OIL SPILL SCIENCE
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NAVIGATING SHIFTING SANDS: OIL ON OUR BEACHES

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During the Deepwater Horizon oil spill, emergency responders documented oil along more than 1,100 miles of shoreline. Oil washed onto and just off Gulf coast beaches. In some places, the sand buried the oil and made cleanup efforts difficult. Ongoing and completed studies are providing information that will enable responders to clean up future spills more effectively and remove the remaining oil from the Deepwater Horizon oil spill.

Oil is visible in the foreground and surf zone in this image from the Gulf Islands National Seashore, FL, that was taken on July 1, 2010. (NOAA)

The Deepwater Horizon oil spill was the worst oil spill in U.S. history with an estimated 172 million gallons of crude oil flowing into Gulf of Mexico waters.[1,2] Oil washed onto more than 1,100 miles of the Gulf coast despite intensive response efforts to stop the oil from reaching the shore.[3] More than half of the oiled shoreline was sandy beaches.[3] The amount of oil reaching the shore ranged from very light to heavy oiling. The U.S. Coast Guard ended all official cleanup

efforts in February 2015 (Captain J. P. Nolan, personal communication, February 26 2015). Still, many people are concerned about the impacts of the remaining oil buried on the sandy beaches and **surf zone** along the Gulf coast.[4]

WHY WAS CLEAN UP SO CHALLENGING?

You probably know how easily sand moves around if you have ever been to the beach. As the waves wash across your feet, you can see and feel sand moving away from some areas and building up in other areas. Gulf of Mexico beaches move in a similar way. Wind patterns in spring and fall push sand up on the beach and cold fronts during the winter blow from the north and erode sand away.[3] Tropical storms and hurricanes move large amounts of sand very rapidly on and off the beach. The movement of sand depends on the direction and strength of the wind and waves.[3]

During the Deepwater Horizon oil spill, **weathered oil** floated on surface waters and eventually reached some beaches. This oil was not fresh, liquid oil. The oil mixed with seawater creating a thick, **viscous emulsion** as it drifted toward shore.[3] The color and consistency of the weathered oil changed based on the length of exposure to sun and water. Some scientists described the emulsion as having the consistency of "mousse" similar to whipped orange-colored peanut butter. Some of this thick emulsified oil washed onshore in patches. Then seasonal wind patterns and storms pushed sand over the weathered oil before it could be cleaned-up. The oil was much more difficult to locate and remove once it was buried.[3]

HOW DO I REPORT OIL THAT I FIND ON THE BEACH?

If you find what you think is oil, call the National Response Center at 1-800-424-8802. Be ready to provide the date, time, place, and describe what you saw.

In the past, beach-goers have mistaken items such as pieces of plant debris and black shoreline critters for oil that has washed up on the beach. From left: A black tunicate, colonial tunicate, and a skate egg case have often been mistaken for surface residual balls (right) on the shore. (Florida Sea Grant photo)

Storm waves also pushed oil above the high tide line (Figure 1). Some of this oil remained stranded as the tide went out.[3,5] The stranded oil patches on the beaches sunk about an inch into the sand and then were covered by wind-blown sand. In some areas, this sand built up on top of this oil and created buried oil patches up to three feet deep.[3,5] However, samples of the buried oil collected

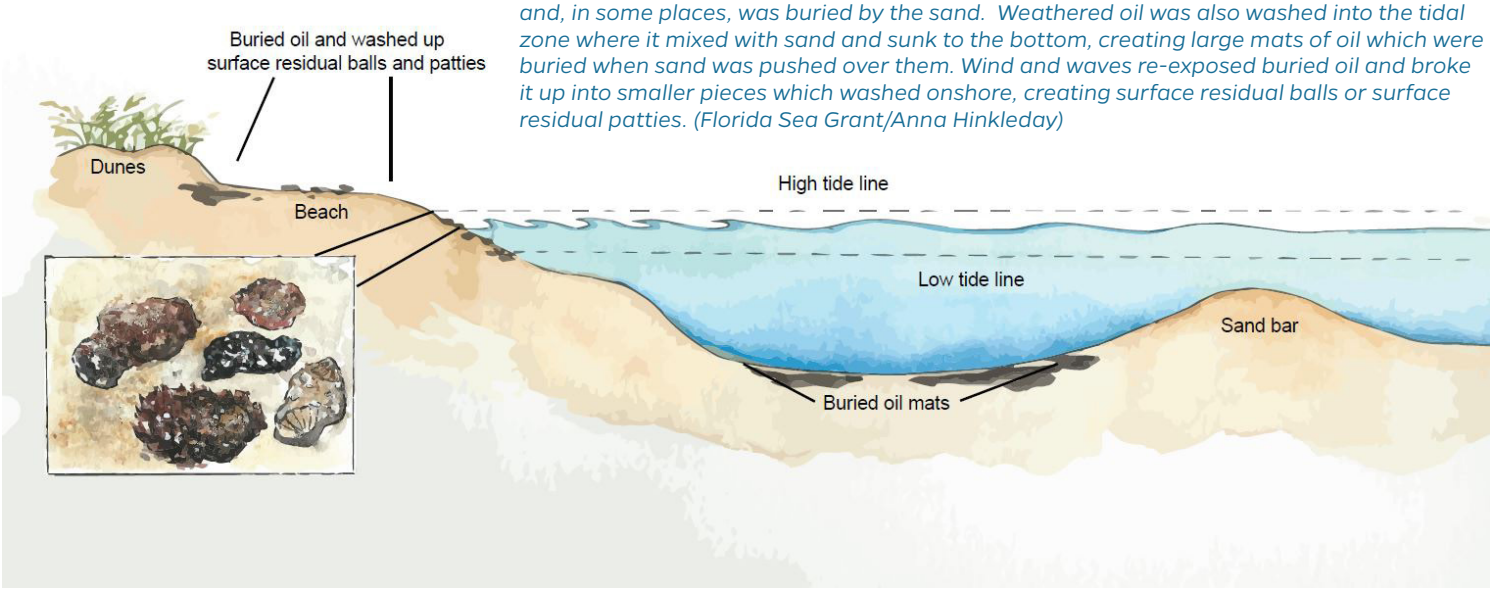


FIGURE 1. *During the Deepwater Horizon oil spill, thick oil washed on the shore in patches and, in some places, was buried by the sand. Weathered oil was also washed into the tidal zone where it mixed with sand and sunk to the bottom, creating large mats of oil which were buried when sand was pushed over them. Wind and waves re-exposed buried oil and broke it up into smaller pieces which washed onshore, creating surface residual balls or surface residual patties. (Florida Sea Grant/Anna Hinkleday)*

FIGURE 2. *Surface residual balls from the Deepwater Horizon oil spill that scientists have found are mostly made up of pieces of sand, shell, and other materials and were loosely bound by oil containing various petroleum chemical such as polycyclic aromatic hydrocarbons. These samples were collected from Little Lagoon Pass, AL, on July 19, 2015 by Professor Clement at Auburn University. (P. Clement, Auburn University photo)*

from above the high tide line had very little oil. More than 90 percent of the weight was from the sand and other materials that had mixed in with the oil.[6]

Weathered oil also washed into the nearshore and **tidal zone** (Figure 1). The tidal zone is the area of the beach covered by water at high tide and exposed to air at low tide. Some of the weathered oil mixed with sand and sank in this area. Layers of sand deposited by near shore currents buried the oil and sand mixture. This process created patches of oil within the nearshore and tidal zones (Figure 1).[7,8] Emergency responders call large patches of oil that are larger than three feet by three feet in size "oil mats".[5]

The patchiness of the oil mats made it hard for emergency responders to determine the location of the buried oil. Over time, emergency responders discovered oil mats along the shore. The oil mats that they found off the barrier islands of Louisiana were as long as 330 feet and up to eight inches thick.[3] They also found oil mats at heavily oiled sites in Florida, Alabama, and Mississippi. These mats were under water between the beaches and sand bars near the beach.[3]

Wind and waves re-exposed buried oil in some areas. Wave energy broke the re-exposed oil mats into smaller pieces. These smaller pieces washed on shore, sometimes onto beaches that had already been cleaned.[3] Smaller pieces of broken up oil mats are called **surface residual patties** or **surface residual balls** based on their size.[3] Some scientists refer to all oil mats and balls as **sand and oil agglomerates**, a term that does not distinguish them by size.[7]

Surface residual patties are smaller than oil mats but larger than surface residual balls. They are typically about four inches to three feet in size.[5] The patties

form when the energy of waves break larger oil mats into smaller pieces. Surface residual patties can also form when oil washes onshore and sinks into the sand. After the oil spill, emergency responders found surface residual patties in areas with low wave energy. This included areas such as the backsides of barrier islands or along beaches and marshes.[5]

Pieces of oil that are smaller than four inches are defined as surface residual balls.[5] Some might think of surface residual balls as "tar balls". Tar balls are typically rubbery or extremely hard with little odor or sand. Surface residual balls that have washed up after the Deepwater Horizon oil spill are very different. They are mostly made up of pieces of sand, shell, and other materials (70-95 percent by weight) and are loosely bound by oil.[3,5,9] They are fragile, sticky, and a brownish color and have a strong petroleum odor.[6,9] Unlike tar balls, surface residual balls are denser than water and roll or bounce along the bottom rather than float.[7] Scientists have found them across all tidal zones since they are small and can move around easily.[5]

HOW WERE OILED BEACHES CLEANED UP DURING THE DEEPWATER HORIZON OIL SPILL?

During an oil spill, emergency responders use skimming, booms, burning, and **dispersants** to clean up oil and protect the shoreline. The methods used depend on of the type of oil, location of the spill, and daily weather conditions. Emergency responders use an approach called Shoreline Cleanup Assessment Technique (SCAT) if oil does reach the shoreline.[10]

During the Deepwater Horizon oil spill, SCAT teams members included federal, state, local, and BP representatives. The SCAT teams conducted regular field surveys to determine the location and amount of oil on the shore.[3] SCAT team members recorded the width, the amount, and the thickness of oil that was found on the shoreline. They designated the oiling along the shore as "heavy," "medium," "light," and "very light" using this information (Figure 3). They also develop a Shoreline Clean-up Completion Plan to clean the oil

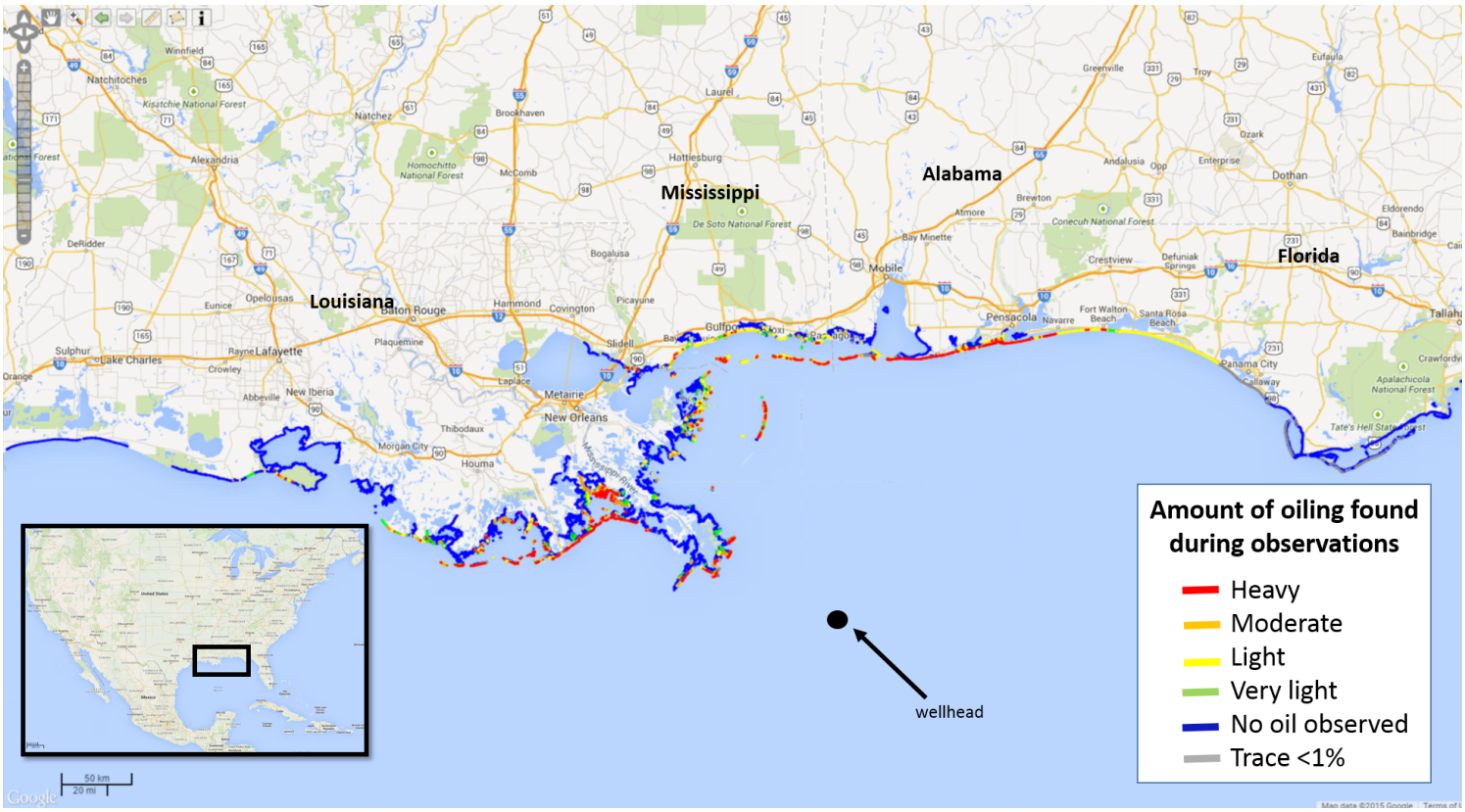


FIGURE 3. *During the Deepwater Horizon oil spill, more than 1,100 miles of shorelines were oiled along the Gulf coast. The amount of oil that observers found on the shoreline ranged from very light to heavy oiling. (Environmental Response Management Application)*

Following manual cleanup at Fourchon Beach, Louisiana, on May 27, 2010, booms made out of pom-poms are set to protect the sandy beach area. (NOAA photo)

up.[3] This plan set cleanup goals and outlined a process determining when cleanup activities were achieved.[11]

Emergency responders used a variety of cleanup methods depending on where they found oil and how people and wildlife used the area. In areas that people used, cleanup crews removed as much visible oil as possible using manual and mechanical cleanup techniques.[3] Cleanup was less intensive in other areas, such as national parks and wildlife refuges. This cleanup method reduced potential negative impacts on the environment and culturally important artifacts.[3] Emergency responders worked with the managers of these areas and decided that digging up and removing the oil would cause more harm to wildlife and the environment than just leaving the oil in place.[6] For example, bringing heavy machinery onto beaches to clean lightly oiled areas could compact sand and make it hard for animals, such as ghost crabs, to burrow. In such cases, it was better to leave the oil alone and let it naturally break down than to remove it.

WHAT IS BEING DONE TO REMOVE THE OIL THAT REMAINS?

Cleanup efforts continue in the Gulf of Mexico region five years after the Deepwater Horizon oil spill. Submerged and buried oil deposits remain and can cause re-oiling of the beaches with surface residual balls.[5] Many studies are underway to gain a better understanding of where buried oil is located, how it might be re-exposed, and how it moves along the sandy bottom of the shore.

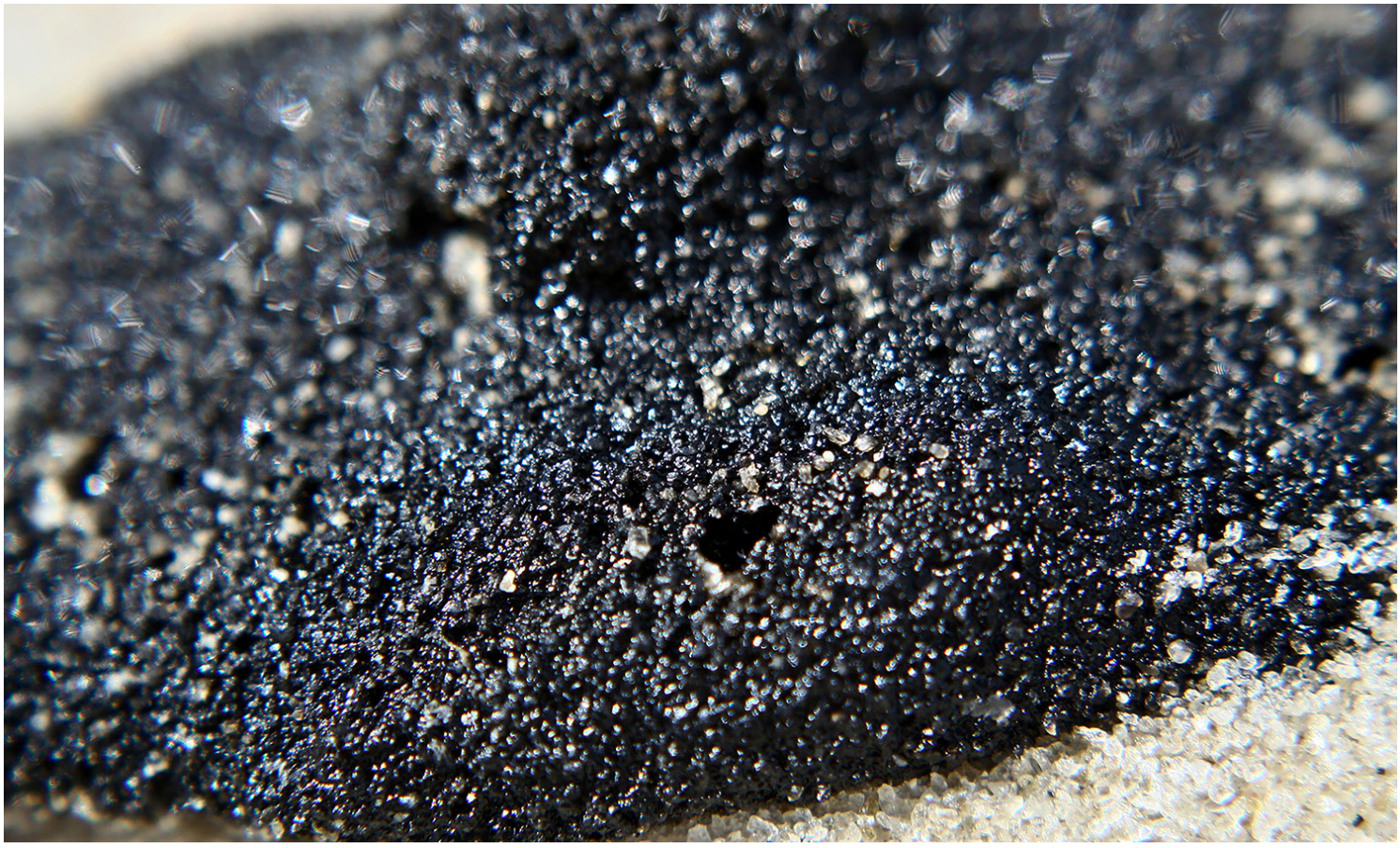
Scientists are using computer models to study how surface residual balls move around the sandy bottom. They have found that surface residue balls are less mobile during normal wave conditions and are more mobile during storm events when there are large waves, more powerful longshore currents in the surf zone, and strong winds.[7] The models show that surface residual balls of different sizes can be picked up and moved around the surf zone during storms.[7] The models also predicted that surface residual balls can become

deposited in inlets when currents carry the surface residual balls along the shore. The surface residual balls are washed into inlets during the incoming tide. They remain trapped in the inlets when they are not carried out by the outgoing tide.[7]

Scientists made balls out of artificial oil (wax) and sand to study how surface residual balls move around the seafloor. They tracked the movement of these balls in the surf zone, the areas of the beach where waves break. Sand buried the artificial oil and sand balls larger than four inches in diameter in the surf zone. The energy of the breaking waves consistently picked up and moved around artificial oil and sand balls that that were smaller than one inch in size. The balls that were one and two inches in diameter also moved along the shore, but less often. Scientists also studied how artificial oil and sand balls move in the **swash zone.** The swash zone is the area of the beach where water rushes after a wave has broken.[12] Scientists found that artificial oil and sand balls

TRACING OIL BACK TO ITS SOURCE

How do emergency responders know that the oil found on beaches is from the Deepwater Horizon oil spill? Similar to people, each type of oil has its unique fingerprint. Oil fingerprints differ based on its chemical makeup. Scientists use specialized laboratory equipment to examine the chemicals in the oil that they are trying to identify and compare it to the chemicals found in oil from known sources. Weathered oil is more difficult to fingerprint because some of the chemicals have broken down over time. Scientists focus on certain chemicals that are more resistant to weathering and persist for a long time in these cases. Once they find the oil fingerprint that is identical, they have a match and can determine the source of the oil they are studying.



A close-up of a surface residual ball found on the beach in Dauphin Island, Alabama. (NOAA photo)

that were smaller than two inches in size were often moved around in this area.[12] These studies supported the model results that smaller surface residual balls are more likely to move around and larger surface residual balls are likely to go through cycles of being buried and unburied.[12]

Scientists discovered that oil moves around even more during major weather events when wind and wave conditions are strong. They monitored beaches during and after Tropical Storm Lee in 2011, Hurricane Isaac in 2012, and Tropical Storm Karen in 2013. All of these storms had strong winds and high wave energy. A few days after each storm, scientists found surface residue balls and patties that had washed onto the beaches.[3,8] They saw a similar pattern after major cold fronts that also brought strong wind and wave energy.[8]

The number of oil mats and surface residual balls found on beaches has decreased since the oil spill occurred in 2010. However, research results suggest sand and oil agglomerates will continue to wash ashore for decades.[7,8,11] Recovering all of the oil may also be difficult. Surface residual balls, for example, are very hard to find in the surf zone once they have broken down to a diameter smaller than the width of a paperclip.[8]

Emergency responders considered the oil removal process complete in Mississippi, Alabama, and Florida in the summer of 2013. The same was true for almost the entire coastline of Louisiana in April 2014. There were six areas in Louisiana, totaling about 2.74 miles, which emergency responders continued to clean. Coast Guard teams and Oil Spill Removal Organizations were on standby to respond to calls of oiling along the Gulf coastline until February 2015 (Captain T. McK. Sparks, personal communication, April 15, 2014).

WHERE DO WE GO FROM HERE?

The Gulf of Mexico Research Initiative (GoMRI) and other research programs continues to fund studies to look at the short-term and long-term impacts of the oiling that occurred on Gulf of Mexico beaches.

The latest information can be found on GoMRI's website at: http://gulfresearchinitiative.org. To access other oil-spill-related publications or view the references in this publication on Sea Grant Oil Spill Science Outreach Program website: www.gulfseagrant.org/oilspilloutreach.

GLOSSARY

Dispersants
Chemicals that are used during oil spill response efforts to break up oil slicks and prevent floating oil from impacting sensitive ecosystems such as coastal habitats.

Emulsion
Occurs when water and oil combine, with one being suspended in the other. For crude oils it refers to the process where sea water droplets are suspended in the oil by mixing due to turbulence.

Sand and oil agglomerates
A term that refers to oil mats, surface residual balls, and surface residual patties and does not distinguish them by size.

Surface residual balls (SRBs)
Pieces of oil that are smaller than four inches in size. SRBs that washed up after the Deepwater Horizon oil spill and were mostly made up of pieces of sand, shell, and other materials loosely bound by oil.

Surface residual patties (SRPs)
Pieces of oil that are typically about four inches to three feet in size. SRPs that washed up after the Deepwater Horizon oil spill and were mostly made up of pieces of sand, shell, and other materials loosely bound by oil.

Surf zone
The area of the beach in which waves break.

Swash zone
The area of a beach where turbulent water washes after an incoming wave has broken.

Tidal zone
The area of the beach covered by tidal waters. This area is above the low tide line and below the high tide line.

Viscous
Sticky, thick consistency.

Weathered oil
When processes such as evaporation, dissolution, bacterial decomposition or exposure to sunlight change the chemical composition and physical appearance of oil.

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