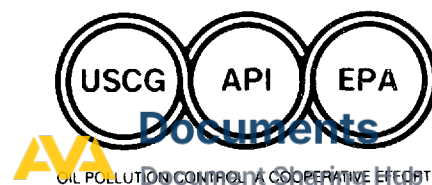


1987 Oil Spill Conference

Prevention,
Behavior,
Control,
Cleanup



1987 Oil Spill Conference

Proceedings

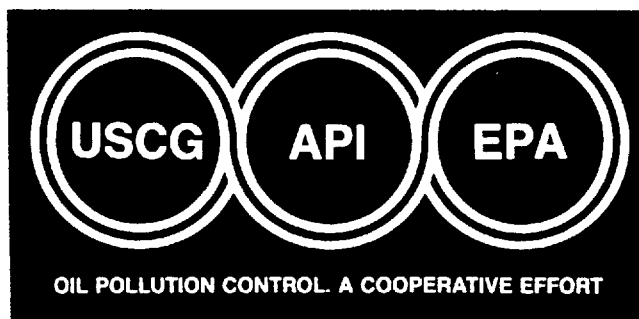
1987 Oil Spill Conference *(Prevention, Behavior, Control, Cleanup)*

Tenth Biennial

April 6–9, 1987

Baltimore, Maryland

*Sponsored by: American Petroleum Institute, Environmental
Protection Agency, and United States Coast Guard*



Documents
Document Sharing Hub

Printed in the United States of America
Library of Congress Catalog No. 75-4161

American Petroleum Institute publication No. 4452

American Petroleum Institute
1220 L Street, N.W.
Washington, D.C. 20005

FOREWORD

This, the 1987 Oil Spill Conference, is our tenth biennial meeting. Our efforts to share the knowledge needed to understand the prevention, behavior, control, and cleanup of oil spills now span two full decades of experience.

Today's conference is a major international forum with representatives from many countries around the world in attendance. As in the past, the conference continues to remain responsive to a changing environment. The focus has been broadened to address not only response to and cleanup of surface water spills, but also new areas of leadership in oil spill response and prevention as they emerge. Sessions at this conference will take an in-depth look at damage assessment, underground spills, a more responsible use of dispersants, and community involvement in response to spill incidents. Moreover, environmental professionals today find themselves taking a more proactive stance, rather than a reactive one, in the response to oil spills and their prevention.

The sponsoring organizations—the United States Coast Guard, the American Petroleum Institute, and the Environmental Protection Agency—have provided leadership and guidance in a cooperative effort between industry and government to provide a varied program of timeliness and technical merit for this conference. Planning has been ongoing for nearly all of the two years since the last meeting.

We hope that the knowledge and contacts developed at this conference will influence your decision to participate in the eleventh biennial Oil Spill Conference to be held in San Antonio, Texas, in 1989.

John A. Lamping

1987 OIL SPILL CONFERENCE COMMITTEES

Steering Committee

Chairman
John Lamping
Amoco Corporation

Vice Chairman
Ronald D. Hill
U.S. Environmental Protection Agency

Lt. Cdr. John S. Clay
U.S. Coast Guard

John S. Farlow
U.S. Environmental Protection Agency

Jack R. Gould
American Petroleum Institute

Vice Chairman
Capt. Robert L. Storch, Jr.
U.S. Coast Guard

Kurt Jakobson
U.S. Environmental Protection Agency

Cdr. Mark L. Lavache
U.S. Coast Guard

June Lindstedt-Siva
Atlantic Richfield Company

Program Committee

Cdr. Mark L. Lavache (Chairman)
U.S. Coast Guard

L. Michael Flaherty (Vice Chairman)
U.S. Environmental Protection Agency
(retired)

Alexandra L. Moore (Vice Chairman)
Amoco Corporation

John P. Bennington
Amoco Transport Company

Lewis R. Brown
Mississippi State University

Gerard P. Canevari
G. P. Canevari Associates

Lt. Cdr. John S. Clay
U.S. Coast Guard

Ron DeNoville
Crawford and Company

John S. Farlow
U.S. Environmental Protection Agency

John Fraser
Shell Oil Company

Jack R. Gould
American Petroleum Institute

Richard Griffiths
U.S. Environmental Protection Agency

William Katz
Spill Control Association of America

Leon Kazmierczak
Sun Oil Company

Gerd Kleineberg
U.S. Coast Guard

J. T. Leigh
Texaco U.S.A.

June Lindstedt-Siva
Atlantic Richfield Company

Clayton McAuliffe
Clayton McAuliffe and Associates

Kenneth Meikle
Environment Canada

Jacqueline Michel
Research Planning Institute, Inc.

Lt. James C. Milbury
U.S. Coast Guard

Anita Miller
U.S. Department of the Interior

Patrick O'Brien
Chevron Corporation

Gary L. Ott
National Oceanic and Atmospheric Administration

William C. Park, III
Mobil Oil Corporation

James Parker
Industrial Marine Services, Inc.

Harold J. Pecunia
Peterson Maritime Services, Inc.

Lt. Cdr. Edward Rosenberg
U.S. Coast Guard

Joseph Smith
Petrochem Services, Inc.

Eleanor Swett
Offshore Devices, Inc.

Edward Tennyson
Minerals Management Service

William Walker
Naval Sea Systems Command

Harold Weiss
Texaco U.S.A.

Edward Wirkowski
Clean Harbors Cooperative

Walter Youngblade
O. H. Materials

Public Relations Committee

Carl F. Meyerdirk (Chairman)
Amoco Corporation

Scott Loll (Vice Chairman)
Atlantic Richfield Company

William Taylor
American Petroleum Institute

CWO Richard M. Meidt
U.S. Coast Guard

Exhibit Chairman
John S. Farlow
U.S. Environmental Protection Agency

Conference Management
Courtesy Associates

Exhibit Management
Trade Associates, Inc.

Treasurer
Jack R. Gould
American Petroleum Institute

Editor
John O. Ludwigson
Consultant

CONTENTS

I—CASE HISTORIES

OPERATIONAL ASPECTS OF THE RESPONSE TO THE <i>ARCO ANCHORAGE</i> OIL SPILL, PORT ANGELES, WASHINGTON	3
Robert A. Levine	
OIL POLLUTION CONTROL AND SPILL RESPONSE CAPABILITY IN THE ROPME SEA AREA	9
P. Bernard Ryan, Derek J. S. Brown	
FRENCH KNOW-HOW IN THE PREVENTION AND FIGHT AGAINST ACCIDENTAL OIL SPILLS	15
Guy Marchard, Gilles Bergot, Marthe Melguen, Georges Peigne	
ADAPTING TECHNIQUES TO CONDITIONS: CLEANUP OF A WASTE OIL SPILL	23
Joseph B. H. Smith	
<i>M/V ALVENUS</i> : ANATOMY OF A MAJOR OIL SPILL	27
Cdr. Anthony C. Alejandro, Lt. Cdr. Jack L. Buri	
THE <i>KAPODISTRIAS</i> GROUNDING AND OIL SPILL CAPE RECIFE, SOUTH AFRICA	33
Desmond A. Lord, Graham I. H. Kerley, Rodney M. Randall, Jacobus S. V. Reddering, Eckart H. Schumann, William E. Bricknell, Sidney Rowe, Robert P. Mason	
CONTAINMENT AND CLEANUP OF A MAJOR OIL WELL BLOWOUT IN TEXAS	39
Christopher L. Quina, Larry C. Thebeau, Charles C. Bond, Patrick Hammack	
ANALYSIS OF SIGNIFICANT OIL SPILL INCIDENTS FROM SHIPS, 1976–1985	43
Pu Bao-Kang	
PROTECTING AN ISLAND'S DRINKING WATER AND DESALINATION PLANT	49
Lt. David J. Kruth, Edward Overton, John Murphy	
RESPONSE TO MAJOR OIL SPILL—TANK BARGE <i>ST. THOMAS</i>	55
Capt. Alexander E. Tanos, Cdr. Tony E. Hart	

II—CLEANUP OPERATIONS

A MOBILE PLANT PROTOTYPE FOR THE RESTORATION OF POLLUTED BEACHES BY WASHING OILY SAND	61
Christian Bocard, Jean-Jacques Quinquis, Christian Such	
TACID: A COMPUTER-BASED INFORMATION SYSTEM FOR ON-SCENE COMMANDERS	67
R. H. Goodman, C. H. Peabody, A. G. Holoboff	
REAL-TIME PROCESSING OF OIL SPILL REMOTE SENSING DATA	71
Yvon J. F. Le Guen, Marc Brussieux, Rolland Burkhalter	
DISPERSANT APPLICATION BY HYDROFOIL: HIGH SPEED CONTROL AND CLEANUP OF LARGE OIL SPILLS	75
Rear Adm. Marcello Vacca-Torelli, Alberto L. Geraci, Antonino Risitano	

ATYPICAL MITIGATION OF AN OIL SPILL, SAM HOUSTON NATIONAL FOREST	81
Warren B. Zehner, James R. Mullins	
BEACH AGITATION FOR CRUDE OIL REMOVAL FROM INTERTIDAL BEACH SEDIMENTS	85
James A. Miller	
DEVELOPMENT OF AN OIL SKIMMING SYSTEM TO MEET NAVY SPECIFICATIONS	91
Joseph B. H. Smith, Charles McLellan, Larry R. Pintler	
REMOTE SENSING TECHNIQUES FOR DETECTING OIL SLICKS AT SEA—A REVIEW OF WORK CARRIED OUT IN THE UNITED KINGDOM	95
Douglas Cormack, Neil Hurford, David Tookey	
EXPERIMENTAL STUDY AND IMPROVEMENT OF THE ROTATING DISC SKIMMER	101
Marios S. Christodoulou, John T. Turner	
COMBATING OIL WITH SIDE-FITTED SWEEPING BOOMS	109
Capt. Erling Blomberg	
CONVERSION OF A U.S. COAST GUARD SKIMMING BARRIER INTO A SINGLE-VESSEL SKIMMING SYSTEM	111
Kevin R. McManus	
NETTING OF VISCOUS OIL	115
Gerard A. L. Delvigne	
COMPARATIVE COSTS OF OIL SPILL CLEANUP TECHNIQUES	123
T. H. Moller, H. D. Parker, J. A. Nichols	
OPERATIONAL AIR SURVEILLANCE AND EXPERIENCES IN THE NETHERLANDS	129
R. C. Schriel	
SWEDISH COAST GUARD STARTS USING THIRD GENERATION MARITIME SURVEILLANCE SYSTEM	137
Olov Fäst	
III—CONTINGENCY PLANNING	
ALASKA CLEAN SEAS: MEETING RESPONSE NEEDS FOR 1987 AND BEYOND	145
Richard V. Shafer	
FIRST AFRICAN OIL SPILL COOPERATIVE: CLEAN NIGERIA ASSOCIATES	151
Godwin E. Omene, E. C. Odogwu, Tom E. Allen	
THE KUWAIT NATIONAL CONTINGENCY PLAN IN ACTION	157
Capt. Namir A. Al-Nakib	
OIL SPILL CONTINGENCY PLANNING IN THAILAND	161
Klavs Bender, Robert Taylor	
UNITED KINGDOM MARINE POLLUTION CONTINGENCY PLANNING—A REVIEW OF THE LAST TWO YEARS	167
Rear Adm. Michael L. Stacey, C.B.	
ROYAL NAVY OIL SPILL RESPONSE POSTURE—DEVELOPMENTS SINCE THE MID 1970s	171
Lt. Cdr. Geoffrey Teasdale, RN (Retd.)	
CANADIAN—U.S. SPILL RESPONSE COOPERATION ALONG THE GREAT LAKES	177
Ted Kaiser, Wilma Godon, Ron Whitehorne, Erich R. Gundlach, Bart J. Baca	
OIL POLLUTION RESPONSE ARRANGEMENTS IN AUSTRALIA: THE GOVERNMENT VIEW (INCLUDING AN UPDATE ON DISPERSANT TESTING)	181
Donald Brodie	

A HISTORY OF THE DEVELOPMENT OF OIL DISPERSANT GUIDELINES FOR ALASKA	189
Cdr. Michael A. Conway	
OIL SPILL CONTINGENCY PLANNING AT NAVY SHORE ACTIVITIES	193
Rebecca L. Biggers	
INTERNATIONAL AND REGIONAL ARRANGEMENTS ON COOPERATION IN COMBATING MARINE POLLUTION	201
David T. Edwards	

IV—DISPERSANTS

METHOD FOR MAKING DISPERSANT-USE DECISIONS BASED ON ENVIRONMENTAL IMPACT CONSIDERATIONS.....	211
B. K. Trudel, S. L. Ross	
EMULSION INHIBITORS: A NEW CONCEPT IN OIL SPILL TREATMENT	217
I. A. Buist, S. L. Ross	
PRELIMINARY MORTALITY EFFECTS OF SEVEN DISPERSANTS ON SUBTROPICAL/TROPICAL SEAGRASSES	223
Anitra Thorhaug, Jeffry H. Marcus	
PROTECMAR: THE FRENCH EXPERIENCE FROM A SEVEN-YEAR DISPERSANT OFFSHORE TRIALS PROGRAM.....	225
Christian Bocard, Gilles Castaing, Jean Ducreux, Claude Gatellier, Jean Croquette, François Merlin	
THE EFFICIENCY OF ELASTOMERS IN OIL SPILL CLEANUP	231
Paul Waters, Albert F. Hadermann	
TOXICITY OF DISPERSED AND UNDISPERSED PRUDHOE BAY CRUDE OIL FRACTIONS TO SHRIMP AND FISH.....	235
Jack W. Anderson, Robert Riley, Steve Kiesser, James Gurtisen	
LABORATORY STUDIES ON THE CHEMICAL AND NATURAL DISPERSABILITY OF OIL.....	241
Mervin F. Fingas, Mark A. Bobra, Ronald K. Velicogna	
OIL SPILL INCIDENTS AND DISPERSANT APPLICATIONS IN KUWAIT	247
Salah M. Al-Mazidi, Omar Samhan	
THE EFFECTS OF OIL AND CHEMICALLY DISPERSED OIL ON NATURAL PHYTOPLANKTON COMMUNITIES	255
M. Scholten, J. Kuiper	
EVALUATION AND CALIBRATION OF A DISPERSANT APPLICATION SYSTEM	259
J. S. Shum, J. H. Nash	
EFFECTIVENESS OF A TYPE III DISPERSANT ON LOW-ENERGY SHORELINES	263
D. I. Little, D. L. Scales	
A COMPUTERIZED TOOL FOR OIL SPILL RESPONSE DECISION MAKING	269
L. Michael Flaherty, John E. Riley, Allen G. Hansen	
ORGANISM EXPOSURE TO VOLATILE/SOLUBLE HYDROCARBONS FROM CRUDE OIL SPILLS—A FIELD AND LABORATORY COMPARISON	275
Clayton D. McAuliffe	
MARINE DISPERSANT PROGRAM FOR LICENSING AND RESEARCH IN SÃO PAULO STATE, BRAZIL	289
Rosalina P. de A. Araujo, Katia Momo, Elenita Gherardi-Goldstein, Marion Grosze Nipper, Peter G. Wells	
BASIC STUDY REVEALS HOW DIFFERENT CRUDE OILS INFLUENCE DISPERSANT PERFORMANCE.....	293
Gerard P. Canevari	

USE OF HIGH-PRESSURE WATER MIXING FOR SHIP-BASED OIL SPILL DISPERSING.....	297
R. Belore	
DATA ANALYSIS AND MODELING OF DISPERSANT EFFECTIVENESS IN COLD WATER.....	303
N. M. To, H. M. Brown, R. H. Goodman	
WHERE HAS ALL THE OIL GONE? DISPERSED OIL DETECTION IN A WAVE BASIN AND AT SEA.....	307
H. M. Brown, R. H. Goodman, Gerard P. Canevari	
DISPERSANT SPRAYING GUN.....	313
Gerard Barbouteau, Michel Angles, Yves Le Gal La Salle	
NEW FRONTIERS FOR OIL DISPERSANTS.....	317
L. Michael Flaherty, John E. Riley	
STRATEGY FOR MONITORING THE SHORT-TERM DISTRIBUTION OF DISPERSED OILS.....	321
Steven F. Railsback, Gordon A. Robilliard, Jack R. Mortenson	
MEASUREMENT AND PREDICTION OF DEPOSITIONAL ACCURACY IN DISPERSANT SPRAYING FROM LARGE AIRPLANES.....	325
Gordon P. Lindblom	
ADVANCE PLANNING FOR DISPERSANT USE.....	329
June Lindstedt-Siva	
INJECTION OF OIL SPILL CHEMICALS INTO A BLOWING WELL.....	335
Tore Audunson, Øistein Johansen, Johnny Kolnes, Stein Erik Sørstrøm	
CONSIDERATIONS FOR DISPERSANT USE: TANK VESSEL <i>PUERTO RICAN</i> INCIDENT.....	341
Capt. David Zawadzki, Lt. Jeffrey D. Stieb, Cdr. Stewart McGee, Jr.	

V—EXTREME WEATHER

RESEARCH AND DEVELOPMENT OF OIL SPILL CONTROL DEVICES FOR USE IN COLD CLIMATES IN JAPAN.....	349
Isao Suzuki, Kenjiro Miki	
A PRELIMINARY FEASIBILITY STUDY OF IN-SITU BURNING OF SPREADING OIL SLICKS.....	359
I. A. Buist	
THE LASER IGNITION DEVICE AND ITS APPLICATION TO OIL SPILLS.....	369
Michael D. Waterworth	
EXPERIMENTAL SPILLS OF CRUDE OIL IN PACK ICE.....	373
I. A. Buist, D. F. Dickins	
IN-PLACE BURNING OF CRUDE OILS IN BROKEN ICE.....	383
Nelline K. Smith, Anibal Diaz	
LASER IGNITION OF OIL SPILLS.....	389
Harry Whittaker	
A TECHNIQUE FOR THE MEASUREMENT OF UNDER-ICE ROUGHNESS TO DETERMINE OIL STORAGE VOLUMES.....	395
R. H. Goodman, A. G. Holoboff, T. W. Daley, P. Waddell, L. D. Murdock, M. Fingas	

VI—FATE AND EFFECTS

AN OIL SPILL AFFECTING CORAL REEFS AND MANGROVES ON THE CARIBBEAN COAST OF PANAMA.....	401
John D. Cubit, Charles D. Getter, Jeremy B. C. Jackson, Stephen D. Garrity, Hugh M. Caffey, Ricardo C. Thompson, Ernesto Weil, Michael J. Marshall	

ENVIRONMENTAL ASPECTS OF THE <i>ARCO ANCHORAGE</i> OIL SPILL, PORT ANGELES, WASHINGTON	407
June Lindstedt-Siva, Dilworth W. Chamberlain, Eugene R. Mancini	
ENHANCED BIODEGRADATION OF A LIGHT CRUDE OIL IN SANDY BEACHES	411
Kenneth Lee, Eric M. Levy	
DEAD ENDANGERED SPECIES IN A CALIFORNIA OIL SPILL	417
Edward A. Simons, Lt. Morgan Akin	
OILED SEDIMENTS IN THE HUMBER ESTUARY FOLLOWING THE <i>SIVAND</i> INCIDENT	419
D. I. Little	
EFFECT OF INFAUNAL BURROW STRUCTURE ON OIL PENETRATION INTO SEDIMENTS	427
S. Howard, D. I. Little	
THE PERSISTENCE OF OIL STRANDED ON SEDIMENT SHORELINES	433
D. I. Little, D. L. Scales	
BIOLOGICAL EFFECTS OF LOW-PRESSURE SEAWATER FLUSHING OF OILED SEDIMENTS	439
S. Howard, D. I. Little	
RELATIONSHIP OF <i>SPARTINA ALTERNIFLORA</i> GROWTH TO SEDIMENT OIL CONTENT FOLLOWING AN OIL SPILL	445
Steve K. Alexander, James W. Webb, Jr.	
OIL-HOLDING CAPACITIES AND REMOVAL COEFFICIENTS FOR DIFFERENT SHORELINE TYPES TO COMPUTER SIMULATE SPILLS IN COASTAL WATERS	451
Erich R. Gundlach	
RECOVERY OF BRITTANY COASTAL MARSHES IN THE EIGHT YEARS FOLLOWING THE <i>AMOCO CADIZ</i> INCIDENT	459
Bart J. Baca, Thomas E. Lankford, Erich R. Gundlach	
THE MANAGEMENT OF OILED PENGUINS	465
Graham I. H. Kerley, Theuns Erasmus	
FUEL OIL EFFECTS ON MEMBRANE PERMEABILITY IN <i>SPARTINA ALTERNIFLORA</i> ROOTS	469
Fitzgerald Booker	
THE FATE OF STRANDED OIL FOUR YEARS AFTER AN EXPERIMENTAL SPILL ON A SHELTERED GRAVEL BEACH	473
Edward H. Owens, Wishart Robson, Blair Humphrey, Dave Hope, John R. Harper	
AN OVERVIEW: REHABILITATION OF OIL CONTAMINATED BIRDS	479
Lynne Frink	
CLEANUP AND EFFECTS OF CRUDE OIL AND FUEL OIL SPILLS IN OSITO CANYON: A COMPARISON	483
Lt. Jack A. Kemerer, MK1 Terrence McGuigan, DC1 Douglas Campbell	
PRELIMINARY ASSESSMENT OF THE EFFECT OF AN OIL SPILL ON A LOUISIANA MARSH	489
Marion Fischel	
THE ROLE OF <i>JUNCUS ROEMERIANUS</i> IN CLEANUP OF OIL-POLLUTED SEDIMENTS	495
Julia S. Lytle, Thomas F. Lytle	
THE IMPORTANCE OF USING APPROPRIATE EXPERIMENTAL DESIGNS IN OIL SPILL IMPACT STUDIES: AN EXAMPLE FROM THE <i>AMOCO CADIZ</i> OIL SPILL IMPACT ZONE	503
Edward S. Gilfillan, David S. Page, Barbara Griffin, Sherry A. Hanson, Judith C. Foster	

IMPACT OF EXPERIMENTALLY DISPERSED CRUDE OIL ON VEGETATION IN A NORTHWESTERN ATLANTIC SALT MARSH—PRELIMINARY OBSERVATIONS	509
Patricia A. Lane, John H. Vandermeulen, Michael J. Crowell, David G. Patriquin	

VII—MODELING

ENVIRONMENTAL BASELINE STUDIES FOR OIL POLLUTION CONTROL IN NIGERIA	517
Jerry N. Nwankwo, Jacqueline Michel, Maylo Murday	
AN EVALUATION OF EPA SHEEN TESTS FOR DRILLING FLUID DISCHARGE.....	521
Maurice Jones, Gordon H. Otto	
DOOSIM—A NEW SIMULATION MODEL FOR OIL SPILL MANAGEMENT.....	529
Øistein Johansen	
COMPARISON OF FEDERAL GUIDELINES FOR NATURAL RESOURCE DAMAGE ASSESSMENT OF A MAJOR OIL SPILL, ISLAND PARK, NEW YORK	533
Gary L. Ott	
THE NATURAL RESOURCE DAMAGE ASSESSMENT MODEL FOR COASTAL AND MARINE ENVIRONMENTS (NRDAM/CME)	541
Thomas A. Grigalunas, James J. Opaluch, Deborah French, Mark Reed	
ESTIMATING MORTALITY OF SEABIRDS FROM OIL SPILLS.....	547
R. Glenn Ford, Gary W. Page, Harry R. Carter	

VIII—LEGAL/ECONOMIC

THE NOTION OF “POLLUTION DAMAGE,” WITH PARTICULAR REGARD TO DAMAGE TO THE MARINE ENVIRONMENT.....	555
Måns Jacobsson	
UNITED STATES PROGRESS TOWARD ENACTMENT OF COMPREHENSIVE OIL SPILL LIABILITY AND COMPENSATION LEGISLATION	559
Capt. Charles R. Corbett	

IX—TRAINING

OIL SPILL TRAINING: THE NEED CONTINUES	565
Robert J. Meyers, J. Larry Payne, Clyde B. Strong	
OIL SPILL TRAINING—AN EFFECTIVE APPROACH	569
Wayne Wiebe	
POLLUTION PREVENTION AT THE PORT OF MARSEILLE AUTHORITY.....	573
P. Jointe	
THE DEVELOPMENT OF A CANADIAN OIL SPILL TRAINING PROGRAM.....	577
S. G. Potter, S. L. Ross, L. C. Oddy	
ON-SCENE COORDINATORS CAN EFFECTIVELY INFORM THE PUBLIC THROUGH THE NEWS MEDIA	583
CWO Richard M. Meidt	
POLLUTION FIGHTING: TRAINING IN FRANCE	587
M. Melguen, J. F. Levy	

X—UNDERGROUND SPILLS

THE UNDERGROUND OIL SPILL AT KOTZEBUE, ALASKA: UNKNOWN CAUSE, ELUSIVE CURE.....	593
John H. Janssen, Douglas L. Kane	
A MODEL FOR MANAGING UNDERGROUND STORAGE TANKS	599
Anne E. Smith, David Cohan, Frank Selker	

A COMPARISON OF SOIL-GAS SAMPLING METHODS USED AT TWO HARBOR SITES.....	605
Victor H. Owens, Walter J. Sexton, Jacqueline Michel	
UNDERGROUND STORAGE TANK CORRECTIVE ACTION TECHNOLOGIES.....	611
Douglas C. Ammon, S. Robert Cochran	

XI—ABSTRACTS OF POSTER PRESENTATIONS

PICTORIAL REVIEW OF TWO OIL SPILLS ON THE TRANS-ALASKA PIPELINE.....	619
Kenneth Hunt	
PLANNING FOR THE USE OF DISPERSANTS	619
Cdr. Tony E. Hart	
DEVELOPMENT OF A GREAT RATE OILY WATER SEPARATING SYSTEM	620
Yvon Le Guen, A. Bonazzi, Georges Peigne, Christian Lemaitre	
LONG-TERM DRIFT IN THE BEAUFORT SEA.....	620
J. W. St. Martin	
A MAJOR INLAND SPILL CASE HISTORY VIEWED AS A CANDIDATE FOR DISPERSANT USE	621
Arnold Paddock	
THE USE OF ENVIRONMENTAL MAPPING IN THE PREPARATION OF OIL SPILL CONTINGENCY PLANS FOR COASTAL AREAS.....	622
G. Dossena, M. Kanu, L. Ceffa	
SURFACE CURRENT MEASUREMENTS FOR VALIDATION OF AN OIL SPILL TRACKING MODEL FOR THE BEAUFORT SEA.....	623
Ivan M. Lissauer, Joseph W. St. Martin	
CONTAINMENT AND RECOVERY OF OIL FROM MUSKEG AREAS	623
Wayne Wiebe	
BIOLOGICAL IMPACTS OF OIL AND GAS DEVELOPMENT IN NORTHWEST PENNSYLVANIA.....	624
Dennis F. Brown, John A. Arway	
THE UTILIZATION OF ENVIRONMENTAL SENSITIVITY INDEX DATA IN A MICROCOMPUTER-BASED GEOGRAPHIC INFORMATION SYSTEM	624
Basil Savitsky	
OIL SPILL SIMULATION FROM THE MARJAN OFFSHORE OIL FIELD	625
William J. Lehr, Robin W. Lardner, Robert J. Fraga	
PROGRESS IN ENHANCED OIL DEGRADATION.....	625
Alain Ladousse, Claude Tallec, Bernard Tramier	
THE EFFECTS OF OIL ON INTERACTING SALT MARSH PLANTS	626
P. Leendertse, M. Scholten	
LONG-TERM OIL WEATHERING UNDER SEA ICE IN EXPERIMENTAL MESOSCALE SIMULATOR.....	627
E. Pelletier, C. Brochu, J. H. Vandermeulen	
BIOINDICATORS AS A TOOL FOR ASSESSMENT OF HYDROCARBON IMPACT AND WEATHERING IN MANGROVE FORESTS.....	628
E. Dutrieux, F. Secchi, O. Guelorget	
COMPUTER SOFTWARE PACKAGES FOR OIL SPILL CONTINGENCY PLANNING	628
Mark West, Allister Brown	
AN EXPERIMENTAL ANALYSIS OF THE FACTORS INFLUENCING THE ACCURACY OF VOLUMETRIC LEAK DETECTION METHODS IN UNDERGROUND STORAGE TANKS.....	629
J. Starr, J. Maresca, J. Farlow, R. Field, M. Kalinoski	

OIL SPILL CONTINGENCY PLANNING IN SOUTH AFRICA.....	629
A. Moldan, L. F. Jackson	
APPLICATION OF HIGH-RESOLUTION SPACE IMAGERY FOR CONTINGENCY PLANNING.....	630
J. Denis, L. Loubersac	
REVISED OFFSHORE OIL SPILL OCCURRENCE RATES FOR THE OUTER CONTINENTAL SHELF.....	630
Cheryl A. Anderson, Robert P. LaBelle	
COMPUTER-BASED CONTINGENCY AND EMERGENCY RESPONSE PLAN FOR THE NATIONAL MARINE SANCTUARY PROGRAM	631
Gordon A. Robilliard, R. Glenn Ford	
ARCTIC OIL SPILL RESPONSE PLANNING GUIDE.....	631
Robert J. Meyers, J. Larry Payne, Ivan M. Lissauer	
EVALUATING THE EFFECTIVENESS OF MARINE ENVIRONMENTAL PROTECTION PROGRAMS: DIRECTIONS FOR DEVELOPMENT.....	632
Lt. Cdr. Robert J. Brulle, Lt. Clayton W. Evans	
EFFECTS OF SOUTH LOUISIANA CRUDE OIL AND DISPERSANTS ON <i>RHIZOPHORA</i> MANGROVES	633
Howard J. Teas, Eirik O. Duerr, J. Ross Wilcox	
ENVIRONMENTAL COAST ATLAS FOR OIL SPILL CONTINGENCY PLANNING	633
Per J. Tømmerraas	
BEAUFORT SEA DISPERSANT TRIAL	634
J. J. Swiss, N. Vanderkooy, S. D. Gill, R. H. Goodman	
FINAL RESULTS OF THE API TROPICS OIL SPILL AND DISPERSANT USE EXPERIMENTS IN PANAMA.....	634
Thomas G. Ballou, Steven C. Hess, Charles D. Getter, Anthony Knap, Richard Dodge, Thomas Sleeter	

SESSION CHAIRMEN AND VICE CHAIRMEN

Program Session	Chairmen	Vice Chairmen
Case Histories I	Stuart Horn Mobil Oil Corporation 150 East 42nd Street New York, New York 10017	Kurt Jakobson U.S. Environmental Protection Agency (OEETD) RD 681 401 M Street SW Washington, D.C. 20460
Case Histories II	Måns Jacobsson International Oil Pollution Compensation Fund 4 Albert Embankment London SE1 7SR United Kingdom	Lt. Cdr. David Pascoe Commandant (G-MER-3) U.S. Coast Guard 2100 2nd Street SW Washington, D.C. 20593
Case Histories III	Thomas Massey U.S. Environmental Protection Agency, Region III 841 Chestnut Street Philadelphia, Pennsylvania 19101	Joseph Smith Petrochem Services, Inc. P.O. Box 337 Lemont, Illinois 60439
Cleanup Operations I	James Butler Harvard University Division of Applied Science Pierce Hall 29 Oxford Street Cambridge, Massachusetts 02138	Ron DeNoville Crawford and Company P.O. Box 5047 Atlanta, Georgia 30302
Cleanup Operations II	Oleg Khalimonov Director, Marine Pollution Control Administration U.S.S.R. Ministry of Merchant Marine 1/4, U1 Zdanova St., Moscow 103759, U.S.S.R.	Gary L. Ott NOAA Scientific Support Coordinator First Coast Guard District Capt. John Foster Williams Federal Bldg. 408 Atlantic Avenue Boston, Massachusetts 02210
Cleanup Operations III	S. Takenaka Maritime Disaster Prevention Center Inoue Akasaka Building Akasaka 1 Chome Minatoku, Tokyo, 107 Japan	Harold Weiss Texaco U.S.A. P.O. Box 509 Beacon, New York 12508
Cleanup Operations IV	Hans J. Crump U.S. Environmental Protection Agency (WH-548B) 401 M Street SW Washington, D.C. 20460	William Katz Illinois Chemical Corp. P.O. Box 2116 1548 Old Skokie Rd. Chicago, Illinois 60035

Program Session	Chairmen	Vice Chairmen
Contingency Planning I	Rear Adm. Gustavo Orozco Peralta Contralmirante CG Demn. Fernando Alencaste Street #300 Lomas Virreyes, Code 11000 Mexico, D.F.	J. T. Leigh Texaco U.S.A. P.O. Box 509 Beacon, New York 12508
Contingency Planning II	Royal Nadeau U.S. Environmental Protection Agency Environmental Response Team Raritan Depot Edison, New Jersey 08837	Jacqueline Michel Research Planning Institute, Inc. P.O. Box 328 Columbia, South Carolina 29202
Contingency Planning III	Lt. Cdr. Gary Reiter 320 Westmoreland Street Apartment A-2 Narragansett, Rhode Island 02882	Edward Wirkowski Clean Harbors Cooperative P.O. Box 1375 1200 State St. Perth Amboy, New Jersey 08862
Dispersants I	Timothy Fields, Jr. U.S. Environmental Protection Agency (WH-548B) 401 M Street SW Washington, D.C. 20460	Gerard P. Canevari G. P. Canevari Associates 104 Central Avenue Cranford, New Jersey 07016
Dispersants II	Cdr. Theodore J. Sampson Commanding Officer U.S. Coast Guard Atlantic Strike Team Elizabeth City, North Carolina 27909	John Fraser Shell Oil Company P.O. Box 4320 Houston, Texas 77210
Dispersants III	Richard Griffiths U.S. Environmental Protection Agency, Office of Research and Development Raritan Depot Edison, New Jersey 08837	William Walker Commander (Code OOC-21C) Naval Sea Systems Command Washington, D.C. 20362
Dispersants IV	June Lindstedt-Siva Atlantic Richfield Company 515 Flower Street Los Angeles, California 90071	Clayton McAuliffe Clayton McAuliffe and Associates, Inc. 1220 Frances Avenue Fullerton, California 92631
Dispersants V	Cdr. Timothy Josiah Commanding Officer U.S. Coast Guard Marine Safety Office P.O. Box D-17 St. Louis, Missouri 63188	Edward Tennyson Minerals Management Service (647) 12203 Sunrise Valley Dr. Reston, Virginia 22091
Dispersants VI	Lindon "Skip" Onstad Clean Seas 418 Chapala Street Suite F Santa Barbara, California 93101	Eleanor Swett Offshore Devices, Inc. Summit Industrial Park Peabody, Massachusetts 01960

Program Session	Chairmen	Vice Chairmen
Extreme Weather I	Lt. Cdr. Dennis Rome Commanding Officer U.S. Coast Guard Pacific Strike Team Hangar 2, Bldg. 390 Hamilton AFB, California 94934	Kenneth Meikle Environmental Protection Service River Road Environmental Technology Centre Ottawa, Ontario K1A 1C8, Canada
Extreme Weather II	Lt. Cdr. Richard Softye Commanding Officer U.S. Coast Guard Gulf Strike Team CG Aviation Training Center Mobile, Alabama 36608	James Parker Industrial Marine Services, Inc. P.O. Box 1779 Norfolk, Virginia 23501
Fate and Effects I	Rear Adm. Michael L. Stacey, C.B. Department of Transport Sunley House 90/93 High Holborn London WC1V 6LP United Kingdom	Lewis R. Brown Mississippi State University P.O. Drawer AS Mississippi State, Mississippi 39762
Fate and Effects II	Jack Gould Health and Environmental Sciences Department American Petroleum Institute 1220 L Street NW Washington, D.C. 20005	Anita Miller U.S. Department of the Interior 200 Chestnut St., Room 502 Philadelphia, Pennsylvania 19106
Fate and Effects III	Cdr. Richard Crane Commanding Officer Central Oil Identification Laboratory U.S. Coast Guard Research and Development Center Groton, Connecticut 06340	Michael Flaherty 10332 Democracy Lane Potomac, Maryland 20854
Fate and Effects IV	Sharon O. Hillman Standard Alaska Production Company 900 East Benson Blvd P.O. Box 196612 Anchorage, Alaska 99519	William C. Park III Mobil Oil Corporation 150 East 42nd Street New York, New York 10017
Fate and Effects V	James P. Marum Mobil Oil Corporation P.O. Box 1031 Princeton, New Jersey 08540	Walter Youngblade O. H. Materials Company P.O. Box 551 Findlay, Ohio 45839
Modeling I	Capt. M. S. Greenham Chief, Coast Guard Emergencies Canadian Coast Guard Place de Ville Ottawa, Ontario K1A 0N7 Canada	Patrick O'Brien Chevron Corporation P.O. Box 7924 525 Market Street San Francisco, California 94120
Modeling II	Rachel Pappworth Witco Corporation P.O. Box 42817 Houston, Texas 77242	Gerd Kleineberg U.S. Coast Guard Research and Development Center Groton, Connecticut 06340

Program Session	Chairmen	Vice Chairmen
Legal/Economic	James Ketcham-Colwill Environmental and Energy Study Conference U.S. Congress 515 House Annex 2 Washington, D.C. 20515	Lt. James C. Milbury Commandant (G-MER-2) U.S. Coast Guard 2100 2nd Street SW Washington, D.C. 20593
Training I	Capt. Peter C. Lauridsen Commander (m) Fifth Coast Guard District Federal Building 431 Crawford Parkway Portsmouth, Virginia 23705	John P. Bennington Amoco Transport Company 200 East Randolph Dr. MC 1108 Chicago, Illinois 60601
Training II	Robert J. Meyers Robert J. Meyers and Associates, Inc. 1441 Cornerstone Village Dr. Suite 207 Houston, Texas 77014	Lt. Cdr. Edward Rosenberg Commanding Officer (t-mss) U.S. Coast Guard Reserve Training Center Yorktown, Virginia 23690
Underground Spills	R. Jones U.S. Environmental Protection Agency, Region VIII 999 18th Street Denver, Colorado 80202	Lt. Cdr. John Clay Commandant (G-ECV-5) U.S. Coast Guard 2100 2nd Street SW Washington, D.C. 20593
Tuesday Poster Session	John S. Farlow U.S. Environmental Protection Agency Woodbridge Avenue Edison, New Jersey 08837	_____
Wednesday Poster Session	John S. Farlow U.S. Environmental Protection Agency Woodbridge Avenue Edison, New Jersey 08837	_____
Wednesday Panel Discussion: Tank Vessel <i>Arco Anchorage</i>	Ian C. White International Tanker Owners Pollution Federation, Ltd. Staple Hall, Stonehouse Court 87-90 Houndsditch London EC3A, United Kingdom	Lt. James C. Milbury Commandant (G-MER-2) U.S. Coast Guard 2100 2nd Street SW Washington, D.C. 20593

Panel Members

Ron DeNville
Crawford and Company
P.O. Box 5047
Atlanta, Georgia 30302

Robert Levine
Arco Marine, Inc.
300 Oceangate
Long Beach, California 90802

Lewey Kittle
Washington State Department
of Ecology
7272 Cleanwater Lane
Olympia, Washington 98504

David Kennedy
National Oceanic and
Atmospheric Administration
NOAA/HAZMAT
7600 Sand Point Way NE
Seattle, Washington 98115

xx

Program Session**Panel Members (cont'd)**

Michael Martin
 Redding Record Searchlight
 P.O. Box 2397
 Redding, California 96099

Lt. Cdr. Gregory Yaroach
 U.S. Coast Guard
 Marine Safety Office
 1519 Alaskan Way South
 Building One
 Seattle, Washington 98138

Thursday
 Panel Discussion:
 Damage Assessment

Chairman

Carol Cummings
 Amoco Corporation
 1615 M Street NW
 Washington, D.C. 20036

Vice-Chairman

Alexandra L. Moore
 Amoco Corporation
 200 East Randolph Drive
 MC 4903
 Chicago, Illinois 60601

Panel Members

Marion Fischel
 Shell Oil Company
 One Shell Plaza
 Houston, Texas 77210

Lewey Kittle
 Washington State Department
 of Ecology
 7272 Cleanwater Lane
 Olympia, Washington 98504

Jacqueline Michel
 Research Planning Institute, Inc.
 P.O. Box 328
 Columbia, South Carolina 29202

Erik Olson
 National Wildlife Federation
 1325 Massachusetts Avenue NW
 Washington, D.C. 20005

Gary L. Ott
 NOAA Scientific Support Coordinator
 First Coast Guard District
 Capt. John Foster Williams
 Federal Building
 408 Atlantic Avenue
 Boston, Massachusetts 02210

Willie Taylor
 U.S. Department of the Interior
 Office of Policy Analysis,
 Room 4450
 18th and C Streets NW
 Washington, D.C. 20240

AUTHOR INDEX

Akin, M., 417
 Alejandro, A. C., 27
 Alexander, S. K., 445
 Allen, T. E., 151
 Al-Mazidi, S. M., 247
 Al-Nakib, N. A., 157
 Ammon, D. C., 611
 Anderson, C. A., 630
 Anderson, J. W., 235
 Angles, M., 313
 Arway, J. A., 624
 Audunson, T., 335

Baca, B. J., 177, 459
 Ballou, T. G., 634
 Barbouteau, G., 313
 Belore, R., 297
 Bender, K., 161
 Bergot, G., 15
 Biggers, R. L., 193
 Blomberg, E., 109
 Board, C., 61
 Bobra, M. A., 241
 Bocard, C., 61, 225
 Bonazzi, A., 620
 Bond, C. C., 39
 Booker, F., 469
 Bricknell, W. E., 33
 Brochu, C., 627
 Brodie, D., 181
 Brown, A., 628
 Brown, D. F., 624
 Brown, D. J. S., 9
 Brown, H. M., 303, 307
 Brulle, R. J., 632
 Brussieux, M., 71
 Buist, I. A., 217, 359, 373
 Buri, J. L., 27
 Burkhalter, R., 71

Caffey, H. M., 401
 Campbell, D., 483
 Canevari, G. P., 293, 307
 Carter, H. R., 547
 Castaing, G., 225
 Ceffa, L., 622
 Chamberlain, D. W., 407
 Christodoulou, M. S., 101
 Cochran, S. R., 611
 Cohan, D., 599
 Conway, M. A., 189
 Corbett, C. R., 559
 Cormack, D., 95
 Croquette, J., 225
 Crowell, M. J., 509
 Cubit, J. D., 401

Daley, T. W., 395
 de A. Araujo, R. P., 289
 Delvigne, G. A. L., 115
 Denis, J., 630
 Diaz, A., 383
 Dickins, D. F., 373
 Dodge, R., 634
 Dossena, G., 622
 Ducreux, J., 225
 Duerr, E. O., 633
 Dutrieux, E., 628

Edwards, D. T., 201
 Erasmus, T., 465
 Evans, C. W., 632

Farlow, J., 629
 Fäst, O., 137
 Field, R., 629
 Fingas, M. F., 241, 395
 Fischel, M., 489
 Flaherty, L. M., 269, 317
 Ford, R. G., 547, 631
 Foster, J. C., 503
 Fraga, R. J., 625
 French, D., 541
 Frink, L., 479

Garrity, S. D., 401
 Gatellier, C., 225
 Geraci, A. L., 75
 Getter, C. D., 401, 634
 Gherardi-Goldstein, E., 289
 Gilfillan, E. S., 503
 Gill, S. D., 634
 Godon, W., 177
 Goodman, R. H., 67, 303, 307, 395, 634
 Griffin, B., 503
 Grigalunas, T. A., 541
 Guelorget, O., 628
 Gundlach, E. R., 177, 451, 459
 Gurtisen, J., 235

Hadermann, A. F., 231
 Hammack, P., 39
 Hansen, A. G., 269
 Hanson, S. A., 503
 Harper, J. R., 473
 Hart, T. E., 55, 619
 Hess, S. C., 634
 Holoboff, A. G., 67, 395
 Hope, D., 473
 Howard, S., 427, 439
 Humphrey, B., 473
 Hunt, K., 619
 Hurford, N., 95

Jackson, J. B. C., 401
 Jackson, L. F., 629
 Jacobsson, M., 555
 Janssen, J. H., 593
 Johansen, Ø., 335, 529
 Jointe, P., 573
 Jones, M., 521

Kaiser, T., 177
 Kalinoski, M., 629
 Kane, D. L., 593
 Kanu, M., 622
 Kelley, M. R., 583
 Kemerer, J. A., 483
 Kerley, G. I. H., 33, 465
 Kiesser, S., 235
 Knap, A., 634
 Kolnes, J., 335
 Kruth, D. J., 49
 Kuiper, J., 255

La Salle, Y. Le G., 313
 LaBelle, R. P., 630
 Ladousse, A., 625
 Lane, P. A., 509
 Lankford, T. E., 459
 Lardner, R. W., 625
 Le Guen, Y. J. F., 71, 620
 Lee, K., 411
 Leendertse, P., 626
 Lehr, W. J., 625
 Lemaitre, C., 620
 Levine, R. A., 3
 Levy, E. M., 411
 Levy, J. F., 587
 Lindblom, G. P., 325
 Lindstedt-Siva, J., 329, 407
 Lissauer, I. M., 623, 631
 Little, D. I., 263, 419, 427, 433, 439
 Lord, D. A., 33
 Loubersac, L., 630
 Lytle, J. S., 495
 Lytle, T. F., 495

Mancini, E. R., 407
 Marchand, G., 15
 Marcus, J. H., 223
 Maresca, J., 629
 Marshall, M. J., 401
 Mason, R. P., 33
 McAuliffe, C. D., 275
 McGee, S., Jr., 341
 McGuigan, T., 483
 McLellan, C., 91
 McManus, K. R., 111
 Meidt, R. M., 583
 Melguen, M., 15, 587

Merlin, F., 225
 Meyers, R. J., 565, 631
 Michel, J., 517, 605
 Miki, K., 349
 Miller, J. A., 85
 Moldan, A., 629
 Moller, T. H., 123
 Momo, K., 289
 Mortenson, J. R., 321
 Mullins, J. R., 81
 Murday, M., 517
 Murdock, L. D., 395
 Murphy, J., 49

Nash, J. H., 259
 Nichols, J. A., 123
 Nipper, M. G., 289
 Nwankwo, J. N., 517

Oddy, L. C., 577
 Odogwu, E. C., 151
 Omene, G. E., 151
 Opaluch, J. J., 541
 Ott, G. L., 533
 Otto, G. H., 521
 Overton, E., 49
 Owens, E. H., 473
 Owens, V. H., 605

Paddock, A., 621
 Page, D. S., 503
 Page, G. W., 547
 Parker, H. D., 123
 Patriquin, D. G., 509
 Payne, J. L., 565, 631
 Peabody, C. H., 67
 Peigne, G., 15, 620
 Pelletier, E., 627
 Pintler, L. R., 91
 Potter, S. G., 577
 Pu, B-K., 43

Quina, C. L., 39
 Quinquis, J.-J., 61

Railsback, S. F., 321
 Randall, R. M., 33
 Reddering, J. S. V., 33
 Reed, M., 541
 Riley, J. E., 269, 317
 Riley, R., 235
 Risitano, A., 75
 Robilliard, G. A., 321, 631
 Robson, W., 473
 Ross, S. L., 211, 217, 577
 Rowe, S., 33
 Ryan, P. B., 9

St. Martin, J. W., 620, 623
 Samhan, O., 247
 Savitsky, B., 624
 Scales, D. L., 263, 433
 Scholten, M., 255, 626
 Schriel, R. C., 129
 Schumann, E. H., 33
 Secchi, F., 628
 Selker, F., 599
 Sexton, W. J., 605
 Shafer, R. V., 145
 Shum, J. S., 259
 Simons, E. A., 417
 Sleeter, T., 634
 Smith, A. E., 599
 Smith, J. B. H., 23, 91
 Smith, N. K., 383
 Sørstrøm, S. E., 335
 Stacey, M. L., 167
 Starr, J., 629
 Stieb, J. D., 341
 Strong, C. B., 565
 Such, C., 61

Suzuki, I., 349
 Swiss, J. J., 634

Taltec, C., 625
 Tanos, A. E., 55
 Taylor, R., 161
 Teas, H. J., 633
 Teasdale, G., 171
 Thebeau, L. C., 39
 Thompson, R. C., 401
 Thorhaug, A., 223
 To, N. M., 303
 Tømmerraas, P. J., 633
 Tookey, D., 95
 Tramier, B., 625
 Trudel, B. K., 211
 Turner, J. T., 101

Vacca-Torelli, M., 75
 Vanderkooy, N., 634
 Vandermeulen, J. H., 509, 627
 Velicogna, R. K., 241

Waddell, P., 395
 Waters, P., 231
 Waterworth, M. D., 369
 Webb, J. W., Jr., 445
 Weil, E., 401
 Wells, P. G., 289
 West, M., 628
 Whitehorne, R., 177
 Whittaker, H., 389
 Wiebe, W., 569, 623
 Wilcox, J. R., 633

Zawadzki, D., 341
 Zehner, W. B., 81

SUBJECT INDEX

References are to the first page of the respective papers in which the subject is discussed.

- Abidjan Convention, 201
 ABSORB. *See* ACS (Alaska Clean Seas)
 ACS (Alaska Clean Seas), 45, 189
 Additive, biological, 317, 411, 625
 Agitation, physical, cleanup method, 3, 85, 407, 439
 Aircraft, use of
 in dispersant spraying, 33, 225, 325, 341, 419, 634
 in surveillance, 27, 33, 71, 95, 129, 137, 341
 Alaska, 145, 189
 spills, 593, 619
 Algae, 255, 275, 401, 533
 Aliphatics, 495, 503
Alvenus (tanker), 27, 111, 451
 American Petroleum Institute, dispersant-use guidelines, 329
Amoco Cadiz (tanker), 15, 43, 171, 225, 451, 459, 503, 559
Antonio Gramsci (tanker), 555
 Aquaculture, 161
 Arabian Gulf, 9, 49, 157, 625
Arco Anchorage (tanker), 3, 85, 407
 Arctic. *See* Cold climate
Argo Merchant (tanker), 583
 Aromatics, 235, 275, 495, 503
 Aspartate animotransferase activity, in spill zone, 503
 Asphalt pavement, 473
 Assessment
 damage, natural resource, 533, 541, 555
 risk, 161, 181
 seabird mortality, 547
 ASTM (American Society for Testing and Materials), dispersant guidelines, 329
 Australia, 181, 369

 Bahrain, State of, 9, 625
 Ballast water, warship, 171
 Barcelona Convention, 201
 Baseline study/information, 401, 517
 Beaches, 55, 247, 401
 bathing, 9, 27, 33, 161
 oiled, cleaning of, 3, 27, 61, 85, 407, 411, 439
 Beaufort Sea, Alaskan/Canadian, 145, 211, 620, 623, 631, 634
 Benthos, 489, 533, 628
 Bering Sea, 145
 Biodegradation, 263, 411, 419, 433, 473
 enhanced, 317, 411, 625
 BIOS (Baffin Island Oil Spill) project, 189, 473
 Birds, 27, 81, 401, 407, 417
 oiled, 33, 407, 465, 479
 rescue organizations, 33, 407, 465, 479
 seabird, 33, 161, 465, 533, 547
 wading, 33, 533
 waterfowl, 533
 Blowout, 39, 275, 335
 Boat(s)
 pleasure/marinas, 55, 123
 spraying by, 33, 75, 225, 259, 297, 419
 Bonn Agreement, 129, 167, 201
 Booms, 3, 23, 27, 55, 85, 109, 145, 171, 349, 407, 573
 Brazil, 289
Brazilian Marina (tanker), 289
 Breakup, spill cause, 43, 341
 Brine-water pollution, 81, 417
 Bubble barrier, subsurface, 145
 Buildings, spill under, 593
 Bulldozers, 3, 85, 407
 Bunker C oil, 341, 349, 445
 Burning, in-situ, as cleanup method, 145, 359, 369, 383, 389
 in forests, 81, 369
 Burrow structure, infaunal, 427

 California, 111, 321, 329, 631
 spills, 341, 417, 483, 547
 Canada
 biodegradation studies, 411, 473
 dispersant use/effectiveness tests, 211, 217, 297, 303, 307, 634
 ice/oil studies, 373, 627
 ignition/burning tests, 359, 389
 marsh studies, 509, 623
 response/training, 67, 177, 395, 569, 577, 628
 CANUSLAK plan, 177
 Cargo, jettison/salvage of, 33
 Caribbean, 201, 223, 619
 spills, 49, 55, 401
 Cartagena Convention, 201
Castillo de Bellver (tanker), 43
Castillo de Monte Aragon (tanker), 43
 CEDRE (Center for Studies, Documentation, Research and Testing), 587
 CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act), 177, 489, 533, 541, 547
 CGA (Clean Gulf Association), 27
 Civil Liability Convention, 1969
 (Convention on Civil Liability for Oil Pollution Damage), and 1984 Protocol, 555, 559
 Clean Bay cooperative, 321
 Clean Caribbean Cooperative, 201
 Clean Seas cooperative, 111
 Clean Sound Cooperative, 3
 Clean Water Act, 39, 81, 177, 317, 533, 541, 559
 Cleanup/recovery, equipment/techniques, 3, 27, 39, 85, 109, 157, 407, 417, 445, 483, 489, 593
 damage from, 459, 623
 Cleanup/recovery, special techniques
 agitation, physical, 3, 85, 407, 439
 burning, controlled, 81, 359, 369, 389
 chemical injection into blowing well, 335
 flushing/washing, 3, 23, 61, 81, 407, 439
 single-vessel skimming system, 111
 CNA (Clean Nigeria Associates), 151
 Coast Guard, Swedish, 137
 Coast Guard, U.S.
 Arctic Oil Spill Planning Guide, 631
 programs, evaluation of, 632
 Coast Watch, Inc., 533
 Cold climate, 189, 593, 619, 631, 634
 tests, 145, 303, 349, 359, 373, 383, 389, 473, 620, 623, 625, 627
 Coliform bacteria, in spill zone, 503
 Collision, spill cause, 9, 43, 49, 55, 111
 COLREG 1972 (Convention on the International Regulations for Preventing Collisions at Sea), 43
 Communication
 among response teams, 3, 269, 565
 with news media/public, 27, 189, 479, 583
 Compensation, 489, 533, 541, 555, 559, 573
 see also Legal aspects
 Computer, use of
 in communication, 269, 565
 in natural resource injury/compensation, 533
 in oil movement/simulation models, 27, 303, 395, 529, 623, 625
 in response/training, 67, 137, 269, 565, 628, 631
 in seabird mortality estimating, 547
 in sensitivity mapping, 624
 Contingency plan/response team
 computerized, 67, 269, 565, 628, 631
 international, 15, 167, 177, 201, 587
 national, 9, 39, 161, 181, 201, 533, 587
 regional, 3, 9, 177, 201, 407
 see also name of country
 Cooperation/cooperatives
 government/industry, 3, 9, 27, 181, 189, 407, 569
 industry, 9, 27, 145, 151, 201, 479, 569
 international, 15, 137, 177, 201, 587
 national, 9, 181, 201, 573, 587
 regional, 3, 9, 55, 177, 189, 201, 407
 Copenhagen Agreement, 201
 Coral reef, 161, 401, 634

- Cost, of spill/spill plan/research, 3, 9, 27, 55, 111, 151, 161, 171, 181, 389, 417, 533, 573, 593, 611
 cleaning, at sea/shoreline, compared, 123
 CPPS (Permanent Commission of the South Pacific), 201
 Crankcase oil, 23
Crassostrea gigas, 503
 CRISTAL (Contract Regarding an Interim Supplement to Tanker Liability for Oil Pollution), 201
 Crude oil
 Alaska North Slope, 3, 85, 407
 Alberta Sweet Mixed Blend, 217, 297, 359, 373, 389, 634
 Arabian Heavy, 289, 451
 Arabian Light, 225, 289, 451
 Avalon J-34, 217
 Campeche, 451
 composition, and dispersant effectiveness, 293
 Cook Inlet, 275
 Ekofisk, 115, 275, 293
 Empire Mix, 495
 Enchova, 289
 Forties, 255
 Garoupa, 289
 Goose Creek, 293
 Hibernia A, B, C, 383
 IFO 60, 49
 Iranian, 9
 Khafji, 349
 Kirkuk, 289
 Kuwait, 217, 293
 La Rosa, 275, 293
 Lago Medio, 473
 Libyan, 445
 Loudon, 293
 Louisiana, 223
 Mexican Isthmus, 111, 401
 Murban, 275, 293
 Nigerian, 255, 263, 495
 Nigerian Forcados, 419, 433
 Norman Wells, 389
 North Sea, 626
 North Slope, 293
 Pilon, 27
 Prudhoe Bay, 145, 235, 275, 383
 Qatar Marine, 465
 Saharan Blend, 293
 San Joaquin Valley, 547
 Saudi Arabian, 111
 Scotian Shelf condensate, 411
 South Louisiana, 293, 445, 489, 633
 Statfjord, 275
 Venezuelan, 401, 445, 451, 495
 Venezuelan Merey, 27
 Western Sweet Blend, 627
 Crustaceans, 161, 255, 275, 401, 427, 489, 533, 628
 eggs/larvae, 275
 shrimp, 161, 235, 289
 Currents, 3, 161, 623
 Damage
 assessment (see Compensation; Legal aspects)
 from cleanup, 459, 623
 pollution, concept of, 555
 Data analysis procedures, 303
 Debris, oily, disposal of, 3, 27, 55, 123, 407, 483, 573
 Decisionmaking
 dispersant-use, 211
 spill response, 269
 Deepwater Port Act, 559
 Degradation, 263, 317, 411, 419, 427, 433, 473, 625
 Delaware Bay & River Cooperative, 479
 Desalination plant, 49, 55
 Design, experimental, of spill impact study, 503
 Diatom species, 255
 Diesel oil, 33, 289, 593, 605
 Dispersant(s), 247, 621
 costs/systems/types, 55, 123, 211, 259, 289, 307, 313, 619
 effectiveness tests, 145, 181, 223, 225, 303, 317, 321, 633, 634
 evaluation factors, 289
 performance, and crude oil composition, 293
 use, guidelines/, 55, 61, 189, 211, 329, 619
 Dispersant(s), spraying of
 by aircraft, 33, 225, 325, 341, 419, 634
 by boat, 33, 225, 259, 297, 419
 by hydrofoil, 75
 Dispersion, 263
 effectiveness-test apparatus, compared, 241
 promoter, chemical surfactant as, 217
 DOOS (Dispersion of Oil on Sea) program, 335, 529
 Drill, to test response plan, 15, 151, 157, 161
 E and P (Exploration and Production) Forum, International Oil Industry, 9
 E-24 (fuel oil barge), 583
 EEC (Economic European Community), 61, 167, 201, 587
 Ekofisk Bravo (blowout), 275
 Elastomers, 231, 317
 Emulsion inhibitor, 217
 Endangered/threatened/rare species, 81, 161, 417
 EPA (Environmental Protection Agency, U.S.) sheen tests, 521
 Equipment
 development, 3, 61, 75, 85, 91, 101, 109, 111, 145, 171, 297, 313, 349, 369, 407, 620
 selection/deployment, 3, 9, 15, 27, 151, 157, 161, 181, 569, 573
 Estuaries, 27, 401, 419, 495
 Evaporation, 349, 373, 411
 Experimental design, of spill impact study, 503
 Exploration/development/production, oil/gas, 9, 39, 81, 247, 275, 317, 335, 417, 459, 624, 630
 Explosion, spill cause, 33, 111, 341
 Feoso Ambassador (tanker), 43
 Fire, spill cause, 43, 341
 Fish/fishery, 223, 275, 533
 commercial, 3, 33, 137, 161, 189, 407, 593
 eggs/larvae, 275, 533
 salmon, 189
 sand lance, 235
 sports, 3, 189, 407
 Florida, and dispersal use, 223, 619
 Flushing. *See* Washing
 Forests
 mangrove, 161, 401, 628, 633, 634
 spills in, 81, 483
 France
 equipment development, 61, 71, 313, 620
 marsh recovery, coastal, 459
 remote sensing data, 71
 response/training/prevention, 15, 167, 573, 587, 630
 studies/trials, 225, 625
 Fuel oil
 No. 1, 593
 No. 2, 289, 445, 469, 533
 No. 5, 33
 No. 6, 33, 55, 289, 445, 583
 Fumes, in buildings, 55, 593
 Fund Convention, 1971 (Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage), and 1984 Protocol, 555, 559
 Funding arrangements, 151, 171, 181, 593
 FWPCA (Federal Water Pollution Control Act), 39, 55, 177
 GAOCSMAO (Gulf Area Oil Companies Mutual Aid Organization), 9, 201
 GAPAM (Antipollution Group of the Port of Marseille Authority), 573
 Gas, from blowout, 39
 Gas/soil sampling methods, compared, 605
 Gelling agent, 317
 Global Hope (tanker), 583
 Globe Asimi (tanker), 555
 Glucose-6-phosphate activity, in spill zone, 503
 Grand Eagle (tanker), 479
 Grasses, 27, 81, 459, 495, 533, 626
 cordgrass, smooth (*Spartina alterniflora*), 263, 445, 469, 489, 495, 509, 626
 salt grass, 489
 seagrass, 223, 634
 Great Lakes (Canada-U.S.), 177
 Grounding, spill cause, 3, 27, 33, 43, 49, 55, 85, 111, 407, 459, 583
 Gulf of Mexico, 211, 223, 495
 spills, 27, 275, 317, 445
 Harbors, 3, 49, 55, 407, 605
 Hawaii, spill, 605
 Helicopter(s)
 dispersant spraying, 225
 equipment/supplies transport, 145
 laser ignition from, 389
 Helsinki Agreement, 201
 Highway spill, 483
 Humber Estuary, United Kingdom, 419
 Hydrocarbons, 247, 263, 275, 427, 439, 489, 495
 Hydrofoil, 75
 Ice
 broken (pack), oil in, 349, 373, 383, 389, 620
 oil under, 145, 395, 627
 Ignition systems, 145, 359, 369, 389
 IMO (International Maritime Organization), 9, 15, 43, 201, 587
 Indonesia, mangroves in, 628

- Industrial area, 3, 33, 161, 189, 247, 407, 417, 593
 Infopol, 587
 Inland spill, 3, 39, 81, 483, 593, 619, 621
 International Bird Rescue Research Center, 407
 International Convention for the Prevention of Pollution from Ships, 1973, and the Protocol of 1978 (MARPOL 73/78), 43, 177, 201
 IOOET (Institute of Ocean Environmental Technology), 349
 IOPCF (International Oil Pollution Compensation Fund), 555
 Iran, 9, 49
 Iraq, 9, 49
Irenes Serenade (tanker), 43
 Italy, 75
 response plan, 622
 ITOPF (International Tanker Owners Pollution Federation Limited), 9, 27, 123, 201
 Ixtoc I (blowout), 275, 317, 451

 Japan, 349
 Jeddah Protocol, 201
Juncus roemerianus, 445, 495

Kapodistrias (bulk carrier), 33
 Kuwait Convention, 9, 201
 Kuwait, State of
 response/training, 9, 157
 spills, 157, 247

 Lagoons, 401
 Laser ignition device, 369, 389
 Leaks, detection methods, 321, 629
 see also Storage tank, underground
 Legal aspects
 court cases, 417, 555, 559
 international, 9, 15, 43, 177, 201, 555, 559
 national, 9, 15, 177, 533, 541, 555, 559
 oil pollution contracts, study of, 517
 Liability. *See* Legal aspects
 Lightering. *See* Salvage
 Lima Agreement, 201
 Logs/lumber, cleaning, 3, 23, 85
 LOOP (Louisiana Offshore Oil Port), 111
 Loss, pure economic/consequential, 555
 Louisiana, spills, 27, 111, 489
 Lubricating oil, 33, 341

Magnum (tanker), 9
 Mammals
 marine, 161, 341
 terrestrial, 81, 417
 MANCHEPLAN, 167
 Manganese, cargo spill, 33
 Mangroves, 161, 401, 628, 633, 634
 Manual cleanup, 27, 123
 Manuals
 chemical application, Arctic, 145
 coastal resource, Arctic, 145
 combat operation, 161
 Map. *See* Sensitivity index/map
 Marine Sanctuaries, National, 631
 Marjan oil field, 625
 MARPOL 73/78 (Marine Pollution Convention), 9, 15, 43, 129, 177, 201, 573
 Marshes, 263, 445, 459, 489, 495, 509, 533, 626
 Maryland, spill, 605
 Massachusetts, spills, 445, 583
 Media. *See* Public relations
 MEMAC (Marine Emergency Mutual Aid Centre), 9, 201
 Membrane permeability, 469
 MEPC (Marine Environment Protection Committee, IMO), 43
 Mesocosms, marine, 255
Metula (tanker), 451
 Military operations, 9, 49, 171
 Mineral (paraffin) oil, 469
 MIRG (Marine Industry Group), 201
Mobiloil (tanker), 583
 Models, spill simulation, 27, 303, 335, 395, 451, 623, 625
 Molluscs, 33, 161, 247, 255, 275, 401, 427, 439, 489, 533
 oyster (*Crassostrea gigas*), 503
 Mousse, 217, 263, 427, 433, 439
 Movement, of oil, 3, 33, 321, 395, 451, 620, 623
 Muck Monster, 3, 85, 407
 Muskeg areas, 623
 see also Marshes

 Nairobi Convention, 201
 Navy, Royal (United Kingdom),
 equipment/response development, 171
 Navy, U.S.
 equipment development, 91
 response plan format, 193
 NCP (National Contingency Plan), 3, 39, 55, 177, 189, 269, 317, 329, 341, 407, 619, 621
 Netherlands, 115, 129, 255, 626
 Nets
 beach-protection, 145
 oil-recovery, 115, 349
 New York, spills, 317, 533
 Nigeria, 517
 response/training, 151, 622
 NOCOP (National Operations Center for Oil Pollution), 201
 NORBITPLAN, 167
 North Sea, 129, 167, 626
 Norway, 167, 335, 529
 response/training, 633
Nova (tanker), 9
 NRDA (Natural Resource Damage Assessment) guidelines/process, 533, 541

 OCS (Outer Continental Shelf), spill rates, 630
 OHMSETT (Oil and Hazardous Materials Simulated Environment Test Tank), tests by, 111, 259, 383
 Oil Companies Institute for Marine Pollution Compensation Services, Ltd., 201
 Oklahoma, spill, 621
 Oman, response/training, 9
 Oregon, spill in, 23
 OSR (Oil Spill Response Service Centre), Ltd., 201
 Outer Continental Shelf Lands Act, 559

 Panama, Republic of, 634
 Caribbean coast, spills, 223, 401
 Park, marine, 161
 Particle-in-fluid model, 529
Patmos (tanker), 43, 555
 Penguin, oiled, 33, 465
 Persian Gulf. *See* Arabian Gulf
 Persistence, oil, 433, 451, 634
 Personnel/manpower, 3, 55, 407, 483, 565
 Pipeline spills
 inland, 81, 483, 619, 621
 nearshore, 157, 445, 489
 Plankton/phytoplankton, 255, 533
 Platform spill, 275, 317, 630
 Pollution damage, concept of, 555
 POLMAR Plan, 15
 POLREP reporting system, 201
 Polymers, 231, 317
 Ports, 3, 23, 111, 157, 181, 407, 573, 605
 Prevention/control, rules/organizations. *See* Legal aspects
 Production-fluid pollution, 81, 417, 521, 624
 Protecmar program, 225
 Public
 reaction/pressure, 189, 417, 489
 relations, 27, 479, 583
Puerto Rican (tanker), 111, 321, 341, 547
 Puerto Rico, 55, 619
 Pumps/pumping, 23, 27, 55

 Qatar, 9, 625

 RCRA (Resource Conservation and Recovery Act), 611
 Recovery, oil, amount/efficiency/rate, 3, 9, 23, 33, 55, 85, 101, 111, 157, 349, 473, 483, 593, 621
 Recreation area. *See* Beaches
 Recycling facility failure, 23
 Reef system, 161, 401, 634
 Regional Seas Programme, UNEP, 201
 Remote sensing. *See* Sensing, remote
 Reptiles, 161
 Research and development. *See* Tests, laboratory/tank/field
 Residential area, 593
 Response. *See* Contingency plan/response team
 ROCC (Regional Oil Combating Centre), 201, 587
 Rocks/seawall, cleaning of, 27, 55
 ROPME (Regional Organization for the Protection of the Marine Environment, 9, 201
 Rush/sedge, 445, 495
 Rutile ore, cargo spill, 33

 Sabotage, spill cause, 619
St. Thomas (tank barge), 49, 55
 Salvage
 of cargo/vessel, 33
 of ship's oil, 27, 33, 55
 SANCCOB (South African National Foundation for the Conservation of Coastal Birds), 33, 465
 Sanctuary, National Marine, 631
 Sand flat, 263, 439
 Saudi Arabia, 625
 response/training, 625

- Sediment, oiled, 247, 263, 401, 407, 419, 433, 439, 445, 473, 489, 495
- Sensing, remote, 27, 71, 75, 95, 129, 137, 181, 225, 373, 489, 630
- Sensitivity index/map/rank, 9, 33, 67, 161, 177, 211, 433, 517, 622, 624, 628, 630, 633
- Separator/separation
sand/oil, 61
water/oil, 115, 620
- Sheen test, 521
- Shellfish. *See* Crustaceans; Molluscs
- Shorelines, 3, 27, 145, 263, 289, 401, 407, 433, 439, 445, 495
/offshore cleaning cost, compared, 123
oil-holding capacity, 451
- Silicate, and diatoms, 255
- Sivand* (tanker), 419
- Skimmers, 3, 23, 55, 85, 171, 231, 407, 573
development/tests, 55, 91, 349
rotating disc, 101
single-vessel system, 111
- Smithsonian Tropical Research Institute, 401
- Socioeconomic aspect/resource, 27, 55, 517, 533
- SOGESTA, Italy, 587
- Soil/gas sampling methods, compared, 605
- SOLAS (International Convention for the Safety of Life at Sea), 43
- Sorbents, 3, 23, 55, 85, 317, 573
- South Africa, Republic of
penguins, oiled, 33, 465
response/training, 33, 629
spill, 33
- South Pacific Region draft protocol, 201
- Soviet Union, 555
- Spartina alterniflora*, 263, 445, 469, 489, 495, 509, 626
- Spartina patens*, 509
- Spills, analysis of, 43
see also Inland spill; Vessel spill
- Spreading, in cold climate, 359, 373
- STCW 1978 (International Convention on Standards of Training Certification and Watchkeeping for Seafarers), 43
- Storage, of recovered oil, 3, 27, 39
- Storage tank, underground
leaks, detection methods, 611, 629
management, 599, 611, 629
spill source, 533, 593
- Storage volume, of oil, under ice, 395
- Stranded oil, study of, 433, 473
- Sugar, cargo spill, 33
- Superfund (Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]), 177, 533
- Surface spill, effect on underground spill, 605
- Surfactant, chemical/indigenous, 217, 293, 317
- Surveillance, spill, 27, 33, 71, 95, 129, 137, 341
- Sweden, 109, 137
- TACID (Technical Advisors Computer Information Database), 67
- Tanio* (tanker), 15
- Tank spill. *See* Storage tank
- TARC (Tiered Area Response Capability) Committee, 201
- Technology, operations study, 517
- Tests, laboratory/tank/field
airplanes, large, spraying from, 325
apparatus, dispersant-effectiveness-test, compared, 241
biodegradation, enhanced, 411
booms, 109, 145
bubble barrier, subsurface, 145
burrow structure, infaunal, 427
control devices, cold-climate, 349
crude oil composition, and dispersant performance, 293
dispersant effectiveness, 145, 181, 223, 225, 293, 303, 307, 634
dispersant evaluation factors, 289
dispersant spraying, depositional accuracy, 325
dispersant-application system, calibration of, 259
elastomers, 231
emulsion inhibitor, 217
fish/shrimp, toxicity to oil, 235
hydrofoil, spraying by, 75
ignition/burning, in-situ, 359, 369, 383, 389
marsh plants, oil/dispersant effect on, 469, 495, 509, 626
nets, 115, 349
organism mortality, and hydrocarbons, 275
phytoplankton, 255
sediment flushing, biological effects, 439
sheen tests, evaluation of, 521
ships, spraying from, 297
skimmers, 91, 101, 111
spray gun, dispersant, 313
stranded oil persistence, 433
surveillance system, 137
Type III dispersant, 263
washing plant, mobile, 61
well, blowing, chemical injection into, 335
- Tetradecane, as test oil, 293
- Texas, spills, 27, 39, 81, 445, 621
- Thailand, Kingdom of, 161
- Thickness, slick, 71, 95, 359
- Topsoil replacement, 23
- Torrey Canyon* (tanker), 15, 171, 189, 459
- Tourist industry, 9, 27, 33, 55, 161
- Training program
bird rescuers, 407, 479
computerized, 269, 565
see also name of country
- Trans-Alaska Pipeline Authorization Act, 559
- Trees, 23, 39, 81
mangrove, 161, 401, 628, 633, 634
- Tri-State Bird Rescue & Research, Inc., 479
- Truck, dump/vacuum, 27, 55, 85
- UFA (United Fishermen of Alaska), 189
- Underground
spill, 533, 593, 605
storage tank, 599, 611, 629
- UNDP (United Nations Development Programme), 201
- UNEP (United Nations Environment Programme), 43, 201
- United Arab Emirates, 9
- United Kingdom
cleanup costs, compared, 123
flushing of oiled sediments, effects, 439
- MPCU (Marine Pollution Contrl Unit),
response plan, 167, 171
remote sensing system, 95
response plan, 171
skimmer, rotating disc, study of, 101
spills, 167, 419
stranded oil persistence, study, 433
Type III dispersant, test, 263
- United States
legislation, 39, 55, 177, 189, 269, 317, 329, 489, 533, 541, 547, 559, 611, 619
response/training, 3, 145, 189, 193, 407, 565, 619, 631
spills, 3, 23, 27, 39, 49, 55, 81, 85, 111, 317, 341, 407, 417, 445, 483, 489, 533, 547, 583, 593, 605, 619, 621, 624
- Urquiola* (tanker), 451
- Vanadium, in oysters, 247
- Vegetation, recovery of, 23, 39, 81, 263, 445, 459, 483, 489, 509, 623
see also Grasses; Marshes; Trees
- Vessel spill
Alvenus (tanker), 27, 111, 451
Amoco Cadiz (tanker), 15, 43, 171, 225, 451, 459, 503, 559
Antonio Gramsci (tanker), 555
Arco Anchorage (tanker), 3, 85, 407
Argo Merchant (tanker), 583
Brazilian Marina (tanker), 289
Castillo de Bellver (tanker), 43
Castillo de Monte Aragon (tanker), 43
E-24 (fuel oil barge), 583
Feoso Ambassador (tanker), 43
Global Hope (tanker), 583
Globe Asimi (tanker), 555
Grand Eagle (tanker), 479
Irenes Serenade (tanker), 43
Kapodistrias (bulk carrier), 33
Magnum (tanker), 9
Metula (tanker), 451
Mobiloil (tanker), 583
Nova (tanker), 9
Patmos (tanker), 43, 555
Puerto Rican (tanker), 111, 321, 341, 547
Sivand (tanker), 419
St. Thomas (tank barge), 49, 55
Tanio (tanker), 15
Torrey Canyon (tanker), 15, 171, 189, 459
Urquiola (tanker), 451
Zoe Colocotroni (tanker), 555
- Vessels, support/workboat, 111
Abeille (tug), 225
Apollo (tow), 341
Brandal, 373
Cecilia West (tank barge), 27
Centurian, 27
Century (salvage), 583
Daphne (cruise ship), 55
Jeb Stuart, 27
Julia B, 55
K. C. Smith (tug), 27
Mark Twain (passenger), 341
Mr. Clean II (skimmer), 341
Point Hope (USCGC), 27
Point Sal (USCGC), 27
Point Whitehorn (USCGC), 55
Saint, 55
Sidney Pelham (offloader), 27
Sun Princess (cruise ship), 55
Ventura, 27

Virgin Islands, U.S., 49, 55, 619
 Volunteer, bird/animal rescue, 407, 533
 VTS (Vessel Traffic Service), 43
 Vulnerability index. *See* Sensitivity index

Washing, cleanup method
 logs/lumber/trees, 3, 23
 sand/sediment, 3, 61, 81, 407, 439
 see also Water
 Washington Conservation Corps, 3, 407
 Washington, spills, 3, 85, 407
 Waste-oil spill, 23

Water
 ballast, warship, 171
 drinking, 49, 55
 jets, 3, 145, 297
 see also Washing, cleanup method
 Wave action, 33, 303, 307
 Weather, heavy
 hindering cleanup, 3, 23, 27, 341
 spill cause, 43
 Weathering, 373, 433, 451, 469, 473, 627, 628
 Well
 blowout, 9, 39, 275, 317, 335, 459

 brine-water pollution, 81, 417
 monitoring/recovery, 593
 Wind action, 3, 33, 161, 620
 Worms, 275, 427, 439, 628

 Zircon ore, cargo spill, 33
 Zoanthid, 401
 Zoe Colocotroni (tanker), 555
 Zones, 289
 intertidal, 85, 275, 401, 411, 433, 439, 473, 495, 533, 634
 subtidal, 275, 401, 533, 634

Section I

CASE HISTORIES

Session 2-B—Case Histories I

Chairman: Stuart Horn
Mobil Oil Corporation

Vice Chairman: Kurt Jakobson
U.S. Environmental Protection Agency

Session 6-C—Case Histories II

Chairman: Måns Jacobsson
International Oil Pollution Compensation Fund

Vice Chairman: Lt. Cdr. David Pascoe
U.S. Coast Guard

Session 9-A—Case Histories III

Chairman: Thomas Massey
U.S. Environmental Protection Agency

Vice Chairman: Joseph Smith
Petrochem Services, Inc.



OPERATIONAL ASPECTS OF THE RESPONSE TO THE *ARCO ANCHORAGE* OIL SPILL, PORT ANGELES, WASHINGTON₁

Robert A. Levine
Arco Marine, Inc.
300 Oceangate
Long Beach, California 90802

ABSTRACT: On December 21, 1985, at approximately 4:25 p.m. PST, the Arco Anchorage ran aground in Port Angeles Harbor. Two holes were torn in the ship's bottom, resulting in a spill of 5,690 barrels (239,000 gallons) of Alaska North Slope crude oil.

This paper describes the Arco Marine response procedure during this spill, and the philosophies and methods used during the spill cleanup. The primary offshore cleanup method was recovery using booms and skimmers. Weather conditions permitted their effective operation. Removal of oiled debris was the primary onshore cleanup method. Port Angeles Harbor is a major timber storage area; log bundles are stored in the harbor awaiting pickup by ships. When log bundles were oiled during the spill, a method was devised to clean them. Oil percolated into coarse sediments on Ediz Hook, the most heavily oiled area. It was determined that large enough quantities of oil were trapped in the sediments to warrant removal. A cleanup method incorporating a combination of physical agitation to a depth of approximately 12 inches and high-pressure water jets effectively removed most of the entrained oil. The paper also describes the waste management plan that was developed.

On Saturday, December 21, 1985, while in the process of anchoring in Port Angeles Harbor, Port Angeles, Washington (Figures 1 and 2), the tank vessel *Arco Anchorage* ran aground, holing tanks 5 Port and 5 Center. At approximately 4:25 p.m. local time, while backing to set the anchor, the vessel struck submerged rocks. The vessel's crew smelled crude oil, immediately notified the U.S. Coast Guard of the accident, and began transferring cargo from tanks suspected of having been damaged to volumetrically slack tanks. At the same time, notifications were made to activate the Arco Marine, Inc. (AMI), Spill Contingency Plan and AMI's Spill Response Team and corresponding government contingency plans and response teams. The initial estimated cargo loss was 4,000 barrels (168,000 gallons) of Alaska North Slope crude oil.

On April 10, 1986, after 110 days of intensive cleanup efforts, cleanup crews closed down the oil recovery effort, officially marking the end of one of the most expensive spill cleanups in U.S. history.

This paper is intended to document the cleanup of the Port Angeles oil spill and to provide some insight into some of the difficulties encountered and some of the lessons learned.

1. The opinions expressed in this paper are the views of the author and not necessarily the official views of Arco Marine, Inc.



Figure 1. Location of Port Angeles in the State of Washington

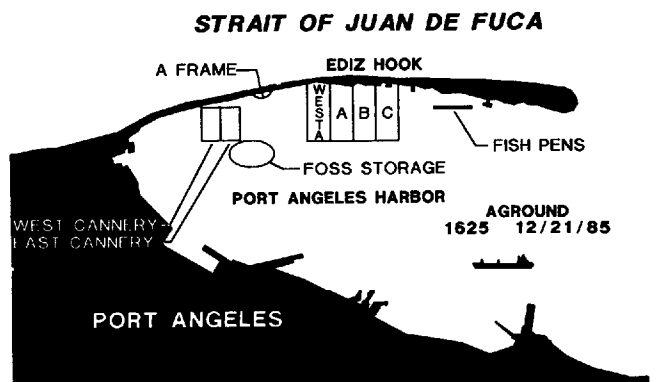


Figure 2. Port Angeles Harbor



Documents

Document Sharing Hub

AMI cleanup philosophy

Prior to examining the Port Angeles spill, it is important to understand AMI's philosophy on responding to oil spills and its response priorities.

- If the oil is from a vessel owned or operated by AMI, AMI is responsible regardless of cause or fault.
- The AMI spill response team is responsible for making the National Contingency Plan work.
- Cleanup is complete when oil can no longer be recovered environmentally (without doing further damage to the environment), technically (when equipment, existing or new, has been exhausted), and economically (when all reasonable resources have been exhausted and gains in cleanliness are no longer justified by expenditures).
- AMI response priorities are dictated by three principal concerns: public and vessel safety, environmentally sensitive areas, and economically sensitive areas.

None of these priorities is established, except for safety, so as to preclude the cleanup effort at the expense of another priority.

Cleanup

Initial response. The initial response to the Port Angeles spill by both the U.S. Coast Guard and AMI focused primarily on protecting public safety, establishing vessel safety, and mitigating the extent of the spill. While part of the vessel's crew worked to pump oil from those tanks suspected of being damaged to minimize cargo loss, other crew members made sure the vessel was safe and that all possible sources of ignition were removed. The crew also verified that the shifting of cargo would not adversely affect the vessel's strength, stability, or damaged stability. At the same time, the Coast Guard began taking necessary steps to establish a safety zone around the vessel and to deploy containment boom. Within 10 minutes of the spill the Clean Sound Cooperative and their contractor, Foss Maritime, had been notified, and initial steps had been taken to activate the cooperative contingency plan and equipment.

By 9:25 p.m., approximately five hours after the spill 4,500 feet of containment boom had been deployed from the Coast Guard Air Station in Port Angeles, the cooperative's local storage, and Western Tug and Transport's Port Angeles facility. Vessels from Foss Maritime, the Coast Guard, Western Tug and Transport, and the Port Angeles Fire Department had all been dispatched and were working to contain the oil found around the vessel. Realizing that the extent of the spill was significant, a second major cleanup contractor was called in.

Port Angeles and vicinity. The Port Angeles area has an ideal, naturally deep harbor, is both an industrial and sport fishing center, and has a wildlife refuge nearby. The harbor is located off the Strait of Juan De Fuca (Figure 3), approximately 20 miles south of Victoria, British Columbia and about 90 miles west of Seattle. The harbor is used extensively as a lumber port, with large areas of both dry land

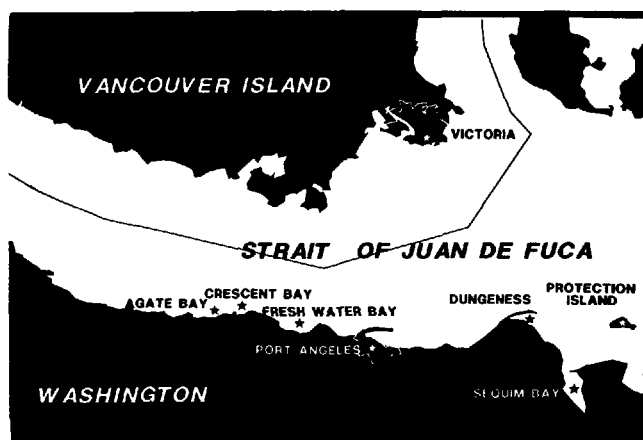


Figure 3. Strait of Juan de Fuca

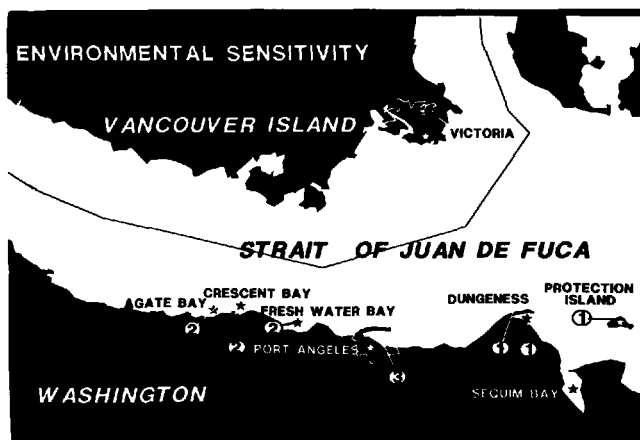


Figure 4. Environmentally sensitive areas near Port Angeles

and water storage for export lumber. Many lumber and lumber-related industries are located locally. The area also supports a large fishing industry and includes both sport and commercial fishing interests. The fishing ranges from that of salmon, halibut, and trout, taken by line and net and farmed within the harbor, to that of sea urchins, crabs, clams, and geoducks. The area also supports large populations of marine birds, with National Wildlife Refuges at Dungeness Spit and Protection Island.

Because of the environmental and economic productivity of Port Angeles and vicinity, response priorities were quickly established. Having determined that the vessel and public safety were not threatened, priorities were established first for protecting those areas that were considered the most environmentally sensitive, Dungeness Bay and inner harbor, Sequim Bay, and Protection Island; second, for those areas judged less sensitive; Agate Bay, Crescent Bay, and Freshwater Bay; and finally, for those areas of the least environmental sensitivity, including Port Angeles Harbor (Figure 4). At the same time priorities were established for those areas considered economically sensitive, starting with Port Angeles Harbor, then Dungeness Bay, and finally, Agate, Crescent, and Freshwater Bays (Figure 5).

Cleanup plan. It was realized very quickly that the spill at Port Angeles was of a significant size and that it could have a significant impact on both the environment and the economy. To minimize spill effects, of the cleanup was divided among the major contractors, with Clean Sound Cooperative and Foss Maritime providing the offshore cleanup, recovered oil storage, and most of the containment. While Crowley Environmental Services provided the cleanup services for the beaches along Ediz Hook (Port Angeles Harbor). In this way it was possible to concentrate the cleanup effort on those areas considered environmentally sensitive without neglecting economically sensitive areas. At the peak of the cleanup activity, work crews were

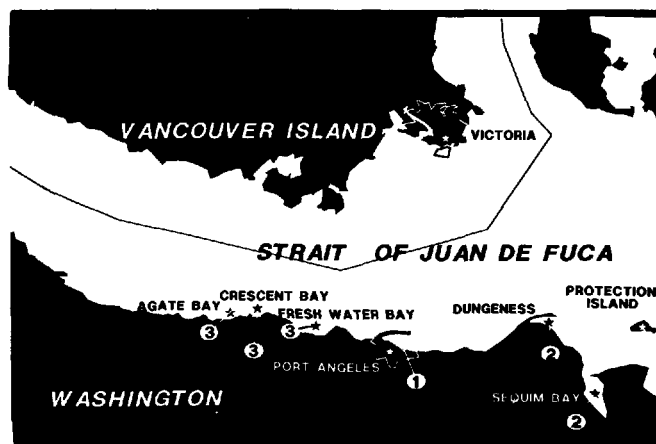


Figure 5. Economically sensitive areas near Port Angeles

brought in from the Washington Conservation Corps to clean the beaches along the Dungeness Spit. This action was taken both to supplement the existing work crews and to take advantage of the Corps's supervision, skills, and concern for the environment. Because of the work load and desire to expedite the cleanup, two additional contractors, Global Diving and Salvage and Reidel Environmental, were brought in to handle the cleanup of logs and the western beaches, respectively.

Problems. The cleanup of a major spill cannot be orchestrated without some problems. In this cleanup, however, three major problems had a significant impact on cleanup duration and cost, which could not have been anticipated. The cleanup of the Port Angeles spill was affected by the weather, logs, and the beach along Ediz Hook.

Weather. At the time of the accident, weather conditions were ideal for a December day in Port Angeles, with clear weather, good visibility, moderate temperatures. The typical forecast thereafter, however, was winds from the east at 5 to 10 knots, continued light easterly winds to 10 knots, with fog to continue indefinitely, though there remained the possibility of some openings. The weather continued in this pattern, with few exceptions, for nearly a month. In some respects the weather provided ideal conditions for protecting environmentally sensitive areas and for oil recovery, while creating severe conditions for locating oil and for the continued operation of the skimming equipment.

Because of the light wind conditions, the movement of oil was influenced primarily by tides and currents. These tides and currents directed most of the oil that left Port Angeles Harbor along the 10 fathom contours, running both east and west (Figures 6 and 7). Along with the light winds came light to dead calm sea conditions, which allowed the skimming equipment to be operated at maximum efficiency. Because the prevalent strong onshore winds never materialized, beach impact outside Port Angeles Harbor was minimal, with oil primarily affecting the elbow of Dungeness Spit and the eastern-facing beaches along Agate, Crescent, and Freshwater Bays.

While the winds provided ideal conditions for skimming oil from the water surface, fog severely restricted and at times prevented overflights to locate oil concentrations and direct equipment. To compensate for the lack of overflight data, the skimmer and spill response vessel operators quickly learned to predict local currents and trajectories and developed a communications system whereby the skimmers were kept in the oil. When a skimmer found itself away from recoverable oil, it would start a systematic search. If oil still could not be located, the other vessels would be contacted, and the skimmer would relocate to another area. This system proved so effective that efficient skimming operations were maintained 24 hours a day, seven days a week, for five weeks. It should be noted that all the skimmers that were capable of working offshore were fitted, either before or during the cleanup, with radar. Without radar the safe operation of the skimmers in fog would not have been possible.

One lesson learned about all the skimming vessels was that, while all have their limitations, all those used were well designed for short-duration cleanup operations. None of the vessels was capable of being operated, as such vessels were in Port Angeles, for long periods without mechanical and electrical failures, or the failure of parts due to wear and tear. However, this equipment should not be expected to

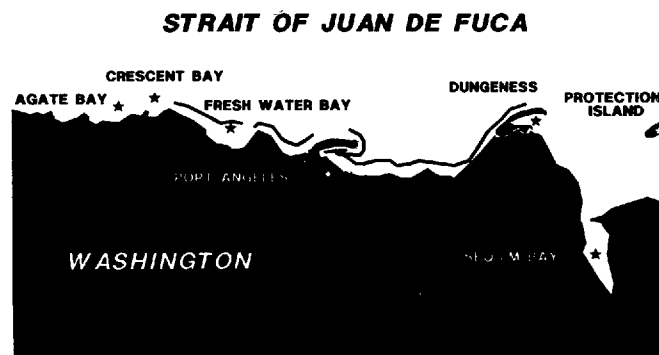


Figure 7. Spread of oil in areas around Port Angeles

operate continuously without repair for five weeks. To overcome the maintenance difficulties experienced, two actions were taken. First, three additional skimming vessels were brought in, with the intention of using them not only for oil recovery, but to increase the size and capacity of the fleet and to minimize the effects of losing any vessel. Second, mechanics and electricians from Foss Maritime and Wight Marine Service were brought in to provide service to any vessel in need on a "house call" basis. Teams were available around the clock to respond to any problems, from fixing hydraulic leaks to installing radars. The repair crews became invaluable not only in keeping the fleet running, but in keeping the shoreside equipment operating. It should also be noted that the manufacturer's spare parts inventories for some equipment was brought to Port Angeles to help facilitate repairs.

Logs. Port Angeles Harbor is one of the State of Washington's centers for lumber export. Logs are loaded on bulk carriers for export to many foreign countries and are rafted for transport within the Puget Sound region. Lumber is also used locally by many forest service industries, including paper and paper products, sawmills, and plywood manufacture. Logs are stored in Port Angeles either on dry land or in the water in large storage areas. At the time of the spill approximately 20 million board feet of lumber were wet-stored around the harbor. Of the 20 million, 15 million board feet of lumber were oiled, and of that 10 million were heavily oiled.

The cleanup of the logs was a slow process that required establishing a temporary logging operation very like that bringing logs to Port Angeles, except that the trees did not have to be recut. The logs were examined to determine the extent of oiling. Lightly oiled logs, which were acceptable to the owners, were isolated and loaded for export or taken to the mills as quickly as possible. Those logs considered to be lightly oiled, but requiring some cleaning, were towed through a "car wash" where they were washed using fire hoses. The heavily oiled logs created an entirely different problem.

Ten days into the cleanup, after an unexpected squall had come through, Port Angeles Harbor was found to be very heavily oiled with large amounts of fresh crude oil. Prior to this time all known sources of oil had been contained while recovery efforts continued. Since the entire known volume of contained oil would not have provided enough oil to have equaled a fraction of that released in the squall, another source was sought, and the logs were the primary suspect.

The logs were stored in seven storage areas (Figure 2), in large rafts called "bags." The bags consist of about 30 to 40 bundles of logs. These bundles are about 40 feet long and 8 to 10 feet in diameter, and are made by strapping 10 to 20 logs together. Because of the density of the wood, the bundles float with 4 to 5 logs visible on the surface and the rest submerged, similar to an iceberg. It was theorized that the oil had been sucked into the "capillaries" between the bundled logs and was trapped, and that during the squall the waves had shaken the bundles sufficiently to break the capillaries, allowing the oil to "bleed." To test the theory a single bundle was removed for examination. All the logs in the bundle, including those that had been 4 to 5 feet below the surface of the water, were found to have been heavily oiled. It was estimated that as much as half a barrel of oil was trapped in the bundle. It was also obvious the logs had to be removed from the water and cleaned. The task of cleaning the logs appeared insurmountable when it was determined that 10 million board feet of lumber had to be cleaned. This represented 33 bags or about 2,300

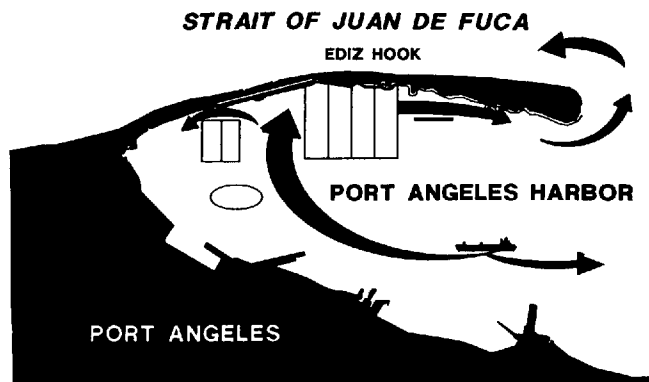


Figure 6. Spread of oil in Port Angeles Harbor

bundles of lumber. The average weight of the bundles was about 45 tons.

After much discussion with the contractors and the Regional Response Team, three logging barges were hired. These barges were designed to pick bundles of logs out of the water using barge-mounted cranes, load the bundles, transport the logs, and then dump the logs back into the water on arrival. By trial and error it was found that the logs could be most effectively washed by dipping the bundles 2 to 3 feet below the surface three or four times, to release any trapped oil, and then by high-pressure water-washing the bundles with a tug-mounted fire monitor. This process not only freed the trapped oil, allowing for containment and recovery, but cleaned the logs sufficiently for acceptance by most owners. As the logs were cleaned, care was taken to ensure that grading stickers were not removed, or if they were found missing, the logs were regraded. After cleaning, the logs were stored on the barges. Eventually the available storage for approximately 6 million board feet was filled; washed lumber had to be put back into the water and taken to a clean storage area. The log-cleaning operations continued until all 10 million board feet were cleaned. The log storage areas were then cleaned using skimmers.

Because the logs had been bundled for temporary water storage and not barge storage, the original plan called for picking each bundle from the barges individually and replacing each in the water. After examining the logs on the barges it was realized that this was not practical and that the logs had to be dumped. Since the logs were not bundled for dumping, a large breakage of bundles and loss of logs was anticipated. To manage the loose logs, a full-scale logging operation was established. This operation involved the towing of logs to a recovery area where they were picked up and placed on log trucks. From the recovery area the logs were taken to a temporary log scaling station, then to a bundling station, and then were placed back into the water and rebagged. Ultimately, some 40% of the dumped bundles were broken and 12% of the logs were sunk or lost. Throughout the entire operation, from cleaning to rebagging, care had to be taken to separate the logs of the different owners.

Ediz Hook Beach. Concurrent with the log cleaning operations, the beaches along the log storage areas were being cleaned. After some unusually rough weather, cleaned areas of beaches were found freshly oiled. It was assumed that the oil had come from the logs. When this occurred again after most of the logs had been cleaned, another source of oil was sought. Initially the beaches were examined at low tide, at night. The beaches were explored using flashlights by digging holes with small camp shovels. As some holes were dug, they appeared to fill with oil that was draining from the beach sands. In places it appeared that 2 to 3 inches below the surface a 4 to 6 inch layer of sand was saturated with oil. The oil appeared to be unweathered and as fresh as the day it was spilled. The initial exploration efforts indicated that the trapped oil was limited to an area of beach referred to as the "A frame," which had been the most heavily oiled site.

After much hole digging and discussion, focusing primarily on whether it was physically possible for oil to penetrate beach sand, it was decided that there was a sufficient amount of oil trapped to

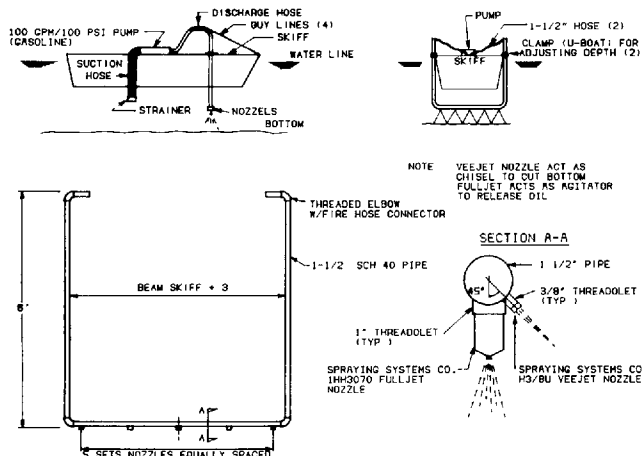


Figure 8. The Muck Monster I

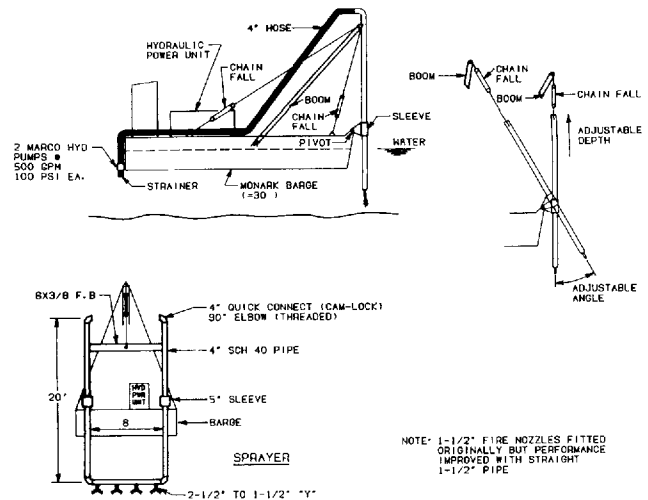


Figure 9. The Muck Monster II

warrant recovery efforts. After more discussion it was decided that, if the sediments below water could be disturbed, the oil that was still fresh would float to the surface, where it could be contained and recovered. Lacking better facilities, the first mechanized attempt at recovery was designed on the side of a dirty car door. A small dredge was designed to cut and stir the bottom to free the oil. The dredge, affectionately called the "Muck Monster" (Figure 8), consisted of a 16 foot skiff equipped with a 100 gallons per minute, 100 psi water pump and a manifold with two sets of nozzles. The Muck Monster worked very successfully, but was found to be extremely slow. Figuring that if the Muck Monster worked a larger, more powerful dredge, it would be even better, and advancing to the back of an envelope, "Muck Monster II" (Figure 9) was designed. Fitted on a 30 foot Monark barge, Muck Monster II consisted of a manifold with eight 1 1/2 inch nozzles powered by two 500 gallons per minute, 100 psi hydraulic driven pumps. The new improved Muck Monster once again proved to be successful, but was still much too slow.

While making improvements in oil recovery, improvements were also being made in exploration techniques. Hole digging advanced from the camp shovel to a backhoe. The penetration of the beach by oil was found to extend for the length of beach that was moderately to heavily oiled, approximately 7,000 feet. It was found that the oil had penetrated as a result of the combination of the beach composition and tidal conditions. The beach along Ediz Hook was made of a combination of coarse grain sand and cobble, making it very porous. This, and the 6 to 10 foot tidal variations that virtually drained the beach, enabled the oil to seep into the beach. Tests showed that the oil that had penetrated was as fresh as samples taken directly from

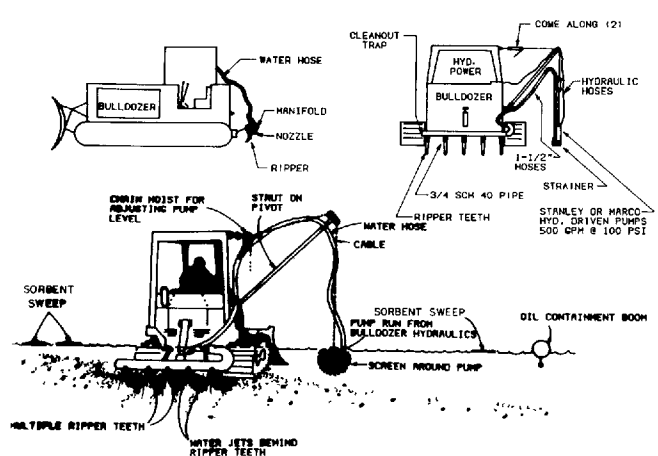


Figure 10. The Muck Monster III

the vessel's tanks the day of the spill. Estimates of oil trapped indicated as much as 75 barrels per hundred yards of beach.

While the Muck Monsters worked, again they worked extremely slowly. Geoenvironmental engineers suggested that mechanical agitation might speed the process. It was suggested that a bulldozer equipped with rippers might prove more efficient. After experimenting with a bulldozer equipped with a homemade ripper it was determined that a combination of rippers and the hydraulic agitation of the Muck Monsters would work best, so "Muck Monster III" (Figure 10) was born. Two bulldozers equipped with rippers were fitted with Marco or Stanley hydraulically driven pumps which supplied water to nozzles mounted directly behind each ripper blade. The combination of mechanical energy provided by the rippers and hydraulic energy provided by the spray nozzles proved to be not only efficient but fast.

To prevent the reoiling of the beach and to facilitate the recovery of oil a careful system of containment and recovery was developed. A 100 or 200 yard by about 30 yard section of beach was isolated, using containment boom, on three sides, and sorbent sweeps were placed three deep parallel to the beach along the surf line. As the sweeps became oiled, fresh sweeps were placed closest to the beach, and the sweeps were then moved toward the water. The sweep farthest outboard, being the most heavily oiled, was removed for disposal. The bulldozers worked parallel to the shore, moving with the tide to keep the rippers submerged. Periodically the bulldozers worked perpendicular to the shore to help ensure that as little oil as possible was left trapped. To help keep sorbent costs to a minimum, rope mops were placed at either end of the containment area for oil recovery.

The beach cleaning operation ran 16 hours a day, six days a week (the seventh day was dedicated to maintenance), for almost six weeks. Estimates of recovered oil ran as much as 50 barrels per 100 yards, with testing showing nearly a 67% recovery. At one point the Muck Monsters were freeing so much oil that a vacuum truck with duckbill was used to recover the freed oil.

Manpower and equipment

The cleanup operation proved to be a test of manpower, equipment and technology. Although not all available equipment was used, most of it was (Table 1). As mentioned earlier, the calm weather enabled the equipment to be used 24 hours a day for most of the spill. Over 600 people worked the spill, with nearly 300 working at the peak of operations. Of those working, approximately 90% were residents of Washington state and 51% were locals.

In any discussion of equipment, the significant amounts of sorbent used (Table 2) must be mentioned. Although the numbers by themselves are not impressive, the sorbents, not including snares, could have covered 18.4 acres, or if laid end to end would have reached 93.7 miles. Ten 40 foot full trucks would be required to deliver all these sorbents.

Table 1. Equipment used in the oil spill response

Skimmers	9
Spill response vessels (including skiffs)	15
Barges	
tank	2
log	3
other	2
Vacuum trucks	11
Rope mops	5
Containment boom	17,800 ft
Helicopters	1

Table 2. Sorbents used in the oil spill response

Pads (100)	1,456
(200)	221
Sweeps	1,634
Rolls	287
Snares	1,378
Booms	344

Recovery and disposal

Of the 5,690 barrels (239,000 gallons) spilled, 3,126 barrels (131,288 gallons) were ultimately recovered and sent to the refinery for refining. Approximately 2,800 cubic yards of debris, including oiled sorbents, were collected. Of the 2,800 cubic yards, 500 cubic yards were nonburnable and were cleaned for disposal as fill for road building or were sent to a landfill. The 2,300 cubic yards of burnable debris were hogged (cut up) and burned as fuel in a hog (waste) fuel boiler. In addition to the burnable debris, 2,180 tons of abandoned logs were removed from the Ediz Hook Beach and were hogged for fuel. Also, three abandoned barges and one building were ultimately removed for disposal as part of the cleanup.

Cost

The cleanup of the Port Angeles spill proved to be one of the most expensive in U.S. history. The effects of the weather, logs and beach cleanup were most evident in the invoices and bills processed for payment. While claims were processed from a number of individuals and companies, the bulk of those paid came from the lumber industry. The best estimate of final costs stands at \$13 million, \$9 million for cleanup and \$4 million for claims.

Conclusions

The cleanup of the Port Angeles spill showed that with established philosophies and contingency plans and the cooperation of the various participants it is possible to clean a spill efficiently. As might be predicted, the spill provided a number of unusual circumstances that required extraordinary efforts to overcome. Yet the spill was cleaned effectively, and environmental impacts were minimized.

Acknowledgments

I would like to acknowledge all those who worked to clean the spill, both those paid and volunteers, who gave their December holidays to the effort, and who toiled for endless hours in miserable conditions without complaint. I would like to thank the members of the Arco Marine, Inc. Spill Response Team for their untiring and irreplaceable contributions. I would also like to acknowledge the Regional Response Team and, in particular, the Pacific Strike Team and members of the Coast Guard Puget Sound Marine Safety Office for their invaluable support. The people of the Coast Guard Air Station Port Angeles should be thanked for their help, hospitality, and friendship, without which a difficult job would have been impossible.

OIL POLLUTION CONTROL AND SPILL RESPONSE CAPABILITY IN THE ROPME SEA AREA

P. Bernard Ryan
Gulf Area Oil Companies Mutual Aid Organization
P.O. Box 30352
State of Bahrain

Derek J. S. Brown
The Bahrain Petroleum Company B.S.C. (Closed)
Awali, State of Bahrain

ABSTRACT: *The ROPME sea area as defined in this paper is the scene of some of the world's most intensive offshore oil exploration and production and the associated crude oil refining and tanker terminaling for oil exportation. The potential for oil pollution in the area is high, with its confined nature making it especially vulnerable to the effects of oil pollution. Awareness of this problem is well developed in the region in both government and industry, and good progress has been made in recent years toward preparing for the big oil spill which has so far not materialized, but which most experts consider inevitable at some time.*

Two distinct groups share the concern for oil pollution. The oil industry has well over 40 companies active in the area in some way. Many of these have a 15 year history of cooperation in oil spill response and continue to play a full role in protecting the environment from the adverse effects of oil pollution. More recently, nations bordering the area have taken an active interest in the problem and have demonstrated an impressive record of commitment and action over the past five or six years. While government and industry have maintained their separate identities, a good working relationship exists between them, and there is good information exchange and practical cooperation between the two groups, most especially at the national level. Future years should see this trend develop even further.

A very impressive arsenal of oil pollution response equipment has been built up in the sea area since two major oil spill incidents in 1980. What is especially noticeable now is the proportion of this equipment that is owned and operated directly by the government agencies. This stands in marked contrast to the situation in 1980. In addition to the equipment resources available, the pool of personnel trained in oil spill response technology and methods is rapidly expanding as a result of seminars, workshops, and training courses that are being organized on a regular basis.

The development of national and regional legislation to control the main sources of man-made pollution, for example, from tanker operations and offshore exploration and production, is in a very active stage and the oil industry is expected to have clear operational guidelines within the next few years.

In the 1980s, a very high degree of awareness of the need to protect the ROPME sea region from the adverse effects of marine oil pollution has arisen, along with two major developments that have given substance to this awareness. First, the Marine Emergency Mutual Aid Centre (MEMAC) was established in Bahrain, with its catalytic and coordinating role for member states in the region. Second national spill response capabilities have been developed in a number of the

states bordering the sea area. Concurrent with these developments within governmental agencies has been an expansion of the response capabilities of several of the major oil companies that operate in the region. Additionally, there has been a change in basic spill response philosophy in many of the oil companies from one based almost entirely upon dispersant spraying to one that increasingly recognizes the role of containment and mechanical recovery in any spill response effort.

The first overall review of oil spill response capability in the ROPME sea area was undertaken in 1980 as part of a workshop held in Bahrain under the joint sponsorship of the United Nations Environment Programme (UNEP) and the International Maritime Organization (IMO). Some aspects of the equipment and contingency planning review undertaken for that workshop were updated at the 1985 Oil Spill Conference.^{3,4} In this paper, we are seeking to provide a brief update of total oil spill response activity as it exists in its two separate, but nevertheless interdependent, agencies, namely, governments and the oil industry, and to review the various regulatory measures being taken to control oil pollution in the area.

Definition: The ROPME sea area

The Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution, which was signed by the States of Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates in 1978, and came into force very shortly thereafter, defines the sea area covered by the convention as that bounded in the south by the coordinates:

16 degrees 39' N	53 degrees 3' 30" E
16 degrees 00' N	53 degrees 25' 00" E
17 degrees 00' N	56 degrees 30' 00" E
20 degrees 30' N	60 degrees 00' 00" E
25 degrees 04' N	61 degrees 25' 00" E

and otherwise by the land masses of the contracting states. It is apparent that the area encompasses all the water mass known variously as the Arabian or Persian Gulf, along with the Gulf of Oman and a broad section of the coastal waters of Oman. This area is illustrated in Figure 1.

Article XVI of the Kuwait Convention also established the Regional Organisation for the Protection of the Marine Environment (ROPME) with headquarters in Kuwait. ROPME administers the convention and associated action plan and protocols. For convenience of reference, the area is referred to as the ROPME sea area.

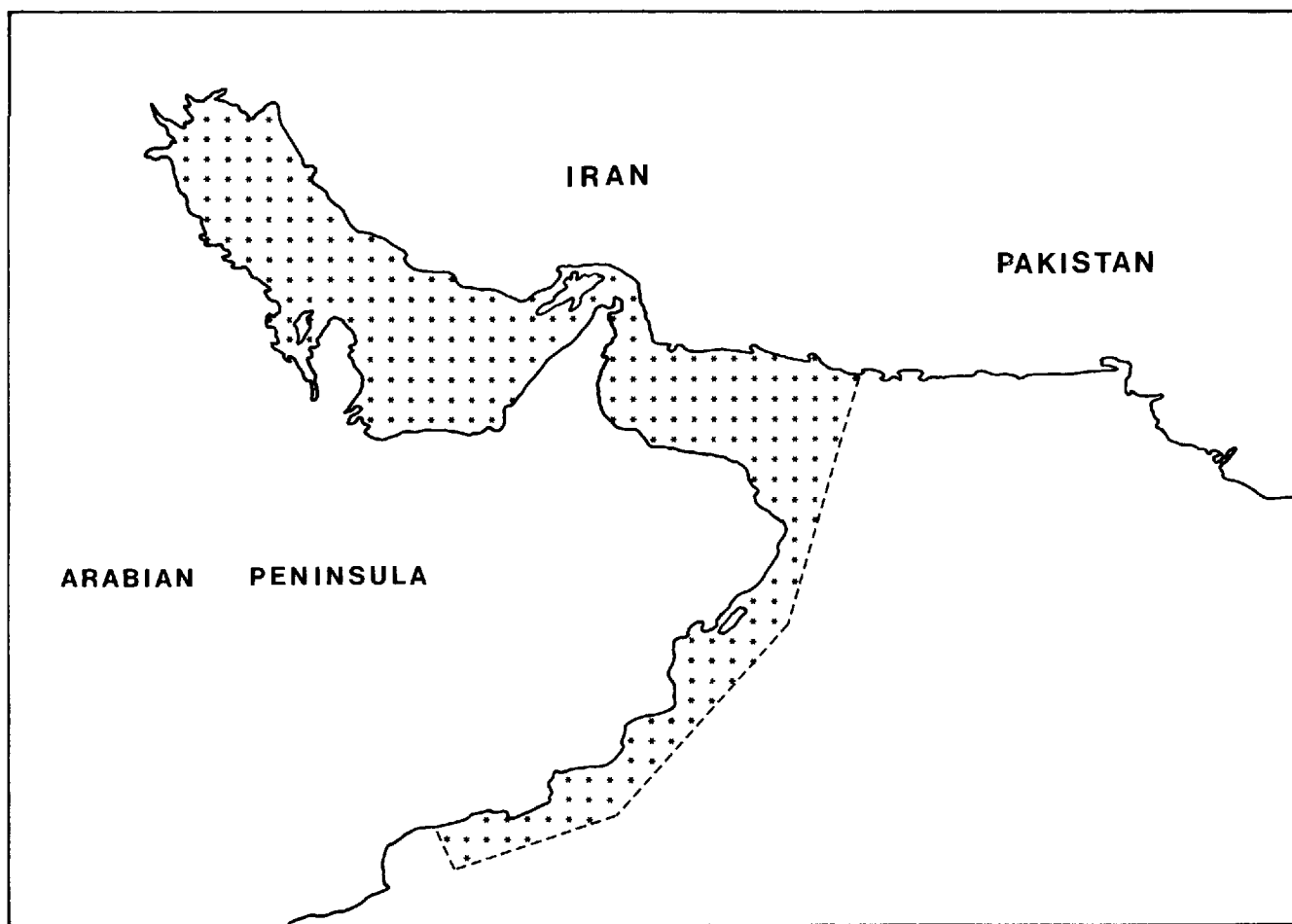


Figure 1. ROPME sea area

Oil spill response planning and capability

The basis of most successful oil spill response operations is a well prepared and practiced oil spill contingency plan, as is well known to the agencies responsible for oil spill cleanup in the ROPME area. The IMO study of oil spill response capability in the region in 1980 clearly showed that national oil spill contingency planning was very much in its infancy and that responsibility for oil spill response was left largely to the oil companies operating in the area. Two major oil spill incidents in the latter half of 1980 illustrated this fact very dramatically,^{1,2,5} to the extent that now national planning for oil spill emergencies is well advanced in most states of the area.

With the exception of the Iranian operators, all the principal oil companies that face the risk of marine oil spills from their operations in the area are members of the Gulf Area Oil Companies Mutual Aid Organisation (GAOCMAO), which is a self-help association of operating oil companies with emphasis on cooperative oil spill responses. The structure, organization and activities of GAOCMAO have been detailed by Ryan and Brown.⁴ A primary condition of membership of GAOCMAO is that member companies must have an up-to-date oil spill contingency plan covering their operations. Each contingency plan details intracompany and intercompany communications networks regarding the personnel responsible for oil spill control and cleanup and procedures to be followed by the company in responding to pollution emergencies.

These company oil spill contingency plans are prepared by each member company; there is no general, standard format. GAOCMAO itself does not possess an oil spill contingency plan since the organization is not operationally active but functions primarily for communications and spill-related information retrieval and dissemination.

GAOCMAO's equivalent of a contingency plan is perhaps its emergency contact list, the detailed inventory it maintains of spill response equipment held by member companies and the organization's file of equipment and materials suppliers worldwide.

At the national level, planning for oil spill response has taken on very much more importance than was the case in 1980, and in a number of cases a very significant operational capability has been developed independent of that maintained by the oil industry. Most states of the area have a national oil spill contingency plan completed or nearing completion. Kuwait's national oil spill contingency plan is perhaps one of the most complete and has been tested on a number of occasions under simulated spill conditions.

The move toward more effective contingency planning in the area has resulted in an increased level of activity in associated functions. Baseline ecological studies have been promoted along with shoreline sensitivity and vulnerability indexing, and oil slick movement modeling. Notable attempts have been made to obtain information in those fields where fundamental knowledge has been lacking, with the study of surface currents in the northern part of the sea area by the use of drifting buoys being a case in point. This latter work has been conducted by the Meteorological and Environmental Protection Administration (MEPA) of Saudi Arabia and has provided much useful information on surface circulation patterns in the sea area north of Qatar.

In terms of operational capability, the situation in the area has greatly changed from that prevailing in 1980. At that time, the capability to respond to oil pollution in the area rested solely in the hands of the oil companies. These companies varied widely in their abilities to mount oil spill response operations, with only a few of the larger companies possessing any large-scale capability. The spraying of chemical dispersants was the response technique generally favored at

that time. Much development on the part of the oil companies has resulted in an increase in mechanical oil containment and oil recovery capability, an aspect of spill response which was only minimally represented in 1980.

National authorities in the area have taken a more positive role in developing their own spill response capabilities. In Kuwait, a variety of equipment has been purchased by the governmental authorities and allocated to various national agencies, including the oil companies, to maintain and operate as required. Overall responsibility for oil spill response in Kuwait (other than small local spills) rests with the national oil spill committee, although in many cases local oil companies will provide the operational expertise. In Saudi Arabia, a very extensive Oil Pollution Control Centre has been established at King Fahad Industrial Port, Jubail, under the direction of the Seaports Authority of Saudi Arabia. This center is well equipped with a wide variety of spill response equipment, including containment, recovery, and dispersant application equipment, and has good support for aerial surveillance of areas at risk. Oman has recently purchased a considerable amount of equipment for use in protecting its coastline from major effects of pollution and is training a very active pollution control group.

Throughout the sea area generally, a very broad range of oil spill response technology is available, including aerial capability to apply dispersant chemicals from both helicopters and fixed-wing aircraft. Data are not currently available to permit any accurate assessment of the total capital investment represented by all the equipment, but it is likely to be approximately U.S.\$50 million. The locations of sites with known equipment stocks of a value of \$250,000 or greater are shown in Figure 2.

Regulatory control of oil spill response and oil pollution

Concurrent with developing national operational capabilities for oil spill responses in the area has been the growing awareness of the desirability of regulating the methods used to combat pollution and to control the types of oil spill chemicals to be used. Mention has already been made of the use of sensitivity mapping as part of contingency planning by some states. The information gained in such mapping has been used to develop a sensitivity index for many coastal regions, and this has been translated into guidelines for oil spill response controllers for the methods of spill combating that may be used. The foremost aspect of these guidelines is the directive relating to the use of oil spill chemicals, particularly dispersants, in sensitive areas. Such controls have only been developed over the past couple of years and are to be welcomed.

While sensitivity mapping and indexing are being carried out nationally, a regional initiative by ROPME is seeking to bring chemical dispersants under control by developing an approval and licensing scheme for products similar to the arrangements in such countries as France, the United Kingdom, and the United States. This scheme would require that all dispersants used in the ROPME sea area should pass an approved series of tests for efficiency and toxicity, and a major effort is now being made to identify the most appropriate test methods. It would be ideal for the region if all the ROPME member states were to agree to one series of tests for dispersant products and for this testing to be carried out at just one or two test centers in the area, with successful products then being approved for use throughout the area. Progress toward identifying a suitable approval regime is good, but it

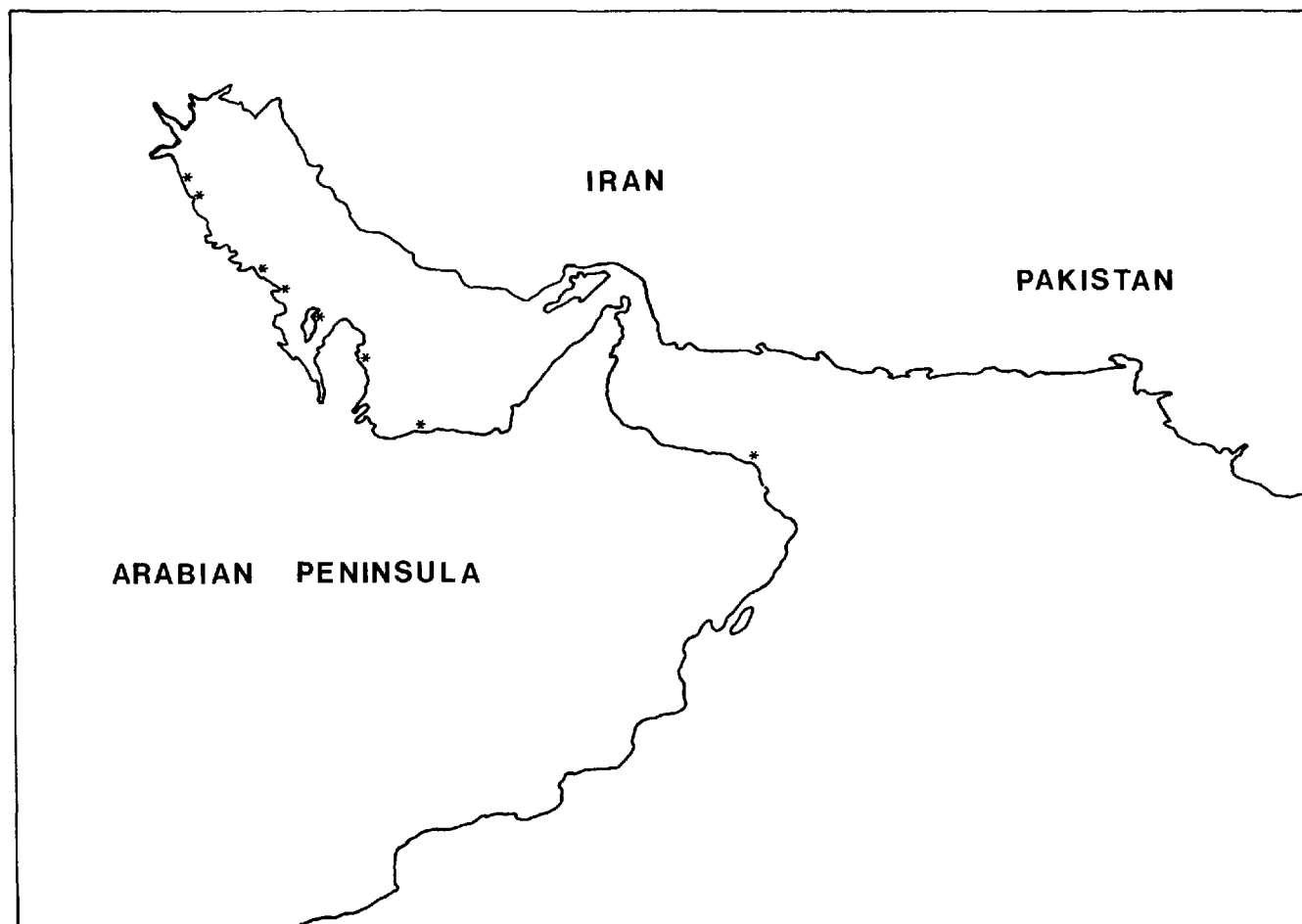


Figure 2. Principal equipment bases (marked with asterisks)



Documents

Document Sharing Hub

will probably be another two or three years before the scheme is finalized.

During the interim, ROPME member states have agreed to adopt a temporary scheme whereby the only dispersants that may be used are those products that have been approved or licensed by recognized testing authorities. Lists of such products are available from ROPME for the benefit of users in the area. GAOCMAO member companies in the area have been using dispersants in their oil spill cleanup operations for the past 15 years and have always maintained relatively large stocks. When introducing the new controls on dispersants, ROPME recognized it would be economically impractical to expect oil companies to discard large quantities of existing oil dispersants if they did not meet the new requirements, and it has granted exemptions for such stocks. In practice, such exemptions have been superfluous for all but a few hundred gallons of dispersant, since it has always been a GAOCMAO regulation that member companies use only dispersants that are approved by a national testing authority.

Ratification of MARPOL 73/78 is a major point of debate in the ROPME area at the present time. The Sultanate of Oman is the only state in the area to have signed MARPOL 73/78, but a careful study of this convention and associated implications is currently being undertaken by all the remaining member states of ROPME. There is a keen interest in having the northern section of the sea area declared a "special area" as defined in the convention, since this would give it special protection from oil pollution arising from oil tanker operations.

One of the principal concerns about ratification at the present time is the question of reception facilities, particularly for oily wastes, and a great deal of study is focusing on the precise requirements for such facilities in the sea area.

Prevention of pollution from offshore mineral exploration and exploitation is the purpose of a new protocol being prepared by ROPME. Though the protocol is not restricted in its provisions to offshore petroleum activities, nevertheless, oil exploration and production operations will be the main activities affected. The protocol is still in the early stages of development, and early indications are that a pragmatic approach to control is being adopted. Oil industry input to the protocol's development is guided by the International Oil Industry Exploration and Production Forum (E and P Forum) with regional support from GAOCMAO. E and P Forum and GAOCMAO participated in the first meeting organized by ROPME to discuss the first draft of the new protocol, and both organizations were generally satisfied with the proposals being made. As with the dispersant regulations and MARPOL 73/78, it is likely to be two or three years at the earliest before details of the protocol are finalized.

National regulations concerning oil discharges are enforced at the ports in the sea area to varying degrees. A feature common to all these ports, however, is the strengthening of regulations and of their enforcement as the move toward increased environmental protection gathers momentum.

The past five or six years have seen the awareness of the need to control oil pollution increase dramatically, and there has been a commensurate increase in regulatory activities to assist in this task as indicated here.

Oil spill emergencies in the sea area

Oil spill incidents prior to 1984 were documented in a previous paper.⁴ Since that time, two further significant incidents have occurred:

1. On December 6, 1985, the 119,000 grt tanker *Nova* collided with the 142,000 grt *Magnum* in the vicinity of the Kharg Island loading terminal, possibly while taking evasive action against a missile attack (though this was never confirmed). The *Magnum*, which was in ballast at the time, suffered structural damage to the bow, but the fully loaded *Nova* sustained a 30 m hole in its port bow area. It is estimated that approximately 70,000 tons of heavy Iranian crude oil was spilled as a result of the collision.

Surveys by the regional Marine Emergency Mutual Aid Centre (MEMAC) based in Bahrain, and by a representative of the International Tanker Owners Pollution Federation (ITOPF) in non-Iranian

waters failed to detect any significant resulting oil pollution. Thus, the bulk of the oil must have been dissipated by natural processes. The remainder stayed in Iranian waters, eventually affecting Iranian coasts.

2. On April 15, 1986, a work barge operating in the vicinity of the Kuwait National Petroleum Company's Mina Abdulla loading terminal damaged the 24 in diameter heavy fuel oil loading line with one of its anchors. The damage resulted in a 5 in diameter hole. The total spill was estimated at approximately 600 tons.

A well-coordinated response operation was mounted by the Kuwait authorities, under the control of the National Committee for Combating Oil Pollution, involving cooperation between the Kuwait Oil Company, a number of government departments, and the Kuwait Institute for Scientific Research (KISR).

The cleanup operation was completed in 10 days. It was estimated that 65 percent of the oil was recovered by mechanical means, 25 percent was naturally or chemically dispersed, and 10 percent reached beach areas.

Apart from the above two incidents, continuing tar ball and tar mat pollution of beach areas has occurred, generated primarily by the damage to oil installations from the conflict in the north of the sea area. This pollution would be classified generally as a nuisance to beach users, and has not resulted in any severe problems, such as at desalination plant water intakes.

However, as stated on a number of previous occasions, the region is statistically long overdue for a major tanker spill, and this situation is aggravated by the continuing conflict between Iran and Iraq that has recently shown disturbing signs of escalation. Coupled with general economic constraints on the maintenance of tankers and the virtual cessation of new tanker building, this means that the probability of a tanker accident causing severe pollution in the area is very real.

Although offshore drilling and production operations are presently somewhat reduced, they also continue to pose a threat, as evidenced by the 1980 Hasbah blowout, and the 1983 Nowruz incident.

Oil spill contingency planning and response training initiatives

Training programs and demonstrations, designed to improve personnel's ability to minimize potential oil spill incidents and to respond effectively and economically in the event of an oil spill, have been a priority concern of oil companies operating in the area since the inception of GAOCMAO.

The Bahrain Petroleum Company B.S.C. (Closed) (BAPCO), in cooperation with CALTEX, began to develop a four day intensive training course program to suit the requirements of this region in 1979. This course, using videotapes, hands-on equipment deployment, and an oil spill response management table top exercise, was launched in 1981. Since that time 24 courses have been held in Bahrain, with nearly 200 participants, over half of whom have been non-BAPCO staff participating on a paying basis. The majority of non-BAPCO participants were from other GAOCMAO member companies, although a significant number of regional government officials have also attended, including the director of the Marine Emergency Mutual Aid Centre in Bahrain (MEMAC). The International Maritime Organization (IMO) recently sponsored two marine officers from the Seychelles to attend one of these courses.

Although to date the BAPCO course has been the only industry training available to outsiders, a number of other GAOCMAO member companies have been running comprehensive training programs for their own staffs for some time, notably the Arabian American Oil Company, Kuwait Oil Company (K.S.C.), and Abu Dhabi National Oil Company. Training courses at the latter company are held at the Ruwais oil spill response base, and it is expected that they will be made available to outsiders for a fee during 1987.

The governments of the sea area have also embarked on an ambitious and far-reaching training program for their own staffs and have invited GAOCMAO members to take part in such programs on a number of occasions. These programs have generally been arranged by ROPME/MEMAC (commencing in 1984) and have taken the form of seminars, workshops, equipment demonstrations, and on two occa-

sions, practice oil spill alerts (including mobilization of equipment), as listed below:

- First Workshop on Marine Pollution Prevention/Control/Response (Basics), May, 1984, Bahrain
- First Equipment Demonstration (involving 12 Manufacturers), August, 1984, Bahrain
- Second Workshop on Operation/Maintenance/Storage of Oil Spill Response, August, 1985, Jubail, Saudi Arabia
- Third Workshop on Oil Pollution/Regional Contingency Planning, October, 1985, Dubai
- First Oil Spill Alert Exercise, December, 1985, Kuwait
- First Annual Seminar (9 papers presented), February, 1986, Bahrain
- Fourth Workshop on Prevention/Control/Response to Regional Marine Pollution, May, 1986, Kuwait
- Second Oil Spill Alert Exercise, October, 1986, Kuwait
- Second Equipment Demonstration (including 8 Manufacturers and QGPC [Offshore] Equipment Stockpile), October, 1986, Doha, Qatar
- Fifth Workshop on Operation/Maintenance/Storage of Oil Spill Response Equipment, and Usage of Dispersants, Doha, Qatar (coincident with Second Equipment Demonstration above).

These initiatives of the oil industry and governments of the region are expected to continue and develop further cooperatively, with the objective of providing an effective and well-trained response organization based in the region, thereby minimizing the expensive recourse to outside agencies in the event of any major oil spill incident in the future.

Future trends

The governments of ROPME member states are showing an increasing commitment to the goal of minimizing pollution and the threat it poses to the area. Training of personnel in all aspects of pollution control and response will provide the region with a core of people competent to protect the marine environment.

Transferring the responsibility to combat oil spills from oil industry to governments, in the case of major pollution incidents, can be expected to continue although individual oil companies will take care of in-house operational spills. It is to be hoped that a regional approach to oil spill responses can be developed to supplement individual national responses to major emergencies. Any such regional initiative can only come from regional governmental organizations such as MEMAC, but would certainly have the backing of the oil industry.

A regionwide aerial monitoring scheme would make a major contribution to enforcing antipollution regulations as well as more specific slick monitoring in actual spill incidents. Any such scheme, however, must wait until conditions in the ROPME sea area return to normal.

References

1. Lehr, William J. and Murat S. Belen, 1983. The fate of two large oil spills in the Arabian Gulf. *Proceedings of 1983 Oil Spill Conference*, American Petroleum Institute, Washington, D.C., pp377-380
2. Ryan, P. Bernard, 1983. Hasbah 6: oil companies response to oil pollution in the Arabian Gulf. *Proceedings of 1983 Oil Spill Conference*, American Petroleum Institute, Washington, D.C., pp371-375
3. Ryan, P. Bernard, 1984. Marine oil spill response capability in the Kuwait Action Plan Region. *UNEP Regional Seas Reports and Studies No. 44*, pp327-338
4. Ryan, P. Bernard and Derek J. S. Brown, 1985. GAOCMO—industry's response to cooperative spill response in the Arabian Gulf. *Proceedings of 1985 Oil Spill Conference*, American Petroleum Institute, Washington, D.C., pp607-613
5. van Oudenhoven, Joseph A. C. M., 1983. The Hasbah 6 (Saudi Arabia) blowout: the effects of an international oil spill as experienced in Qatar. *Proceedings of 1983 Oil Spill Conference*, American Petroleum Institute, Washington, D.C., pp381-388

FRENCH KNOW-HOW IN THE PREVENTION AND FIGHT AGAINST ACCIDENTAL OIL SPILLS

Guy Marchand
Mission Interministérielle de la Mer
3 Place Fontenoy
75007 Paris, France

Gilles Bergot, Marthe Melguen, Georges Peigne
Centre de Documentation de Recherche et d'Expérimentation
sur les Pollutions Accidentelles des Eaux
B.P. 308, 29274 Brest Cedex, France

ABSTRACT: *As the victim of several oil spills caused by oil tanker accidents along its coasts during the 1970s, France has created a specific organization, including a research and documentation center, and developed all necessary means to prevent further major pollution and to protect its coastline.*

The French program is unique in the fact that it is first of all concerned with the prevention of accidents. In addition, French know-how is characterized by the establishment of intervention plans (POLMAR plans, sea and land) which are designed to prepare for and coordinate the fight against accidental water pollution at sea and on the coastline.

An antipollution operation also relies on the existence of the necessary means to carry it out, as well as specialized equipment which is ready to be put to work at sea as well as on the coastline by competent authorities. In the case of oil spills occurring in other countries, France is prepared to share its experience and know-how thanks to its groups of experts such as those of CEDRE and of the port of Marseilles.

On March 16, 1978, the *Amoco Cadiz* sank off the Breton coast and its cargo of 223,000 tons of oil was spilled into the sea, polluting more than 300 km of coastline.

At that period, the national provisions for the prevention and clean-up of accidental oil spills were insufficient to deal with a pollution accident of that magnitude. Shortly thereafter the French Government took action to reinforce existing ways and means in all areas in order to be better prepared in case of pollution and to better minimize its effects.

Today, national policy is oriented toward prevention of pollution, but antipollution operations are in no way neglected.¹ Eight years after the *Amoco Cadiz*, this national policy has proved its effectiveness, especially during the accidental oil spill of the ship *Tanio* in March 1980.

Prevention of accidental oil spill pollution

After being the victim of a number of oil spill incidents, France has elaborated a rigorous prevention policy relying on European and international legislation, both reinforced by national measures.

Security of maritime navigation. The measures are essentially designed to ensure improvements in four areas as follows.

1. Inspection procedures have been strengthened in order to enforce the rules for construction, equipment, and use of sea-going vessels.

During inspection, the Centres of Security of Maritime Affairs verify whether a vessel conforms to the security legislation of international conventions, notably the MARPOL 73/78 convention.

The Memorandum of Understanding on Port State Control, signed in Paris on January 26, 1982, enabled a standardization of inspections for foreign vessels in the European countries which were cosigners. The Administrative Center of Maritime Affairs centralizes information regarding inspected vessels and puts this information at the disposal of the cosigners of the agreement.

2. The information available to the authorities regarding maritime navigation along French coasts has been improved. A decree of March 24, 1978 instituted a system for identifying tankers transporting petroleum products when they enter French territorial waters or when they have an injury at less than 50 nautical miles from the French coastline. This law has been reinforced by Protocol I of MARPOL 73/78, which, since October 1983, provides that any event which causes or could cause a pollution accident will be reported to the proper authorities.

3. Vessels carrying potential pollutants now must stay at a greater distance from the French coastline. Navigating within seven (7) nautical miles of the coast is forbidden to these tankers, except in specially-listed channels and estuaries which give access to ports.

With the French initiative, the traffic separation scheme of Ushant was modified by the International Maritime Organization (IMO) in January 1979 in order to push back the tanker traffic of hydrocarbons and dangerous substances to waters further than 27 miles from the coastline.

4. Penalties for maritime traffic violations and for oil spill pollution accidents have been strengthened. A 1983 law has permitted sanctions for an offense against laws forbidding oil dumping at sea, as defined by MARPOL 73/78, committed by French or foreign vessels in territorial waters or in the Exclusive Economic Zone, as well as carelessness, negligence or non-conformity to laws which results in an accident at sea causing pollution in territorial waters.

Monitoring of maritime navigation. The necessary means for applying preventive measures have been reinforced. Two complementary organizations have enabled this role to be assured:

Five Maritime Rescue Coordination Centers (CROSS), equipped with military personnel, can coordinate sea rescue operations, insure the monitoring of maritime navigation (notably in the traffic separation schemes), and monitor pollution. Related to the Secretary of State for the Sea, these centers are responsible to the Maritime Prefect for their operational missions (Figure 1).

Sixty-five semaphores of the French Navy ensure optical monitoring and radar coverage of the French coastline.

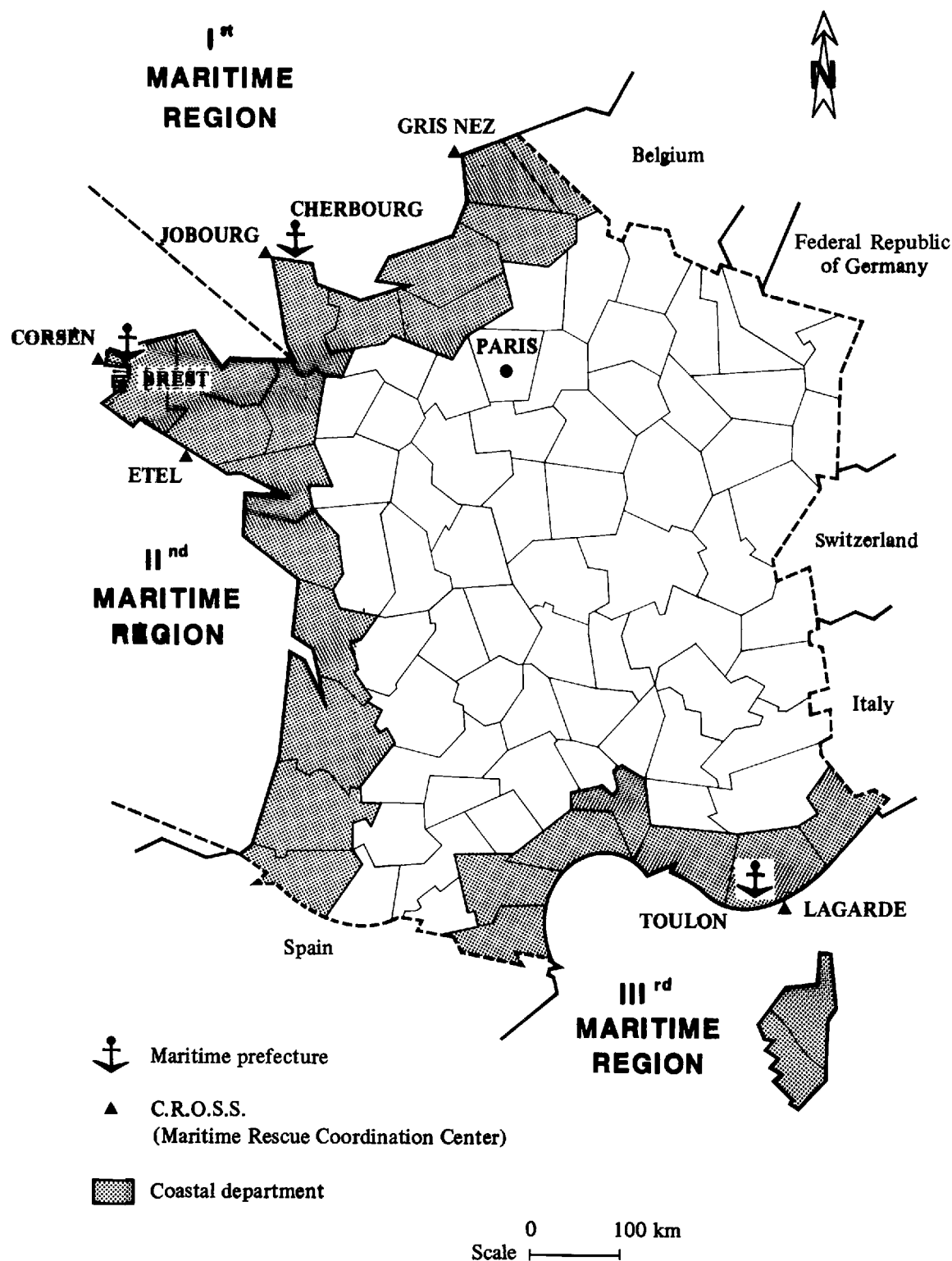


Figure 1. French administrative organization

The missions of the CROSS centers related to monitoring navigation were significantly enlarged after the *Amoco Cadiz* accident. Three of the centers ensure the particularly careful monitoring of maritime traffic and the traffic separation scheme for the English Channel (Figure 2). Created recently, their means of transmission and detection are extremely up-to-date.

Intervention at sea in the case of a pollution threat. In each maritime

region, specific ways and means have been installed in order to assist a vessel in difficulty.

Four powerful civilian tug boats, chartered by the French Navy and put at the disposal of the Maritime Prefects are continually prepared to assist any vessel in difficulty. This assistance may be deemed necessary by the Maritime Prefect if he so judges. Also, thirty-two towing exercises (on September 30, 1986) of large vessels have taken place

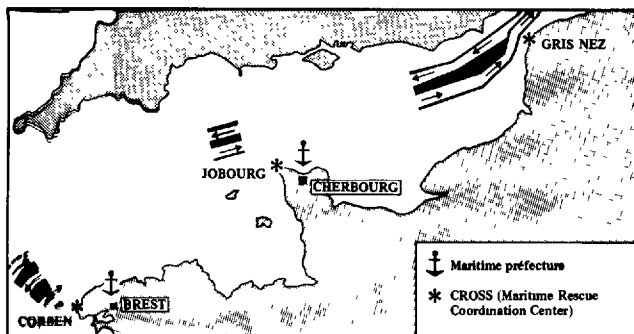


Figure 2. Navigation monitoring of the English Channel and location of maritime authorities

under diverse weather conditions. These exercises, as well as numerous interventions at sea, have enabled verification of the effectiveness of the existing antipollution organization.

Evaluation and intervention teams can be placed on board the damaged vessels by helicopter. Composed of military personnel who are competent in various shipboard functions, their role is to evaluate the danger, to inform the Maritime Prefect, and eventually to undertake any necessary immediate actions on board (such as preparation for towing, short-term repairs, or preparation for ship evacuation).

Evaluation of the measures for preventing pollution accidents at sea. The preventive measures initiated by the French government have already proven their worth. Respect for traffic laws in the plan of traffic separation has continued to improve: 15,729 offenders were counted in 1979, whereas there were ten times fewer in 1985. Furthermore, thanks to all the preventive measures which were taken since the *Amoco Cadiz* accident, France has not had a major pollution problem since the *Tanio* shipwreck of March 7, 1980. Finally, increased conformity of the vessels to the norms imposed by international conventions, notably MARPOL 73/78, has led to a real lessening of petroleum spills at sea.

The affidavits of pollution infraction have consequently followed the same downward curve (Figure 3).

Fight against accidental oil spill pollution

The effectiveness of a national prevention policy cannot totally eliminate the risk of a pollution accident. Large efforts have been made in order to reinforce the national plan of readiness for an accident in all its aspects: improving existing response programs, and increasing the response potential in both trained personnel and equipment.

The national intervention policy against accidental pollution. The first directives organizing the fight against pollution were enacted in 1970 after the *Torrey Canyon* accident. The experience gained from other accidents has improved the concepts regarding the antipollution organization which was totally modified in a new directive of October 12, 1978 organizing the POLMAR Plan² which takes into consideration what has been learned from the *Amoco Cadiz* experience.

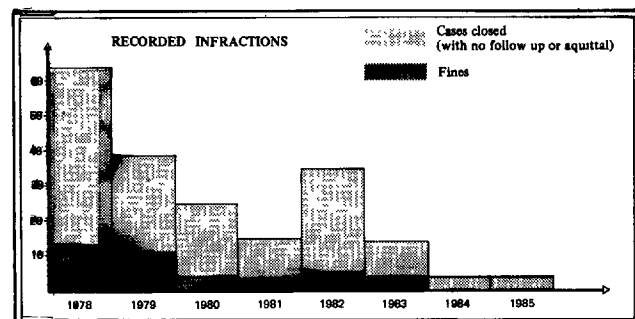


Figure 3. Evolution of pollution infractions affidavits from 1978–1985



Figure 4. Lightening of a vessel in difficulty

At sea, the responsibility to prepare for and conduct antipollution operations is given to the Maritime Prefect, a general Navy officer who possesses large military and civil responsibilities and with whom resides the authority of the government at sea.

In each maritime region, the Maritime Prefect has established, in connection with the local elected authorities and the various users of the marine environment, an intervention plan for offshore pollution (plan POLMAR-MER) which inventories all the means available for a pollution response operation. In the event of a maritime accident, the Maritime Prefect directs the POLMAR-MER (POLMAR-SEA) plan. If the magnitude of an accident justifies the use of the POLMAR-MER plan, the Maritime Prefect sets the plan in action. In doing so, he has access to the Intervention Fund which is the responsibility of the Minister of the Environment, and which provides for any exceptional expenditures.

On shore, in each of the 26 coastal departments, the Prefect (Commissaire de la République) representing the French Government within the department prepares a POLMAR-TERRE (POLMAR-LAND) plan in connection with locally elected officials, users of the marine environment, associations for protection of the environment, and scientific experts.

The POLMAR-TERRE plan comprises a number of elements such as an inventory of zones to be protected and their priority, plans for installing booms designed to protect these areas, inventory of antipollution equipment both publicly and privately owned, and a list of storage sites and treatment centers for recovered products.

Begun at sea, the cleanup operations may be continued on the coast. Small-scale incidents can be treated by the coastal communal authorities directly affected, but in the case of an exceptional pollution accident, the above-mentioned Prefect can put the POLMAR-TERRE plan into action and direct the antipollution activities under

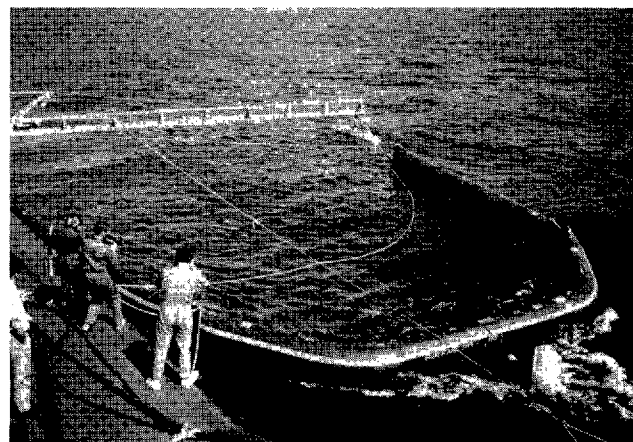


Figure 5. Sirene 20 recovery device

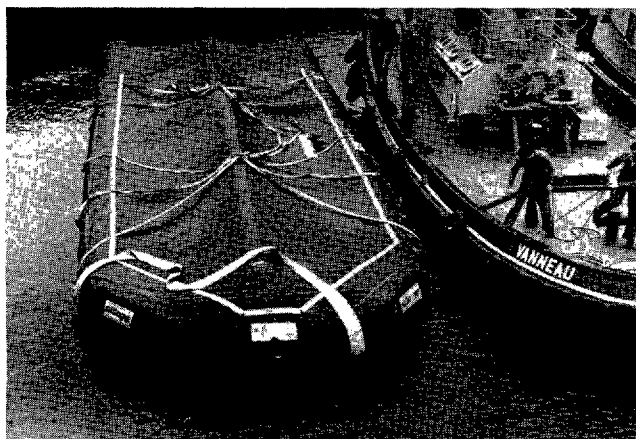


Figure 6. The flexible floating tank, Pollutank

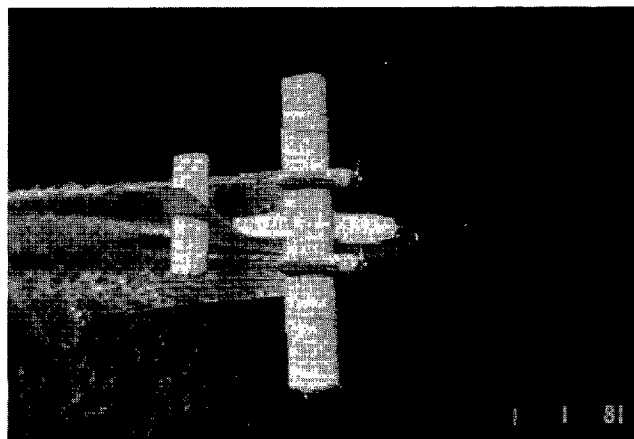


Figure 8. Fire combating plane adapted to dispersant spraying

the authority of the Minister of the Interior. As with incidents at sea, for exceptional expenses on land, the Prefect can ask for assistance from the Intervention Fund of the Minister of the Environment.

Coordination of antipollution activities. Since 1978, the coordination structures have been reinforced. At the central level, all maritime problems of this nature are periodically examined, if necessary by the Interministerial Committee of the Sea, whose work is prepared by the Interministerial Mission for the Sea. In this way, in March 1986, all the existing national antipollution provisions were reviewed.

If a pollution accident is of an exceptional magnitude and if there is a necessity to coordinate the POLMAR-TERRE and MER operations, this coordination falls under the authority of the Minister of the Interior who meets with a staff of directors in the operational center of the Direction of Civil Defense and Security (CODISC).

At the local level, a regional maritime conference with representatives of the various administrations involved in maritime questions, will verify coherence between the preparation of the POLMAR-MER and POLMAR-TERRE plans.

If cleanup operations are simultaneously taking place at sea and on the coastline, the coordination of activities will be supervised by a permanent conference with representatives from the Maritime Prefect and the Commissaire de la République (Prefect) of the particular department concerned.

Appeal to specialized organizations. Antipollution operations at sea and on land need specialized knowledge. To meet this demand, the POLMAR instruction has created a Center of Documentation and Research and Development on Accidental Water Pollution (CEDRE). The principal role of CEDRE is an improvement of antipollution techniques and a documentation of the techniques.³ CEDRE also assists government agencies in preparing intervention

plans. In the event of a pollution incident, CEDRE provides technical advice to those responsible for antipollution activities.

In addition, the French Navy has created a Commission for Practical Antipollution Studies (CEPPOL) in order to meet its specific needs; the Minister of the Interior (Directorate of Civil Defense and Security) possesses, at the heart of the civil security units, response sections which have specifically designed antipollution equipment; and French authorities may require advice from research centers such as IFREMER (Institut Français pour l'Exploitation de la Mer) and IFP (Institut Français du Pétrole).

Response techniques and methods for oil spills

The antipollution effort which resulted from the *Amoco Cadiz* shipwreck used specific equipment which France developed after the *Torrey Canyon* accident, and, to a large degree, nonspecific equipment. Significant effort has been made in designing and testing equipment, in order to be well prepared for pollution response operations,^{7,8} and testing dispersants as well as sorbents and other products adapted to oil spill treatment.^{5,6}

Aware of the limitations imposed by each method of cleaning up pollution, as well as the variety of types of pollution which could be encountered, the French authorities as well as the research centers have not designated any particular antipollution technique. Thus, research and development on means of combating pollution has been carried out, primarily by CEDRE, in close association with the manufacturers concerned with antipollution activities. In particular, research and experimentation have concerned the following aspects of pollution response.

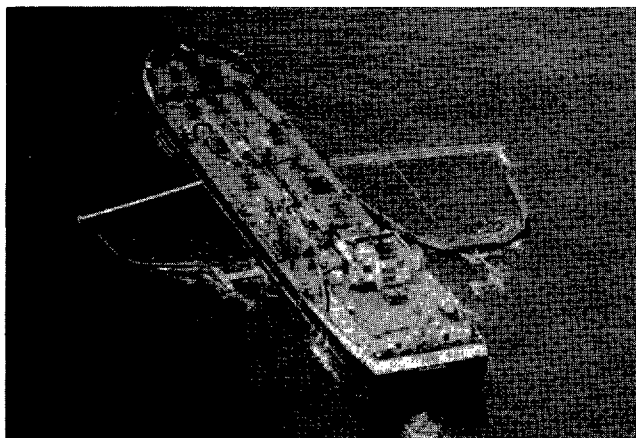


Figure 7. Coastal oil tanker equipped with Sirene 20 and ESCA recovery devices



Figure 9. Heavy helicopter (Super-Frelon) equipped with dispersant spraying equipment

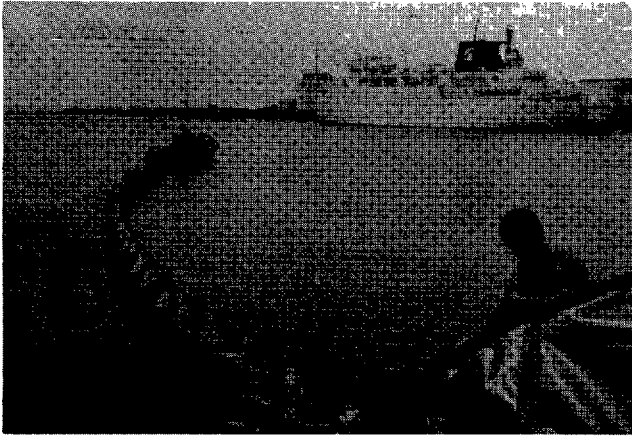


Figure 10. Balear boom

Lightening a vessel in difficulty. The French Navy and the port authorities have access to heliportable pumping devices. The effectiveness of these pumps being greatly reduced in the presence of viscous hydrocarbons, research has been oriented toward methods for pumping viscous products. Figure 4 shows the lightening of a vessel in difficulty.

Confinement and recovery at sea. It is in this field that the French strategy has most advanced during the past few years.

The first approach which was chosen was very pragmatic. Priority was given to the perfection of existing equipment in order to incorporate it in units adapted to the naval capabilities of the French Navy. The basic recovery device was chosen to be the Sirene 20, a direct suction skimmer integrated with an inflatable boom (Figure 5), which has proved to be effective in moderately choppy sea. This device has been tested on numerous occasions, towed by two vessels as well as by one vessel with a jib-boom.⁹

The storage and transportation of the recovered products at sea are accomplished by means of floating tanks having capacities of 100 to 200 cubic meters. CEDRE offered its services to the industry for the study and creation of a tank with a removable roof, the Pollutank (Figure 6). Concurrently, it also helped the French Navy in testing the emptying and cleaning of another flexible tank (Dracone).

It soon became obvious that despite their limitations it was necessary to study specific devices for recovery in high seas, capable of recovering and storing large amounts of pollutant. But the studies which were undertaken on specialized vessels did not produce enough convincing data.

For these reasons, another approach has concentrated the research on the use of existing vessels with large storage capacity which can be used as supports for recovery devices. Two vessels seem best adapted

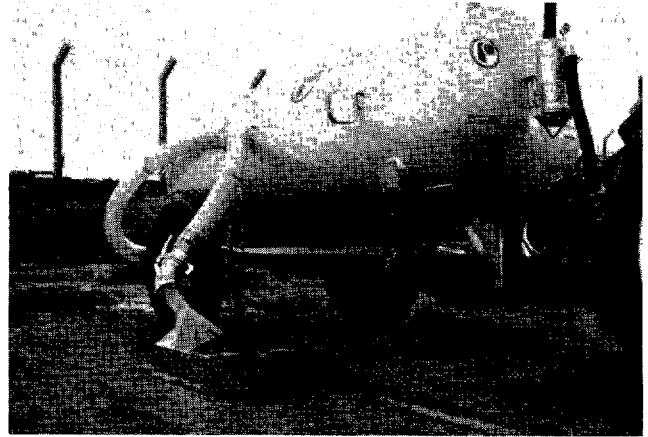


Figure 12. Polluge—suction head adapted to a vacuum tank trailer

to this work: the pumping dredgers and the small coastal oil tankers. CEDRE has studied a recovery device which has been designed specifically to be used on an oil tanker, the high sea ESCA (Figure 7).

Although the use of booms in high seas has generally met with skepticism, during the Castor tests which were done with the Navy, CEDRE was able to verify that under certain conditions the use of booms can be undertaken. This could be to encircle a localized source of pollution or to increase an area which is swept by a recovery device.

Treatment of oil spills by dispersants. Although a recovery at sea is preferable, unfavorable weather conditions and an emergency situation may make it necessary to spray dispersant products. The French point of view is a compromise between the two extreme solutions, which are on one hand the refusal to use any dispersants and on the other hand using them as a privileged response method.⁵

The dispersants approved in France are mildly toxic, and their massive use in coastal areas may have dangerous consequences for the environment. A geographical limit at sea has therefore been determined, beyond which it is possible in any case to use large amounts of dispersants without a major risk to the environment.

A program of tests at sea (PROTECMAR operations), directed by the French Petroleum Institute (IFP) has given essential data on the effectiveness of treatment methods, the behavior of treated oil, and on operational problems. It has been noted that the proper spraying of dispersants is a fundamental element in the effectiveness of their use. The spraying equipment which already exists on planes and light helicopters has been improved, and equipment better adapted to use with heavy helicopters (such as the Super-Frelon) and to shipboard application have been designed (Figures 8 and 9).

Use of sorbents and other products. If the research and investments have been oriented toward intervention in the case of a major inci-



Figure 11. TMB boom



Figure 13. Rolba—adapted screening machine for beach cleaning



Figure 14. Egmolap land scraper

dent, the recovery of small oil slicks also has been studied. A significant study program by CEDRE and the French Petroleum Institute has investigated the recovery of agglomerated slicks by trawling.

Laboratory tests and tests at sea have identified a selection of floating sorbents, perfected dissemination systems for the sorbents, and developed the SEYNIP trawl nets, several units of which were purchased by the French Navy. In the case of an oil spill, these means will be put into action by fishing vessels which are accustomed to installing trawl nets.

In the same way, field and laboratory experiments have enabled an assessment of other antipollution products such as gelling agents, demulsifiers, and sinking agents.

Confinement and recovery in a coastal area. Protection of particularly sensitive areas is a priority. French authorities have at their disposal more than 35 km of booms to ensure this protection. Technical specifications which define the qualities and expected performances of the coastal protection booms have enabled the selection of three types of booms: the Balear 335 filled with expanded plastic foam (Figure 10), the self-inflating TMB Offshore (Figure 11), and the inflatable boom Polluguard.

Numerous exercises which are systematically carried on along the French coastline with the assistance of the Technical Service of the Lighthouses and Buoys have enabled verification of the validity of the boom deployment plans and training of the antipollution personnel in installing the protective booms.

However, a protection program without a simultaneous recovery program is an inefficient operation. In the field of coastal recovery, a national effort has enabled the improvement of two existing devices, the Egmopol and ESCA barges, and the use of the Sirene 20 towed by coastal vessels or anchored in rivers or big estuaries subject to



Figure 16. Portable vacuum tank VIP

currents. In addition, studies have been conducted for pumps adapted to viscous products (such as the EGMO W. pump).

Finally, as we previously mentioned for the treatment of oil spills at sea, products such as sorbents could also be used in coastal areas. Research has indeed been done in selecting the most efficient sorbents and in improving the conditions under which they are used, especially to protect zones which are ecologically sensitive such as coastal salt marshes.

Oil recovery on shore. The coastal cleaning operations which were done after the *Amoco Cadiz* and *Tanio* accidents were able to show the limits of traditional techniques based on manual recovery and the use of agricultural or public works equipment. A priority has been given to the development of new collection equipment which is more productive and more selective, therefore limiting the quantity of waste products.^{4,6}

The study of the problem took two directions: (1) improvement of existing pumping and collection equipment through design of a suction head which could be adapted to an agricultural vacuum tank trailer (Polluge, Figure 12), and adaptation of screening for beach cleaning machines (Rolba, Figure 13) for continuous removal of old oil products; and (2) designing specific equipment such as a device adapted to a front-end loader which permits to scrape up oil on the sand or in water, and to separate it from water (Egmolap land scraper, Figure 14), and the perfection of a selective roller which is hitched to a tractor and which can pick up the oil deposited on sand (Figure 15).

Furthermore, the efficiency for collecting oil in hardly accessible zones has been improved thanks to the design of light-weight, easily maneuvered and easily carried equipment such as the individual vacuum tank VIP (Figure 16).

Restoration of polluted zones. In order to eliminate pollution which



Figure 15. Selective oil recovery roller

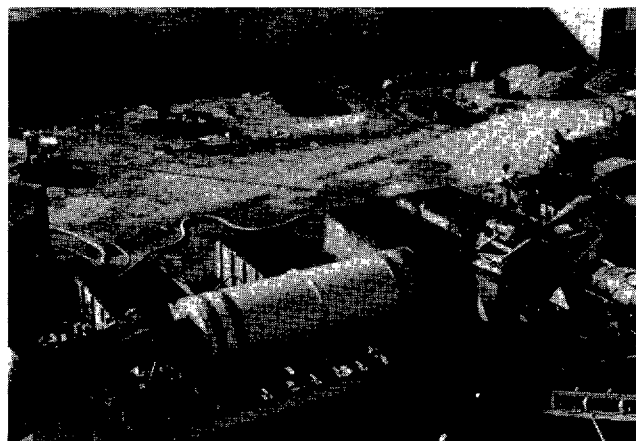


Figure 17. Mobile cleaning unit for polluted sand

remains in the sand after the cleaning operations, diverse techniques such as underwater polluted sand washing have been tested with success.

In addition, rock cleaning operations which were done during the *Amoco Cadiz* and *Tanio* cleanups permitted tests of cleaning techniques (cleaning with high pressure hot water jets) and improvements in the use of these techniques.¹⁰ Several tests, conducted since 1980, also permitted a selection of efficient cleaning products with low toxicity.

Storage of polluted waste. Studies regarding intermediate storage of waste have led to more rational techniques, and better adapted equipment has been designed such as flexible storage basins.

Criteria that have to be taken into consideration for a choice of temporary storage sites have been defined, and used in determining a national inventory of sites at which recovered waste could be dumped.

Waste treatment. The spills which have occurred on the French coastline have given a good basis for study of waste treatment and in particular the improvement of a quicklime treatment for solid residues.

A mobile polluted sand washing unit (Figure 17) which can be moved close to the beach, was designed and tested in 1985. This equipment enables return of the washed sand to the beach, avoiding transportation costs.

The policy of stockpiling pollution products and equipment. Development, adaptation, and evaluation of antipollution equipment has enabled the selection of equipment best suited to the desired goals. The French Government is involved in a comprehensive acquisition program for this equipment in order to respond more quickly and more efficiently to major oil spills. For this reason two types of stockpiles have been created (Figure 18).

- Stocks of products and equipment for antipollution interventions at sea are created and managed by the French Navy in each Maritime Region. They are composed of lightening equipment, high sea and port recovery devices, booms, floating tanks and dispersants, sorbents, and sinking agents as well as the necessary equipment for their application.
- The management of the products and equipment for a land antipollution intervention is under the responsibility of the Direction of

Table 1. Antipollution equipment stored by French authorities

Means stored by the French Navy (as of March 1, 1986)	Means stored by the Secretary of State for the Sea (as of April 15, 1986)
• 5,305 m of booms • 16 flexible floating tanks • 4 coastline recovery devices • 16 high sea recovery skimmers • 2,155 m³ of dispersants • 229 tons of hydrophobic chalk • 195 tons of sorbents	• 36,085 m of floating booms • 36 recovery devices • 19 storage tanks • 5 beach cleaning machines • 521 hot water pumps • 4 cold water pumps • 98 emptying pumps • 250 m³ of dispersants • 94 tons of sorbents

Ports and Maritime Navigation by the Secretary of State for the Sea. The equipment is distributed along the coastline in: eight storage centers for the booms, bringing the total length to more than thirty-five kilometers (as opposed to less than fifteen in 1980) and enabling a rapid protection of zones exposed to pollution; and two centers for land cleaning operations (recovery devices, hot water pumps, small scale equipment) in Brest and Marseilles.

Table 1 shows the importance of the equipment stored in the above mentioned stockpiles.

During the antipollution operations, consignment of this equipment to a polluted zone is decided on a central level by the Direction of Defense and Civil Security of the Ministry of the Interior, after approval by the Direction of Ports and Maritime Navigation.

In addition to this equipment there is also that which belongs to the local communities (such as beach cleaning machines), to the petroleum companies with coastal installations, and to other private enterprises.

Personnel training and antipollution exercises. In order to obtain peak effectiveness, the various antipollution agencies on land and at sea have undertaken training programs for personnel who would be involved in pollution operations.

Personnel training can also be achieved while testing an intervention plan during exercises simulating real examples of pollution. In this way, every year the coastal booms from the storage centers of POLMAR equipment are put at the disposal of other services in the framework of an exercise program intended to implement departmental protection plans for the coast.

Also, the conditions for a simultaneous implementation of the POLMAR-MER and -TERRE plans are re-verified every year during the INTERPOLMAR exercises, jointly organized by the Third Maritime Region, and the Prefects of one or several Mediterranean coastal departments.

Finally, let us remember that the various field experiments at sea or on the coastline performed in order to assess and improve the ways and means of an antipollution offensive are also occasions for training antipollution intervention personnel.

Conclusion

Eight years after the *Amoco Cadiz* shipwreck and six years after that of the *Tanio*, France now has a large task force at its disposal in the field of combating accidental oil pollution.

The strength of France's antipollution effort is based first and foremost on the prevention of accidents, thanks to the powerful means of towing which have been installed by the French Navy, and also to the personnel of the CROSS and semaphores who constantly monitor the entire coastline to ensure that the rules of navigation are respected, especially by the vessels transporting petroleum products or dangerous chemical substances.

In addition to the prevention of accidents, an organization for combating major pollution, both at sea and on land, has been established.

This organization takes shape when the POLMAR-MER and -TERRE plans are set into motion in the case of a foreseeable disaster; the efficiency of the plans is systematically reviewed during appro-

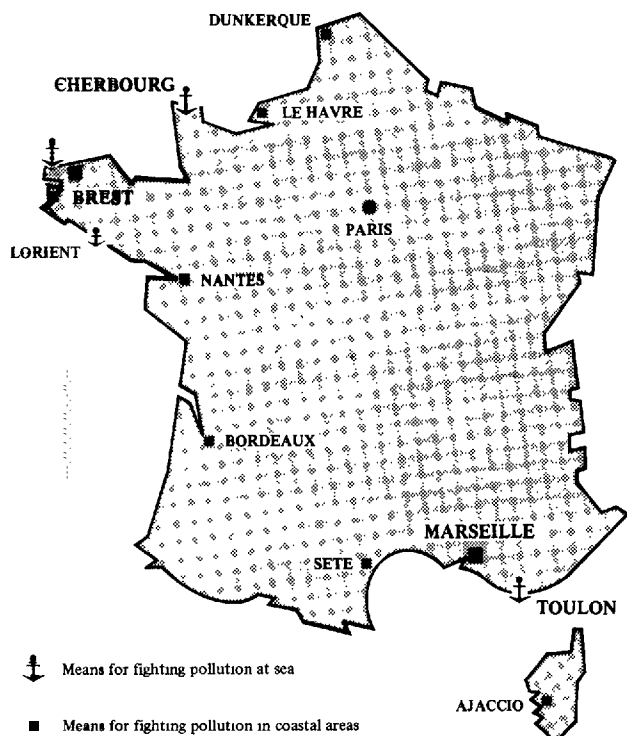


Figure 18. Location of French antipollution equipment storage centers

prate tests. At the heart of the antipollution organization there is a stock of specialized equipment. This equipment is provided to deal with all the aspects of an antipollution response and is to be used by trained personnel. The equipment has been, in most cases, designed, tested and evaluated by CEDRE in close cooperation with French industry.

If the research which deals with equipment is continuing, notably in the field of lightening petroleum tankers and in dispersant spraying techniques, it is also to be noted that efforts are being made in the field of technological awareness.

This suggests that the large research program carried out by CEDRE and its partners during the past eight years has practically achieved its goals and from now on will be focused on the conditions for optimal use of the material and on training of skilled antipollution personnel, to be organized by the appropriate French authorities.

Despite the imperfections of the French organization and technology in the antipollution field, on an international level it seems that the French program is in an excellent position.

This fact is without a doubt related to the already long and unhappy history of our country in dealing with accidental oil spills. As a result of experience, France has developed an exceptional competence and know-how in preventing maritime accidents and in combating pollution.

It is this particular "savoir-faire" which France wishes to make known on an international level and, if necessary, share with other countries.

Acknowledgments

This paper was prepared with the collaboration of the administrations directly involved and notably with Commander Jean-Yves Comby, staff officer of the French Navy, Jean-François Levy of the

Secretary of State for the Sea, Paul Lefevre and Paul Pierron of the Ministry of the Interior.

References

1. Beraud, A., and J. C. Sainlos, 1985. Accidental Marine Oil Pollution: French policy and response. *Proceedings of the 1985 Oil Spill Conference*, American Petroleum Institute, Washington, D.C., pp97-98
2. Circulaire et instruction du 12 Octobre 1978 relatives à la préparation et à la lutte contre les pollutions marines accidentelles. (J.O. du 14 Octobre 1978, pp. 3,570-3,576.)
3. CEDRE, 1986a. Bilan Succinct de Sept Années d'Activités du CEDRE. 177pp
4. CEDRE, 1986b. Guide Pratique de Nettoyage du Littoral à la Suite d'une Pollution Accidentelle. Direction des Ports et de la Navigation Maritimes, CEDRE. 120pp
5. Croquette, J., 1980. French Recommendations for the Use of Dispersants at Sea to Control Oil Slicks. Rapports techniques du CEDRE. 21pp
6. Croquette, J., 1985. The Use of Products Other than Dispersants. Rapports techniques du CEDRE. 10pp
7. Denis, J., and R. Pasquet, 1983. New developments in beach clean-up techniques. *Proceedings of the 1983 Oil Spill Conference*, American Petroleum Institute, Washington, D.C., pp279-282
8. Peigne, G., 1984. Skimmers. Rapports techniques du CEDRE. 60pp
9. Peigne, G., 1985. ECUMOIRE II: Evaluation of three oil recovery devices. *Proceedings of the 1985 Oil Spill Conference*, American Petroleum Institute, Washington, D.C., pp13-18
10. Quinquis, J. J., 1985. Cleaning Rocks and Coastal Structures. Rapports techniques du CEDRE. 8pp

ADAPTING TECHNIQUES TO CONDITIONS: CLEANUP OF A WASTE OIL SPILL

Joseph B. H. Smith
Ferguson Harbor Service, Inc.
P.O. Box 830
Hendersonville, Tennessee 37077

ABSTRACT: Waste oil from an oil recycling facility in Portland, Oregon, was discharged accidentally into nearby Smith Lake. The cleanup effort was hampered by a number of factors, including vegetation in the lake and subfreezing temperatures. The recovery method that proved most successful consisted of washing the oil toward the shore, where it was picked up by rope mop and belt mop skimmers. Approximately 10,000 gal of emulsified oil were eventually recovered.

Topsoil was removed along the shoreline to a depth of 2 in. The property owner (the Port of Portland) also required that 18 in. of soil be removed in the area where the oil had entered the lake. New topsoil was installed and seeded.

On January 16, 1985, a separator pond malfunction at a Portland, Oregon, waste oil treatment and recycling facility resulted in the discharge of 3,500 gal of used crankcase oil. The oil traveled to a ditch and then through a culvert to Smith Lake, where it spread over about an acre of water (Figure 1).

Crowley Environmental Services (CES) was contracted on January 21 to recover the spilled oil. The cleanup effort, including site restoration, lasted 12 weeks. Cleanup operations were hampered both by weather conditions and by vegetation in the spill area.

Preparation for oil recovery

The first action performed by the CES crew was to deploy 1500 ft of 8 × 12 in. Kepner Seacurtain containment boom. The entire spill was contained within 24 h.

On the third day of the cleanup operation, an additional 400 ft of boom was used to divide the spill area into seven sections. Sorbent sweeps (3M Type 126) were used instead of containment boom to section off areas containing little or no oil (Figure 2).

The spill area was approximately 0.25 mi long by 75 yd wide. It consisted mainly of a dense growth of small (up to 5 in. diameter) willow trees, which stood in water up to 6 ft deep. An area 20 ft wide was cleared along the shoreline to allow equipment access and to provide oil recovery sites.

Perpendicular to the shoreline, swaths were cut through the trees to the outer edge of the containment area (Figure 3). The cleared areas were necessary to facilitate the movement of oil to the recovery sites and to provide access for personnel and equipment.

Skiffs were used to transport cut willows back to the shore for disposal. The trees were put into a chipper, which deposited chips into 30 yd dumpsters. Trees too large for chipping were sawed into firewood, which was distributed by the Port of Portland, the owner of the property, to low-income families.

Recovery

Clearing continued, one section at a time, while oil recovery began in the first section that was prepared.

Beginning at the outer edge of the spill area, oil was washed from the dense willow thickets into the access paths. From there it was washed to oil skimmers, which were located near the shore.

The first washing method that was tried was high-pressure pumps in skiffs. This technique proved to be awkward, because of the size of the boats and the inconvenience of handling the suction hose in such tight quarters. A more easily handled alternative was the Hale floating pump, in which the pump, flotation device, and water intake are

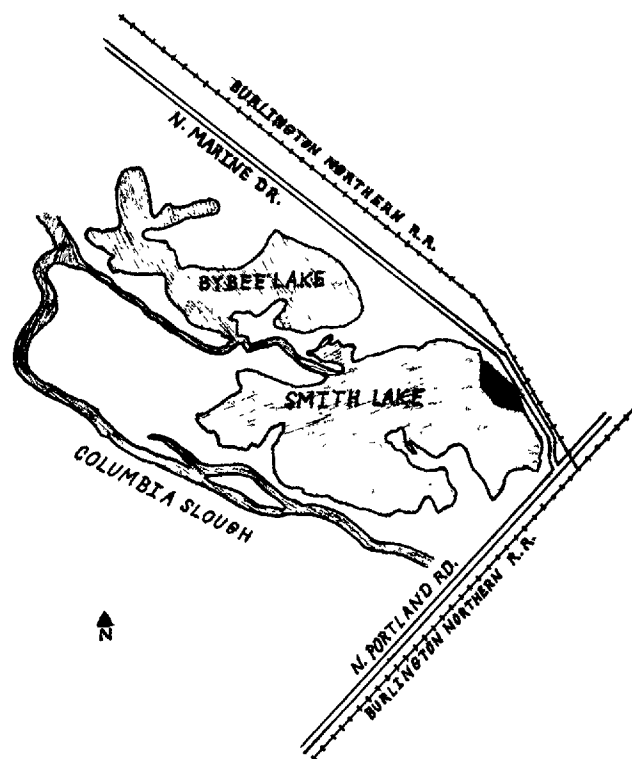


Figure 1. Smith Lake in North Portland with the darkened area in the northeast corner of the lake representing the spill.

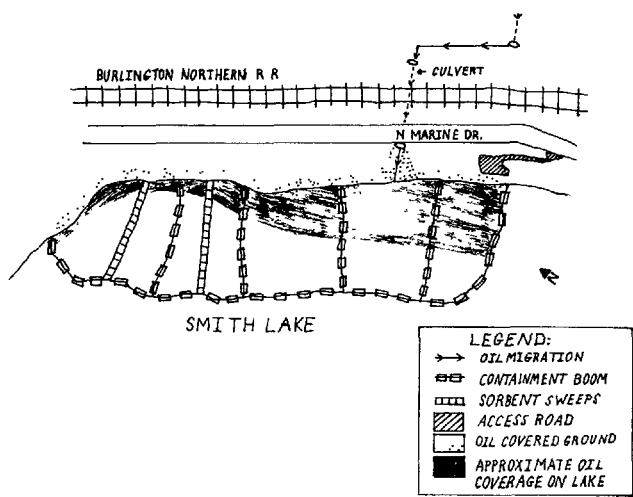


Figure 2. Containment and sectioning of recovery area

all in one unit, thereby eliminating the need for skiffs or suction hoses. (This pump is used by forest fighters to obtain water from shallow streams in remote areas.) The floating pump was used for the remainder of the cleanup operation.

For the first day of recovery, a Skim-Pak (weir type) skimmer was used. This method became impractical when debris from the tree-cutting and brush removal operations, together with broken ice, prevented oil from reaching the mouth of the skimmer. For the skimmer to function it was necessary to have one laborer removing debris from the mouth of the skimmer at all times (Figure 4).

The skimmers used for the remainder of the cleanup were rope mop and belt mop skimmers: the Oil Mop Mark I-4E and Mark II-9DPT and an Alden A3 skimmer. These skimmers effectively recovered oil in the presence of debris and broken ice. Since they did not require an attendant at all times (Figure 3), labor efficiency was increased.

The recovered liquid was transferred from the skimmer sumps to vacuum trucks, where the mixture was allowed to settle and separate. The water was drained back into the recovery area. The oil was measured and then returned to the spiller for processing.

After each section was cleaned, oil sorbent sweeps were placed parallel to the shoreline to prevent oil leaching off the shore from recontaminating the cleaned areas (Figure 5). The sweeps were changed periodically as weather conditions caused oil to migrate from the shore back into the lake.

A few sorbent pads (3M Type 156) were placed in the middle of each clean section to indicate whether oil was getting past the sweep barriers. The sorbents were checked on a daily basis.



Figure 3. View of access path with rope mop skimmer functioning unattended in foreground

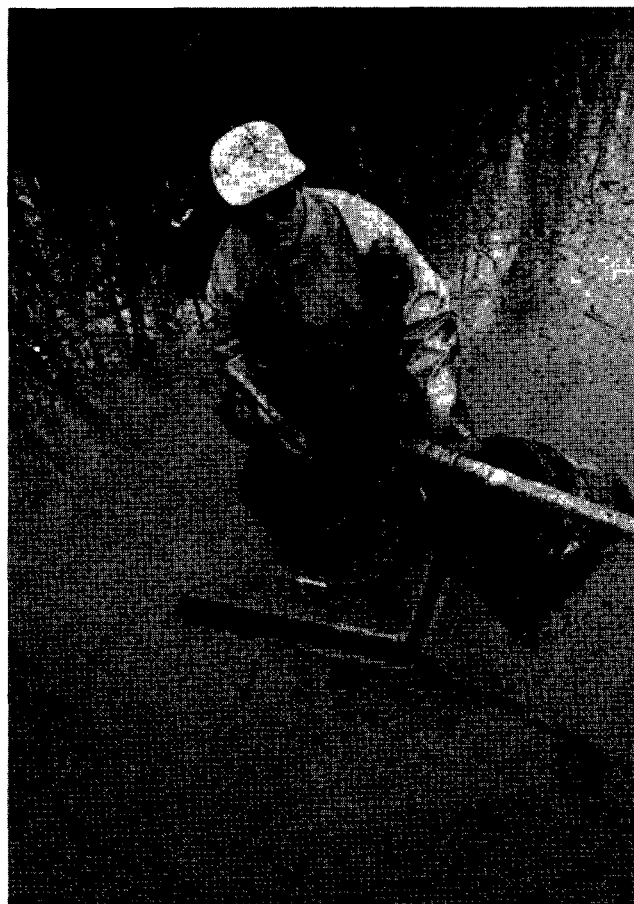


Figure 4. Weir type skimmer and attendant, who was required at all times

The skimmers recovered an average of 320 gal per day. In the 23 days of skimming operations, a total of 7,418 gal of emulsified oil were recovered. In addition, 2,000 to 3,000 gal of oil were picked up by 3M sorbents and debris, which were taken to a nearby disposal facility. The increase in volume of recovered liquid over the amount of oil spilled was attributed to emulsification resulting from both the length of time the oil stayed in the water and frequent precipitation.



Figure 5. Oil sorbent sweeps near shoreline

Shoreline cleanup and restoration

The water level dropped about 1 ft during the course of the cleanup operation, leaving oil on the topsoil in an area 10 ft wide. The Port of Portland required the removal of 2 in. of topsoil in an area extending from the lakeshore to the point where no oil was discernible.

The Port of Portland also required that three soil samples be taken from the 20-ft-wide area where the oil had entered the lake. A control sample was taken from an uncontaminated area nearby. On the basis of the soil tests, the Oregon Department of Environmental Quality (DEQ) ordered the removal of 18 in. of soil.

CES suggested replacing the humus-rich topsoil with primary sludge from a paper mill. The sludge, which has been proven effective as a soil amendment,¹ was to be provided free of charge by the Crown Zellerbach mill in Camas, Washington. Besides being a cost-saving measure, use of the sludge at Smith Lake would provide an opportunity to study its long-term effectiveness as a soil amendment for recontouring after a spill.

Both DEQ and the Port of Portland gave their approval for the experiment, but the spiller's insurer would not indemnify CES against damage that might occur. Instead of using the sludge, CES obtained 660 yd of topsoil from a local supplier, at a cost to the spiller of \$3,960. The topsoil was spread and seeded with fescue.

The access road to the spill site was regraded to its previous condition. Final inspection by the Port of Portland occurred on April 18, 1986.

Reference

1. Einspahr, Dean and Marianne Harder Fiscus, 1984. Paper mill sludge as a soil amendment. *1984 Environmental Conference Proceedings*, pp253-257

M/V ALVENUS: ANATOMY OF A MAJOR OIL SPILL¹

Cdr. Anthony C. Alejandro
U.S. Coast Guard Marine Safety Office
2875 75th Street and Highway 69
Port Arthur, Texas 77640

Lt. Cdr. Jack L. Buri
U.S. Coast Guard Marine Safety Detachment
150 Marine Street
Lake Charles, Louisiana 70601

ABSTRACT: At 12:36 p.m. on July 30, 1984, the United Kingdom tank vessel *Alvenus* grounded with catastrophic structural failure in the Calcasieu River Bar Channel about 11 nautical miles south-southeast of Cameron, Louisiana, creating the largest oil spill from a ship ever encountered in the Gulf of Mexico. The vessel's hull buckled and fractured vertically on both the port and starboard sides and across the tank tops in way of its No. 2 port, center, and starboard cargo tanks. Between July 30 and August 4, 1984, the *Alvenus* discharged approximately 2.7 million gal of viscous Venezuelan Merey and Pilon crude oil into international waters of the Gulf of Mexico. Attempts to contain and recover the oil at sea were rendered ineffective by rough seas and the magnitude of the spill. A well-defined 75-mile slick of oil traveled west from the *Alvenus* for over 100 miles, arriving on Texas beaches on August 3 and 4 between the town of Gilchrist, and San Luis Pass at the west end of Galveston Island.

Beach cleanup crews were reasonably prepared for the massive influx of oil and were able to remove the oil with only minimal environmental damage. Sensitive inland estuaries were spared by a combination of chance (the oil passed inlets during ebb tides) and prestaged booms. However, economic damage was great, since Galveston's resort beaches were heavily oiled during the height of the tourist season. Damage to the vessel was extensive and estimated at \$4.9 million by the vessel's owner. Loss of cargo was estimated at approximately \$1.7 million at \$26.00 a barrel.

The Coast Guard and cleanup crews encountered a major problem when a large portion of the slick approached the shoreline, absorbed suspended solid particles, and sank in the nearshore surf zones at Galveston Island. No effective method of collecting the oil in the submerged state was discovered. Cleanup crews had to wait until the oil beached itself, a process that took several weeks.

Chronology

July 30, 1984. At 12:45 p.m., agents for the tanker *Alvenus* informed the Coast Guard Marine Safety Detachment in Lake Charles that the British registered tankship, en route to Lake Charles, Louisiana, was soft aground and leaking crude oil into the Gulf of Mexico due to substantial hull damage in way of number two cargo tanks (Figure 1). The tanks contained approximately 65,500 barrels of Venezuelan Merey and Pilon crude oil. The grounding occurred at about

12:36 p.m., while the vessel was inbound 11 mi south of the Calcasieu River entrance jetties, between Calcasieu Pass Channel entrance buoys 19 and 20. The grounding was later attributed to a combination of vessel squat and isolated channel shoaling.

At the time of the incident, three Coast Guard marine inspectors from Marine Safety Office (MSO) Port Arthur, Texas, were in the vicinity in a Coast Guard leased helicopter. Their attention was drawn to the then distant *Alvenus* because of the oil slick emanating from the vessel. At 1:15 p.m., they reported to the Marine Safety Office that the *Alvenus* had sustained major structural failure transversely across the number 2 center, port, and starboard cargo tanks. The failure extended from below the waterline on the port side, up to the deck, across the entire deck, and down the starboard side to below the waterline (Figures 2 and 3). The *Alvenus* now was out of the channel and spilling oil which had already formed a heavy, dark, 1.5 mi tear-shaped slick. Based on this information, the incident was declared a major oil spill. The Gulf Strike Team (GST) was alerted and asked to begin assembling equipment and personnel for sea containment and removal of oil. Local Coast Guard personnel contacted numerous companies owning seagoing tank barges equipped with steam coils, to use for storage of oil recovered from the water. One company offered that its tank barge was available and was located in the Sabine River, Texas. Later this same company would refuse to permit oil contaminated with sea water to be pumped into that barge.

At 3 p.m., the agents for the *Alvenus* informed MSO Port Arthur that *Alvenus* Shipping Corp. was assuming financial responsibility for the oil cleanup. The owners contracted Maritime Loss Control to coordinate the pollution response, lightering, and salvage efforts. Prior to this, Conoco Oil Co. of Houston, the owners of the oil, had contacted MSO Port Arthur to offer their assistance should the owners not assume financial responsibility.

By 4 p.m., 14 nonessential *Alvenus* crew members were removed, leaving 20 crew members aboard. Precautions were taken to prevent the outbreak of fire by continuously pumping inert gas into the ruptured number 2 cargo tanks. Decks in way of the damage were covered with foam, and all electrical power forward of the accommodation spaces secured. Heavy discharges of crude oil continued to flow from both sides of the vessel. A major concern was the numerous aircraft employed by the news media, which at times flew within 50 ft of the stricken vessel, prompting the MSO to request the Federal Aviation Administration (FAA) to impose a restricted airspace over the vessel.

Members of the Louisiana Department of Fish and Wildlife, Louisiana Department of Natural Resources, Texas Department of Water Resources (TDWR), Texas Parks and Wildlife (TDPW), U.S. Fish and Wildlife Service (USF&WS), U.S. Environmental Protection Agency (EPA) Region Six, and National Oceanic and Atmospheric

1. Opinions expressed in this paper are solely those of the authors and do not necessarily represent the views of the U.S. Coast Guard.