

Improvements for the Mechanized Cleanup of Oiled Sand Beaches

Phase 1—Final Report

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Executive Summary

Historically, cleanup of oiled sand beaches has focused on strategies involving manual, mechanical, and flushing tactics. Often, these strategies are used concurrently. This study addresses potential improvements to strategies involving mechanical tactics.

There exists an extensive body of oiled sand beach cleanup and treatment experience gained from over 40 years of shoreline response operations and trials. This knowledge provides a solid basis for the development of new or improved tactics that could be adapted to the cleanup of oiled sand beaches.

Traditional mechanical sand beach tactics rely on use of equipment designed for earth-moving and construction, recreational beach litter removal, sand and gravel processing, and agricultural applications. Associated equipment is generally large and capable of moving or processing large volumes of material. As a result, use of these tactics must be carefully planned and executed to prevent undesirable environmental effects. Over the past decades, a number of new purpose-specific sand beach machines have been proposed to improve the state-of-the-art. Unfortunately, very few of have proven to be commercially viable and fewer are currently available. Application of these existing machines should be considered in future planning and response. Although the development of new purpose-specific mechanized beach cleaning equipment is always possible, no promising new candidates were identified during this study.

Improvements in mechanized sand beach cleaning, however, can be advanced through expanded (new) application of existing technologies designed for other purposes. Example industries which can potentially provide new equipment and tactics include pipeline construction, sand and gravel processing, mining, agriculture, industrial vacuum systems and hazardous material remediation.

In the short term, advancements can be made through streamlining the decision-making process. Decisions regarding oiled sand beach cleanup appear to be intrinsically straightforward; however, beaches are dynamic, are important environmentally, and frequently are major recreational or amenity resources. Response decisions and the selection of appropriate tactics should be science-based, in a manner similar to decisions regarding oiled marsh/wetland or bedrock intertidal habitats.

Phase 2 of this study is planned to identify and catalogue additional applicable tactics and equipment from related industry. Phase 2 will also include development of guidance documents to assist in the improved selection and implementation of new and/or mechanical oiled sand beach cleanup tactics and equipment.

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Acronyms and Abbreviations

API	American Petroleum Institute
AMOP	Arctic Marine Oilspill Program
AMSA	Australian Maritime Safety Authority
ASTM	American Society for Testing of Materials
CEDRE	Centre of Documentation, Research and Experimentation on Accidental Water Pollution
CONCAWE	Conservation of Clean Air and Water in Europe (European Oil Company Organization for Environment, Health and Safety)
DWH	Deep Water Horizon (oil spill)
EPA	Environmental Protection Agency
ESA	Federal Endangered Species Act
FEL	Front-End Loader
FAC	Florida Administrative Code
FLA DEP	Florida Department of Environmental Protection
GOM	Gulf of Mexico
HTTD	High temperature Thermal Desorption
IPIECA	International Petroleum Industry Environmental Conservation Association (Global Oil and Gas Industry Association for Environmental and Social Issues)
ITOPF	International Tanker Owner's Pollution Federation
IOSC	International Oil Spill Conference
LTTD	Low Temperature Thermal Desorption
MC252	2010 Deep Water Horizon oil spill
MOP	Manual of Practice
NHPA	National Historical Preservation Act
NOAA	National Oceanographic and Atmospheric Administration
ODC	Operation Deep Clean
SCAT	Shoreline Cleanup Assessment Technique
USCG	United States Coast Guard

Improvements for the Mechanized Cleanup of Oiled Sand Beaches

Phase 1—Final Report

1.0 Introduction

This report summarizes the results of Phase 1 of a study to improve the state-of-the-art in the Mechanized Cleanup of Oiled Sand Beaches. The Phase 1 effort includes identification of current practice based on a review of historical experience and applicable case histories, including recent events such as the Deepwater Horizon oil spill. Phase 1 also recommends improvements in operational practices and equipment.

For purposes of this study, sand beaches are defined as extending from the intertidal zone to the backshore (the landward limit of marine processes and therefore the general limit of potential oiling). Sand is defined as granular material that may include clastic rock and mineral fragments, shell, coral and carbonate fragments. Sand has a grain size in the range from 0.0625 to 2.0 mm (0.0025 to 0.079 in) in diameter, but in generic usage may include small amounts (less than 10 %) of granules, silts, or clay sediments.

The term “mechanized” refers to the utilization of machinery, including motorized devices, other than hand tools to facilitate oil spill control and treatment or cleanup, and includes purpose-designed equipment and equipment designed for other applications. Non-mechanical sand beach cleanup tactics include manual cleanup, water flushing, chemical treatment, bioremediation, and burning. Non-mechanical tactics are not addressed in this study.

2.0 Objectives

2.1 Phase 1

Phase 1 (this report) summarizes current practice for Mechanized Cleanup of Oiled Sand Beaches and provides the basis for development of operational tools and recommendations for improvement of future mechanized sand beach cleanup operations, including application of new technologies and equipment.

2.2 Phase 2

Phase 2 of this program will include a review and Catalogue of Response Guidelines for Mechanical Cleanup of Oiled Sand Beaches based on the review of historical and current practices. The Phase 2 document will include information on tactics, equipment specifications, operating parameters and standard operating practice. The catalogue will contain an introduction and description of each tactic in addition to summary information matrices or other data presentations. Note: The Catalogue may be used as a stand-alone document or attached to the Manual of Practice (described below) as a supporting appendix. Phase 2 is expected to encompass:

- Preparation of a **Manual of Practice for the Mechanical Cleanup of Sand Beaches**. This Manual of Practice (MOP) will be designed for Emergency Response use and will focus on selection and implementation of candidate physical procedures for mechanized cleanup of sand beaches. Although the selection process will be based primarily on physical/mechanical factors, guidance will be included for the identification and evaluation of potential environmental consequences of candidate actions as part of the selection process (“response guidelines”).
- Preparation of a report presenting **Recommendations for Projects or Studies on Modifications, Engineering, and Demonstration Testing** to improve existing mechanical sand beach cleanup technologies.

- Preparation of a **Review of Potentially Applicable Existing and Developing Equipment and Tactics from Other Industries**. Target industries may include, but not be limited to earth moving, pipeline construction, mining, agricultural, and hazardous waste management. Identify promising technologies and equipment for development studies and/or demonstration testing as appropriate.

2.3 Phase 3

Phase 3 of the program is under consideration and the scope, funding mechanisms and timing for further work (if any) have not been formalized at this time.

3.0 Background Information on Mechanical Cleanup of Oiled Sand Beaches

3.1 Mechanisms for Oil Burial on Sand Beaches

Spilled oiled can be incorporated in shoreline sediments by a variety of mechanisms including:

- Fluid oil deposited on the shoreline surface may soak directly into underlying sediments. This is typical of oils having low viscosity, such as distillate fuels and some fresh lighter crude oils. Penetration into the sediments is dependent on factors including viscosity of the oil, sediment grain size and water content, degree of sediment compaction, and factors such as presence of biogenic pathways (animal burrows). Normally vertical penetration of oil will stop at the beach ground water surface. If there is enough oil, the entire overlying zone may be oiled and there may be a floating layer on the groundwater surface. A similar effect may occur when solid or viscous oil deposited on the surface is heated by the sun and decreases in viscosity sufficiently to migrate downward; the latter effect is most common when oil is deposited or stockpiled in the supratidal zone;
- Floating oil may also be deposited on the shoreline in discontinuous irregular patterns in the swash zone or as scattered tar balls or residue accumulations;
- Oil deposited on the surface can be covered (buried) by wind-blown clean sand or clean sand that is deposited by natural onshore or along-shore processes (accretion). Layering with depth is possible;
- Surface deposits of oil can be covered by sand when dunes collapse during storms;
- Oil deposited on shoreline surfaces can be mixed with clean underlying or adjacent sediments by wave action and longshore transport and be re-deposited at depth and/or in adjacent locations. Downward mixing of oil may be deeper than the groundwater water level. Development of multiple oil layers is also possible;
- Burial depths on open shorelines are generally less than several meters;
- Surface and subsurface oiling can co-exist; and
- Oil may flow or fall into animal burrows.

3.2 Oil Properties, Distribution and Weathering

3.2.1 Oil Properties

Surface and subsurface cleanup tactics are controlled primarily by the physical characteristics of the oil “on the beach”. Once exposed to weathering, these properties can be expected to differ from MSDS and standard product specifications, and must be assessed on a case-by-case basis. The following properties/characteristics are important to the selection of cleanup tactics:

- **Density:** The density of crude oil and products is dependent on their composition and temperature. Oil density is measured as specific gravity. Specific gravity is a comparison between the weight of the substance and that of freshwater at 15.6°C (60°F), which is assigned a value of 1.0000. Therefore, oil that floats has a specific gravity less than the water it is in, and oil sinks if its specific gravity is greater (keeping in mind that the specific gravity of sea water ranges from approximately 1.02 to 1.07).

The oil industry commonly uses API gravity (°) for density measurement. API Gravity (°) can be calculated from specific gravity using the following formula:

$$\text{API Gravity (°)} = [141.5/\text{specific gravity (@60F)}] - 131.5$$

Oil with a specific gravity of 1.0 has an API gravity of 10.0°. A high API value represents a light oil whereas a low value represents a denser oil.

Oil density typically increases as evaporation and other weathering processes occur, and ultimately some oils may sink. Crude oils may also emulsify when spilled on water and exposed to mixing energy. Emulsification and incorporation of sediment also influence the effective density of the overall mixture. Density is an important consideration in the selection a cleanup tactic and must be monitored continually for changes that could affect the use of that tactic.

- **Pour Point:** Pour point is the temperature below which oil does not flow.
 - Many crude oils have pour points that are near or at ambient temperature, with the effect that they can change from liquid to solid and back depending on the ambient temperature range. Pour point can be expected to change as the oil weathers. High pour point oils tend to be solid at ambient temperatures and have good potential to be screenable;
- **Viscosity:** Viscosity is a measure of the resistance of a fluid which is being deformed by either shear or tensile stress, and may be thought of as a measure of fluid friction. Simply stated, the less viscous the fluid, the greater its ease of movement (fluidity). Oils having high viscosity are less likely to penetrate into sediments, may require special handling procedures, and may be screenable;
- **Emulsification:** Crude oil tends to form emulsions which consist of small drops of water incorporated in the oil when subject to mixing energy such as wave action or turbulence associated with a well blowout or pipeline release. Formation of emulsions (mousse) tends to increase the volume and persistence of the spilled oil and can impact behavior and cleanup requirements. Emulsions typically do not flow, although they may exhibit measurable viscosity. As a result, they do not tend to penetrate into sediments when grounded on shorelines, although some emulsions have limited stability and may separate into oil and water phases over time or when heated (as by the sun) at which point oil may then penetrate into sediments. Stable emulsions and emulsions with incorporated sand may also be recoverable through mechanical means;
- **Asphalt/Paraffin Content:** Crude oils, and residual fuels associated with their refining, contain varying percentages of asphaltic and paraffinitic (waxy) components which can impact their behavior, persistence, and cleanup tactics. Crudes containing significant amounts of asphaltic compounds tend to be viscous, sticky, and persistent. Conversely, paraffinic oils tend to be less viscous, slippery and less persistent; and

- **Friability:** Friability refers to the cohesiveness of accumulations of oil/emulsions and sediment. In some cases, oil and sand forms aggregates or sand adheres to the outside of residue accumulations forming armored oil clasts. Friability describes the ease with which such accumulations of oil crumble, and is an important factor in the selection and use of many mechanical tactics. For example, cohesive accumulations can be recovered using techniques such as screening, whereas friable material can break into smaller particles that may be difficult to screen and thus require other treatment tactics.

3.2.2 Oil Distribution

Oil on and buried within sediment shorelines is unlikely to be uniformly distributed. In most cases, oil is deposited on the mid to upper tidal zone in irregular patterns by wave action, storm surges, and other marine processes. Resulting concentrations of oil may range from heavy to very light, both vertically and horizontally. Understanding this typical irregular distribution pattern is important in selecting mechanical beach cleanup tactics and in optimizing their performance.

Surface Oil Distribution: Shoreline oil characteristics are described in the Shoreline Cleanup Assessment Technique (SCAT) Manual (Owens and Sergy, 2000). SCAT descriptions for surface oil distribution include:

Trace (TR)	<1 %
Sporadic (SP)	1–10 %
Patchy (PT)	11–50 %
Broken (BR)	51–90 %
Continuous (CN)	91–100 %

Surface Oil Thickness: Surface oil thickness refers to the average or dominant oil thickness within the segment or zone. Using SCAT nomenclature, thickness is defined as follows:

- **Thick Oil (TO):** accumulations of fresh oil (including pools) or mousse >1 cm (0.39 in) thick
- **Cover (CV):** >0.1 cm (0.039 in) to <1 cm (0.39 in) thick
- **Coat (CT):** >0.01 cm (0.004 in) to <0.1 cm (0.039 in) thick; can be scratched off with fingernail on coarse sediments or bedrock
- **Stain (ST):** <0.01 cm (0.004 in) thick; cannot be scratched off easily on coarse sediments or bedrock
- **Film (FL):** transparent or translucent film or sheen

Surface Oil Character: Surface oil character provides a qualitative description of the form of the oil, and using SCAT nomenclature is defined as follows:

- **Fresh (FR):** un-weathered, low viscosity oil
- **Mousse (MS):** emulsified oil (oil and water mixture) existing as patches or accumulations, or within interstitial spaces

- **Tar Balls (TB)**: discrete balls, lumps, or patches on a beach or adhered to the substrate. Tar ball diameters are generally <10 cm (3.94 in)
- **Tar Patties (PT)**: discrete lumps or patches >10 cm (3.94 in) diameter that are on a beach or adhered to the substrate
- **Tar (TC)**: weathered coat or cover of tarry, almost solid consistency
- **Surface Oil Residue (SR)**: consists of non-cohesive, oiled, surface sediments, either as continuous patches or in coarse-sediment interstices. (**Note**: The terms SRB and SRP, surface residue balls and patties, respectively, were used throughout the Deepwater Horizon response to characterize agglomerated sand-oil mixtures held together by oil residue coating the sand particles)
- **Asphalt Pavement (AP)**: cohesive mixture of oil and sediments
- **No Oil Observed (NO)**

Subsurface Oil Description The SCAT Manual defines the subsurface oiled zone as “the vertical width or thickness of the oiled sediment layer when viewed in profile by digging a pit or trench”. SCAT terminology for describing subsurface oil distribution includes:

Saturated	(Continuous : 91–100 %)
Layers	(Broken : 51–90 %)
Patchy	(11–50 %)
Sporadic	(<10 %)
Multiple layers	
Depth of over burden	
Water level	

SCAT also defines specific characteristics of buried oil, including:

- **Subsurface Asphalt Pavement (SAP)**: adhesive mixture of weathered oil and sediment situated completely below a surface sediment layer;
- **Oil-Filled Pores (OP)**: pore spaces in the sediment matrix that are completely filled with oil; often characterized by oil flowing out of the pores when disturbed;
- **Partially Filled Pores (PP)**: pore spaces filled with oil, which does not generally flow out when exposed or disturbed;
- **Oil Residue as a Cover (>0.1 cm: 0.039 in) or Coat (0.01–0.1 cm: 0.004–0.039 in) (OP)**: oil coating on sediment and/or some pore spaces partially filled with oil. Cover/Coat can be scratched off easily with fingernail;
- **Film or Stain (<0.01 cm: 0.004 in) (OF)**: oil residue on sediment surfaces. Non-cohesive. Cannot be scratched off easily;
- **Trace (TR)**: discontinuous film or spots of oil on sediments, or an odor or tackiness with no visible evidence of oil; and
- **No Oil (NO)**: no visible or apparent evidence of oil.

3.2.3 Weathering

Changes in the physical characteristics of stranded oil can be critical, but often overlooked, factors in the design of an effective sand cleanup operation. A primary mechanism of change is known as weathering (although properties can also change in response to temperature, emulsion formation/collapse, and other factors). Significant property changes can decrease the effectiveness of some tactics or render them useless. Changes in oil properties should be expected and should be monitored so that tactics can be adjusted or changed as appropriate.

3.3 Effects of Mechanical Operations on Sand Beaches

3.3.1 General

Any mechanical cleanup operation results in some level of environmental impact. These impacts may range from immeasurable to significant, and as a result, potential impacts of proposed actions should **always** be considered before proceeding, and re-evaluated periodically as the response progresses. If necessary, a Net Environmental Benefit approach (Efroymson et al., 2003; Robberson, 2012; IPIECA, 2000) can be used to gauge the relative significance of a particular action versus an alternative action or doing nothing. The following discussion includes examples of potential factors that should be considered.

3.3.2 Sand Removal and Beach Stability

Beach stability and shoreline erosion are of significant concern in many regions. Mechanical removal can involve the removal of as much as $4.0 \text{ m}^3/\text{m}$ ($5.23 \text{ yd}^3/1.09 \text{ yd}$) length of oiled sand shoreline and manual removal as much as $2.5 \text{ m}^3/\text{m}$ ($3.27 \text{ yd}^3/1.09 \text{ yd}$) (Owens et al., 2009). During the 1993 *Bouchard B-155* Tampa Bay response (Owens, Davis, Michel, and Stritzke, 1995), 14.5 km (9.00 mi) of sand beach with surface and buried oil were cleaned by a combination of manual and mechanical tactics. The volume removed averaged to $1.9 \text{ m}^3/\text{m}$ ($2.49 \text{ yd}^3/1.09 \text{ yd}$) by length or $1.4 \text{ m}^3/\text{m}^2$ ($1.83 \text{ yd}^3/1.19 \text{ yd}^2$) by area.

Historically, indiscriminate use of mechanized tactics (such as use of bulldozers) on sand beaches have been reported to have removed unnecessarily large amounts of clean sand and/or mixed oil deeper into the beaches, resulting in the need to remove even more sand. Although there is minimal documentation in the literature to support many of these reports, it is probable that excess sand removal has in fact taken place and some level of undesirable impact has occurred during historical responses. Awareness of these issues can minimize uncontrolled use of tactics which indiscriminately remove or contaminate excess sand. Cleanup tactics which minimize sand loss are always preferred.

In all cases, sand beach operations should consider potential impacts resulting from sand disturbance and removal on the overall shoreline ecology and sedimentary balance. This balance may be sensitive to seasonal and event – related factors such as storms, and weather and seasonal projects should be included in tactics evaluation. Assistance in the determination of processes active during an event can be obtained from a number of knowledgeable sources including:

- U.S. Army Corps of Engineers;
- State and local governments;
- State and Federal Park and Wildlife Refuge agencies;
- local engineering companies;
- University experts; and
- National Weather Service.

3.3.3 Sand Compaction

Any foot traffic and mechanized equipment operation on a sand beach results in some degree of compaction and may injure organisms living in the sand. A measure of potential ground compaction by mechanical operations is ground pressure. Ground pressure can be calculated by dividing gross vehicle weight by its surface foot print (reported in bars or pounds per square inch: “psi”). It is important to recognize that the size and gross weight of a piece of equipment does **not** automatically equate to its ground pressure. Off road equipment, for example, is commonly configured to improve its ability to operate in soft (low trafficability) environments by increasing its footprint, thus lowering the ground pressure at points of contact. Table 3.1 presents approximate ground pressures for representative pieces of equipment used on the Deepwater Horizon oil spill. Also presented for comparison is the approximate range of ground pressure associated with responder foot traffic.

Table 3.1 Representative Ground Pressures for Beach Cleaning Equipment

Equipment	Gross Weight kg (lb)	Approximate Ground Pressure bars (psi)
Oil Responder (adult male oil spill responder)	80 (175)	0.17–0.2 (2.5–3.0)
Towed Wheel Screener (BT 3000)	6,200 (14,000)	0.75 (11.0)
Self-propelled Wheel Screener (C5000)	4,200 (9,200)	0.8 (11.5)
Tracked Force Feed Loader (Sand Shark)	13,000 (28,500)	0.4 (6.0)
Towed Multi-stage Wheeled Sifter (Sand Shark)	5,200 (11,500)	1.0 (15.0)

(Source: manufacturer’s data)

As suggested in this table, use of tracks can significantly reduce ground pressure. In many cases, ground pressure can be lowered simply by adding larger tires, installing tracks on wheeled vehicles (such as motor graders), or simply reducing tire pressure.

3.3.4 Ecological Effects

Human activity, including operation of mechanical equipment on beaches, has the potential to damage or disrupt organisms living there, or those which utilize the shoreline for nesting, resting, transit from the water to backshore areas, or other purposes. Sensitivities are often seasonal and may, or may not, be significant at the time of a response. In the U.S., activities and potential impacts to Threatened and Endangered Species must be consistent with the Federal Endangered Species Act (ESA). Regardless, ecological sensitivity must be considered in all cases.

3.3.5 Cultural Resources

Shorelines may contain artifacts of historic and/or cultural significance, locations of other cultural value, and even burial sites. As sand beaches are dynamic, they are not as sensitive in this regard as other shoreline types, but occurrences can occur, even at shallow depths. In the U.S., the protection of historic and cultural resources is mandated under the National Historic Preservation Act (NHPA) (1996), and all activities must be consistent with its provisions.

3.3.6 Amenity Uses

Sand beaches are typically accessible to, and used by, the public and have high amenity value. This value can escalate dramatically seasonally in many areas, and will often drive cleanup schedules and levels of effort.

3.4 Shoreline Properties and Selection of Tactics

Shoreline characteristics can control selection cleanup tactics. Relevant characteristics include:

3.4.1 Access and Trafficability

Equipment access to the beach and the ability to stage and operate equipment there can create important limitations on selection of tactics. Access can consist of pre-existing roads or landing craft access. If roads do not exist, the general topography of the area should be examined to determine its suitability for construction of temporary access roads and staging areas. In some cases, use of portable roadways such as used by the military, or use of landing craft may be necessary. It is important to remember that any disruption associated with access and staging likely involves restoration following the response.

Trafficability refers to the ability of the beach sediments (bearing strength) to support personnel and mechanized equipment. Beach compaction is the primary factor in determining trafficability. Beaches that are relatively flat and can be walked on normally will usually support most types of light vehicle traffic. Use of heavier equipment may require modification to the equipment (lower tire pressure, flotation tires, or tracks) or special equipment. In some cases, beaches may support vehicular traffic for only a limited number of passes. Procedures evaluating trafficability have been developed by the military (cone penetrometer measurements) to support amphibious landing on sand beaches are available and can be used for the assessment of heavy equipment feasibility, if necessary (Corps of Engineers, 1963; Willoughby, 1977).

3.4.2 Surface Morphology

Surface morphology can impact the performance of some mechanical tactics. Flat surfaces are necessary for efficient operation of some equipment, including motor graders and scrapers. Use of mechanized tactics on irregular surfaces may result in either removal of excess clean material or incomplete oil removal. Operations on such surfaces may require the use of smaller and more maneuverable equipment or manual tactics.

3.4.3 Sediment Stability

Excavation in beach sand can be difficult. The angle of repose of some beach materials is so low that excavations cannot be kept open long enough to complete observations. This commonly occurs with dryer sands. Slumping of material into pits and trenches dug below the water table is typical.

3.4.4 Environmental, Cultural and Political Sensitivity

Disruption to areas with particular sensitivities, such as those with as environmental, cultural, or political concerns, can influence selection of techniques, with intrusive and high activity techniques often being problematic.

3.5 Operational Variables

The success or failure of most tactics can be influenced by a number of controllable factors. These factors include:

3.5.1 Manufacturer's Specifications

Equipment manufacturers' specifications should be interpreted conservatively. This is particularly the case with utilization of equipment designed for other applications. Oil spill recovery operations involve

many unpredictable conditions, some of which can be expected to change over the course of the response. Sand beach conditions often require specific equipment to be operated differently than would be normal for their intended use.

3.5.2 Operator Experience

Many standard cleanup tactics utilized equipment and operators that are intended for different operating objectives and environmental conditions. In most cases, operators are trained to maximize the pickup of materials. For oil spill cleanup, slower and more precise equipment operation may be required for efficient recovery of oil and oil sand (and minimization of clean sand removal). In such cases, retraining of equipment operators may be beneficial.

3.5.3 Controllable Parameters

Most types of equipment have a variety of operational parameters that can be controlled. These may include: depth of cut, forward speed, blade angles, belt speeds, vibratory shaker rates, flow rates, retention times, and many others. “Trimming” the operating variables for particular piece of equipment and situation is generally required. This process is conducted by operator “feel”, experimentation, and periodic performance testing. Adjustments can be particularly important in maintaining efficiency as the oil weathers. Performance indicators should be developed, periodically measured, and adjustments made as appropriate.

3.5.4 Accessories and Modifications

Most commercial equipment manufacturers offer a variety of accessories for their equipment. These can include different blades, buckets, rippers, screen sizes, tire sizes, flotation ties, tracks, attachable rubber squeegee blades, and many other equipment-specific options. In addition, experience has also shown that special modifications may also be necessary. These types of modifications include installation of flashings to prevent unnecessary loss of sand from part of some machines, lowering of tire pressure to improve trafficability, etc.

3.5.5 Availability

Even the most efficient piece of equipment is of little value if it is not available. Much of the equipment currently utilized for mechanical sand beach cleanup consists of conventional construction and agricultural machinery, which is readily available in most areas as are parts and services. Commercial beach cleaners have also become reasonably available in recent years, although parts, including non-standard size screens, may not be standard shelf items and may need to be specially manufactured. A number of oil spill-specific types of equipment have been proposed and manufactured. As a result of low demand, many of these devices never evolved beyond the prototype stage, and of those that have been manufactured, most were only offered for short periods and are no longer available. Availability is therefore a major consideration in the selection of any emergency response equipment.

3.5.6 Locational Control (Vertical and Horizontal)

Surface cleanup can be conducted visually. Subsurface cleanup is more difficult unless detailed subsurface information is available. GPS positioning/tracking equipment is available and can be attached to self-powered equipment to locate pre-identified subsurface deposits, track areas treated, and reoccupy treatment lines.

4.0 Mechanical Sand Beach Cleanup Practice Review

4.1 Introduction

The Platform A Blowout in the Santa Barbara channel in 1969 resulted in the oiling of 35 miles of the California coastline and the mortality of 3600 birds, ten seals and dolphins, and countless fish and marine invertebrates. Many consider that event as a major impetus to the environmental awareness movement in the United States. In reaction to this event, new regulations were promulgated and oil spill research and development efforts initiated on the part of industry and the federal government. Part of the resulting Research and Development (R&D) effort focused on shoreline cleanup tactics, including treatment of sand beaches using mechanized equipment, which consisted primarily of earthmoving equipment which forms the basis for mechanized sand beach cleanup to this day. For this reason, the Phase 1 practice review was extended as far back as 1969.

4.2 Literature Review

The literature review focused on event case histories sand beaches and use of mechanized cleanup tactics was reported. International as well as domestic cases were included. The review also included searches for applicable equipment, research and development projects and oil spill equipment manufacturer literature.

Document sources examined included, but were not limited to, the following:

- Proceedings of the International Oil Spill Conference (1969 to 2011);
- NOAA Summaries of Significant U.S. and International Spill – Oil Spill Case Histories 1967–1991;
- NOAA Interactive Oil Spill Maps (for more recent data);
- Proceedings of the Arctic Marine Oil Spill Program (AMOP);
- CEDRE – Major Oil Spill Summaries;
- International Tanker Owners Pollution Federation, Limited, Oil Spill Case Histories;
- Australian Maritime Safety Authority (ASMA) Major Spills in Australia;
- Oil Spill Solutions, Case Histories and Tactics;
- World Catalogue of Oil Spill Response Products (various editions);
- Oil Spill Equipment Manufacturers' Literature (various);
- Beach Cleaning Equipment Manufacturers' Literature (various); and
- Other Equipment Manufacturers' Literature.

In conducting the literature review, it was quickly realized that details of mechanical sand beach cleanup operations were generally not well documented, if documented at all. Table 4.1 presents a summary of those spill events which were identified as involving some level of mechanical beach cleanup. Listing in this table does not mean that use of mechanical tactics comprised the primary response. In fact, mechanical tactics were often secondary. Nor does the reporting of a tactic or piece of equipment indicate that the tactic or piece of equipment was or was not effective. The listing is, however, believed to be indicative of situations and general mechanical tactics, but is not intended to be an exhaustive examination of all historical events.

Table 4.1 Historical Oil Spills Involving Mechanical Cleanup Tactics on Sand Beaches

Date	Name/Location (Reference)	Size/Oil Type	Mechanical Procedures Used
12/16/11	TK Bremen, France (Reference: Cedre website – Spills)	1103 bbl (150 tonnes) IFO 120 293 bbl (40 tonnes) Marine diesel	• Surf washing
4/21/10	Deepwater Horizon Gulf of Mexico, U.S. (References: NOAA Incident News website; NOAA BP Oil Spill Archive website; Restore The Gulf website; Gulf of Mexico Restoration website; Gulf Update website; Owens et al., 2011a,b; Santner et al., 2011a,b; VanHaverbek et al., 2011)	4,900,000 bbl (666,400 tonnes) Southern Louisiana crude	• Commercial beach cleaners • Trackhoe, FEL, bulldozer excavation • Portable sand washing and screening plants • Tilling • Sediment relocation
3/11/09	Pacific Adventurer Australia (Reference: AMSA website)	Heavy Fuel Oil	• Excavation by backhoe, FEL • Commercial beach cleaners
12/8/04	MV Selendang Ayu Alaska (References: Shirgenata et al., 2008; NOAA Incident News website)	8024 bbl (109 tonnes) IFO 380	• Tilling • Berm relocation
7/27/03	Tasman Spirit Pakistan (Reference: Cedre website – Spills)	198,529 bbl (27,000 tonnes) Iranian crude	• “Mechanical” shoreline cleanup (Not otherwise specified)
11/15/02	MV Prestige Spain (References: Cedre website – Spills; NOAA Incident News website)	228,524–595,588 bbl (61,000–81,000 tonnes) Heavy Fuel Oil	• Mechanical where possible • Oleophilic roll machines • Commercial sand screeners • Surf washing
3/29/01	Baltic Carrier Denmark (Reference: Cedre website – Spills)	20,580 bbl (2,799 tonnes) Heavy Fuel Oil	• Mechanical recovery (track hoes, FEL) • Coarse sediment washing
7/5/00	TB Penn Narragansett, RI (Reference: NOAA Incident News website)	300 bbl (40.8 tonnes) #6 Fuel Oil	• Sediment agitation using FEL
12/12/99	Erica France (References: LeGuerrou et al., 2003; Cedre website – Spills)	147,059 bbl (20,000 tonnes) #6 Fuel Oil	• Tilling (deep harrowing) • Screening belts to remove tar balls to 30 cm
5/14/96	Chevron Pipeline Spill Hawaii (Reference: NOAA Incident News website)	1000 bbl (136 tonnes) #6 Fuel Oil	• Mechanical tilling of coarse sand

Date	Name/Location (Reference)	Size/Oil Type	Mechanical Procedures Used
3/31/94	TV Seki & Baynuna UAE (Reference: Pearson et al., 1994)	761,905 bbl (103,612 tonnes) Iranian Light Crude	• Mechanical beach trials • Berm relocation • Tilling
1/7/94	TB Morris Berman San Juan, Puerto Rico (References: NOAA Incident News website; Petrae, 1995; Stanton, 1995)	#6 Fuel Oil	• Sand removal
8/10/93	Bouchard 155, Tampa Bay, Fla. (References: Owens et al., 1995; NOAA Incident News website)	7810 bbl (1062 tonnes) #6 Fuel Oil	• Motor graders, front end loaders • Surf washing • Tilling
4/1/91	Haven, Italy (References: Curl et al., 1992; Cedre website –Spills; NOAA Incident News website)	1,029,412 bbl (140,000 tonnes) Crude oil	• “Mechanical” shoreline cleanup (Not otherwise specified)
2/13/91	Sanko Harvest W. Australia (References: Curl et al., 1992; NOAA Incident News website)	4400 bbl (598 tonnes) Fuel Oil	• Graders and FEL used on heavily oiled beaches
1/19/90	Arabian Gulf Kuwait (Reference: Curl et al., 1992)	8,000,000 bbl (1,088,000 tonnes) Kuwait crude	• Berms and trenches • Mechanical (not otherwise specified)
12/29/89	Aragon Portugal (References: Curl et al., 1992; Cedre website –Spills; NOAA Incident News website)	175,000 bbl (21,525 tonnes) Mexican Maya crude	• Mixed mechanical recovery (Not otherwise specified)
7/30/84	Alvenus Calcasieu R Louisiana (References: Curl et al., 1992; Cedre website – Spills; NOAA Incident News website)	65,000 bbl (8,840 tonnes) Venezuelan Merecy and Pilar crude	• Shallow excavation (Fleets of motor graders used)
11/12/83	Olympic Alliance English Channel (References: Curl et al., 1992; Cedre website – Spills)	87,000 bbl (11,832 tonnes) Iranian Light crude	• Mechanical equipment (Not otherwise specified)
9/28/83	Sivand England (References: Curl et al., 1992; NOAA Incident News website)	48,000 bbl (6,528 tonnes) Nigerian crude	• Excavation using FEL
2/19/83	Ocean Eagle San Juan, Puerto Rico (Reference: Curl et al., 1992)	70,000 bbl (9520 tonnes) Venezuelan crude	• Mechanical used (Not otherwise specified)
10/2/80	Hasbah 6 Qatar (References: Curl et al., 1992; NOAA Incident News website)	100,000 bbl (13,500 tonnes) Crude	• Excavation/mechanical used (Not otherwise specified)
11/1/79	Burmah Agate Galveston, TX (References: Curl et al., 1992; NOAA Incident News website; Thebeau, 1981)	Nigerian crude	• Used FEL to pick up manual piles – removed too much sand

Date	Name/Location (Reference)	Size/Oil Type	Mechanical Procedures Used
3/13/79	Sea Valiant France (Reference: Cedre website – Spills)	221 bbl (30 tonnes) #6 Fuel Oil	• Mechanical shoreline cleanup (Not otherwise specified)
3/6/78	Amoco Cadiz Brittany, France (References: Curl et al., 1992; Bellier, 1979; Bocard, 1979; Hann, 1979; NOAA Incident News website; Cedre website – Spills)	1,619,048 bbl (220,191 tonnes) Arabian/Iranian Lt crude/Bunker C	• Vacuum trucks/wagons • Trench/sumps • Surface scraping • Excavation • Tilling • Sediment relocation
1/9/78	Brazilian Marina Brazil (References: Curl et al., 1992; NOAA Incident News)	73,600 bbl (10010 tonnes) Kuwait crude	• Excavation by FEL
5/12/76	Urquiola Spain (References: Curl et al., 1992; Cedre website – Spills; NOAA Incident News website)	73,300 bbl (9969 tonnes) Lt Arabian, Bunker Fuel	• Use of mechanical equipment inc. graders, dozers, FELs: not successful and mixing at depth reported
2/2/76	STC 101 Chesapeake Bay, Virginia (References: Curl et al., 1992; NOAA Incident News)	5959 bbl (810 tonnes) #6 Fuel Oil	• Removal using FELs
1/18/73	Oregon/Arizona Standard California (Reference: Curl et al., 1992)	20,400 bbl (2,774 tonnes) Bunker C	• Mechanical (debris and oiled sand removal) • Mixing at depth
7/22/72	Tomano Casco Bay, Maine (References: Curl et al., 1992; NOAA Incident News website)	2380 bbl (324 tonnes) #6 Fuel Oil	• Heavy equipment (Not otherwise specified)
2/4/70	Arrow Nova Scotia (References: Curl et al., 1992; NOAA Incident News website)	77,000 bbl (10,472 tonnes) Bunker C	• Mechanical used but mixed oil into sediment scrapers not effective
4/30/69	Hamilton Trader Liverpool, England (References: Curl et al., 1992; Cedre website –Spills; NOAA Incident News)	4000 bbl (544 tonnes) #6 Fuel Oil	• Mechanical (Not otherwise specified)
1/28/69	Platform A Blowout Santa Barbara, CA (References: Curl et al., 1992; NOAA Incident News website)	100,000 bbl (13,600 tonnes) Calif. crude	• Mechanical, oiled straw and limited excavation
3/18/67	Torrey Canyon England (References: Curl et al., 1992; Cedre website – Spills)	860,000 bbl (116,960 tonnes) Kuwait crude	• Mechanical, including bulldozing