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Understanding Ocean Engineering: Gulf Currents & HAZMAT Issues

Michael Klein., P.E., CHMM

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What is an Ocean Engineer?

- Ocean engineers combine several types of engineering. It is a mix of techniques and skills from:
  - Mechanical
  - Electrical
  - Civil
  - Chemical
- We have experience and expertise in the application of engineering principles for successful outcomes in ocean environments.

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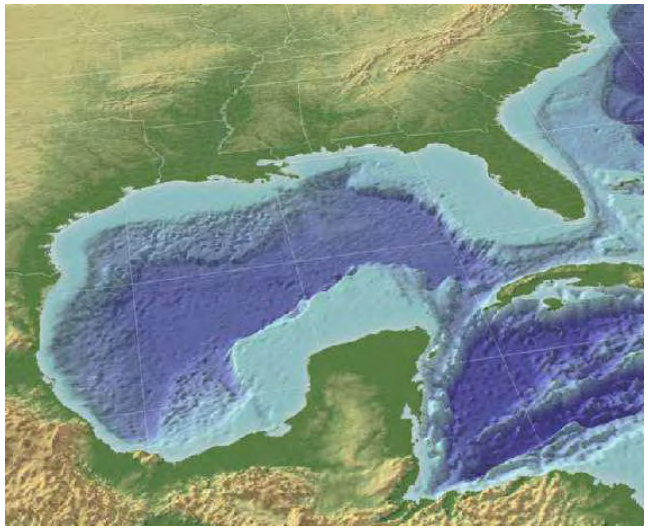
Gulf of Mexico: *Geography*

- The Gulf of Mexico is a dynamic, almost landlocked body of water dominated by prevailing southeast winds and influenced by the Gulf Loop Current and Mississippi River flow.
  - Bordered on the east by the Florida peninsula, to the north by Alabama, Mississippi and Louisiana.
  - To the west by Texas, Mexico and the Yucatan peninsula.

Gulf of Mexico: *Geography*



- Bordered and nearly landlocked by North America and Mexico
- Connects to Atlantic Ocean via Florida straits north of Cuba
- Connects with Caribbean Sea via Yucatan Channel between Mexico and Cuba

- Area of 615,000 sq. miles
- Sigsbee Deep at 3804 meters deepest point
- Site of 65 million year old Chicxulub crater

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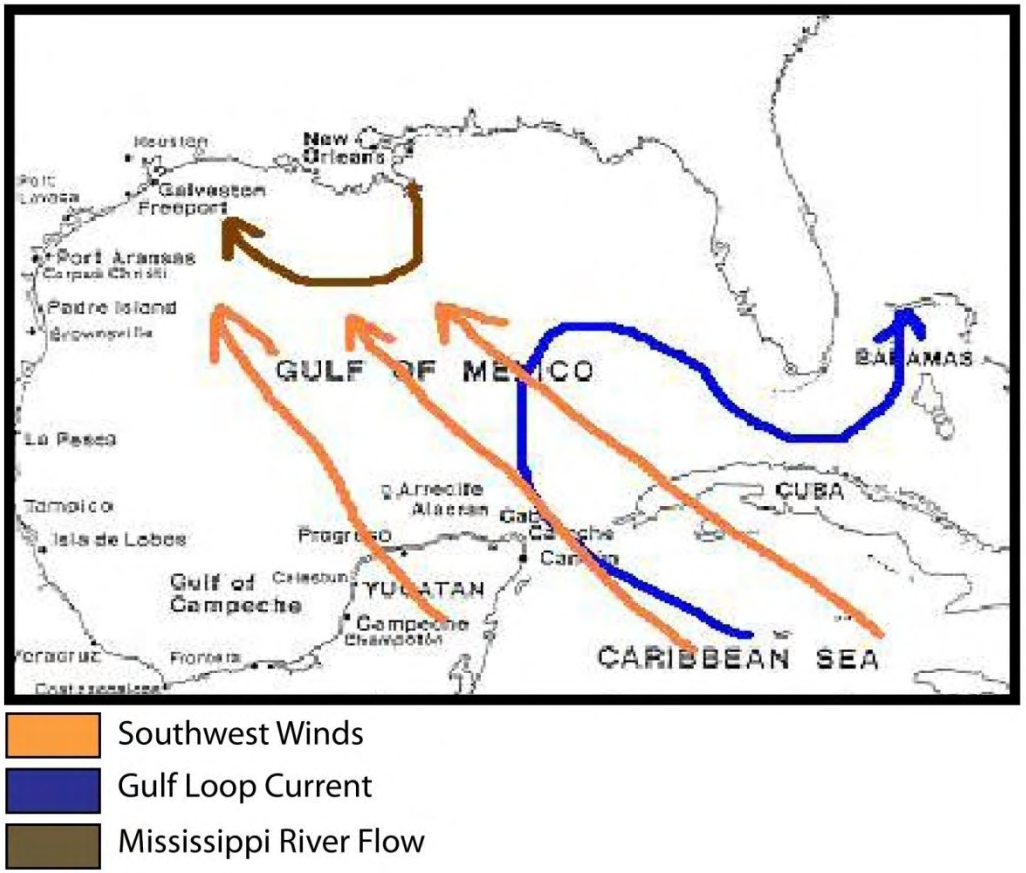
Gulf of Mexico:
Currents and Prevailing Winds



Source: University of Texas at Austin Marine Science Institute

Gulf of Mexico:
Currents and Prevailing Winds

- Prevailing winds blowing from the southeast move Caribbean water through the pass between Yucatan and western Cuba, forming the Gulf Loop Current.
- This current moves north towards the Mississippi and Alabama coast lines then curves south along the west coast of Florida and exits the Gulf between the Florida Keys and the north shore of Cuba.

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Gulf of Mexico:
Currents and Prevailing Winds

- The Gulf Loop current moves north along the east coast of Florida and joins the Antilles current, forming the Gulf Stream.
- The Gulf Stream travels north up the east coast of the United States then curves east towards Europe. It carries warm, tropical water north.
- This is one of the reasons that commercial fisheries off the Grand Banks in New England are so productive.

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Gulf Currents and Oil Spill Interaction

- Current data indicates that the spreading oil slick has grown in size so that it is poised to connect with the Loop Current that sweeps around the Gulf.
- Once "entrainment" (oil is incorporated into the Gulf Current) occurs, the oil would be pulled quickly south along Florida's Gulf coast and out into the Florida Straits, between the United States and Cuba.

Gulf Currents and Oil Spill Interaction

- Should the oil slick enter the Florida Loop Current ocean circulation models show it heading out to sea, past the Dry Tortugas islands, before it is caught up in the Gulf Stream and makes its way up the U.S. East Coast.
  - Whether or not the oil spill will get into shallow water on its possible ocean journey would be totally dependent on winds

Gulf Currents and Oil Spill Interaction

- Depending on local winds, Florida's southwest beaches and the Florida Keys, along with coral reefs and the fragile ecosystem of the Everglades, could be spared from the oil slick.
- The oil making landfall anywhere will depend on what the winds are doing at that particular point in time.

Hazmat Considerations of Crude Oil

- Crude Oil (CAS number 8002-05-9): Crude oils vary in physical characteristics such as color, viscosity and specific gravity.
- Color ranges from light yellow-brown to black.
- Viscosity varies from free-flowing to a substance that will barely pour.
- Specific gravity is used to classify crude oil as light, medium (intermediate), or heavy.
- Crude oil, which may consist of hundreds of individual compounds must be refined to separate the constituent into useful fractions.
- Each crude oil is a unique mixture, not matched exactly in composition or properties by any other sample of crude oil.

Hazmat Considerations of Crude Oil

- Individual compounds of crude oil can be classified into the following two categories:
  - Hydrocarbons, which include alkanes (normal and branched chains), cycloalkanes, alkenes, aromatics, naphthenoaromatics; and
  - Non-hydrocarbons, which include nitrogen, sulfur and oxygen (NSO) compounds, asphaltenes and resins (including NSO heterocyclics), metallo-organics, and inorganic metal salts.

General Hazard/Toxicity Summary

- In general, spilled oil is most harmful when shallow, productive waters; porous sediments; low energy aquatic environments or special-use habitats are affected.
- Examples of high risk locations are
  - Wetlands
  - Sheltered tidal flats
  - Shallow bays
  - Coarse sand and gravel beaches
  - Sites with concentrated reproductive and migratory activities

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Petroleum Impact: *Fish*

- Crude oil and petroleum products vary considerably in their toxicity, and the sensitivity of fish to petroleum varies according to species.
- The water soluble fractions of crude oil can stunt fish growth.
- The impacts to fish are primarily to the eggs, larvae, and early juveniles, with limited effects on the adults.

Petroleum Impact: *Fish*

- The general effects of petroleum are difficult to assess and quantitatively document due to the seasonal and natural variability of the species.
- Fish rapidly metabolize aromatic hydrocarbons due to their enzyme system.

Potential Effects of Petroleum: *Fish*

- There are several potential effects of petroleum on the fish
  - depressed feeding.
  - decreased swimming activity and increased mortality (observed effect).
  - mortality to eggs and larvae.
  - mortality or other effects of fish maintained in mariculture enclosures
- Finally, there are several sublethal effects such as fin erosion, ulceration of the integument, liver damage, lesions in the olfactory tissue, reduced hatching success, reduced growth, change in egg buoyancy, malformations that interfere with feeding, arrest of cell division, and genetic damage.

Potential Effects of Petroleum: *Fishing Industry*

- Potential effects include:
  - exclusion of fishermen from the fishing grounds and other disruption of fishing which can change the population balance to date.
  - tainting of fish (such as change in flavor or smell) and the public's fear of tainting, mortality or other effects of non-motile inshore species.
  - loss of livelihood not only for fishermen but for other industries supported by this commodity.

Petroleum Impact: *Birds*

- Oiling of feathers is considered to be the primary cause of most bird deaths following oil spills
  - Oil disrupts the fine strand structure of the feathers resulting in
    - loss of water repellency and
    - in decreased body insulation

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Petroleum Impact: *Birds*

- Natural response to oil matted plumage is preening; oiled birds often ingest petroleum while attempting to remove the petroleum from their feathers.
  - The effects of ingested petroleum include:
    - Anemia
    - Pneumonia
    - Kidney and liver damage
    - Decreased growth
    - Altered blood chemistry
    - Decreased egg production and viability
- Chicks may be exposed to petroleum by ingesting food regurgitated by impacted adults.

Toxicity of Crude Oil

- The toxicity of crude oil can be interpreted as the toxicity of a complex mixture of inorganic and organic chemicals.
- Uncertainty exists in the use of dose-response relationships based on crude oil as a whole mixture.
- An alternative approach which is often used is the "indicator chemical approach."
  - This involves selecting a subset of chemicals from the whole mixture that represents the "worst-case" in terms of mobility and toxicity.

Indicator Chemical Approach

- This approach can be used with crude oil with the subsets of chemicals being:
  - Volatile organics such as benzene, toluene, ethylbenzene, and xylenes (known as BTEX; if present)
  - Polynuclear Aromatic Hydrocarbons (PAHs).
- BTEX are of interest because they are soluble in water, highly mobile in the environment, and represent the more volatile and soluble components of crude oil.

Indicator Chemical Approach

- Benzene is an EPA defined “Class A” carcinogen.
- PAHs are not highly mobile but are of interest because they are prevalent in crude oil, represent the heavier or less volatile crude oil components, and several are known animal carcinogens.
- PAHs and their transformation products are among the most hazardous constituents of crude oil.

Indicator Chemical Approach

- Crude oil contains, on the average, approximately 1% polynuclear aromatic hydrocarbons (PAHs).
- Concentrations of total carcinogenic PAHs (like benzo(a)pyrene) reported in the literature range from 12 mg/l to less than 100 ug/l.

Oil Weathering Process

- After oil is discharged into the environment, a wide variety of physical, chemical and biological processes begin to transform the discharged oil.
- Collectively, these processes are referred to as weathering, and act to change the composition, behavior, routes of exposure and toxicity of the discharged oil.

Oil Weathering Process

- Weathered oil is composed of relatively insoluble compounds, and often coalesces into mats or tarballs.
- As a result, the potential for exposure to fish through water column toxicity is lessened, as is the potential for birds or mammals to encounter the oil.
- For example, penetration of oil into marsh vegetation may depend on oil viscosity; weathered oils penetrate less than fresh oil.

Oil Weathering Process

- Alternatively, certain species are known to ingest tarballs and the potential for exposure to those resources may increase as the oil weathers.
- The loss of the lighter fractions through dissolution and/or evaporation during the weathering process can cause normally buoyant oil to sink.
  - Thereby contaminating subtidal sediment and contributing to water column toxicity.

Oil Weathering Process

- After the loss of the volatile, soluble, and easily biodegraded compounds, the remaining compounds can become concentrated.
- Weathered oil becomes less acutely toxic, but due to polynuclear aromatic hydrocarbons (PAHs) of high molecular weight, it remains toxic.

Oil Weathering Process

- The primary weathering processes are physical phenomena; these include:
  - Spreading
  - Evaporation
  - Dissolution
  - Dispersion
  - Emulsification
  - Sedimentation

Oil Weathering Process

- Chemical weathering processes include photo degradation and oxidation.
- Biological weathering processes include (microbial) biodegradation and ingestion and depuration by organisms.

Oil Weathering Process

- These processes occur for all discharges, but the rate and relative importance of each process depends on
  - spill characteristics,
  - environmental conditions, and
  - physicochemical properties of the spilled material.

Hazmat Response to a Release of Crude Oil

- Most crude oil is defined as Medium Oils per the NOAA/Hazardous Materials Response and Assessment Division (HMRAD) Shoreline Countermeasures Manual for tropical coastal environments.
  - About 1/3 will evaporate within 24 hours.
  - Maximum water-soluble fraction is 10-100 mg/l.
  - Oil contamination of intertidal areas can be severe/long term.
  - Impact to waterfowl and fur-bearing mammals can be severe.
  - Chemical dispersion is an option within 1-2 days.
  - Cleanup most effective if conducted quickly.

Response to an Oil Spill On Water: *Boom*

- Boom technology comes in many sizes, shapes, and types and is used primarily to deflect and/or collect oil.

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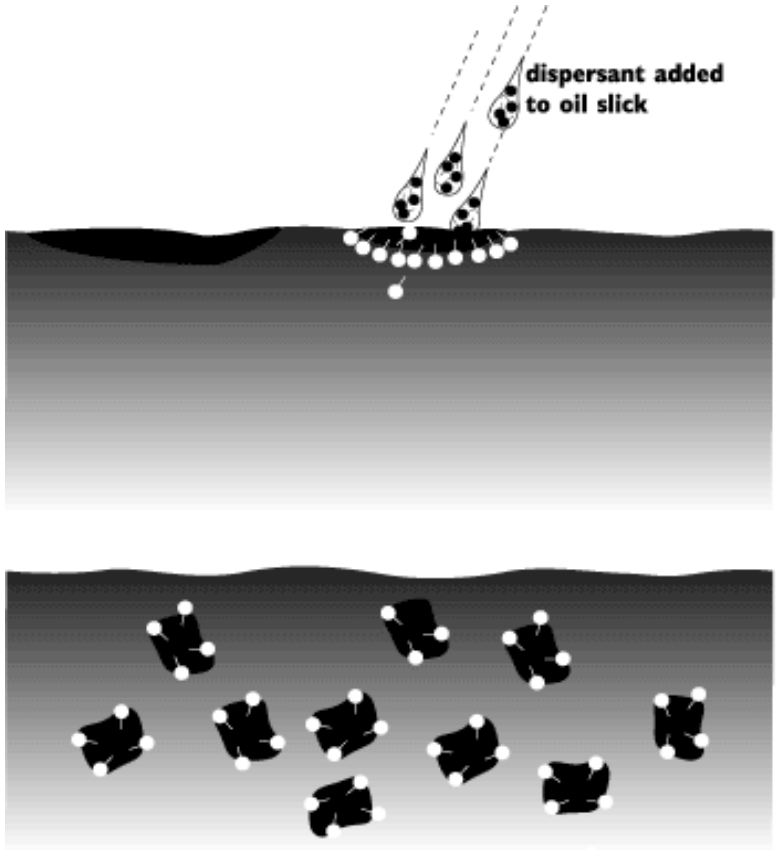
Response to an Oil Spill On Water: *Burning*

- Fresh oil contains gases which are very volatile. By igniting these gases whole oil slicks can be reduced to tarry residue.
- Many factors effect whether or not a burn can occur and if it will be successful.
- Burning is highly dependent on the amount of time the oil has been on the water because when a burn is conducted fumes from the oil are ignited, not the actual oil.
- As oil weathers on the water, these fumes dissipate and eventually are insufficient to start combustion.

Response to an Oil Spill On Water: *Dispersants*

- Dispersants work much like the detergent soap that you use to clean grease from your dishes (but dispersants are less toxic).
- They contain molecules with a water-compatible ("hydrophilic") end and an oil-compatible ("lipophilic") end.
- These molecules attach to the oil, reducing the interfacial tension between oil and water, breaking up the oil slick, as shown on the following slide.

Response to an Oil Spill On Water: *Dispersants*



Source: ITOPF

Response to an Oil Spill On Water: *Skimming*

- Skimming is a mechanical system for removing oil from the surface. This process was created based on the reality that oil is lighter than water.

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Response to an Oil Spill On Water: *On the Beach*

- Bioremediation
  - Utilizes beneficial microbes, surfactants, micronutrients and bio-stimulants to stimulate the growth of "oil-eating" microbes.
  - The process is adopted where excavation is impractical and involves either bio-stimulation or bio-augmentation.

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Response to an Oil Spill On Water: *On the Beach*

- Biostimulation involves aeration and the application of selected micronutrients and bio-stimulants.
- Bio-stimulation is only effective when indigenous microbial populations, present in the substrate, are high enough to degrade the contaminants and when these microbes can readily adapt to foreign contaminants.
- Bioaugmentation involves the application of beneficial microbes, that have an affinity towards a specific contaminant.
- Stimulation of indigenous organisms by the addition of nutrients is the approach that has been tested most rigorously.

Response to an Oil Spill On Water: *On the Beach*

- Chemical Cleaning
  - In an attempt to avoid Hot Water & High Pressure treatment, chemical cleaners were tested which removed oil from the beach for collection.
- Hot Water and High Pressure
  - By using hot water at high pressure, cleanup crews blast oil off beaches into the water where it can be skimmed off.

Response to an Oil Spill On Water: *On the Beach*

- This method usually does more harm than good by driving the oil deeper into the beach and by killing every living thing on the beach.
- This was used extensively after the Exxon Valdez spill due to public and state pressure to make the beaches "look clean again," despite the known risks.
- Areas left alone to be weathered by winter storms were shown to be cleaner and harboring more life than those cleaned by high-pressure washing.

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Response to an Oil Spill On Water: *On the Beach*

- Manual Treatment
  - Manual treatment incorporates the use of shovels, rakes, absorbent materials and human hands.

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Response to an Oil Spill On Water: *On the Beach*

- Mechanical Treatment
  - Tractors, backhoes, front-end loaders, and other machines are used to move beach and scoop up asphalt collections for disposal.

surftotal.com

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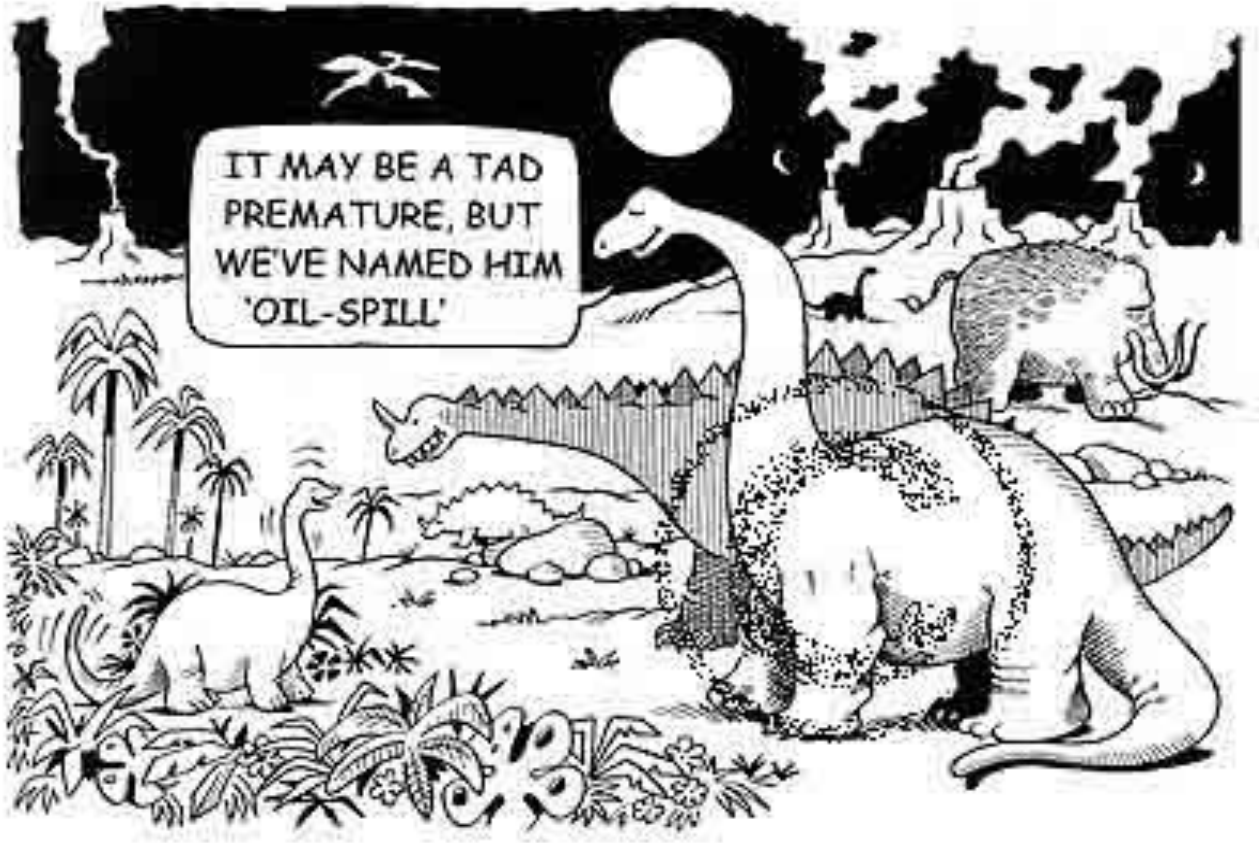

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Questions?

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Title Of Presentation

Bartley J. Eckhardt P.E.
& Arthur Faherty

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