration tools or improved versions of old, "tried and true" ones. Who will set the next record for deepwater drilling? That is unknown, but what is known is that the drilling will be as safe and environmentally responsible as industry and MMS can possibly make it!

MOVING INTO DEEPWATER

Above: The submarine Johnson Sea-Link. *Photo by Gregory S. Boland.*

The typical shallow-water oil well produces 100 barrels of oil a day, but deepwater (greater than 1,000 feet deep) wells are producing 30,000 barrels in the same period! With such high recovery amounts, why hasn't the deepwater Gulf of Mexico been developed long before now? The answer lies in a complex combination of economic, environmental, informational, and technological challenges.

In the early 1970s and 1980s, the Minerals Management Service (MMS) limited the size and location of offshore leases. However, concern about dependence on foreign oil prompted the Government to rethink its leasing policies. Although the policies were relaxed, the 1986 oil price bust led to reduced exploration and leasing activity. It was not curtailed for long, however. In 1987, Shell's discovery in the Auger field opened industry eyes to the amount of oil lying under the Gulf. But the costs of exploration and the necessary infrastructure for development in the deepwater Gulf can be enormous. Congress recognized that economic incentives were vital to future expansion. The Deep Water Royalty Relief Act (DWRRA), passed in 1995, provided royalty relief in specific water depths. According to MMS statistics, as a result of the DWRRA, the percentage of deepwater leases rose from 17% of the total leases in 1994 to 70% in 1997. The expansion in deepwater activity was led by several factors including royalty relief and advances in technology.

Increased interest in deepwater leasing and exploration was accompanied by a greater awareness of the need to know more about the marine environment before deepwater exploration moved full speed ahead. It soon became clear that the job of studying and protecting the environment needed the input of both MMS and other stakeholders. So, MMS enlisted the help of academia and industry by holding a workshop. Together they compiled a list of the information they felt was vital to ensure the protection of the environment and the safety of workers.

Four priorities for study were identified by MMS and its academic and industry partners:

1. Characterize the rates and effects of deepwater blowouts or pipeline leaks.
2. Initiate a Gulfwide study of the ecology of deepsea life.
3. Undertake intensive observations of the currents in the deep Gulf.
4. Analyze the socioeconomic effects of deepwater development and exploration on ports and coastal facilities.

Studies addressing each priority were initiated and continue to add to a database of scientific and environmental information that will guide future exploration and leasing plans.

Exploring and developing the deepwater Gulf is not only an environmental challenge, it is a technological challenge. Not only are developers drilling deeper than ever before, but they are drilling in relatively high-speed currents, among newly discovered animal communities and atop salt layers that can inhibit seismic data gathering. New advances in technology and exploration methods are happening almost daily and the volume of regulatory oversight concerning their implementation is growing with them.

Because technology is advancing so rapidly, the industry saw the need for greater flexibility and speed in the approval process. To meet this challenge, MMS developed a Deep Water Operations Plan (DWOP) process to

UNIQUE CHALLENGES

Deepwater exploratory wells for oil and gas can cost $25 to $40 million per well, and it is not unusual for that cost to quickly rise to $80 or even $100 million because of delays and other issues. With limited budgets, the operators are looking for ways to cut costs without increasing risk.

One example of this scenario occurred during a ChevronTexaco project. ChevronTexaco hired the Transocean drill ship *Discoverer Deep Seas* under a long-term contract. Upon completion of the Toledo Project, ChevronTexaco planned to drill the Tiger Prospect with the *Discoverer Deep Seas* at a location only 9 miles away. While drilling the Toledo, ChevronTexaco approached the MMS with a plan to cut several days from their drilling plan.

The deployment of the riser and the blowout preventer (BOP) system takes up to two and a half days to complete, as does their retrieval. Each of these five days in the drilling schedule cost ChevronTexaco approximately $400,000 for the rig and for hiring specialty personnel. After analyzing the effects and costs of pulling the riser to surface, ChevronTexaco and Transocean proposed to pick the BOP 2,000 feet off the bottom and sail slowly to the Tiger field. Oceanographers were consulted and further analysis was performed to determine the effects of the currents and the additional loads from the travel on the riser system. A safe transit speed was calculated on the basis of the analysis. The MMS approved the procedure and the move was successfully made, saving over $1 million.

…exploration was accompanied by a greater awareness of the need to know more about the marine environment in the Gulf…

Above: A blowout preventer (BOP) used for deepwater drilling projects. Note the man standing on the top.

provide a means by which industry can learn, well in advance of significant spending, if new methods of development and production are acceptable to MMS. In many cases, custom designs are being developed, employing new space age materials and unique operating characteristics, all of which need to be independently verified by MMS through the Technical Assessment and Research Program, ensuring safety of operations and protection of the environment.

At present, there are more than 90 oil and gas discoveries in the deepwater Gulf of Mexico. A wide-ranging strategy for exploring and developing deepwater and ultra deepwater (greater than 5,000 feet) in the Gulf of Mexico has been developed and continues to be updated by MMS, industry, and academia to protect both workers and the environment. Encouraging development while protecting the environment, improving the identification of our Nation's resources, and protecting the safety of its citizens are the challenges of deepwater. And as we move even deeper, the challenges will continue to grow – and so will the rewards.

For more information on Deepwater Development:

Deepwater Development: A Reference Document for the Deepwater Environmental Assessment, Gulf of Mexico OCS (1998 through 2007) (MMS Publication 2000-015)

Website: www.gomr.mms.gov/homepg/whatsnew/publicat/gomr/00015.pdf

Deepwater Gulf of Mexico 2002: America's Expanding Frontier (MMS Publication 2002-021)

Website: www.gomr.mms.gov/homepg/whatsnew/techann/2002-021.pdf

Deepwater Research by MMS' Technical Assessment and Research Program

Website: www.gomr.mms.gov/tarprojectcategories/deepwate.htm

Above: A deep-sea crab, Rochinia crassa. *Long appendages are considered by some as a deep-sea adaptation to prevent sinking into soft oozes. Photo by Gregory S. Boland.*

EXPLORING THE COMMUNITIES OF DEEPWATER GULF OF MEXICO

DENSITY & DIVERSITY

The Gulf of Mexico is 12,000 feet deep at its deepest point. Life at that depth must be able to survive harsh conditions. Yet, even in these seemingly inhospitable environs, animal communities thrive. And we are just beginning to understand the extraordinary diversity that inhabits the depths.

There are two general categories of benthic (bottom-dwelling) communities in the Gulf: those that live in or on soft sediments, which allow the animal to burrow and hide, and those that attach themselves to the hard surfaces on the bottom(such as coral or sponges). But in either category, the communities confront cold temperatures, tremendous water pressure, and a lack of light and food.

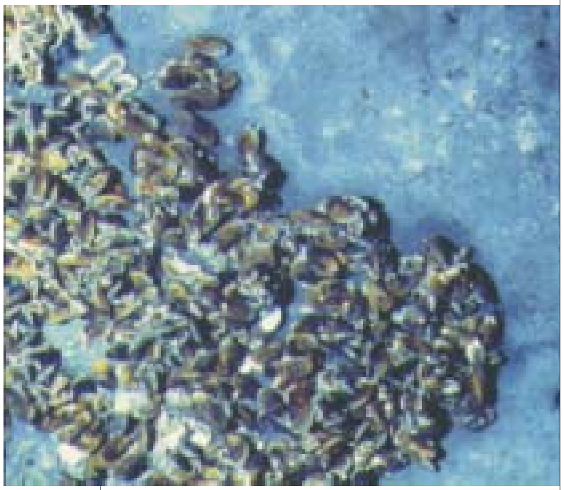
The surface waters of the Gulf are warmed by sunlight and air temperature. But as one travels deeper into the depths, the water becomes colder – eventually reaching a temperature of approximately 39 degrees F. at around 3,300 feet. Below that depth, the water temperature remains roughly the same.

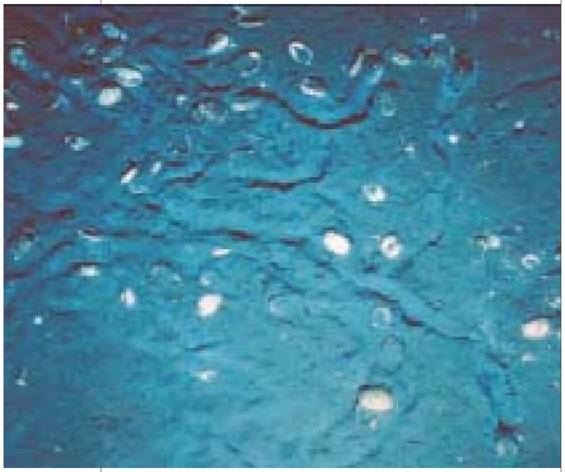
A man standing on the shore of the Gulf will experience 14.7 pounds of pressure per square inch (called one atmosphere). But as he descends below the water, he experiences an increase of approximately one atmosphere for every 33 feet he descends. According to industry, the deepest recorded dive by an unassisted skin diver is 60 meters (197 feet). The deepest recorded dive by a scuba diver is 313 meters (1,027 feet). But benthic communities can survive even at the deepest part of the world's oceans at 36,000 feet.

The Gulf food chain begins at the water's surface. Small animals known as zooplankton graze on single-celled plants called phytoplankton, which produce their own food through photosynthesis. Zooplankton are eaten by small fish, which are eaten by larger fish. The leftover biological waste and digested food will sink to the bottom and has been described as an "organic rain." But despite the "rain," the benthic communities that dwell in sediment layers exist in an energy-poor environment. The majority of animals in the deepwater Gulf feed by straining the water, sweeping sediments, or scavenging for decaying bits of organic matter. The exception is the Gulf's chemosynthetic communities.

Despite the total absence of light, chemosynthetic communities thrive in the Gulf. They live on dissolved gases through a symbiotic relationship with specialized bacteria living in their tissues.

Research sponsored by MMS has identified four major types of chemosynthetic communities: tube worms, mussels, large clams living on the surface, and small clams living





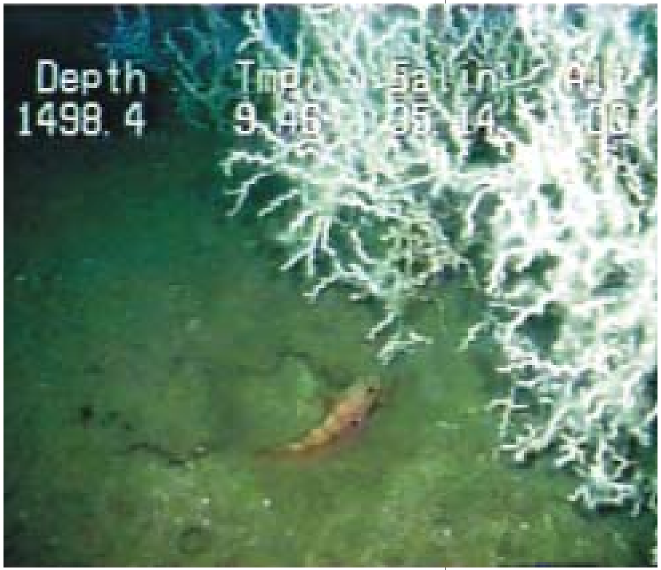
A chemosynthetic mussel bed (top) and a chemosynthetic assemblage of clams (above) living in the vicinity of hydrocarbons seeping from the bottom. Note how sharply defined is the boundary between the mussel bed and the surrounding soft bottom. Deep-sea images by Gregory S. Boland.

Fishes of the Deep . . . . *Deep-sea images by Gregory S. Boland*

Ray

Scorpion Fish

Hake



Above left and above: Deepwater Lophelia *coral in dense thickets located less than 55 miles east of the Mississippi River delta. Photos courtesy of Harry Roberts/LSU.*

beneath the mud. All of them use symbiotic bacteria to convert dissolved methane or sulfide into a carbon food source. These animals, which exist around hydrocarbon seeps, create new habitat that attracts other snails, fishes, worms, sea stars, shrimp, and crabs. The result? A greater biomass than that of the surrounding seafloor.

What effect does oil and gas exploration have on these diverse animal communities? All indications thus far are positive and it appears that energy production in the Gulf has not harmed these communities at all. Before exploration is done in the deep Gulf, a special environmental review is undertaken to determine its potential effect on any nearby sensitive biological communities. Even areas that have the possibility of harboring chemosynthetic communities are avoided. To learn more about where these unique communities exist, new studies are underway to foster better understanding of the fragility or robustness of deep-sea marine life. A more complete knowledge of these benthic communities will enable MMS to make better decisions to protect the density and diversity of each community.

For more information on Deepwater Communities:

Characterization of Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral (GM-03-02)

Website: www.gomr.mms.gov/homepg/regulate/environ/ongoing_studies/gm/GM-03-02.html

Northern Gulf of Mexico Continental Slope Habitats and Benthic Ecology (MMS Publication 2002-063)

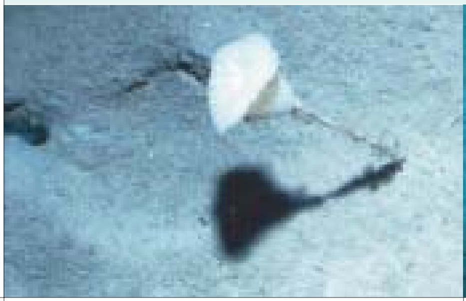
Website: www.gomr.mms.gov/homepg/regulate/environ/studies/2002/2002-063.pdf

Stability and Change in Gulf of Mexico Chemosynthetic Communities (MMS Publication 2002-035)

Website: www.gomr.mms.gov/homepg/regulate/environ/studies/2002/2002-035.pdf

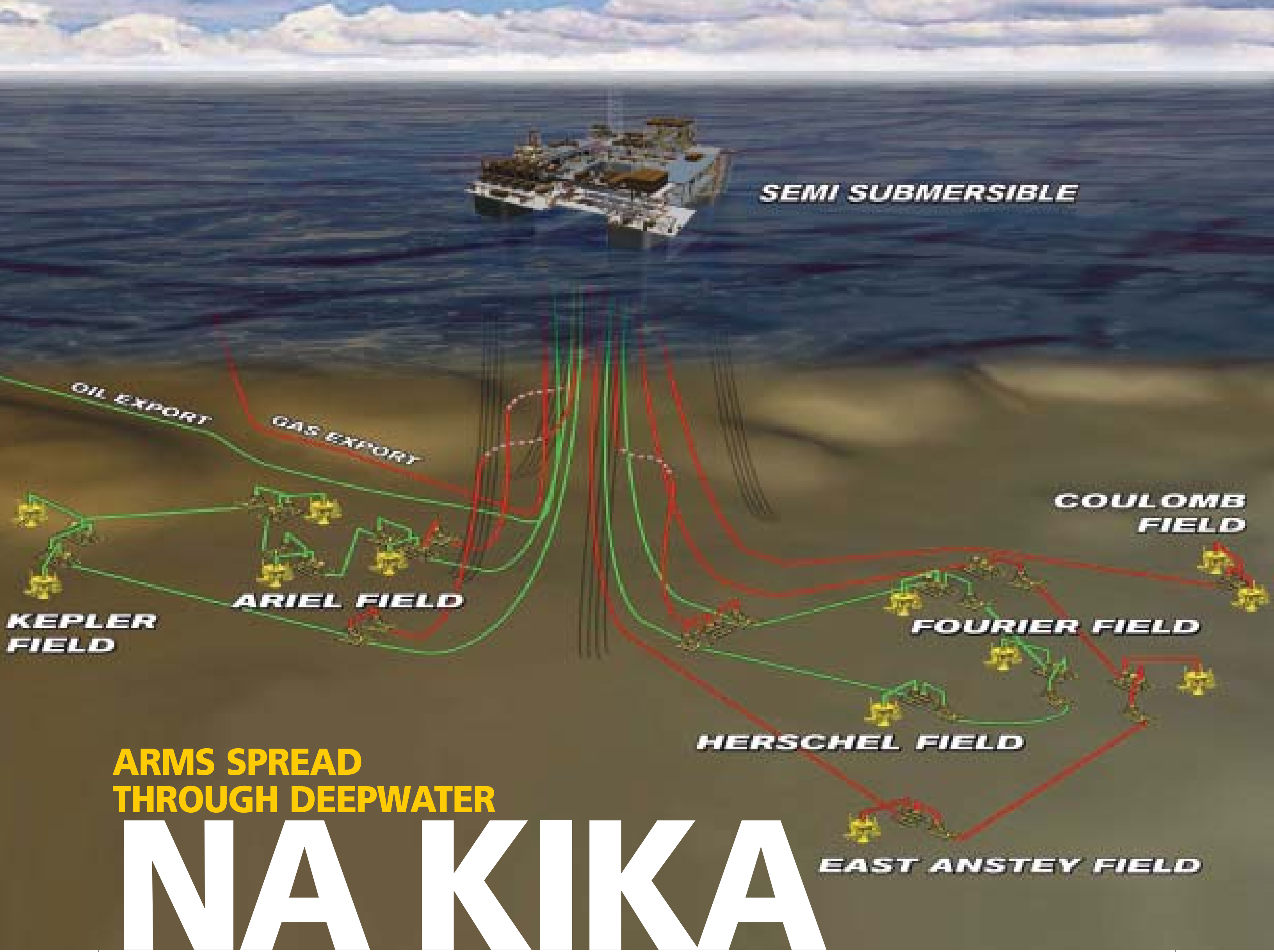
Invertebrates of the Deep . . . . *Deep-sea images by Gregory S. Boland*

Sponge



Anemone

Squid



Above: The Na Kika complex, tying six fields to a host facility. Artist rendition courtesy of Shell Offshore Companies.

ARMS SPREAD THROUGH DEEPWATER

NA KIKA

BRINGING CHALLENGE & INNOVATION TO THE GULF OF MEXICO

As improvements in exploration and scientific techniques advance and our energy needs continue to increase, the economic development of resources in the Gulf of Mexico becomes more attractive for oil and gas companies. The Minerals Management Service (MMS), cognizant of the costs, risks, and technological challenges of deepwater development, has attempted to ease the way for such development while continuing to protect the environmental health and safety of the Gulf. One example of the partnership of government and industry bringing new technology to the Gulf is the Na Kika project.

The Na Kika facility sits atop six independent fields approximately 140 miles southeast of New Orleans in 5,800 to 7,600 feet of water. Located in Mississippi Canyon Block 474, the Kepler, Ariel, and Herschel fields are primarily oil, while the Fourier and East Anstey fields are primarily gas. It is estimated that Na Kika will ultimately recover 300 million barrels of oil at a total project cost of $1.26 billion, excluding lease costs.

Appropriately named for the multi-armed octopus god of the Gilbert Islands, Na Kika is the largest subsea umbilical project in the world. Owned jointly by Shell (responsible for the design and installation) and BP (responsible for production), the permanently moored floating facility is setting world records and achieving technological firsts in the deepwater Gulf of Mexico. It hit the deepest water depth ever for a development well, installed the first pipe-in-pipe risers in the world and is the first deepwater subsea well with three co-mingled reservoirs.

Na Kika is an engineering marvel. Reviewing all the technological innovations that were necessary to construct and operate the platform was (and is) a daunting task.

Realizing the value of academia and industry in helping it keep abreast of those and other new innovations, MMS has chosen to participate in DeepStar, an industry consortium formed to address the unique technological challenges posed by deepwater exploration and development.

The partnership between DeepStar and MMS has allowed participants to address issues of concern and to cooperate in finding answers to those concerns without undue delays in implementing innovative technology. The goal of both organizations is to meet safety and environmental mandates while encouraging further exploration and development in the Gulf of Mexico.

To that end, the Deepwater Operations Plan (DWOP) was created to address the technological challenges associated with deepwater exploration and development. The DWOP allows developers to submit proposed new technologies and methods ahead of time so that they can know whether these new methods will be acceptable to MMS. It also allows MMS and industry to discuss possible alternatives and allows flexibility in the encouragement and implementation of new ideas. The MMS also works with industry through the Offshore Operators Committee (OOC), an industry cooperative formed to address operational issues in the Gulf of Mexico.

The use of a semisubmersible floating platform such as Na Kika in the Gulf was the subject of study by both environmental and engineering

Above: Na Kika semisubmersible platform, all 40,000 tons, being transported offshore. Photo courtesy of BP Exploration & Production Inc.

representatives. Their technological and environmental concerns were raised after the recent accident of P-36, a platform of similar design that sank off Brazil in 2001. The results of the investigation in the accident led to the determination that P-36 sank as a result of a sequence of events that began with the undue pressure and subsequent rupture of a drain tank. Before approving the construction of Na Kika, MMS initiated an extensive review of those events and called for the creation and implementation of safeguards to ensure that a similar incident would not occur in the Gulf of Mexico. The developers of Na Kika, Shell Oil and BP had initiated a similar, thorough review.

As industry moves deeper into the Gulf of Mexico, the challenge to balance economic and development issues on one hand and safety and environmental concerns on the other will continue to grow. But technological innovations and improved methods of exploration that address those concerns are being developed almost daily. And, as with the Na Kika project, the cooperation between MMS, academia, and industry will make the move to deepwater both economically and scientifically

A WELL BY ANY OTHER NAME – NAMING DISCOVERIES IN THE GULF

What would you do if you wanted to talk about your great oil discovery in the Gulf but you didn’t want anyone to know where it was? You’d pick a nickname for your discovery! Perhaps you’d refer to your find as Na Kika, or Bullwinkle, or even a racehorse. And how do you pick a name for your new discovery? Just look at some of the current nicknames being used in the Gulf – the possibilities are endless!

Mythological creatures are popular nicknames for platforms in the Gulf. Na Kika, the largest subsea umbilical project in the world, is named for the multi-armed octopus god of the Gilbert Islands. Other projects named after mythological creatures include Medusa, Ariel, Poseidon, or Triton.

Some names are descriptive pictures of the platform itself. Bullwinkle, the name of the tall and lanky moose of cartoon fame, is appropriate for the world’s tallest fixed platform. Other projects named after television characters include Popeye, Rocky (Bullwinkle’s ever-present partner), Mad Dog, and King Kong.

Other projects are named after powerful geologic structures such as the Matterhorn or Devil’s Tower. Some are named for geographical areas like Morpeth, Tahoe, Allegheny, Holstein, Camden Hills, Aspen, or Serrano. Seattle Slew is named for a champion racehorse, and Balboa and Marco Polo are named for famous explorers.

But the nicknames of some projects are not so easily classified! What images do Arnold, Macaroni, Oregano, and Ladybug bring to mind? They may just reflect the sense of humor of the company naming them!

Although MMS provides a system for the official names of fields and wells, the nicknames chosen by oil and gas exploration companies remains a purely creative and perhaps lighthearted aspect of the serious technical business of exploration.

FOR MORE INFORMATION:

Deepwater Operations Plan Guidelines

Website: www.gomr.mms.gov/homepg/regulate/regs/ntls/00-n06a2.pdf

DEEPWATER POINTS OF INTEREST

Deepwater Program

The Archaeological and Biological Analysis of World War II Shipwrecks in the Gulf of Mexico: A Pilot Study of the Artificial Reef Effect in Deepwater

The MMS has announced the funding of a pilot study to examine the artificial reef effect of World War II shipwrecks in the deepwater region of the Gulf of Mexico. This study is a joint partnership between MMS and NOAA's Office of Ocean Exploration, through the National Oceanographic Partnership Program (NOPP), and is designed to conduct a biological and archaeological investigation of seven World War II shipwrecks in water depths ranging from 400 to 6,500 feet.

The biological component of this study is intended to approach one basic question: do man-made artificial structures or objects, i.e., shipwrecks, function as artificial reefs in deepwater? Although there is not yet a complete understanding of how artificial reefs function on the continental shelf, particularly in the photic zone above 100 meters (328 feet), it is generally accepted that artificial reefs can serve a positive function by the creation of new hard-bottom habitat in areas where hard-bottom is naturally lacking (most of the Gulf of Mexico).

The archaeological objective of the study is to ground-truth, document, positively identify, and assess the National Register status of seven wrecks sunk during World War II. This objective will require both historical research and field investigation to be conducted for each site.

For more information:

Study Summary

Website: www.gomr.mms.gov/homepg/regulate/environ/ongoing_studies/gm/GM-03-07.html

Past Foundation

Website: www.pastfoundation.org

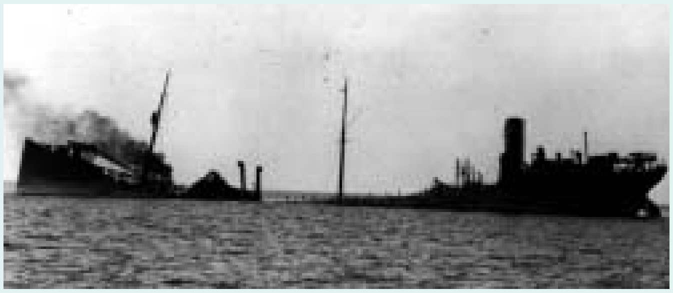
NOPP

Website: www.nopp.org/

www.nopp.org/iDuneDownload.dll?GetFile?AppId=103&FileID=255534&Anchor=&ext=.pdf

NOAA Office of Ocean Exploration

Website: www.oceanexplorer.noaa.gov/



Right: The oil tanker David McKelvy *shortly after being torpedoed by the* U-506, *May 13, 1942.*

Extended-Reach Drilling in Deepwater at Platform Heritage

Platform Heritage stands in 1,075 feet of water in the Santa Barbara Channel, a mere 8 miles off the coast of California. Installed in 1989, this 60-slot platform's first production was from the Pescado field. About 40 wells (including sidetracks and redrills) have been drilled to date in the field, producing from the Monterey formation heavy oil reservoir and lighter gravity oil sandstone formations, with peak production at 62,000 barrels of oil per day in 1995. ExxonMobil, the operator, had originally planned a new platform to develop the adjacent Sacate field, but advanced drilling and production technology eliminated this need. Instead, they are developing the Sacate field using extended-reach wells from Platform Heritage. The longest reach Sacate well has 21,277 feet of horizontal displacement. Peak production from the Sacate field was approximately 10,000 barrels of oil per day in 2001. Twelve extended-reach wells have been drilled to date; extended-reach drilling has proven to have less impact on the environment than installing new platforms and pipelines. Future wells are in the planning stages as additional reserves are identified. As with other areas of the OCS, extended-reach wells are providing access to greater resources with fewer platforms. Both fields are part of the Santa Ynez Unit, which incorporates 16 leases and two other platforms and associated pipelines.

Oil and Gas Milestones of the Gulf of Mexico

- **First Gulf Discovery –**
  1947 at Kerr-McGee's Ship Shoal 32, 10 miles off the Louisiana coast in 18 feet of water. 56 years later, it is still producing!
- **Deepest Water Depth –**
  10,011 feet by the Transocean drillship *Discoverer Deep Seas* on November 16, 2003, at Alaminos Canyon Block 951 on ChevronTexaco's Toledo prospect.
- **Tallest Fixed Platform –**
  Bullwinkle's structure, completed in 1983, is the world's tallest pile-supported, fixed steel platform and is taller than the Empire State Building.
- **First Floating Production Facility –**
  Auger, a tension leg platform, installed in the Gulf of Mexico in 1987.
- **First Production SPAR –** Neptune, installed by Oryx in 1996.
- **Largest Discovery –**
  Thunder Horse, discovered in 1999.
- **Deepest OCS Production –**
  Na Kika will become the deepest OCS production at 7,600 feet in 2004.

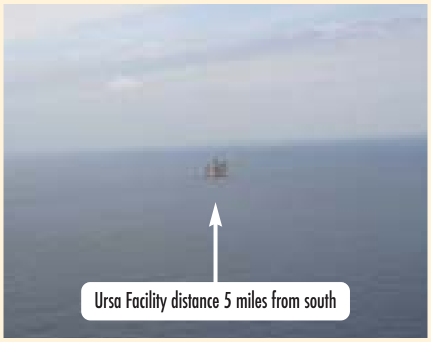
Photo courtesy of Naval Research Laboratory.

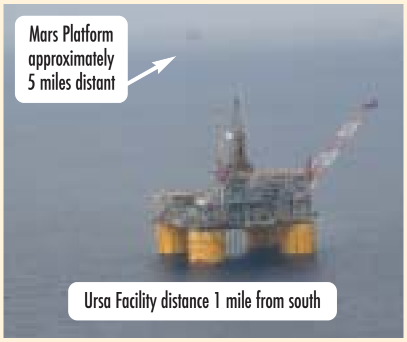
Gas Hydrates: Ice That Burns

Gas hydrates are naturally occurring ice-like solids in which water molecules trap gas molecules in a cage-like structure known as a clathrate. Gas hydrate looks very much like ordinary ice, but if you put a match to it, it burns with a soft orange flame, like the pilot light on a gas stove.

Although many gases form hydrates in nature, methane hydrate is the most abundant natural gas. Hydrates are found in locations with high pressure and low temperature, such as near-surface sediments in deepwater environments. The volume of carbon contained in methane hydrates worldwide is estimated to be twice the amount contained in all fossil fuels on Earth, including coal.

Platform Size – Coming Into View





Yes, Ursa is large – but in the expanse of the open Gulf, it's easy to lose your perspective. Even though we talk about 4,000 structures offshore, the area occupied by these structures is less than one ten-thousandth of a percent of the Gulf of Mexico!

Manage the Nation's offshore resources; protect the ocean environment

Na Kika in the Gulf of Mexico. Photo courtesy of BP Exploration & Production.

NEW WAVES

Late-breaking News & Information

"One fundamental tool on the horizon for advancing our understanding of the marine realm is the Integrated Ocean Observing System. Successful implementation of the IOOS will be a huge advance in our ability to observe, monitor, and forecast ocean conditions."

– Admiral James D. Watkins, U.S. Navy (Retired) Chairman,
U.S. Commission on Ocean Policy, 2003

Working with other members of the National Oceanographic Partnership Program (NOPP), the Minerals Management Service (MMS) is working with Ocean.US, NOPP's office for integrating ocean observing activities, to make IOOS a reality. The MMS Alaska Outer Continental Shelf Region will be working with Ocean.US and the Alaska Ocean Observing System to plan the study entitled *Surface Circulation Radar Mapping in Alaskan Coastal Waters: Field Study Beaufort Sea and Cook Inlet.* The development of the IOOS requires an effective synergy between research and more operational elements, and this 2004 MMS study fits the bill! Stay tuned for future developments!

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