1995

Managine for Effectiveness and Efficiency in Oil Spill Response

Peter A. Tebeau
University of Rhode Island

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APPROVED

DR. NIELS WEST

UNIVERSITY OF RHODE ISLAND
1995
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<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2.0</td>
<td>Background and Perspective</td>
<td>3</td>
</tr>
<tr>
<td>3.0</td>
<td>Oil Spill Cleanup: Processes, Participants, Organization and Criteria for Success</td>
<td>6</td>
</tr>
<tr>
<td>4.0</td>
<td>Economic and Environmental Concepts Related to Efficiency</td>
<td>16</td>
</tr>
<tr>
<td>5.0</td>
<td>The Importance of Policy and Perception</td>
<td>26</td>
</tr>
<tr>
<td>6.0</td>
<td>Approaches Adopted During Recent Major Spills</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>EXXON VALDEZ Spill in Prince William Sound</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>AMERICAN TRADER Spill off Huntington Beach</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>The 1993 Tampa Bay Oil Spill</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>MORRIS J. BERMAN Spill at San Juan</td>
<td>50</td>
</tr>
<tr>
<td>7.0</td>
<td>Observations on Various Approaches to Resolving the &quot;How Clean Is Clean&quot; Issue</td>
<td>57</td>
</tr>
<tr>
<td>8.0</td>
<td>Developing A Standard Approach And Providing Decision Support Information</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>Developing a Standard Strategic and Tactical Model</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>Providing Information To Support the Decision Process</td>
<td>63</td>
</tr>
<tr>
<td>9.0</td>
<td>Summary and Recommendations</td>
<td>73</td>
</tr>
<tr>
<td>10.</td>
<td>References</td>
<td>76</td>
</tr>
<tr>
<td>Figure #</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>Model of the overall management and decision-making process in oil spill response.</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Diagram showing the relationship between marginal cleanup cost and marginal cleanup benefit.</td>
<td>17</td>
</tr>
<tr>
<td>3</td>
<td>Diagram depicting the net environmental benefit associated with various countermeasures and cleanup actions.</td>
<td>19</td>
</tr>
<tr>
<td>4</td>
<td>Diagram depicting the positive net environmental benefit of a cleanup action.</td>
<td>21</td>
</tr>
<tr>
<td>5</td>
<td>Diagram showing the relation between natural resource damage and cleanup activities.</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>Diagram showing the variation of cleanup costs during a typical oil spill response operation.</td>
<td>24</td>
</tr>
<tr>
<td>7</td>
<td>Diagram showing the progression of cleanup costs and direct results during a typical major spill operation.</td>
<td>25</td>
</tr>
<tr>
<td>8</td>
<td>Map showing the location and advance of oil from the EXXON VALDEZ oil spill.</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>Diagram showing the shoreline cleanup decision process followed during the summer of 1989 EXXON VALDEZ shoreline cleanup effort.</td>
<td>35</td>
</tr>
<tr>
<td>10</td>
<td>Diagram showing the shoreline cleanup decision process followed during the summer of 1990 EXXON VALDEZ shoreline cleanup effort.</td>
<td>37</td>
</tr>
<tr>
<td>11</td>
<td>Map showing the general location and coastal area impacted by the AMERICAN TRADER oil spill.</td>
<td>41</td>
</tr>
<tr>
<td>12</td>
<td>Diagram showing the spill response decision process for the AMERICAN TRADER oil spill.</td>
<td>44</td>
</tr>
<tr>
<td>13</td>
<td>Map showing the general location and area impacted by the 1993 Tampa Bay oil spill.</td>
<td>47</td>
</tr>
<tr>
<td>14</td>
<td>Diagram showing the shoreline cleanup decision process followed during the Tampa Bay oil spill.</td>
<td>49</td>
</tr>
<tr>
<td>15</td>
<td>Map showing the general location and area impacted by the MORRIS J. BERMAN oil spill.</td>
<td>52</td>
</tr>
<tr>
<td>16</td>
<td>Diagram showing the shoreline cleanup decision process followed during the MORRIS J. BERMAN oil spill.</td>
<td>54</td>
</tr>
<tr>
<td>Figure #</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>17</td>
<td>&quot;How Clean Is Clean&quot; monitoring and signoff form used during the MORRIS J. Berman oil spill.</td>
<td>56</td>
</tr>
<tr>
<td>18</td>
<td>Generalized strategic model for managing oil spill cleanup operations.</td>
<td>59</td>
</tr>
<tr>
<td>19</td>
<td>Generalized tactical model for planning and managing shoreline cleanup operations and resolving the &quot;how clean is clean&quot; issue.</td>
<td>61</td>
</tr>
<tr>
<td>20</td>
<td>Matrix of shoreline cleanup methods vs. shoreline habitats from the API Shoreline Cleanup Manual.</td>
<td>65</td>
</tr>
<tr>
<td>21</td>
<td>Matrix of shoreline cleanup methods vs. shoreline types from the Environment Canada Shoreline Cleanup Manual.</td>
<td>66</td>
</tr>
<tr>
<td>22</td>
<td>Representative output of CAMEO Valdez showing the tracking of shoreline cleanup progress during the Exxon Valdez oil spill.</td>
<td>69</td>
</tr>
</tbody>
</table>
**LIST OF TABLES**

<table>
<thead>
<tr>
<th>Table #</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Various agencies, organizations and parties, their responsibilities</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>and agendas; and criteria for success in oil spill cleanup.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&quot;How clean is clean&quot; procedures and criteria used for the cleanup</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>of sandy beaches during the Tampa Bay oil spill.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>&quot;How clean is clean&quot; criteria used in the MORRIS J. BERMAN oil</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>spill.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Sample shoreline cleanup planning summary which could be</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>incorporated into Area Contingency Plans.</td>
<td></td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Acronym/Description</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------</td>
<td></td>
</tr>
<tr>
<td>ACP</td>
<td>Area Contingency Plan</td>
<td></td>
</tr>
<tr>
<td>ADEC</td>
<td>Alaska Department of Environmental Conservation</td>
<td></td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
<td></td>
</tr>
<tr>
<td>FOSC</td>
<td>Federal On-Scene Coordinator</td>
<td></td>
</tr>
<tr>
<td>HCIC</td>
<td>How Clean Is Clean</td>
<td></td>
</tr>
<tr>
<td>ICS</td>
<td>Incident Command System</td>
<td></td>
</tr>
<tr>
<td>ISCC</td>
<td>Interagency Shoreline Cleanup Committee</td>
<td></td>
</tr>
<tr>
<td>NCP</td>
<td>National Contingency Plan</td>
<td></td>
</tr>
<tr>
<td>NEB</td>
<td>Net Environmental Benefit</td>
<td></td>
</tr>
<tr>
<td>NEBA</td>
<td>Net Environmental Benefit Analysis</td>
<td></td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
<td></td>
</tr>
<tr>
<td>NRD</td>
<td>Natural Resource Damage</td>
<td></td>
</tr>
<tr>
<td>NRDA</td>
<td>Natural Resources Damage Assessment</td>
<td></td>
</tr>
<tr>
<td>OPA 90</td>
<td>Oil Pollution Act of 1990</td>
<td></td>
</tr>
<tr>
<td>OSC</td>
<td>On-Scene Coordinator</td>
<td></td>
</tr>
<tr>
<td>SCAT</td>
<td>Shoreline Cleanup Assessment Team</td>
<td></td>
</tr>
<tr>
<td>SHOP</td>
<td>State Historic Preservation Office</td>
<td></td>
</tr>
<tr>
<td>TAG</td>
<td>Technical Assessment Group</td>
<td></td>
</tr>
<tr>
<td>USCG</td>
<td>U. S. Coast Guard</td>
<td></td>
</tr>
</tbody>
</table>
MANAGING FOR EFFECTIVENESS AND EFFICIENCY IN OIL SPILL RESPONSE

1.0 INTRODUCTION

Responding to oil spills, even spills of moderate proportion, requires the commitment of substantial manpower and equipment on the part of the responsible party or the federal government. Throughout the response operation, successful spill management entails choosing the most effective and efficient countermeasures and cleanup techniques to remove or neutralize oil in the environment, minimize overall environmental damages from the spill, and insure that the objectives and expectations of government agencies, responsible parties, and the public are met.

As the response progresses, effective and efficient management requires determining when response operations should be terminated. In making this decision, the On-Scene Coordinator (OSC) must deal with the complex "how clean is clean" (HCIC) issue, which requires an often subjective determination on when a point of diminishing returns has been reached in the cleanup effort. Beyond this point, further expenditure of resources will have little effect on preventing damage and/or accelerating recovery, and may cause more damage than if no further action is taken. Dealing with this issue often results in considerable controversy among the agencies and organizations involved in the response effort.

The purpose of this treatment is not to rigorously define and resolve all of the processes and issues involved in effectively and efficiently managing oil spill cleanup and dealing with the "how clean is clean" issue. Rather, the objective is to characterize the current strategic doctrine and practice used in dealing with these spill management issues, and provide some insight into how this management process can be improved and supported.

First of all, the overall oil spill cleanup process is reviewed, outlining the activities and organizations involved, the participants and their roles, and the criteria for success. Following this, the important economic and environmental concepts related to the effectiveness, efficiency and overall success of oil spill cleanup operations are reviewed. The importance of government policy and public perception is also discussed.
Given this general background on oil spill response, and the factors that govern effectiveness and efficiency, four major spill response efforts are reviewed. This review will identify various approaches that have been used to choose effective and environmentally sound cleanup techniques, manage the level of effort expended, and decide when the cleanup effort should be terminated. The various approaches are summarized noting the advantages, disadvantages, and specific applications of each.

Having characterized current doctrine and practice, a general model is proposed that can serve as a template for planning and managing cleanup activities and resolving the "how clean is clean" issue. The information needed to support this decision process is also described. Finally, the various observations and conclusions are summarized, along with specific recommendations for improving the process.
2.0 BACKGROUND AND PERSPECTIVE

The study of oil spill response as a unique operations management problem began almost thirty years ago with the TORREY CANYON spill in 1967 off the coast of England. At this point it became clear that major oil spills posed a significant threat to the marine environment, and that governments and industry were experiencing great difficulty in responding to these incidents. Since then a great deal of effort has been devoted to developing oil spill response organizations, technologies, and doctrines to better cope with significant and catastrophic spills. These developments are chronicled primarily in the Proceedings of the Biannual International Oil Spill Conferences (held on odd-years 1969-1995), as well as in the extensive technical literature on the subject.

Much attention has been given to the organizational structure and dynamics that evolve during significant and catastrophic spills, and the strategic decisions that are made, particularly during the initial stages of the response. Less attention has been given to the decisions which govern effectiveness and efficiency on a day to day basis, and the decision process used in resolving the "how clean is clean" issue.

Before proceeding further, it is important to carefully specify what is meant by effectiveness and efficiency, as the two terms are often used interchangeably in the literature. A clear, concise explanation of these terms is provided by Walker et al. (1994) as follows:

Response effectiveness relates to the accomplishment of response objectives - doing the right things (as specified by law, regulation and policy) - such as

- Conducting the response safely, without injuries or deaths;
- Preventing further spillage of oil;
- Maximizing oil recovery;
- Minimizing the environmental impact of the spill; and
- Ensuring the media and public perceive the response as effective.

Response efficiency relates to the ability to use resources appropriately - doing the right things correctly (or getting the right things done with the right amount of
resources) - such as:

- Mobilizing and using the type and number of resources appropriate for the spill;
- Attaining the sustained maximum output from available resources;
- Keeping the scale of the response effort in proportion to the size of the spill and the threat of environmental damage; and
- Drawing a balance between the cost of damage mitigation and the damage that might otherwise occur.

Near the end of the spill response effort, these last two considerations become important in resolving the "how clean is clean" issue and terminating the response at the appropriate point.

Oil spill response organizations are under intense pressure to be both effective and efficient. The pressure for effectiveness comes from those external to the oil spill response community, such as elected officials, government administrators, the media, environmental interest groups (non-governmental organizations) and the public at large. The pressure for efficiency comes from within including government resource managers, oil company management, stockholders, and marine insurance companies (Walker et al., 1994).

Prior to the EXXON VALDEZ oil spill, there was little mention of this aspect of oil spill response in the literature and various spill response manuals. However, during the EXXON VALDEZ spill, effective and efficient management of oil spill cleanup operations took on new significance and became an important issue throughout the various stages of the response effort. This was due to the size of the spill, the complexity of the response, and the often conflicting viewpoints held by Exxon, the Federal OSC and the State of Alaska. The issue of "how clean is clean" drew particular attention as it became clear that the Coast Guard, Exxon, and the State of Alaska were faced with a seemingly open-ended cleanup task which would ultimately require several years of effort at an enormous cost ($2.2 billion).

Subsequent to EXXON VALDEZ, the issue has surfaced in several other significant spills, and has been dealt with using various approaches. It is becoming clear that ensuring effective and efficient cleanup, and resolving the "how clean is clean" issue, is not a well-defined process or decision which arises at a specific point. Rather it is a complex issue
that evolves and must be dealt with throughout the response operation. This issue is highly sensitive to the specific technical parameters of the spill, the interaction of the various agencies and stakeholders managing the response effort, and the reaction and expectations of the public at large.
3.0 OIL SPILL CLEANUP: PROCESSES, PARTICIPANTS, ORGANIZATIONS AND CRITERIA FOR SUCCESS

Before dealing with some of the specific issues and experience related to managing the level of effort during spills and resolving the "how clean is clean" issue, it is useful to review oil spill response doctrine and practice. This includes describing the decision making process, the individuals and organizations involved and the criteria for success.

There are three major phases associated with oil spill cleanup:

- Contingency Planning
- Spill Response, and
- Damage Assessment, Restoration and Monitoring.

Each of these three phases has an impact or provides feedback on the effectiveness and efficiency of the oil spill cleanup effort.

The national mandate for these activities is contained in the Oil Pollution Act of 1990 - OPA 90 (U.S. Congress, 1990). The procedures, participants and organizational structure for carrying out Contingency Planning and Spill Response activities are detailed in the National Oil and Hazardous Substances Pollution Contingency Plan (U.S. EPA, 1994). The National Contingency Plan (NCP) is the single most influential document governing oil spill response in the United States. The first NCP was published in September 1968 as a federal government interagency agreement following the TORREY CANYON spill. It was re-published in 1970 by the Council on Environmental Quality as the first federal oil spill response regulation. Most recently it was updated following OPA 90 to reflect the more aggressive oil spill response requirements arising from the EXXON VALDEZ and other major spills which occurred in 1989 and 1990.

With respect to contingency planning, the NCP itself serves as the overall contingency plan at the national level outlining federal and state roles and responsibilities, procedures and available resources for response. Within each Federal Region, Alaska, Oceania in the Pacific and the Caribbean, the NCP is supplemented by a Regional Response Plan. At the local level, where most spill response operations are focused, a detailed spill response implementation strategy is outlined in the Area Contingency Plans (ACPs). The ACPs are
a unique requirement of OPA 90 which recognizes that a clearer strategy and improved tactical coordination is required at the local level to deal with major and catastrophic spills. The ACPs tailor the implementation strategy to the resources, and the expectations and policies of the government agencies and industry organizations in the area where the spill occurs. In the coastal zone, these areas correspond to the area of responsibility of the Coast Guard Captain of the Port.

These Area Contingency Plans are particularly important to the effectiveness and efficiency of the response effort as these decisions and issues are generally tactical and site specific in nature. It is during the contingency planning phase that the initial consensus is reached on which tactics will be employed, what resources are available and how these resources will be deployed and managed in the field.

The second major phase in the sequence is the spill response itself. It is during this phase that cleanup operations are initiated and managed to recover spilled oil from the environment and mitigate the impact of oil that cannot be removed. The NCP outlines the specific elements of the spill response operation as follows:

- **Discovery and Notification:**
  Response agencies and organizations are alerted that a spill has occurred or is imminent.

- **Preliminary Assessment and Initiation of Action:**
  The federal On-Scene Coordinator (OSC) evaluates the magnitude and severity of the discharge and the threat to public health and welfare or the environment, assesses the feasibility of removal, and identifies the potentially responsible parties.

- **Containment, Countermeasures, Cleanup and Disposal:**
  This includes defensive actions such as controlling the source and defensive booming to protect sensitive areas, recovery or treatment of the oil to mitigate impacts, and disposal of recovered oil and oiled debris in an environmentally sound manner.

- **Documentation and Cost Recovery:**
  This includes collecting and maintaining documents to support cost recovery for cleanup resources utilized, as well as for litigation and scientific purposes.

Figure 1 depicts the overall decision-making process for initiating, managing and terminating spill response operations. At the outset of the spill, strategic decisions are made on whether to respond or not, and the techniques and technologies that will be employed, as depicted in the upper portion of the diagram. To some extent these decisions
Figure 1. Model of the overall management and decision-making process in oil spill response.
may have been pre-determined and pre-approved in the contingency planning process. Options are narrowed and focused in the first hours and days of the spill depending on the size, location, and environmental and economic resources threatened by the spill.

For instance, a spill of significant size that remains offshore may be dealt with using mechanical recovery and in-situ burning. Offshore response is generally more efficient and less environmentally damaging especially under moderate wind and wave conditions. A spill that quickly moves onshore may require defensive booming and dispersant application to protect sensitive areas. If the oil comes ashore, extensive shoreline cleanup may be required to remove oil from the shore and prevent oil migration back into sensitive coastal waters. Shoreline responses are generally less efficient and more environmentally damaging. Thus the initial strategic decisions, which are often dictated and constrained by the specific nature of the spill, weather conditions and location; to some extent pre-determine the level of effort and effectiveness of the response.

This strategic decision-making process requires a clear understanding of the technology and operational constraints of various countermeasures and cleanup techniques, the anticipated environmental effects, and any policy constraints that may apply (e.g. restrictions on the use of dispersants or in-situ burning in specific areas as per the contingency plans). Strategic decisions are usually made in the first few hours and days of the response. This time period has been described as the "emergency phase" by Ott, Lindstedt-Siva and Walker (1993), when decisions are focused on major options and issues. These initial decisions are generally made in an authoritative manner by federal and state officials, and follow guidelines outlined in regulations, contingency plans and other policy documents.

Once strategic decisions have been made and cleanup initiated, the spill response enters a tactical phase which may typically span several weeks or months depending on the magnitude and complexity of the response. Managing level of effort in the tactical phase requires reaching a consensus on a day-to-day basis on which techniques should be used to contain, treat or remove the oil from a specific location; and to what extent the technique should be employed so that the response is effective and efficient. As depicted in the bottom portion of Figure 1, achieving effectiveness and efficiency throughout the tactical phase requires monitoring and evaluating cleanup operations with respect to the direct results produced (oil recovered, miles of shoreline cleaned), the secondary environmental effects (damage caused by the cleanup operations), and the cost.
It is during this tactical phase that the issue of "how clean is clean" is first addressed, and ultimately becomes the primary issue in determining when the response effort should be terminated. As operations progress during the tactical phase, the "how clean is clean" decision (as well as others) are not likely to be clear cut and authoritative. During this phase, described as the "overhaul phase" by Ott, Lindstedt-Siva and Walker (1993), the decision-making process becomes more fluid often involving numerous participants and stakeholders with differing objectives and agendas, particularly in resolving the "how clean is clean" issue. Reaching a decision during this phase often requires diplomacy as the needs of the various parties must be addressed and differences reconciled. Decisions are reached more through consensus building rather than authoritative mandates by federal and state officials. The other critical factor that enters the decision process during this phase is the perception of the public, which will support or object to terminating cleanup operations depending on their perception of the success or failure of the cleanup effort.

The third phase associated with spill cleanup is damage assessment, restoration and long-term monitoring. This process generally begins near the end of the response operations, with a Natural Resource Damage Assessment (NRDA). This process attempts to quantify the injury to the environment and lost use of the resources affected. OPA 90 mandated revision of NRDA regulations specifically for oil spills. Accordingly regulations were drafted by the National Oceanic and Atmospheric Administration (NOAA, 1994). A concise overview of the process is provided by Reinharz (1995). The scope, complexity and methodologies used in Natural Resource Damage Assessment are described in detail by Grigalunus and Opaluch (1993). Luthi et. al. (1993), and Robilliard et. al. (1993).

Once damages have been evaluated and quantified, a restoration plan is formulated and implemented to accelerate recovery of the impacted areas. Long-term monitoring of this recovery is carried out (often for a decade or more after the spill) to study the effects of the spill itself, the effectiveness of countermeasures and cleanup operations during the spill, and the impact of restoration actions after the spill. It is particularly important in providing feedback on the effectiveness of countermeasures and cleanup actions as the positive and negative benefits of these actions may not be fully apparent at the end of the response operations. It is also significant that even though the two activities are separated in time and addressed under different regulations, the two are linked in that successful cleanup should reduce natural resource damage and the need for restoration in a quantifiable manner. Several of the NRDA models and formula recognize this by giving credit to the
spiller for oil removal during the response (NOAA, 1994; Geselbracht and Logan, 1993).

Adding to the complexity of oil spill response operations is the variety of participants, stakeholders and interested parties involved in the process. The response participants are those agencies, organizations and individuals which have a direct role in the execution of the response effort. For Federal agencies, these roles are defined under OPA 90 and the National Contingency Plan. The roles of state agencies are specified under various state laws, regulations and plans. The roles and responsibilities of the spiller (the responsible party) are mandated under OPA 90.

Stakeholders can be characterized as agencies, organizations and individuals who do not have an official role in the response effort itself, but who have a direct economic, environmental or political vested interest in the outcome of the response effort. These stakeholders include natural resource trustees, port authorities, shoreline property owners, fishermen, recreational users, insurers and elected officials.

Interested parties can be described as organizations and individuals not directly involved as responders or stakeholders, but who are concerned with the outcome. They will monitor the situation and often bring pressure to bear on the participants if the response is perceived as unsuccessful. In this sense they regard themselves as being stakeholders, and will often enter the process as such. Interested parties include the media, non-governmental environmental organizations, citizens groups and the public at large. These individuals, agencies and organizations can facilitate or constrain the decision-making process depending on their objectives and agendas (Mew, Rooney-Char and Webb, 1983). Table 1 summarizes various participants, stakeholders, and interested parties; their responsibilities and agendas; and criteria for success in spill response, that is, how they view the issues of effectiveness, efficiency and "how clean is clean".

In carrying out cleanup operations, the various participants assemble and interact within the framework of an organizational structure or response management system which is generally specified at a strategic level in the contingency planning process, but often modified during the operation itself. The characteristics of these organizational structures have been widely researched and discussed in the literature. A thorough review of the design and dynamics of various response management systems and current practice both nationally and internationally is provided by Walker et. al. (1994). They describe three
Table 1  Various agencies, organizations and parties; their responsibilities and agendas; and criteria for success in oil spill response.

<table>
<thead>
<tr>
<th>PARTICIPANTS, STAKEHOLDERS, AND INTERESTED PARTIES</th>
<th>RESPONSIBILITY AND AGENDA</th>
<th>CRITERIA FOR SUCCESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal On-Scene Coordinator</td>
<td>Meet mandates of OPA 90 and National Contingency Plan.</td>
<td>Balance mitigation and removal results and environmental effects. Control costs for federal response.</td>
</tr>
<tr>
<td>State On-Scene Coordinator</td>
<td>Meet requirements of state regulations and contingency plans.</td>
<td>Balance mitigation and removal results and environmental effects.</td>
</tr>
<tr>
<td>Local Officials</td>
<td>Represent municipalities in ensuring natural and economic resources within jurisdiction are protected and restored. Ensure health &amp; safety of population.</td>
<td>Satisfy local public that appropriate action is being taken by agencies and responsible party.</td>
</tr>
<tr>
<td>Responsible Party</td>
<td>Meet spiller requirements under federal and state regulations.</td>
<td>Control costs and company liability. Preserve public image.</td>
</tr>
<tr>
<td>Resource Trustees</td>
<td>Protect and restore natural resources</td>
<td>Remove or treat oil while minimizing cleanup impact. Cost is not an issue.</td>
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<tr>
<td>Insurance Companies</td>
<td>Meet terms of contract with responsible party.</td>
<td>Cost is a paramount issue; minimize cleanup costs and claims.</td>
</tr>
<tr>
<td>Environmental Organizations</td>
<td>Represent interests of the environment. Serve as watchdog for agencies and responsible party.</td>
<td>Protect and restore the environment. Cost is not an issue.</td>
</tr>
<tr>
<td>National and Local Media</td>
<td>Provide public with information on spill and response effort.</td>
<td>Information on spill of interest to the general public is provided in a timely manner. Responding officials are accessible to media personnel.</td>
</tr>
<tr>
<td>General Public</td>
<td>Voice concern for resources impacted, and opinion on actions of the agencies and responsible party.</td>
<td>Wants immediate action, and clear indication that agencies and responsible party are resolving the problem.</td>
</tr>
</tbody>
</table>
types of response management systems in detail: the traditional military command and control system, the current U.S. National Response System as described in the NCP, and the Incident Command System (ICS).

Current U.S. practice favors the Incident Command System (ICS) as the response management system of choice. ICS was initiated as a response management system for fighting forest fires and dealing with other natural disasters. The system is described in detail by Hunter (1993). The basic structure of ICS is an incident commander supported by interactive teams covering operations, logistics, finance and planning. The underlying principle of ICS is that the system must have flexibility to adapt to the specific spill scenario. Attributes that allow for this adaptation include:

- Common terminology
- Modular organization
- Integrated communications
- Unified command structure
- Consolidated action plan
- Manageable span of control
- Pre-designated span of control
- Pre-designated incident facilities, and
- Comprehensive resource management.

Since EXXON VALDEZ its strengths have been recognized by the spill response community, and it has been adapted to this function.

A primary attribute of a response management system which allows it to deal with the issues of effectiveness, efficiency, and "how clean is clean", is the system's ability to adapt to a changing scenario and respond to outside pressure. Walker et. al. (1994) characterize response management systems as being closed or open in this regard. A closed system is one which depends on a hierarchical structure, centralized direction, and internal feedback; and does not interact with its technological, political, economic or socio-cultural environments. The traditional military command and control system can be characterized as a closed system.
An open system relies on both external and internal feedback, distributed decision making by small ad hoc teams, and a high degree of flexibility and innovation. Feedback from external environments is the critical determinant in system behavior. The ICS can be characterized as an "open system". Throughout this discussion it will become clear that an open system is far more capable of managing for effectiveness and efficiency in oil spill response, and dealing with the "how clean is clean" issue.

Defining success in oil spill response is a critical but somewhat elusive issue. In general terms, success in oil spill cleanup is based on meeting the defined goals and objectives of the response operations. Goals are the general "important results" expected in any response operation. These are defined in strategic policy documents such as the National Contingency Plan (NCP). The NCP specifies that response operations in the U.S. be directed at three primary goals:

- Insuring safety of human life;
- Stabilizing the situation to preclude further damage;
- Use of all necessary containment and removal tactics in a coordinated manner to ensure a timely, effective response that minimizes impact to the environment.

Achieving the first and second goal usually involves making specific decisions and implementing them in a straightforward manner at the outset of the spill. Attaining the third goal involves effectively dealing with a range of issues throughout the response effort.

Defining success in regulations is important; but understanding how success is perceived by the various response participants, stakeholders and interested parties is equally important. As outlined in Table 1, each agency, organization and party will perceive success differently. As part of their study, Walker et. al. (1994) provide a summary of perceived criteria for success for oil spill response. This summary is based on a thorough review of the current literature, and the results of a survey conducted among federal government agencies, federal On-Scene Coordinators, state spill response representatives, representatives of potential responsible parties (tanker and facility owners & operators), technical advisors and cleanup contractors. When asked the question "what constitutes a successful response?", survey participants responded in various ways. Various attributes of a successful response (success factors) included:
- Damage to the environment is minimized.
- Public and media perceive the response as successful.
- The response is expeditious.
- The spread of oil is minimized.
- The involved government agencies, responsible party and other participants are satisfied.
- The maximum possible amount of oil is removed.
- There is multi-party synergism.
- There are no injuries or fatalities.
- Cost are controlled.
- A response organization is established and maintains command and control.
- Proper and least disruptive (environmentally) cleanup techniques are employed.
- There is appropriate restoration of the environment.

Clearly different individuals judge the success of the response operation by different criteria. It is also interesting that some of the criteria are not directly related to the effectiveness and efficiency of the cleanup effort.
4.0 ECONOMIC AND ENVIRONMENTAL CONCEPTS RELATED TO EFFECTIVENESS AND EFFICIENCY

In understanding how the spill response effort can be managed to ensure effectiveness and efficiency, it is necessary to understand certain economic and environmental concepts.

In a strictly economic sense, successfully managing a spill response can be described as balancing the benefit derived vs. the cost of the cleanup operations. In terms of economic theory, a business will produce a good or service (expend effort) until a point is reached where the marginal cost (cost of producing the next unit of product or service) equals the marginal revenue (the financial return from that unit). At this point profit is maximized; beyond this point profit diminishes.

To extend this concept to oil spill cleanup, one should ideally expend additional effort in cleaning up a spill until the point is reached where the marginal cleanup cost (cost of removing or neutralizing the next unit of oil) equals the marginal cleanup benefit (the dollar value of the natural resource damage prevented by removing that next unit of oil). Beyond this point, it would be less expensive to restore the resource or provide compensation for the damages.

Figure 2 shows how these two parameters might be expected to vary as a function of the barrels of oil recovered or treated (as with dispersants or in-situ burning). Ideally, the response effort would be terminated at the point where the two curves intersect, that is, when marginal cleanup cost begins to exceed marginal cleanup benefit. In practice, values for marginal cleanup cost and marginal cleanup benefit are difficult to determine or even estimate. Marginal cleanup cost accounting is possible but requires significant effort. Marginal cleanup benefit is very difficult to quantify as it requires affixing dollar values to environmental resources, and determining the degree to which the cleanup effort reduces the cost of natural resource damage. As evidenced by the Natural Resource Damage Assessment (NRDA) process, such estimates are imprecise and subject to much interpretation and controversy (Grigalunas and Opaluch, 1993; Bennett, Peacock and Goodspeed, 1995). It is also unlikely that a response effort would be terminated exactly at the point where the two curves intersect, as current laws and regulations treat removal and restoration as separate issues. Agency policy and public opinion will generally require cleanup to a point where further effort is clearly impractical or environmentally damaging.
Figure 2. Diagram showing the relationship between marginal cleanup cost and marginal cleanup benefit.
This may be well beyond the point where marginal cleanup cost exceeds marginal cleanup benefit.

Along with economic considerations, proper spill management requires understanding the environmental considerations. The tradeoff between the damage caused by oil left in the environment versus damage caused by attempts to mitigate it has long been recognized as a critical issue. Cleanup impacts can be severe as encountered in the TORREY CANYON response where the use of toxic dispersants to remove oil from the shoreline severely retarded recovery of the shoreline ecosystem. More recently, hot water washing of the shoreline following the EXXON VALDEZ spill was found to be more detrimental to shoreline ecosystem recovery than leaving the oil in place for natural removal, although hot water washing may have prevented ongoing reentry of oil into the adjacent waters (Mearns, 1993). Accordingly, recent cleanup technology development efforts are focusing on less intrusive, more environmentally benign methods of removing or neutralizing oil in the environment, such as bioremediation for shorelines and less toxic dispersants for open water treatment of spills. In attempting to balance the environmental impacts of the oil with the environmental impacts of various countermeasures and cleanup actions, the important concept is that of Net Environmental Benefit (NEB).

Undertaking countermeasures and cleanup actions can have a range of possible outcomes as illustrated in Figure 3. The vertical axis corresponds to the environmental value provided or integrity of the resources affected by the spill, the horizontal axis corresponds to time after the spill. Curve A represents the baseline case where a spill occurs and no cleanup is attempted. As always, the spill results in resource degradation, but after some period of time the environmental value/integrity returns to its original state (as is usually the case). Curve B is typical of the case where an environmentally benign countermeasure has been implemented (e.g. offshore mechanical recovery or in-situ burning), such that the resource is spared the full impact of the spill and recovery is accelerated. Curve C represents an optimum scenario for shoreline cleanup where the cleanup operations cause some additional disruption and damage to the ecosystem, but recovery is accelerated over the long-run. Curve D represents a worst case scenario where an aggressive, environmentally intrusive response effort is implemented such that significant additional damage occurs, and recovery is actually retarded.
Figure 3. Diagram depicting the overall net environmental benefit associated with various countermeasures and cleanup actions.
The "net environmental benefit" of the response activities is the measure of prevented environmental damage relative to the baseline case. Another way of describing the net environmental benefit is the acceleration in time of the recovery process as compared to the baseline case (as illustrated in Figures 3 and 4). It can also be depicted by the shaded area in Figure 4 which represents the net damage prevented by initiating the cleanup.

An extensive treatment of the impact of shoreline cleanup operations, focused on the net environmental benefit issue is provided in a report by AURIS Ltd. (1994). The results of the study are summarized by Sell et. al. (1995). After a thorough review of the outcome of past shoreline cleanup operations, the report concluded that the recovery time for various ecosystems was three to five years. It also concluded that this recovery time was often independent of whether shoreline cleanup had been attempted or not. The report further recommended that from an environmental standpoint, shoreline cleanup should be pursued only when it can be expected to significantly accelerate recovery, that is, promote recovery in less than 3 to 5 years. Of course, little is known on the capability of specific techniques and technologies to accelerate recovery, and how this accelerated recovery varies with different shoreline types.

In economic terms, achieving a net environmental benefit in spill response means that the cleanup activities result in a net decrease in the dollar value of the aggregate natural resource damage (NDR) caused by the spill. The aggregate NRD is the sum of the NRD due to the oil itself and NRD caused by the cleanup. This is illustrated in Figure 5 originally presented by Dunford, Hudson, and Desvouges (1991). The optimum level of effort from an environmental standpoint is reached when the aggregate NRD is minimized. This does not include socio-economic considerations (such as total removal from areas of high public use such as bathing beaches) which may require expenditure of cleanup effort well beyond the optimum point described above.

In practice, the precise quantification of economic and environmental costs and benefits and the determination of efficiency endpoints will be difficult. However, these concepts should be kept in mind, and overall trends in efficiency recognized so that the cleanup effort does not proceed beyond some reasonable level, as is sometimes the case in addressing other environmental cleanup projects. Supreme Court Justice Stephen Breyer refers to this problem as "tunnel vision", that is, when the single-minded pursuit of a single goal carries an endeavor to a point where it brings more harm than good (Breyer, 1993). This often
Net Environmental Effect of Cleanup

Figure 4. Diagram depicting the positive net environmental benefit of a cleanup effort (shaded area).
Relation Between Natural Resource Damages (NRD) and Cleanup Activities
(Dunford, Hudson, Desvousges, 1991)

Figure 5. Diagram showing the relation between natural resource damages (NRD) and cleanup activities.
results in expending the majority of the funding on solving "the last ten percent" of the problem.

Although it is difficult to quantitatively monitor the parameters described above, it is certainly both possible and beneficial to keep track of overall cleanup progress vs. cleanup cost. This can be most easily monitored during the response by tracking tangible results (the barrels of oil recovered or miles of shoreline treated), and computing the unit cost of barrel removed or mile treated. A simple method of computing unit cost is to divide the total recorded or anticipated cost by the total barrels recovered or total miles of shoreline treated. A more precise and useful figure in gauging effectiveness and efficiency over time, and addressing the "how clean is clean" at a specific point in time, is the "current unit cost". This can be derived by dividing the costs incurred during a specific time period (week or day), by the barrels recovered/miles of shoreline treated during that specific week or day.

Figure 6 shows how daily cost, total cost, and unit cost may be expected to vary as the response progresses. Daily costs usually start at a moderate level and then escalate as more equipment and personnel are brought on-scene. As operations peak, so does the daily cost. As the response effort matures and operations decline, daily costs decline and the total cost approaches a certain level. Unit costs can be expected to increase as more effort and funds are expended in recovering each additional unit of oil and cleaning each additional mile of shoreline.

Figure 7 shows a typical comparison between tangible results (barrels recovered/miles of shoreline treated) and the unit cost of cleanup (either average or current). The exact shape of the curves and values reached will vary from spill to spill. The curves presented are typical of a major spill response such as during the EXXON VALDEZ and AMERICAN TRADER spills (Noerager and Goodman, 1991; Carpenter, Dragnich and Smith, 1991; Card and Meehan, 1991). The number of miles of shoreline "treated" will also vary significantly from spill to spill based on the criteria for "adequate treatment" or "how clean is clean". However, one can expect that as the response continues, total barrels recovered and miles of shoreline will approach a specific value, while unit cleanup costs will begin to escalate significantly (perhaps exponentially). It is useful to record these values, as is now being done during various major spills, and plot them to so that trends can be recognized and understood, and the point of diminishing return can be identified.
Figure 6. Diagram showing the variation of cleanup costs during a typical oil spill response operation.
Tracking Direct Results vs. Cost During Cleanup Effort

Figure 7. Diagram showing the progression of cleanup costs and direct results during a typical major spill response operation.
5.0 THE IMPORTANCE OF POLICY AND PERCEPTION

The final consideration in determining appropriate level of effort and resolving the "how clean is clean" issue is regulatory policy, and public perception and opinion. Both factors are often intermingled and may subjectively impact cleanup activities. Regulatory policy on the appropriate level of effort is often stated in very general terms and expressed as overall spill response "goals" as discussed above. This policy generally evolves in the course of a specific response as goals are translated into specific strategic and tactical objectives and action plans.

Accordingly, policy guidelines remain somewhat descriptive and vague. The Oil Pollution Act of 1990 requires that the President, in accordance with the National Contingency Plan (NCP) and Area Contingency Plan (ACP), ensure "effective and immediate" removal of a discharge (Sec. 4201, OPA 1990). In addressing the removal responsibilities of responsible parties, Section 4202 requires removal of a worst case discharge to "the maximum extent practicable". In implementing OPA 90, the revised National Contingency Plan leaves determining the appropriate level of effort in cleanup to the discretion of the On-Scene Coordinator (OSC) in consultation with other response agencies and the natural resource trustees. Response termination is determined by the OSC in consultation with the Governor or Governors of the affected states.

Although the revised NCP does not provide specific criteria, it does recognize the need for specific information to properly address the net environmental benefit issue. Specifically, Section 4.1.4 of Appendix E of the NCP calls for the development of a Fish and Wildlife and Sensitive Environments Plan Annex to Area Contingency Plan (EPA, 1994). This Annex provides technical guidance on the environmental effects of various countermeasures and cleanup techniques. The Annex is designed to "identify potential environmental effects on fish and wildlife, their habitats, and other sensitive environments resulting from removal actions or countermeasures including the option of "no removal". The Annex should also "establish priorities for application of countermeasures and removal actions to habitats within the geographic region of the ACP". Given these provisions in the ACP, it appears that decision-making on level of effort and "how clean is clean" is being appropriately left up to the OSC in consultation with other participants and stakeholders at the local level.
In managing spill response efforts in the coastal zone, Coast Guard OSCs follow the generic guidelines provided by the Coast Guard Marine Safety Manual (USCG, 1995). The current version of this manual states that removal is "complete" when:

- no oil is detectable in the water or on adjoining shorelines; or
- further removal causes more environmental harm than good; or
- cleanup is excessively costly in view of risk prevented; and
- activities required to repair unavoidable damage resulting from removal actions have been performed.

The Marine Safety Manual also provides general guidance on ensuring efficiency. In managing a federally funded response, that is one in which the Coast Guard is actively managing the cleanup, the OSC is directed to:

- minimize the elapsed time from notification to equipment deployment,
- match equipment and personnel to spill characteristics,
- minimize the cost of labor equipment and materials, and
- rapidly secure (demobilize) those resources no longer needed.

As in the NCP, the "how clean is clean" decision is left to the OSC based on the set of "common sense" principles outlined above. Although this provides discretion and flexibility in reaching the decision, it may complicate the decision-making process when the OSC is subjected to differing views and agendas by the other response agencies and resource trustees, which are often influenced by public reaction and pressure.

Public perception and expectations are often critical factors in determining the dynamics and agendas for interaction between the various response agencies and resource trustees. As with other issues in our society, perception is often more powerful than reality, and in fact becomes reality in the context of the specific issue or event. Oil spills are highly visible events which generate intense public concern further stimulated by the media and special interest groups. Consequently, the perceived impact of an oil spill may have little relation to the actual long-term biochemical and physical impacts on the resources, but may be extremely important in influencing how the response effort is managed. Although oil spills
are relatively short-lived events and other environmental insults may be far more damaging in the long term, this overall environmental perspective is easily overshadowed by the public's emotional reactions (Ott, Lindstedt-Siva, and Walker, 1993).

Even more important to the management of the spill than the perceived impact is the perceived adequacy of the response efforts. If the public perceives that an effective response effort is being mounted and that the authorities are in control of the situation, they are less likely to pressure the various legislators and agencies and influence the management of the response. On the other hand, if the response efforts are perceived as inadequate and uncoordinated, and agency officials are perceived as confused and not in control, public pressure will be brought to bear often without understanding the true scientific, technological and operational constraints. Such perceptions may persist throughout the spill despite actual progress and ultimately complicate the "how clean is clean" determination. There will be a continued reluctance particularly on the part of local and state agencies, and resource trustees to sign off on a response effort that is perceived as an overall failure.

The key to managing public opinion and pressure is the accurate and timely dissemination of information by a central source. Care must be taken not to exaggerate the potential damages, or inflate expectations on the ability to respond. In a crisis, the two biggest problems faced by an organization are the loss of public confidence and the fear of the unexpected by groups affected by the event (Meidt, 1991). From the point of view of the OSC, the key to dealing with public perceptions in crisis relates to the ability to coordinate the information flow within the response organization, focus the information being imparted, and provide this information to the media in a timely fashion.

In summary, successfully managing level of effort during oil spill cleanup requires sufficient information on both the progress and expenditures in cleanup effort and the associated environmental effects. Tradeoffs must be made based on both the qualitative and quantitative data available, the current policy as specified in the regulations and guidelines, and the expectations and perceptions of the stakeholders and other interested parties. The overall goal is to foster an informed consensus decision-making process that optimizes effectiveness and efficiency throughout the spill; and leads to resolution of the "how clean is clean" issue, and a smooth termination of the response.
The discussion above outlines some of the key concepts and critical factors in managing level of effort and resolving the "how clean is clean" issue. Although regulations and agency guidelines provide some general criteria in addressing these decisions, the specific criteria and procedures are left to the discretion of the spill responders. Accordingly various approaches to dealing with these issues have evolved during recent majors spills. The following analysis looks at four such spills: the EXXON VALDEZ spill in Prince William Sound, Alaska in 1989, the AMERICAN TRADER spill in Long Beach, California in 1990, the Tampa Bay in 1993 in Florida (which involved three vessels), and the MORRIS J. BERMAN spill in San Juan, Puerto Rico in 1993.

EXXON VALDEZ Spill in Prince William Sound

On March 24, 1989, the EXXON VALDEZ ran aground in Prince William Sound spilling approximately 11 million gallons (262,000 barrels) of Prudhoe Bay Crude. The oil would eventually impact 1,100 mile of coastline in Alaska, making it the largest and most environmentally damaging spill in U.S. history. At the height of the response, more than 11,000 personnel and 1,400 vessels were involved in the cleanup effort (NOAA, 1992). The response effort is documented in detail in the Federal On-Scene Coordinator's Report (USCG, 1993). Figure 8 shows the initial location and movement of the spill, and the large area ultimately affected.

The EXXON VALDEZ spill was immediately described as "a catastrophic oil spill". Walker et. al. (1994) describe such spills as

"those rare events which involve a release on the order of millions of gallons of oil into the marine environment in a location and under such circumstances that economic, environmental, political, social and cultural impacts result."

These spills generally constitute a Tier 3 spill as defined by the International Petroleum Industry Environmental Conservation Association (IPIECA) in that "substantial resources will be required and support from national and international cooperative stockpiles will be necessary" (IPIECA, 1991). As such, catastrophic spills represent "worst case" occurrences.
Figure 8. Map showing the location and advance of oil from the EXXON VALDEZ oil spill (from USCG, 1993).
On a strategic level, the EXXON VALDEZ spill represents a case where the success of the response effort was heavily constrained by the spill scenario, and to a large extent predetermined by the key events during the initial days of the response. The primary determining factor in the response effort was the enormous quantity of oil released. In touring the spill area on March 26, the Governor of Alaska remarked

"We simply don't have enough equipment to contain it. No one does. You couldn't contain it with all of the equipment in Alaska" (USCG, 1993).

The second determining factor was the weather. Initial conditions were suitable for several offshore countermeasures and cleanup techniques including mechanical recovery, dispersants, and in-situ burning. However, within four days of the spill, a major storm had precluded effective implementation of these techniques by dispersing the slick over a wide area, driving much of the oil ashore, and emulsifying the oil that remained in open water which made dispersants and in-situ burning infeasible. Given this limited "window of opportunity", it was estimated that only 20% to 25% of the oil could have been recovered, even if all equipment in the U.S. inventory could have been marshaled and had worked perfectly (USCG, 1993).

The initial response was also complicated by difficulties in reaching strategic decisions on the use of dispersants. Although dispersants had been pre-approved for a large area within Prince William Sound, the Alaska Department of Environmental Conservation (ADEC) was reluctant to approve their use without extensive preliminary testing. This reluctance was based on concern for longer term impact of the dispersed oil on fisheries and other marine resources in Prince William Sound. Although the testing of dispersants continued into April, ADEC never approved full-fledged use until the window of opportunity had passed.

Likewise, in-situ burning was employed but only as a test (Allen, 1991). On March 25, a highly successful test burn was conducted in which 15,000 gallons of oil were removed from the water. On March 26 the results of these tests were reviewed and a decision to proceed with in-situ burning on large scale was made. Unfortunately, the in-situ burn option had to be abandoned because of an approaching storm forced cleanup crews to take shelter, and ultimately emulsified the oil, rendering it unburnable.

Containment and mechanical recovery operations were initiated within hours of the spill. Containment booming of the fish hatcheries in Prince William Sound was successfully
accomplished at several locations. Mechanical recovery met with reasonable success but was limited by the amount of equipment available on-scene and the logistics of moving additional equipment into Prince William Sound (Noerager and Goodman, 1991; Harrison, 1991).

In reality, aggressive implementation of all cleanup techniques within hours after the spill would not have removed significant amounts of oil from the environment. Even though additional supplies of dispersants were ultimately delivered to Valdez, these would have treated only 10% of the oil at best (USCG, 1993). In-situ burning equipment was available but only in limited quantities such that only a fraction of the oil might have been burned. Consequently, the slowness of the decision-making process did not, in itself, significantly impact the overall result of the response effort. However, it did contribute to a growing public perception that the response effort was slow and poorly coordinated, and plagued by a lack of consensus among the federal and state agencies, and the Exxon oil company.

Although offshore cleanup operations continued on a limited scale throughout the summer of 1989, the bulk of the response effort quickly centered on a labor intensive, costly shoreline cleanup effort. In the end, the cleanup operation would span three years and cost in excess of $2 billion.

Throughout the shoreline cleanup process, several alternatives were investigated including the use of cold and hot pressure washing, the use of surfactant chemicals in washing the oil from the beaches, and the use of bioremediation to accelerate natural degradation of the oil. An elaborate mechanical removal and cleaning technique was also proposed during the summer of 1990. The On-Scene Coordinator's report thoroughly documents how each of these techniques was tested and evaluated during the spill itself, often under stringent protocols that seemed more suitable to the laboratory than field decision-making. This was often done in response to differing opinions and agendas among the various participants and stakeholders on the effectiveness of pressure washing, chemical washing and bioremediation.

As a result of these differing opinions, a compromise was reached which favored cold water pressure washing, and later hot water pressure washing. Although there was ongoing concern over the secondary effects of hot water, high pressure cleaning, it soon became the preferred technique largely because of the perceived need to produce visible
cleanup results. Follow-up long-term monitoring has since shown that the natural cleaning process (let nature take its course) would have been an effective, more environmentally benign option in removing oil from both exposed and sheltered beaches. Monitoring has shown that beaches treated with hot water flushing took longer to recover compared to other beaches which were left alone (NOAA, 1992; Mearns, 1993).

Controversy over cleanup techniques and technologies continued as the response progressed. Chemical surfactants were favored by Exxon to enhance pressure washing, but discouraged by EPA based on general concern over the toxicity and effectiveness of such agents. Conversely, both the EPA and Exxon favored bioremediation, and undertook a major study to investigate its use in Prince William Sound. This was in contrast to the State of Alaska which was less than enthusiastic about the technique, viewing it as somewhat of a last resort or "polishing technique", only to be applied when all other techniques had been tried. During the second year of the response, a complex technology was proposed which would physically remove material from the beaches, clean it, and return it to the shore. This removal and cleaning process, which came to be termed the "rock washer", was touted by ADEC but opposed by the federal government and Exxon.

In determining which techniques were appropriate, the desired level of effort, and when cleanup efforts were sufficient, a number of approaches evolved. During much of the shoreline cleanup effort, these issues were resolved by what can best be described as a "general consensus approach" whereby cleanup techniques were selected and implemented through consultation among the major participants and stakeholders. In addressing the "how clean is clean" issue, the Federal On-Scene Coordinator (FOSC) terminated cleanup efforts on a particular segment of beach when it was judged clean enough based on the qualitative assessment and a general consensus by a group of experts.

This group of experts evolved along with the spill response effort itself, starting as a team of ad-hoc work groups with representation from the major response participants (e.g. Coast Guard, EPA, NOAA, State of Alaska, Exxon) and various stakeholders (resource trustees and non-governmental organizations). On March 30, 1989 three such work groups were formed, one to rank affected areas for cleanup priority, a second to identify cleanup techniques, and a third to make final assessments of the cleanup performed. These work groups came to be identified as the "Shoreline Assessment/Cleanup Assessment Team". As the complexity of the cleanup increased, and the shoreline cleanup spread
outside of Prince William Sound, formal Interagency Shoreline Cleanup Committees (ISCC) were established which combined the functions of the various shoreline cleanup work groups which had been created immediately following the spill. An ISCC was established for each of the four major response zones (Prince William Sound, Seward, Homer, and Kodiak), which were sub-sections of the affected coastline in Southern Alaska designated to facilitate management of the extensive cleanup operation (see Figure 8).

The shoreline cleanup decision-making process followed by the ISCC is shown in Figure 9 as described by Teal (1991). Within each of the four major areas, cleanup priorities were established based on the overall environmental, economic, and historic/cultural sensitivity of each segment. Cleanup efforts were focused on anadromous fish streams, spawning areas, fish hatcheries, commercial fishing areas, subsistence fishing and hunting areas, marine mammal haulout and pupping areas, and archaeological sites. On-site evaluations were conducted by the Shoreline Cleanup Assessment Teams (SCAT), organized by Exxon to conduct detailed shoreline surveys. Each SCAT consisted of a marine ecologist, an archaeologist, and a geomorphologist. The function of these teams was to:

- Evaluate on-site treatment priorities,
- Develop treatment recommendations,
- Implement shoreline treatment when called for, and
- Evaluate post treatment conditions.

Based on the site assessment and recommendations of the SCAT, a work plan was prepared by Exxon. It was then reviewed by the Alaska State Historic Preservation Office (SHPO) and forwarded to the FOSC. The FOSC forwarded the work plan to the ISCC for follow-up review. The ISCC met daily to review the shoreline data that was collected, the proposed work plans, and the resource constraints outlined by Exxon.

Overall, the SCAT/ISCC decision process proved very effective. In a later evaluation of the ISCC's role by several of its principal members, it was determined that

"the combination of daily interaction, broadly based and early agency and non-governmental involvement, and reference to a common information base contributed to the streamlining of decision making at a time when expeditious decision making was essential" (USCG, 1993).
Figure 9. Diagram showing the shoreline cleanup decision process followed by the Interagency Shoreline Cleanup Committee during the summer of 1989 EXXON VALDEZ cleanup effort (from Teal, 1991).
The shoreline decision-making process became more tactical in nature in the summer of 1990 as the cleanup focused on the more heavily oiled areas. The process was modified to be more expeditious and site-specific. While overall cooperation had developed among the involved agencies during the previous winter, specific differences often arose on the best cleanup approach and level of effort needed for each segment, which had to be ironed out quickly on a case by case basis. To achieve this, the work plan review process was incorporated into the work plan development, such that the process became more vertically integrated as shown in Figure 10.

The "working through" process in the summer of 1990 was largely accomplished by a newly formed FOSC advisory committee, the Technical Assessment Group (TAG). This group consisted of representatives from the Coast Guard, NOAA, ADEC and Exxon. The TAG was smaller and could develop consensus recommendations and provide them to the FOSC more quickly than the ISCC which it replaced. However, it did not involve the participation of the non-governmental organizations, and its meetings were not open to the press and general public as was the case with the ISCC meetings. This understandably left some stakeholders and interested parties (e.g. The Sierra Club) feeling that they had been cut out of the decision process (USCG, 1993). This led to accusations that the TAG violated the State of Alaska's "sunshine laws" and spurred additional controversy over the cleanup effort and its outcome.

Under the new process, recommendations on environmental priorities and constraints were formulated by a Resource Advisory Group (RAG), which included stakeholder representation as had the ISCC. These were combined with recommendations on shoreline cleanup technologies by the Shoreline Assessment Team to produce site-specific cleanup recommendations for TAG consideration. The TAG would then consult with the SHPO regarding impact on archaeological and cultural resources, and land managers for natural resource impact. The TAG would then either make a no treatment recommendation (NTR) or pass a specific plan for treatment on to the FOSC for approval.

Because of land manager concerns, a process evolved that gave land managers two opportunities to provide input. The first occurred during the formulation of the plan as described above when the TAG requested review from the State Technical Advisory Group, a parallel group which included land managers, before making its initial recommendations to the FOSC. The second occurred when the recommendations were
Figure 10. Diagram showing the shoreline cleanup decision process followed during the summer of 1990 EXXON VALDEZ cleanup effort (from Teal, 1991).
forwarded to the FOSC, such that land managers were given an additional 24 hours to provide additional input.

Once the work plan was approved by the FOSC, it was implemented by Exxon, with the results monitored by the Coast Guard and NOAA. As the cleanup operations on a particular segment neared completion, the final "how clean is clean" assessment was made by Coast Guard, NOAA and ADEC representatives, and a final sign-off or continued cleanup recommendation made to the FOSC.

The general consensus approach embodied in the ISCC/TAG process was driven to some extent by the subjectivity of "how clean is clean" issue, the lack of specific policy on the issue (as discussed above), and the overall complexity of the situation. It was further driven by the range of agendas and opinions held by the entities involved in the decision process, and the need for a system flexible enough to deal with the varied shoreline types on a segment-by-segment basis. Despite these complicating factors, the "general consensus" approach proved robust enough to support the decision process in most cases. The members of the ISCC and later TAG were able to reach a consensus on when each segment was clean enough, such that response operations could be gradually scaled back.

In addition to the general consensus approach, two additional, more structured approaches were proposed during the cleanup effort. During the summer of 1990, a "quantitative analytical approach" was proposed by the State of Alaska. This approach was proposed to determine when physical removal of oil from the shoreline had proceeded far enough to warrant follow-up application of bioremediation agents to the shoreline. The standard proposed was that physical removal had to proceed until an equivalent oil residue concentration of 5 g/kg in the sediments was achieved (USCG, 1993). This standard was based on the assumption that the biodegradation rate with the treatment was on the order of 5 g/kg per year, such that all remaining hydrocarbons would be removed within a year.

As described in the Federal On-Scene Coordinator's Report (USCG, 1993), this numeric standard caused considerable controversy between ADEC, Coast Guard, NOAA and Exxon. Exxon characterized the state's proposal as "illogical and technically flawed", and maintained that the use of quantitative criteria to specify cleanup techniques would be disruptive to field operations. NOAA asserted that "Achievement of such a standard would be difficult to measure, excessively time consuming, and subject to a wide range of
possible errors”. The Coast Guard FOSC adopted the position held by Exxon and NOAA. Although the proposal was never formally withdrawn by the State of Alaska, it was never formally adopted either, and the TAG continued to make shoreline cleanup decisions based on the "general consensus approach" (USCG, 1993).

Another approach used in the course of the Exxon Valdez was the formal "Net Environmental Benefit Analysis" approach or NEBA. This approach was used in evaluating the viability of the so-called "rock washer" project, proposed by the State of Alaska during the 1990 cleanup effort. The net environmental benefit concept had been recommended by Exxon as the guiding principal for 1990 cleanup efforts.

The "rock washing" apparatus envisioned was a large, barge-mounted processing plant that removed beach material from the shoreline, transported it to the barge via conveyor belt, cleaned it, and returned it to the beach. From the outset the rock washer appeared to be a formidable engineering effort, as well as being environmentally intrusive. The FOSC requested that NOAA conduct a detailed NEBA study to compare the benefits of excavation and rock washing with the benefits of natural cleanup. The study sought to identify criteria and sites where operation of the "rock washer" would produce a net environmental benefit. The NEBA study concluded that a net environmental benefit would be achieved only in isolated cases. Disagreement immediately ensued between Exxon and the State of Alaska over the study conclusions (USCG, 1993). NOAA reasserted its position stating that there was "no net environmental benefit to be gained by shoreline excavation and washing" and that "this technology has the potential of aggravating the injury to the environment caused by the spill" (NOAA, 1989). Based on NOAA’s recommendation, the FOSC did not authorize the project.

The NEBA approach stands out as the most comprehensive and well-documented process for reaching a decision on the appropriateness of a specific technology, and the level of effort required for implementation. However, it should be noted that the approach was time consuming (it took several weeks), and required collection of substantial quantities of engineering and scientific data. In the EXXON VALDEZ spill, this time was available as the response had evolved into a protracted cleanup effort (lasting years), and much of the required scientific knowledge had been acquired during the course of the response effort. In other major spill response efforts, this is not likely to be the case.

39
The EXXON VALDEZ spill was significant in that it once again demonstrated the difficulties encountered in dealing with catastrophic oil spills, and the need to upgrade the nation's capability to respond to such spills. The spill was pivotal in spurring public opinion and Congressional action which resulted in the passage of national oil spill legislation in OPA 90. The magnitude and complexity of the spill required far more coordination and more complex decision making than previous major spills. The length of the cleanup effort, the number and sensitivity of the natural resources impacted, and the enormous cost of the effort required a far more deliberate and organized approach to managing for effectiveness and efficiency, and resolving the "how clean is clean" issue.

The debate on the effectiveness and efficiency of the EXXON VALDEZ cleanup effort continues. Lloyds of London, and affiliated marine insurance companies, have entered into litigation with Exxon, refusing to pay much of the cleanup costs associated with the spill. Lloyd's contention is that the cleanup effort was excessively costly and not directed at mitigating environmental damage, but rather controlling adverse public reaction to the spill (National Underwriter, 1993; New London Day, 1995). As the costs were not justified on the basis of "appropriate cleanup actions", the insurers maintain that the expenses are not covered. Regardless of the ultimate judgment in the case, it is likely that future cleanup expenditures will be more closely scrutinized on the basis of effectiveness and efficiency.

AMERICAN TRADER Spill off Huntington Beach

On February 7, 1990 the oil tanker AMERICAN TRADER grounded on one of her own anchors off Huntington Beach, California spilling 400,000 gallons (9,500 barrels) of North Slope crude which ultimately impacted 14 miles of recreational beach along Southern California's populated coast. The location and area impacted by the spill are shown in Figure 11. As such, the AMERICAN TRADER spill constituted a "significant spill" which usually involves a discharge of a medium to major volume (10,000 - 100,000 gallons in a coastal area), which has the potential for causing substantial environmental and economic impact and a high level of outside interest. As with catastrophic spills, response to "significant spills generally requires additional personnel, cleanup equipment and other resources beyond what is available in the immediate area (Walker et. al., 1994).
American Trader Oil Spill Overflight Observations

Platform: Jet Ranger
Date, Time: 2/12/90, 0745-0975
Observers: Reilly (NOAA), Johnson and Carlson (State Lands Commission)

On-scene weather observation:
Winds 6-8 knots
Overflight Altitude: 100-250 ft.

Moderate beach impacts were seen between Bolsa Chica and Huntington Beach Pier. Light shoreline impacts southward to 1 mile N of the Newport Beach pier.

Relative Thickness*
- Sheen
- Medium
- Heavy

*Map only indicates relative position and thickness of oil. Total amount of oil seen decreases each day due to natural weathering and dispersion processes. Typically, "medium" today is lighter than "medium" yesterday.

Figure 11. Map showing the general location and coastal area impacted by the AMERICAN TRADER oil spill (from MSO LA/LB, 1991).
The response to the spill was immediate, well-organized and effective due largely to favorable weather, the availability of oil spill recovery equipment, good strategic planning, and cooperation between the responsible party and federal government (Rolan and Cameron, 1991; Card and Meehan, 1991; MSO LA/LB, 1991). An offshore response was mounted in the first few days following the spill employing 15 major skimming systems and 25 support vessels which resulted in recovery of 25% of the spilled oil (an optimum percentage for mechanical recovery). Beach cleanup involved the mechanical removal of oil sludge by 1,300 workers. Heavy equipment was minimized in an effort to reduce shoreline damage. In all, the cleanup proceeded in textbook fashion employing proven technologies such that the spill response was completed by April 3.

Unlike EXXON VALDEZ, the first few days of the AMERICAN TRADER response were marked by rapid mobilization of the spill response organization, and decisive action on the choice of various countermeasures and cleanup strategies. The rapid formation of the response structure can be attributed to the extensive contingency planning on the part of the federal agencies and the responsible party (British Petroleum), prompted largely by the lessons learned in during the EXXON VALDEZ spill. This contingency planning included adopting the Incident Command System response management system, which greatly facilitated coordination of the response operation (Rolan and Cameron, 1991).

Throughout the cleanup process, technologies for offshore recovery and shoreline cleanup were chosen following the "general consensus" approach. Given the availability of equipment and favorable weather conditions (light offshore winds and calm seas) a highly successful mechanical recovery operation was immediately initiated. Plans for deploying oil containment booms to protect sensitive wetlands areas within Anaheim Bay and Newport Bay were quickly implemented. The issue of dispersant use was quickly resolved with the consensus being that dispersants should not be used due to the availability of mechanical cleanup alternatives, the proximity of shoreline ecosystems, and the absence of any conclusive threat to specific wetland areas. Although the bulk of the spill would remain offshore for several days due to favorable winds, shoreline cleanup resources were also quickly mobilized.

These timely and decisive actions of the response participants were instrumental in pre-determining the overall effectiveness of the response, and in instilling confidence in local government and the general public. To reinforce this confidence, the Coast Guard and
British Petroleum instituted a focused and coordinated public information program in the first few hours of the spill. The Coast Guard also insured that the local governments were directly involved in the decision-making process by establishing response coordination centers in Huntington Beach and Newport Beach. This media and government relations program enhanced the consensus building process which facilitated effective management of cleanup efforts and response termination.

On February 13, the winds shifted from offshore to onshore and substantial quantities of oil came ashore along a 14 mile section of the Huntington Beach/Newport Beach area. In planning the beach cleanup effort, every effort was made to balance the removal of the oil with the environmental impact of the cleanup operation. The decision was quickly made to limit removal operations on the sand beaches to labor intensive but environmentally benign manual methods and exclude heavy equipment to minimize the removal of sand from the beaches. Where beach rock and jetties were oiled, removal was generally restricted to cold water washing, with hot water being employed only when environmental effects were not an issue.

In approaching the "how clean is clean" issue, a two-step beach cleanup approval process was adopted. A beach was deemed to be sufficiently cleaned when:

- No hydrocarbon odor, visual evidence of oil, or "oily feel" existed on the beach.
- The average hydrocarbon level of the berm, low tide zone, and high tide zone samples taken every 500 feet along the beach segment was less than 100 ppm (using the EPA 418.1 test method).

The first of these criteria is consistent with the first test specified in the Coast Guard Marine Safety Manual (USCG, 1995). The second was derived from a standard test normally used to certify the soil in old oil fields to be clean enough for follow-on residential development (Patrea, 1994). The two step shoreline cleanup decision process is depicted in Figure 12.

The overall approach can be described as a "general consensus approach supported by quantitative analytical data". Overall, the approach was effective in managing the level of effort and resolving the "how clean is clean" issue. However, Card and Meehan (1991) point out that the quantitative standard was dictated by the high public use of the beach, and...
Figure 12 Diagram showing the spill response decision process for the AMERICAN TRADER oil spill.
the need to provide some further assurance to the public that the beaches were safe. For beaches that are less heavily utilized, the quantitative analytical test would be unwarranted. It should also be noted that the sampling strategy was somewhat arbitrary (500 feet), and that the test was not originally designed for marine spill situations. However, as it was accepted by the parties involved, it probably facilitated the decision to terminate cleanup by reinforcing the conclusion with the local governments and the public that the beaches were indeed safe for human recreational use.

In summary, the M/V AMERICAN TRADER spill response has been widely regarded as one that was effectively and efficiently managed, and one of the more successful response efforts on record. This success can be attributed to three important factors.

The first factor is the spill characteristics. The spill was of moderate size, confined to a limited area, and subject to favorable weather conditions allowing for an optimum mechanical recovery effort offshore, and a straightforward cleanup effort on the beaches. As the impacted shoreline was adjacent to an urban port area, the logistics of assembling and deploying cleanup resources was greatly simplified. This is in contrast to the EXXON VALDEZ spill which was an order of magnitude larger, hampered by adverse weather, and which required cleanup operations in remote areas, greatly complicating logistics.

The second factor contributing to the success was the recent revision of the Area Contingency Plan (which was prompted by EXXON VALDEZ), and a spill exercise which had been completed just prior to the spill. This facilitated rapid mobilization of the response management system based on the Incident Command System, and allowed for general cooperation and consensus building throughout the response effort.

The third important factor was the timely and focused dissemination of information to stakeholders, the press and the public. Briefings were routinely scheduled, and local officials and resource trustees were directly involved in the decision process. Despite negative public reaction over the fact that the spill had occurred, the public soon perceived the subsequent response effort as being coordinated and effective.
The 1993 Tampa Bay Oil Spill

The Tampa Bay oil spill of August 10, 1993 is noteworthy both in terms of its cause, complexity and the organization of the shoreline cleanup effort that ensued. The spill began with the collision of three vessels at the entrance to Tampa Bay channel including the bulk phosphate carrier M/V BALSA 37, and two tug/barge combinations OCEAN 255 and B. No. 155. The collision resulted in a spectacular explosion and fire on the OCEAN 255 which required a complex and dangerous fire fighting and salvage effort and resulted in a 32,000 gallon spill (762 barrels) of gasoline, jet fuel and diesel (Kichner, 1995). The Barge B. No. 155 was holed causing a near instantaneous release of 330,000 gallons (7857 barrels) of heavy No. 6 oil. The M/V BALSA was also severely damaged and intentionally grounded to avoid capsizing and sinking. Thus in the early hours of the spill, the Coast Guard FOSC had many issues to contend with in addition to containing and recovering spilled oil.

The oil discharge constituted a "significant spill" with the cleanup effort involving protective booming, offshore recovery, shoreline and mangrove cleaning and wildlife rescue operations. In the early stages of the response, protective booms were effectively deployed to protect environmentally sensitive areas at Egmont and Mullet Keys. The bulk of the oil was initially carried offshore by prevailing winds and currents which allowed an intensive skimming operation and recovery of over half of the oil (Harbert, 1995).

On August 15, shifting winds drove the remaining oil ashore along a 14-mile stretch of beaches from St. Petersburg to North Redington Beach and into Boca Ciega Bay and the Intercoastal Waterway. Eventually, 20 miles of shoreline, seawalls, docks and residential canals were contaminated requiring an extensive shoreline cleanup effort. Figure 13 shows the general location and coastal area impacted by the spill. The shoreline cleanup effort was unique in that it included recovering oil on the beaches as well as oil submerged in intertidal areas, and clearly demonstrated an evolving approach to shoreline cleanup monitoring and development of specific qualitative "how clean is clean" criteria.

As with EXXON VALDEZ, the strategic planning and monitoring of the shoreline cleanup effort was delegated to a group of spill response specialists known simply as the "Technical Committee". The group was composed of representatives from NOAA (Scientific Support Coordinator and support staff), State of Florida (Department of Natural Resources,
Oiling continues north along beach to Redington Beach Long Pier.

Figure 13. Map showing the general location and area impacted by the 1993 Tampa Bay oil spill (from Owens et. al., 1995).
Division of Beaches and Shores), and the responsible party (Maritrans LP) carrying out the cleanup. The Technical Committee proceeded with the complex task of planning, implementing and monitoring shoreline cleanup following an organized sequence as described by Owens et. al. (1995), and depicted in Figure 14. The sequence involved the following key steps:

- Form a team of experienced individuals with representation from all affected stakeholders.
- Conduct preliminary surveys to determine the overall extent of contamination and the cleanup issues to be addressed.
- Identify various options (technologies and methodologies) and implementation strategies.
- Conduct any necessary field tests to verify the effectiveness of potentially viable technologies and methodologies, and determine the potential for adverse environmental effects.
- Develop criteria on when and where technologies and methodologies should be used, and to what degree they should be pursued (set "How Clean Is Clean" criteria).
- Monitor cleanup activities as they proceed.
- Assess condition of beach to determine "how clean is clean". Terminate or continue adapting techniques as required.

The Tampa Bay spill shoreline cleanup largely involved the removal of oil from sandy beaches where the oil had been deposited and then buried under sand by subsequent incoming tides. The primary issue faced by the Technical Committee was whether to use environmentally intrusive mechanical methods (front-end loaders and graders) for removing the oil layer or manual methods (workers with shovels). The mechanical option provided for quick removal of the oil but also removal of large amounts of sand and disruption of beach geomorphology. The manual option minimized this impact but required more manpower and time. The Technical Committee decided that the mechanical method would be employed for heavily oiled sections of beach, while the manual option would be employed for lightly oiled sections, and polishing activities on heavily oiled sections following mechanical removal. In adopting this approach, a balance was sought between minimizing environmental impact to the beach, while restoring an important recreational resource to service. There was some urgency involved in this as local officials wanted access to the bathing beaches restored by the approaching Labor Day holiday.
Figure 14. Diagram showing the shoreline cleanup decision process followed during the 1993 Tampa Bay oil spill.
In resolving the "how clean is clean" issue, a three tiered visual inspection process was followed using a defined spatial "sampling" scheme and somewhat subjective qualitative criteria. These criteria are shown in Table 2 and represent an attempt to make more generic guidance (such as in the CG Marine Safety Manual) more tangible and scenario specific. Perhaps more significantly they represent a benchmark for consensus building by the Technical Committee which ultimately decided if the beaches were clean enough. This approach, which can be described as a "general consensus with specific qualitative criteria" provided for an effective cleanup effort and smooth termination of the shoreline cleanup operations prior to the Labor day deadline.

MORRIS J. Berman Spill at San Juan

On January 7, 1994, the tank barge MORRIS J. Berman ran aground on a nearshore reef 200 yards offshore of Punta Escambron in San Juan, Puerto Rico. Figure 15 shows the general location and area impacted by the spill. The barge immediately began leaking heavy No. 6 fuel oil which impacted the adjacent shallow lagoons and shoreline. In all, approximately 800,000 gallons (19,000 barrels) of No. 6 were lost. The oil continued to leak from the barge during the week following the grounding causing reoiling of the beaches following initial removal and hampering the cleanup effort. To alleviate this problem, the barge was refloated on January 15, towed to a scuttling site 20 nautical miles northeast of San Juan, and sunk (at "scuttling site" indicated in Figure 15).

Immediate countermeasures and cleanup offshore included lightering of the barge (prior to the intentional sinking), and skimming operations. These measures resulted in the removal of 17,700 barrels of oil from the water or leaking barge. Shoreline cleanup focused on manual methods. Shoreline cleanup technology selection was once again made through the general consensus of the major participants in consultation with key stakeholders. Surface and buried oil was generally removed using shovels, rakes, and sifting screens to remove oil from sand. Conveyor driven separators were used in some areas. Sand, rocks and gravel were either washed with a chemical treating agent (Corexit 9580) and replaced, or in some cases hauled away and disposed of. Care was taken to conduct cleanup operations in a manner that would cause minimal damage to the environment. Special care was taken to protect turtle nesting areas, beach dunes, and historic structures and archeological sites which had been contaminated by the oil. Inaccessible areas with high energy environments were left for natural cleaning. All things considered, the cleanup effort was
Table 2. How clean is clean procedures and criteria used for cleanup of sandy beaches during the Tampa Bay oil spill of 1993.

Beaches are divided into segments corresponding to municipalities (North Reddington Beach, Redington Beach, Madeira, Treasure Island, St. Petersburg, Egmont Key, Ft. DeSoto Park (beach)).

Once beach cleanup contractors determine that their efforts on a particular beach are completed, a three tiered process goes into effect. First, a small technical group consisting of appropriate representatives (Coast Guard, state, county, etc.) conducts two preliminary checks for subsurface and surface oil. The third and final check includes appropriate local officials who have authority to make final recommendations to the Federal On-Scene Coordinator (FOSC). These recommendations will be presented to the FOSC who will then make the final decision on whether the beach cleanup has been completed. Additionally, the responsible party will need to perform routine maintenance on the beach over the ensuing weeks if necessary (i.e. tar balls washing up on the shore, etc.)

1. Subsurface oil check

   A. **Red Zones:** Areas of known subsurface oil (historical). A series of 3-5 pits (on top of berm, halfway down the berm, and in the mid-intertidal) will be dug perpendicular to the shoreline at regular intervals (50-100 ft.).

   B. **Yellow Zones:** Areas where subsurface oil has not been previously reported, or has been removed with no indication of additional oil burial. Pit intervals may be spaced to 300 ft. Pits are inspected for any layers of subsurface, black oil. Any areas needing additional cleanup are marked and contractors notified.

2. Surface oil check

   Once an area has passed the subsurface check, the technical group conducts a walk-through for any visible black surface oil or large areas of heavy stain. Small quantities of tarballs in the surf zone will not be flagged, since these will be picked up by the standby response crew. Sand will be checked for smell or feel of oil.

   Areas that have passes both subsurface and surface checks are ready for final inspection.

3. Final Recommendations

   A group consisting of appropriate officials (including local officials) conducts a final walk through the area. Sporadic pits can be dug to check for subsurface oil, and visual checks conducted for surface oil and oil smell, along with oily feel checks of the sand. After this walk, officials will have the opportunity to make the final recommendation to the FOSC.

   This will be an iterative process and at any point additional cleanup activities can be conducted if deemed necessary.
Figure 15. Map showing the general location and area impacted by the MORRIS J. BERMAN oil spill (from MSO San Juan, 1994).
well-planned, skillfully implemented, and effectively managed to ensure optimum cleanup in accordance with the ACP.

In addressing the "how clean is clean" question the FOSC in San Juan adopted an approach similar to that used in the Tampa Bay spill, that is "general consensus with specific qualitative guidelines". In implementing the process, the contaminated shoreline area was divided into 15 zones, with most of the zones being further subdivided into segments. Each beach supervisor would determine when cleanup was judged to be complete according to the guidelines that had been promulgated. He would then request inspection by the Shoreline Assessment Team which would make the final cleanup termination recommendation to the FOSC. The Shoreline Assessment Team was made up of both Federal and Commonwealth representatives including the (Coast Guard, NOAA, Puerto Rico Department of Natural Resources (DNR) and Puerto Rico Environmental Quality Board (EQB)). The specific guidelines adopted are summarized in Table 3 (NOAA, 1993). Figure 16 shows the shoreline cleanup and "How clean is clean" decision-making process for the BERMAN spill. Figure 17 shows the checkoff sheet used to support the process.

In summary, the MORRIS J. BERMAN spill involved adapting the shoreline cleanup decision process that had proved successful at Tampa Bay. Specific qualitative guidelines, particularly suited to the spill scenario and location, appear to have facilitated the "how clean is clean" decision process in San Juan. Consensus was ultimately reached on all segments, and the cleanup smoothly brought to closure.
**Figure 16.** Diagram showing the shoreline cleanup decision process followed during the MORRIS J. BERMAN oil spill.
Table 3. How clean is clean criteria used in the MORRIS J. BERMAN spill.

Sand Beaches

Surface Sediments - Must be free of visible oil, oily feel and the smell of oil. Tarballs should be minimal and high recreational use beaches should be monitored for tarballs. Sand replacement and sand washing should be completed for heavily oiled, very high use, recreational beaches.

Buried Oil - Beaches should be sampled at regular intervals for buried oil layers; buried oil layers should be removed. Sand that is merely stained may be left in place.

Beachrock

Areas of High Recreational Use - Heavily oiled natural bedrock areas should be cleaned using shoreline cleaning agents and high pressure/hot water flushing (one treatment only). Residual oil should left in place as the objective is not to remove all oil but to enhance natural removal.

Areas with Limited Recreational Use or No Access - Remove gross accumulations of oil from accessible sites, and leave remaining oil for natural removal. This was deemed appropriate as most inaccessible areas were also high energy areas.

Rip Rap

High Recreational Use Areas - Heavily oiled rip rap should be cleaned using shoreline cleaning agents and high pressure/hot water flushing (one treatment only). Residual oil should left in place as the objective is not to remove all oil but to enhance natural removal. Inaccessible, high energy areas that pose risks to workers should be left to natural recovery.

Areas with Limited Recreational Use or No Access - Remove gross oil at accessible sites; leave the rest to natural cleaning as sites are located in high energy settings.

Seawalls

High Recreational Use/High Visibility Areas - Clean using hot-pressure washers to the extent that they do not feel tacky when touched. Residual staining may remain.

Other Seawalls - Remove gross oil that continues to generate a sheen. Hot pressure wash those seawalls that will further contaminate boats or are near staging areas. Residual staining may remain.

Submerged Oil

Accumulations of submerged oil should be removed (oil is still liquid and can be vacuumed), particularly in sheltered, shallow lagoons. Scattered accumulations in other areas should be removed consistent with operational limitations. Oil should be recovered until declining effectiveness renders further recovery impractical.
### How Clean Is Clean (HCIC)

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<th>Location</th>
<th>Beach Supervisor’s Inspection (#1)</th>
<th>Survey Team Inspection (#2)</th>
<th>Touch-up</th>
<th>Final Recommendation</th>
<th>FOSC Approval</th>
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Figure 17. "How Clean is Clean" monitoring and signoff form used during the MORRIS J. BERMAN oil spill.
7.0 OBSERVATIONS ON VARIOUS APPROACHES TO RESOLVING THE "HOW CLEAN IS CLEAN" ISSUE

In reviewing the evolution of various approaches to the "how clean is clean" issue, several observations can be made characterizing the utility and limits of each.

General Consensus Approach - This approach appears to be flexible and effective in a majority of situations, and particularly in complex response efforts which involve a variety of technologies, shoreline types, and conflicting opinions and agendas. It allows some form of consensus to be reached even under difficult circumstances. Without some degree of consensus, resolving the "how clean is clean" issue is impossible.

General Consensus Based on Specific Qualitative Criteria - This is an extension of the general consensus approach which appears to be evolving as a standardized method based on the major spills in Tampa Bay and San Juan. The "how clean is clean" guidelines are tailored to a specific location and spill response scenario. As in the case of the MORRIS J. Berman spill, they clearly reflect the concept that a point will be reached where further cleanup will increase rather than prevent environmental damage, and recognize the value in specific situations of choosing the natural recovery option.

Analytical Quantitative Approach - This approach may be useful in certain situations, but should be used with some caution, and only as a backup to a more flexible, qualitative approach. Analytical tests should be specified according to an existing standard, and be scientifically justified. They should be clearly linked to a particular environmental risk or health hazard associated with the specific spill. In general, they will be most useful when there is already general consensus and cooperation among the parties involved in making the "how clean is clean" determination.

Net Environmental Benefit Analysis - This is a comprehensive, scientifically documented procedure for determining if a cleanup technology is appropriate and how far it should be carried. It is thorough but time consuming, and will only be applicable to certain longer-term cleanup projects such as the rock washer. However, there may be value in conducting NEBA studies on generic technologies in generalized environments as part of the contingency planning process, to allow refinement of the qualitative guidelines that can be used during the actual response.
8.0 DEVELOPING A STANDARD APPROACH AND PROVIDING DECISION SUPPORT INFORMATION

In reviewing several spill response efforts, and particularly those during the 1993 Tampa Bay and the MORRIS J. BERMAN spill in San Juan, it is clear that a consistent approach is evolving for effectively and efficiently managing shoreline cleanup and resolving the "how clean is clean" issue. The purpose of this section is to propose a generalized model for this process, describe how the model can be implemented during contingency planning and response, and identify the necessary information and computational tools required to support the decision process. Fortunately, many of these information sources and tools exist or are under development.

Developing A Standard Strategic and Tactical Approach

A general model for effective and efficient management of response operations is shown in Figure 18. The model shows two distinct phases to the spill response effort, a strategic planning phase and tactical execution phase, similar to the process depicted in Figure 1.

During the strategic planning phase, various response options are screened to determine which are appropriate to the spill scenario in question. Response options are chosen based on the overall applicability of the technology, the resources available to make use of the technology, and the environmental risk addressed by the technology.

Technology options considered will include mechanical recovery of the oil using booms and skimmers, in-situ burning of the oil, application of dispersants at sea, and a range of shoreline cleanup options for various shoreline types. Each option will be evaluated based on the overall applicability to the scenario (e.g. mechanical recovery for small harbor spills and heavier oils offshore, in-situ burning for large crude oil spills at sea, dispersant application for small spills which threaten sensitive resources, and special mechanical recovery techniques for oils that sink). Estimates are made of the equipment and personnel required to implement the technologies. Significant environmental risks associated with both the spill itself and the countermeasures are identified. Regulations and policies that constrain the use of a particular technology (such as exclusion zones for dispersant use or in-situ burning) must also be considered.
Figure 18. Generalized strategic model for planning and managing oil spill cleanup operations.
As outlined in the National Contingency Plan, the groundwork for this strategic decision making should be accomplished well in advance of the actual spill during the development of the Area Contingency Plan (ACP). In this plan, anticipated spill scenarios for particular ports and coastal areas are evaluated, environmental risks analyzed, and response options developed. The result is a set of specific action plans that can be quickly implemented once the spill occurs. The ACP process is accomplished by the Area Committee which include representatives from the major participating agencies and organizations, and will foster consensus building well in advance of the actual spill.

Once these strategic action plans have been formulated by the designated participants, they should be communicated to the various stakeholders. Stakeholders should be informed of the selected technology options, the rationale for choosing the option, the environmental risks involved, and the expected level of success in terms of the percentage of oil that can be reasonably treated or removed. The plans should be described in non-technical terms that can be easily understood by the stakeholders, the press and the general public. These descriptions should also be developed during the contingency planning process when a consensus can be reached on expected results and criteria for success. This will prevent the release of conflicting versions of response expectations during the actual response.

Once a spill occurs, the strategic options are reviewed, the action plan adjusted, and response resources are deployed expeditiously. Initial information briefings are conducted for stakeholders and the press. At this point, the response effort enters the tactical phase. The results and impacts of cleanup operations are assessed based on the progress made (barrels of oil recovered, dispersed or burned; sections of shoreline cleaned), the resources expended and their cost, and the observed effects of the cleanup both positive and negative. An overall assessment is made of the effectiveness and efficiency of operations based on the readily available quantitative data on progress, cost and effects. If specific operations (e.g. mechanical recovery, in-situ burning, shoreline cleaning) are judged to be effective and efficient, they are continued. If not, they are terminated ideally through the consensus of key response agencies.

A similar process is followed in addressing the specific problems and issues in shoreline cleanup. As shown in Figure 19, the first step in the process is to assemble the Shoreline Cleanup Assessment Team (SCAT). The team conducts a preliminary shoreline survey to determine the degree of oiling, sediment penetration, condition of the oil, and unique
Figure 19. Generalized tactical model for planning and managing shoreline cleanup and resolving the "how clean is clean" (HCIC) issue.
conditions that will aid or constrain cleanup options. The team will then review data from
the Area Contingency Plan and other readily available sources of information on the
suitability of specific cleanup technologies for specific shoreline types, and the availability
of resources to implement these technologies. Environmental sensitivity and shoreline
cleanup effectiveness data will be accessed to determine the expected results and impacts of
these technologies. Ideally these data will already be compiled for each shoreline segment.
If deemed appropriate, small scale tests will be conducted with various techniques to
supplement these data and refine the strategic plan.

Once the plan is agreed to by the response participants, operations are initiated and the
results monitored and evaluated based on results (e.g. linear kilometer or square meter of
shoreline treated, percentage of oil removed), quantity and cost of resources expended, and
observed and expected environmental effects. As it becomes clear that results are
diminishing with the effort expended on a particular section of shoreline, a "how clean is
clean" determination is made based on specific qualitative criteria. Operations on a specific
segment are then continued or terminated as appropriate.

In shoreline cleaning in particular, pre-planning is essential due to the complexity of the
problem and the often differing views on which techniques may be best suited to a specific
shoreline segment and spill scenario. By pre-planning for various shoreline types and
segments, sufficient technical information can be gathered in advance, and a consensus
action plan formulated by the Area Committee. The shoreline cleanup strategy should also
be communicated to affected stakeholders (e.g. property owners and resource trustees).
Ideally conflicts can be resolved prior to the spill, and a consensus reached on the expected
outcome.

Pre-spill planning is also necessary in addressing the "how clean is clean" issue which
generally focuses on the shoreline cleanup operation. Before cleanup operations are
initiated, an overall strategy for addressing the HCIC issue is formulated and qualitative
guidelines developed as occurred in the 1993 Tampa Bay Spill and the MORRIS J.
BERMAN spill. To the extent possible, these region specific guidelines should be
developed during the contingency planning process, and incorporated as part of the Fish
and Wildlife and Sensitive Environments Plan Annex of the Area Contingency Plan. Each
of the predominant shoreline types within the region should be addressed.
Providing Information to Support the Decision Process

An overall approach to effectively and efficiently managing oil spill cleanup operations has been outlined above. This approach has evolved during several major spill response efforts in recent years. As discussed briefly above, implementation of this approach requires information to support both the strategic planning process which begins in the development of the Area Contingency Plan, and the tactical implementation of the plan.

The strategic planning process requires information in three important areas:

- The expected performance of various countermeasures and cleanup techniques, equipment and treating agents to remove or mitigate the impact of oil on the surface of the water and on shorelines.

- The environmental effects associated with various countermeasures and cleanup actions.

- The availability of equipment, treating agents, deployment resources, and personnel to implement the technologies within the window of opportunity for effectiveness.

Information in the first area is readily available. The general applicability of cleanup techniques for on-water removal and treatment has been widely documented. General guidelines on the resource requirements, performance, procedures and windows of opportunity have been provided in various reports (Allen, 1988; Nordvik, Simmons and Champ, 1995) and in various spill response manuals (Exxon, 1992; NOAA, 1994).

The characteristics of various pieces of equipment (e.g. booms, skimmers, pumps, storage devices, dispersant applicators) and products (e.g. sorbants, dispersants, cleaning agents) are compiled in the World Catalog of Oil Spill Cleanup (Schulze, 1993) which exists in both hard copy and computer database form. Information on the effectiveness and toxicity of dispersants and other chemical treating agents is compiled in the National Contingency Plan Product Schedule. The NCP specifies that treating agents must be tested and listed in this Product Schedule to be used on spills in U.S. waters (EPA, 1994). Additional information on dispersants and sorbants has been compiled in computer databases developed by the USCG and NOAA. Many of the comprehensive oil spill response decision support systems now being developed contain a wealth of information on techniques, equipment and products to facilitate strategic planning (Ishiki, 1995; Mark, 1995).
In the second area, generic information on the environmental effects of various on-water countermeasures and cleanup techniques is also available. Toxicity data for approved oil spill treating agents are provided by the NCP Product Schedule. The potential effects of in-situ burning on the environment and human health have been rigorously investigated since the EXXON VALDEZ spill. These research efforts are well-documented in the literature (NIST, 1994). Computer models are being developed to predict the smoke plume trajectory associated with in-situ burning operations and the distribution of contaminants.

Information on the appropriateness and environmental effects of shoreline cleanup techniques is available in several shoreline cleanup manuals, which provide generic guidelines on response strategies based on shoreline type, type of oil, and degree of oiling. These manuals include the NOAA Shoreline Cleanup Manuals for temperate and tropical waters (NOAA 1992a and 1993), the American Petroleum Institute Shoreline Cleanup Manuals (API 1985 and API/NOAA 1995), and the Environment Canada Shoreline Cleanup Manual (Owens, 1995a). General guidelines for developing strategies are provided in a concise tabular format in the API and Environment Canada Manuals as shown in Figures 20 and 21. More specific net environmental benefit discussions are provided in the NOAA manuals for temperate and tropical regions.

In meeting requirements in the third area, data on the availability of equipment, materials and deployment platforms are generally compiled at the local level as part of the Area Contingency Plan. Information on national assets to support response to catastrophic spills is compiled in the Response Resources Inventory maintained by the Coast Guard's National Strike Force Coordination Center (NSFCC, 1995).

In summary, much of the information required for spill response strategic planning as outlined in the upper portions of Figures 18 and 19 is readily available. For certain techniques, including dispersant application and in-situ burning, this information is being compiled in computer databases with supporting analytical tools to allow responders to develop preliminary strategic options, and rapidly refine the response strategy once the specifics of an actual spill are known (Allen and Dale, 1995; Ishiki and Chan, 1995).
Figure 20. Matrix of shoreline cleanup methods vs. shoreline habitats from API Shoreline Cleanup Manual (API, 1985).

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<thead>
<tr>
<th>Methods</th>
<th>Beach/Cleaning Machines</th>
<th>Booms/Smurmers</th>
<th>Burial</th>
<th>Burninng</th>
<th>Dispersants</th>
<th>Eanh Barriers</th>
<th>High Pressure Flushinng</th>
<th>Low Pressure Flushinng</th>
<th>Management (Draining)</th>
<th>Herdinng</th>
<th>Vacuum Pumpinng</th>
<th>VeQetation Croppinng</th>
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Habitats

- Open Waters—Offshore/Nearshore
- Open Waters—Enclosed Bays & Harbors
- Soft Bottom Subtidal
- Seagrass Beds (Intertidal)
- Seagrass Beds (Wade Zone Subtidal)
- Rocky Subtidal—Open Hard Bottom & Rocky Reefs
- Kelp Beds
- Exposed Rocky Intertidal
- Sheltered Rocky Intertidal
- Sandy Beaches (Exposed)
- Sandy Beaches (Sheltered)
- Sheltered Tidal Flats
- Gravel/Cobble Beach (Exposed)
- Sheltered Gravel Beaches
- Sheltered Cobble Beaches
- Coral Reefs (Lagoons)
- Coral Reefs (Deep Fore, Flats, Crests)
- Mangrove Forests
- Salt Marshes

P = Preferred
V = Viable
NA = Not Advisable
A = Avoid
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<tr>
<th>Technique</th>
<th>Bedrock</th>
<th>Solid Man-Made</th>
<th>Boulder</th>
<th>Pebble-Cobble</th>
<th>Sand-Gravel</th>
<th>Sand Beach</th>
<th>Sand Flat</th>
<th>Mud Flat</th>
<th>Marsh</th>
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Potential Impact: H = High  M = Moderate  L = Low

Figure 21. Matrix of shoreline cleanup methods vs. shoreline types from Environment Canada Shoreline Cleanup Manual (Owens, 1995a).
To support the tactical monitoring and evaluation of operations as the response proceeds, additional information is required in real time. This includes information on:

- Progress made in terms of volume of oil treated or recovered, and length or area of shoreline cleaned.
- Resources used and ideally the cost of cleanup operations (in terms of total cost and unit cost).
- The observed effects of the cleanup effort both positive and negative.

In recording progress, data on the volume of oil treated or recovered are routinely collected during spill response operations and compiled on a daily basis. Data on shoreline cleanup are also routinely collected and can be compiled and plotted as was done during the EXXON VALDEZ spill. Early in the spill response, an effective computerized progress tracking tool was developed called CAMEO (Computer Aided Management of Emergency Operations) VALDEZ (Haas, 1991). This system recorded progress in miles of shoreline cleaned, and compared progress to cleanup projections by the FOSC and Exxon as shown in Figure 22. Progress was also measured in units called "Clydes" (Cleanup Yield During Exxon Spill) which were calculated to quantitatively describe level of effort (Olsen, 1989). This calculation integrated the length and width of shoreline cleaned with the degree of oiling and relative difficulty of cleaning a particular section of shoreline (a function of shoreline type, oil penetration and quantity of debris). CAMEO VALDEZ proved highly useful in allowing responders to track progress on the enormous and complex cleanup effort. The system has been adapted and used in several other major spills. Similar systems are being incorporated into spill response DSS.

Tracking the resources expended and actual cost of response operations is somewhat more challenging as it involves more elaborate real-time accounting. However, in response to the escalating costs of spill cleanup, On-Scene Coordinators and responsible parties are often contracting spill response management consultants to provide this support (Evans, 1994; Dufour, 1995). This accounting service keeps track of the resources expended by logging cleanup personnel and equipment on and off the cleanup site using an electronic bar code system. Resources expended can then be converted to costs knowing labor rates and equipment rental rates. This is now automatically accomplished in a DSS developed by Magnavox whereby total cost and daily costs are automatically computed and recorded (Mark, 1994; White, 1995). Such data can be easily fed into computer tracking tools such
as CAMEO VALDEZ, so that cost and progress can be displayed together as depicted in Figure 22. It is also possible to construct simple models which will project resource levels and cleanup costs based on the current resources employed and current costs, and the amount of cleanup work remaining.

Determining the positive and negative effects of the cleanup effort in real-time is more challenging still. As mentioned above, spill cleanup manuals and databases provide general guidance on cleanup technology performance and environmental effects, but cleanup impact often depends on the specific spill scenario and characteristics of the site itself. These characteristics include the overall environmental sensitivity, as well as the presence of important economic, recreational, and historic & archaeological resources. In addition, these effects can be subtle at first, with the full impact not evident until long after the response effort has been completed.

Since EXXON VALDEZ, there has been renewed emphasis on studying the effects of both the oil and the countermeasures and cleanup techniques employed. This includes short-term effects particularly for on-water techniques such as dispersant application and in-situ burning and shoreline oil removal techniques. Specific monitoring protocols are being developed for judging the effectiveness of these techniques. Long-term effects are also being monitored more closely, particularly for shoreline cleanup, and refined monitoring protocols are being developed. This includes the designation of set-aside beaches for significant spills whereby small segments of beach are deliberately not cleaned to serve as a baseline for judging the positive and negative benefits of those that are cleaned. In some cases, segments of oil beaches are being used as experiment sites for longer-term testing of cleaning techniques such as pressure washing, cleaning with surfactants, and bioremediation.

The results of these field studies, and those from laboratory scale experiments, are being recorded in an impressive collection of papers and reports on the subject. However, this literature cannot be quickly accessed to provide specific facts relevant to a specific scenario during a spill response operation, and is cumbersome even for contingency planning purposes. To overcome this, efforts are underway to compile this scientific knowledge into computerized "knowledge bases" which can rapidly retrieve the information relevant to a specific scenario and site, and present it in a format to facilitate decision-making.
Figure 22. Representative output of CAMEO VALDEZ showing the tracking of shoreline cleanup progress during the EXXON VALDEZ oil spill.
For instance, a sophisticated DSS tool for shoreline cleanup, called SHORECLEAN, has been developed to predict the environmental impact of oil on shorelines based on type of shoreline, type of oil, oil penetration and area covered (Lamarche et. al., 1995). Output data includes oil persistence and shoreline recovery times, and suggested cleanup techniques. SHORECLEAN is based on the knowledge contained in the various shoreline cleanup manuals, the results of laboratory studies, and the results of field observations. The current version focuses on shorelines in temperate climates, versions for Arctic and tropical shorelines are planned.

One area where information is somewhat lacking is in the performance of specific shoreline cleanup techniques and their efficiency. Specifically, data should be compiled on the expected percentage of oil removed under various oiling conditions, using various techniques. Data on the associated level of effort and unit cost would also be very useful in selecting specific techniques for sections of shoreline. Unfortunately, compiling such a performance and efficiency database requires gathering and analyzing the results and cost data from actual spills. Although some data is being gathered at certain spills, there is no formalized protocol and database system for accomplishing this at present.

Above all, final judgment of the effectiveness of various cleanup techniques must be made during the response effort by teams of experts. It is impossible to fully forecast in advance the results and impact of a particular technique on a specific shoreline that has been oiled. Variables such as oil type, temperature, wave conditions, and beach accessibility all come into play. In the Tampa Bay Spill and the MORRIS J. BERMAN spill, cleanup techniques were tested on small representative sites to provide preliminary indication of positive and negative effects. However, each section of shoreline is unique, and environmental and oiling conditions can change in the course of a response effort. This requires ongoing monitoring and assessment of cleanup effectiveness.

A procedure which may facilitate the selection of cleanup techniques and monitoring of progress, and making the "how clean is clean" determination is development of site specific templates for the various shoreline types for incorporation in the Area Contingency Plan. In this process, the various shoreline types in a given area would be determined (e.g. sandy recreational beaches, marsh areas, tidal flats, cobble beaches). For each shoreline type, a shoreline cleanup template would be developed using data from existing cleanup manuals, environmental sensitivity maps, output from databases and models such as
SHORECLEAN, and local knowledge from spill responders and the scientific community. Each template would include a general description of the shoreline type in the specific area, a description of the projected effectiveness of various cleanup techniques, some estimate of the level of effort and cost associated with these techniques, and "preliminary" criteria for determining "how clean is clean".

These templates would be prepared by potential spill responders within the local area, and ideally by those individuals who would comprise the "experts" on the Shoreline Cleanup Assessment Teams (SCATS). The templates would be reviewed by the Area Committees to obtain consensus on the overall approach. A sample template showing general structure and format is shown in Table 4. This sample was prepared using shoreline data on an actual segment oiled during the MORRIS J. Berman spill.

Each segment of shoreline within the area would be referenced to one of these templates. This could be easily accomplished within the framework of existing computer DSS which allow access to both text database information and GIS type maps within the same system. Instituting such a procedure would have two benefits. First it would insure that the necessary data for planning, implementing and monitoring shoreline cleanup is available and pre-screened such that decision makers and stakeholders are all working from a common reference point. Second, it would facilitate the consensus building process during a spill by beginning this process during the development of the Area Contingency Plan, when decisions can be made without the pressures and agendas that often arise during an actual response.
Table 4. Sample shoreline cleanup planning summary which could be included in Area Contingency Plans.

<table>
<thead>
<tr>
<th>No: 3D</th>
<th>Segment Name: Puerta de Tierra Beach</th>
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</thead>
</table>

**Location Description:** Segment extends from the ruins in front of the National Guard Building to the seawall at the Naval Reserve Officers Club. Beach is easily accessible via secondary roads in the area. Beach is accessible by small boat from seaward. Private residences and recreational facilities are located along the entire length of this segment.

**Beach Type:** Sandy beach with coarse-grained sand

<table>
<thead>
<tr>
<th>Environmental Value</th>
<th>Cultural Value</th>
<th>Economic Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No sensitive environmental resources on beach. No sensitive resources directly offshore.</td>
<td>Historic ruins near National Guard Bldg. Do not attempt to clean without consultation</td>
<td>Moderate recreational use. Oil removal of 90% or greater is desired.</td>
</tr>
</tbody>
</table>

**CLEANUP TECHNIQUE**

<table>
<thead>
<tr>
<th>Cleanup Technique</th>
<th>Oil Removal</th>
<th>Environmental Impact</th>
<th>Level of Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oiling with Light Fuel Oils Allow natural cleaning by wave action. Tilling of sand near surf zone will expedite cleaning. Collect oil with sorbants in surf.</td>
<td>90 - 100%</td>
<td>Light</td>
<td>Low</td>
</tr>
<tr>
<td>Oiling with Light/Med Crude Flushing with cold or hot water. Collect oil at surf line with sorbants. Manual excavation where oil has penetrated.</td>
<td>90 - 95%</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Oiling with Heavy Crude/Fuel Oil Requires excavation using heavy equipment. Manual excavation for shallow penetration. Wash or replace heavily contaminated sand.</td>
<td>90 - 100%</td>
<td>Moderate</td>
<td>Very High</td>
</tr>
</tbody>
</table>

**How Clean is Clean Criteria:**

**Surface Sediments** - Must be free of visible oil, oily feel, and smell of oil. Tarballs should be minimal, monitoring for tarballs should continue. As beach has moderate to heavy recreational use, sand replacement is required.

**Buried Oil** - Beach must be sampled at regular intervals for buried oil layers; buried oil should be removed. Sand that is merely stained may be left in place.
9.0 SUMMARY AND RECOMMENDATIONS

In reviewing several oil spill response efforts, beginning with the EXXON VALDEZ spill in March 1989, it is clear that responders are becoming more aware of effectiveness and efficiency in managing oil spill response operations. Better response management is being driven by government and public concern for the damage oil spills cause to the environment, and the escalating cleanup costs, which must be borne by government, industry, and ultimately the general public. Terminating oil spill cleanup at the appropriate time to maximize net environmental benefit and control costs is becoming more important, such that the "how clean is clean" issue is being addressed in the literature, and in oil spill response training curricula.

Recent experience shows that spill responders will adopt different approaches in selecting cleanup techniques, determining appropriate level of effort, and resolving the "how clean is clean" issue. All three decision processes are necessary to ensure effectiveness and efficiency. In the previous discussion, four specific approaches have been identified:

- General Consensus Approach,
- General Consensus Based on Specific Qualitative Criteria,
- Analytical Quantitative Criteria, and
- Net Environmental Benefit Analysis.

Each approach has proved effective in a specific spill scenario. The approach that is evolving as generally accepted practice is the General Consensus Based on Specific Qualitative Criteria as demonstrated during the 1993 Tampa Bay spill and the MORRIS J. BERMAN spill. This approach appears to provide a well-defined decision-making process which can be adapted to the specific circumstances of a spill. The approach can be modeled as shown in Figures 18 and 19 to provide guidance in developing strategic and tactical plans for future response efforts.

Reviewing current doctrine and practice in recent major spills indicates that four elements are critical in making the decision process effective. First, there must be consensus on the strategic and tactical plan for dealing with a specific spill among both response participants and stakeholders. This consensus must begin in the contingency planning phase and be cultivated throughout the response effort.
Secondly, the process must be flexible to adapt to changing circumstances and agendas. In some cases, it may be necessary to adopt one of the other three approaches. For instance, the quantitative analytical criteria were used during the AMERICAN TRADER spill to meet the expectations of stakeholders and preserve consensus. In other cases, it may be impossible to assign specific qualitative criteria for determining "how clean is clean" such that the decision must be made on the "best judgment" of the experts on-scene. For longer term cleanup efforts involving complex technologies, a formal net environmental benefit analysis may be required. Responders should be aware of all of these approaches, and be prepared to combine them or adapt them as the spill scenario dictates.

The third critical element is accurate and accessible information on anticipated and actual results of a cleanup effort (e.g. percentage of oil removed, length or area of shoreline cleaned), information on the environmental impacts of both the oil itself and the cleanup techniques, and quantitative data on anticipated resource requirements and resources expended and their cost. Recording results is a straightforward process during the spill, and a substantial amount of data on environmental impacts has become available in recent years. The most critical information gap is the lack of data on performance, resource requirements, and cost of specific cleanup techniques under specific circumstances. This last information category is particularly important in ensuring cleanup efficiency.

The fourth critical element is the confidence and support of the public. A cleanup effort can never be considered successful if the media, interested parties and general public perceive it as being uncoordinated and ineffective. If this occurs, they can be expected to exert pressure through government agencies and elected officials often directed toward specific agendas. This will complicate decisions on choosing effective and efficient techniques, determining appropriate level of effort, and resolving the "how clean is clean" issue to smoothly terminate cleanup operations.

In ensuring that these four critical elements are met during a spill, three specific actions are recommended. First, managing for effectiveness and efficiency, and resolving the "how clean is clean" issue should be specifically addressed in developing the Area Contingency Plans. Necessary information to support the decision process can be compiled in advance as portrayed in Figure 4. In addition, the decision-making process for addressing these issues should be practiced in spill response exercises. In the past, such exercises have focused exclusively on initial notification and mobilization of the response organization and
resources, with little emphasis on the longer term management issues. Addressing these issues in advance will set the stage for consensus building and flexibility during an actual spill.

Secondly, efforts in compiling data on anticipated results and environmental impacts of various cleanup techniques should continue. In addition, special emphasis should be placed on establishing a "knowledge base" of expected performance vs. expected resource requirements and cost for specific techniques under various circumstances. Data should be recorded and analyzed, particularly for major spills, in the same manner as the environmental impact data. Protocols and action plans for accomplishing this should be developed and become part of the spill response process.

Finally, an effort should be made to inform the public of the techniques which will be used, expected results, and criteria for success during a spill response operation. This public outreach plan should be included in the ACPs, and public education material prepared in advance. Mechanisms for obtaining feedback and gauging public reaction should also be established in advance, and implemented immediately once a spill occurs to deal with "expectation management" issues that arise. This will ensure that the public is not misled by the media or special interest groups in perceiving that a response effort, that is well-executed and successful within the limits of technology and resources, is a failure.
10. REFERENCES


NSFCC, 1995. Descriptive material on the NSFCC Response Resources Inventory obtained from National Strike Force Coordination Center, Elizabeth City, NC, April, 1995.


