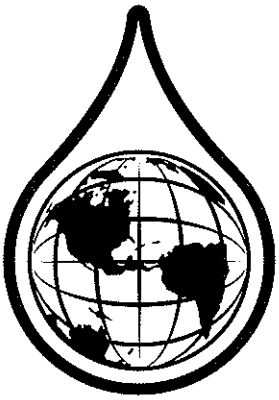
Environment Canada Environnement Canada
Atlantic Region Région de l'Atlantique

Information Bulletin



Sensitivity Mapping

A discussion of the development of Sensitivity Maps and their role in protecting the environment.

Canada

Environment Canada - 25 Years of
Environmental Achievement

Environnement Canada -
25 années de réussites environnementales

March 1997

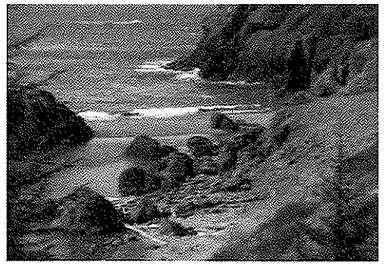
Environment Canada
Environmental Emergencies Section
45 Alderney Drive
Dartmouth, Nova Scotia
Canada
B2Y 2N6

Catalogue Number En40-229/7-1997E
ISBN 0-660-16899-5

This booklet was printed on paper containing recycled fibers.

Introduction

Coastal zones are complex and dynamic environments representing the confluence of three very diverse ecological elements: the land, the sea and the air. In many parts of the world these areas are being subjected to numerous stresses as a result of expanding human populations, extensive and intrusive resource extraction activities, and increased marine traffic. Vessels carrying crude oil and its products represent a significant proportion of this increased traffic. As a result, the potential for oil spills has also increased, as has the consequent threat to the significant biological resources and unique habitats of the coastal zone.



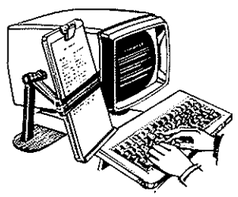
In recognition of the potential for oil spill damage, the identification of sensitive coastal areas and resources has long been an important tool in both oil spill contingency planning and oil spill response operations. The compilation of detailed information on the extent and distribution of oil sensitive resources into an easily accessible and user-friendly format has been the objective of sensitivity mapping efforts for many years.

The Evolution of Sensitivity Maps

One of the earliest methods of presenting large amounts of information on specific features in a given geographical area was the preparation of a resource map. This map allowed users to view resource and human-use data along with sensitive habitats, potential impacts and various other relevant factors. Initially the resource map depicted this information on single sheets, with each sheet representing a different theme. For example, one map would show the fishery resource and a separate map of the same area would show the location of sensitive bird colonies. A series of maps could be grouped together into a resource atlas which, when augmented with complementary text, provided a wealth of data which could not readily be portrayed on maps alone. All of the early sensitivity mapping efforts were based on the use of these resource maps in paper format.

The next development saw the use of transparent sheets on which resource and sensitivity information was plotted. The transparent sheets could then be overlaid on a base map to provide the required information on selected resources. The user could choose the overlay relevant to the specific situation.

These traditional paper maps and transparent overlays provide a comprehensive reference on the marine and coastal environments and resources and, in many cases, portray useful sources of detailed data. They are, however, expensive to reproduce and update, and often, differences in scale between mapping systems make comparison of information difficult.



With the development of powerful personal computers, many agencies are storing environmental information in computer databases, and computers with the appropriate software are being used much more frequently for sensitivity mapping.

Approaches to Sensitivity Mapping

During the past 20 years, considerable effort has been expended by agencies all over the world to develop sensitivity maps and include them in contingency plans. To map marine coastal zones, the five basic approaches described below have been developed:

The Environmental Sensitivity Index (ESI) which has been in use in the United States since 1979, was developed by the National Oceanic and Atmospheric Administration (NOAA). It involves the production of color-coded maps showing shoreline types and sensitive biological and human-use resources. The data elements are represented by specific symbols, and lists of biological species present during each season are included.

The FWS Wetlands Classification System consists of a series of overlays on topographic maps. It is a habitat sensitivity ranking system for saltwater wetlands, and was developed specifically for areas covered by the Louisiana Oil Port Contingency Plan.

The Woodward - Clyde System uses a series of black-and-white maps showing the geomorphology of the shoreline and separate, subjective indices for oil persistence, biological sensitivity, and human-use resources.

The Marine Industry Group (MIRG) System uses black-and-white, page-sized maps with symbols indicating sensitive biological resources, and a facing page of text describing a subjective ranking for sensitive locations.

The British Columbia, Canada System is a computerized database consisting of a hierarchical classification scheme summarizing shore-zone types, and using wave exposure/oil residence indices to define shoreline sensitivity.

All of these currently used methodologies rank the shorelines according to sensitivity; identify oil-sensitive biological and human-use resources, and provide useful information on countermeasures.

Some sensitivity maps assign priorities to areas for protection and/or cleanup actions, while others provide detailed resource and habitat information but leave decisions on assigning priorities to those in charge of response operations. The first approach is more objective and is based on pre-spill planning considerations, which are made under much less stressful conditions than those which exist during an actual spill. On the other hand, when the decision on ranking sensitive areas is left to the person in charge of spill response, actual conditions in the field at the time of the spill can be incorporated into the decision-making process.

Elements of Sensitivity Mapping

Shoreline Types

Most sensitivity maps include a classification of the shorelines based on a variety of environmental characteristics. The shoreline can be characterized by type (e.g. substrate, grain size, tidal elevation), and its sensitivity can be determined from an analysis of the effects of wave and tidal energy; the persistence of oil; the biological productivity of the area, and the ease of clean-up.

Sensitivity maps portray segments of the coastline which are similar in type and composition, and identify the preferred options for cleanup.

In general, the lowest sensitivity rankings are assigned to shorelines which:

- are exposed to high energy waves and tidal currents on a regular basis
- are located where strong wave-reflection patterns occur

- have an impermeable substrate, like bedrock
- have an intertidal slope of 30 degrees or greater, which results in a very narrow intertidal zone
- are populated by attached organisms which are hardy and accustomed to high energy environments

Low sensitivity shorelines include exposed rocky cliffs, man-made retaining walls and breakwaters. Sensitivities increase as the permeability of the substrate increases from bedrock to fine-and-medium-grained sand to coarse-grained-sand to mixed sand and gravel, and as exposure decreases from fully exposed cliffs and bluffs to sheltered tidal flats and vegetated wetlands. Wetlands such

as marshes are the most sensitive shoreline types because of the high biological activity, the difficulty of cleanup efforts, and the potential for long term damage.

A knowledge of the sensitivity of the shoreline provides responders with important information on the preferred clean-up methods. It is, however, only one element to be considered in developing response options. For example, although an exposed rocky shore may be assumed to have a low priority for protection it may, in effect, be highly sensitive if it supports a seabird colony in the midst of its breeding season. Similarly, a sandy shore which might be considered only moderately sensitive because it could be easily cleaned may, in reality, be highly sensitive if it is a popular tourist amenity. It is therefore important to include other elements as well when developing sensitivity maps.

Biological Resources

Literally hundreds of animal and plant species may be at risk when an oil spill occurs. On sensitivity maps various groupings of these species are represented by specific patterns and/or symbols. For example, the symbol for raptors includes falcons, osprey, and/or bald eagles. The use of representative symbols avoids unnecessary clutter on the map and renders the maps much more useful to decision-makers.

Many marine and coastal species are wide ranging and may be present over a very large area at any one time. Since maps showing the entire range of such species would be of little use to those responsible for determining protection priorities, most sensitivity maps show only those areas at greatest risk. These include feeding and breeding grounds; seabird colonies; estuaries important to migrating shorebirds; birthing, resting or molting areas; turtle nesting beaches; bird rookeries; major migration routes, and areas where there are documented sightings of threatened or endangered species.

The biological resources commonly shown on sensitivity maps include:

- mammals, both marine and terrestrial (e.g. whales, dolphins, seals, walruses, polar bears)
- birds (e.g. pelagic or offshore birds, diving birds, shorebirds, waterfowl, raptors)
- fish (e.g. pelagic fish, groundfish)
- shellfish (e.g. crustaceans, molluscs)
- reptiles (e.g. sea turtles)

Human Use Resources

Human use resources are often at risk following an oil spill. These resources, identified on sensitivity maps by appropriate symbols, include:

- high use recreational beaches
- natural resource management areas, parks, camping sites, sport fishing areas, scuba sites

- marinas, anchorages, harbours, slipways or boat ramps
- residential and cottage uses
- resource extraction sites, subsistence fishing harvest sites, water intakes, mining locations, log storage sites
- special areas, archaeological and/or historical sites, important upwelling area

Countermeasures Considerations

In developing spill response measures and evaluating appropriate protection activities, it is necessary to have as accurate a picture as possible about the status of oil spill countermeasures. Information on where dispersants can be used and where they are stored; where booms can be deployed and where they are stockpiled; where boats can be launched and helicopters landed would all be included on sensitivity maps or in text accompanying them.

The legend from a typical Sensitivity Map developed in the Atlantic Region is shown on page 6. The legend shows the many elements which can be included on a sensitivity map.

How Sensitivity Maps Are Used

Contingency Planning / Spill Response

When preparing spill response contingency plans, sensitivity maps can be used to designate those areas which should be protected in the event of a spill. Contingency planning may also involve the development of shoreline cleanup strategies based on the shoreline type and uses, important information which can be obtained from sensitivity maps. Seasonal differences in the presence of resources are also often portrayed on sensitivity maps. These differences can be significant, and can result in changes to the description of the resources at risk. Contingency plans would then identify different response strategies for different times of the year based on an analysis of the sensitivity maps.

During a spill response, the data contained in sensitivity maps can be used to make time-critical decisions such as whether or not to use chemicals to disperse an oil slick or whether to deploy exclusion booms to protect certain vulnerable resources. In addition, sensitivity maps can be used to determine the need for and the extent of special actions to be incorporated into the spill response. For example, exclusion zones may need to be established for aircraft in order to eliminate the disruptive impact of engine noise above bird rookeries and marine mammal haulouts during nesting and pupping season. These areas can

TYPICAL MAP LEGEND

Atlantic Regional Sensitivity Mapping Program

BIOLOGICAL RESOURCES

Boundaries (Used in GIS) | Basic Symbols | Endangers Species

Mammals
- Shore Associated Mammals
- Marine Mammals:
  - Cetaceans (whales, dolphins, porpoises...)
  - Sea Otter and Pinnipeds (sea lions, seals,...)
- Major Migration Routes

Birds
- Pelagic
- Coastal Zone Birds (diving birds)
- Colony
- Shore Birds
- Raptors
- Major Migration Routes

Fish
- Spawning area
- Pelagic
- Groundfish
- Migratory
- Major Migration Routes

Shellfish
- Crustacean
- Mollusk

Vegetation
- Land
- Marine

OPERATIONAL CONSIDERATIONS

- Land Access Site
- Foreshore Flats (Approach Concerns)
- Rocky Reef (Approach Concerns)
- Exposed Rock
- Lighthouse
- Boat Launch
- Automated Weather Station
- Helipad
- Clean-Up Equipment Depot
- Marine Navigation Aid
- Marine Navigation Light

HUMAN-USE RESOURCES

Recreation
- Small Craft Harbour
- Marinas
- Anchorage Sites
- Residential / Cottage Use
- High-Use Recreational Beach
- Camping
- Scuba Diving Site
- Sport Fishing

Resource Extraction
- Water Intakes
- Aquaculture
- Subsistence
- Mining

Special Area
- First Nation
- Park (type is specified in the database)
- Archeological / Historical Site
- Important Upwelling Area

Environment Canada - Atlantic Region
Sensitivity Mapping Program

be plotted on maps and distributed to pilots.

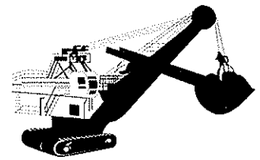
The complexity of the decisions which must be made quickly and under the stress of an emergency situation is daunting. Economic realities have to be weighed against ecological and social resources, and inevitably some compromises have to be made. Decisions on shoreline cleanup techniques can have far-reaching, environmentally damaging and expensive consequences. When a spill occurs, having the relevant resource information on one set of maps greatly enhances the initial assessment of the spill situation, and allows a rapid evaluation of the potential impacts of the spill. Sensitivity maps facilitate the identification of the most important and vulnerable coastal areas and resources, and enable the development of rational and reasonable shoreline protection priorities and cleanup techniques.

Training

For oil spill response training activities to be most effective, they must mirror what could happen in real-life situations. By providing a valuable tool for developing and describing credible and practical spill scenarios, sensitivity maps enable trainers to create the best simulations for training purposes.

Environmental Impact Analyses

Sensitivity maps can also be valuable to developers and/or project proponents involved in preparing environmental impact analyses for proposed developments which could affect coastal areas. Such developments include



onshore and offshore construction projects, transportation and pipeline projects, and resource exploration and extraction activities. The wealth of relevant data on biological, physical and social resources incorporated in sensitivity maps can lead to a much more focussed environmental impact analysis. In addition, because much of the required data is already available in a user-friendly format, the need for costly and time consuming field research and analysis is minimized.

Coastal Zone Management

Sensitivity maps are of use to coastal resource managers involved in activities related to the protection and wise use of coastal resources. While the maps contain large amounts of information on both resources and conflicting demands, they can also expose weaknesses and gaps in the available information base for a particular area, thus helping to focus research efforts by experts.

When regularly updated, sensitivity maps can also provide an excellent record of the "status quo", and a method of determining the effectiveness of policies and programs implemented to protect and enhance the coastal zone.

Other Uses

Sensitivity maps can be used to educate members of the public on the many environmental issues that need to be addressed in the coastal zone and, in this regard can be a

valuable asset in socioeconomic planning activities for communities and regions.

They are also useful in developing status reports and/or briefing materials for response personnel and others at the time of a spill.

How Sensitivity Maps Are Prepared

It is obvious from the preceding discussion that an extremely wide variety and large volume of data is required to complete a sensitivity map for a specific region or area. At the heart of every mapping project, however, is the base map, which shows major features but which is not cluttered with numerous themes, labels and symbols. Base maps usually include coastlines, political boundaries, significant cultural amenities, and hydrographic features.

The scale of the base map is an important issue which must be decided very early in the sensitivity mapping process. As the scale of the base map increases, the costs of acquiring and analysing the data required for the rest of the exercise also increases. Experience to date indicates that a 1:50,000 scale base map is required to meet the demands of emergency responders.

Once the base map is completed, detailed information is obtained for incorporation into the mapping system. When paper maps are used, this information is recorded on individual transparent sheets, each of which addresses a particular theme. By overlaying selected sheets on the base map, information specific to the needs of decision-makers can be obtained. When computer systems are used, the required layers or themes can be electronically generated, overlain on the base map and viewed by the users either on the computer screen or on hard copy printouts.

In most cases, at least some of the data required for sensitivity maps is available from existing data sources like topographic maps, charts, photographs and scientific publications. Much of the required environmental data is held by organizations such as conservation groups, research institutions and resource agencies responsible for commercial and sustenance harvesting of fish, archaeological sites, marine birds, marine mammals, fish, and shellfish.

This pre-spill inventory type data is only one information source from which sensitivity maps can be prepared, but it is the one on which the majority of sensitivity maps rely almost exclusively. Other information sources include "real-time" data and community and/or stakeholder input.

Real-time data refers to the information obtained at the time of a spill, and includes such things as sea-state, wind speed, and shoreline contamination. The benefits of this type of information are obvious and, with increasing abilities to survey sensitive

resources and immediately plot results, real time data can play an important role when using sensitivity maps in emergency situations.

Where data gaps exist, additional field work must be conducted to complete a sensitivity map. Such work may consist of field surveys, literature research, aerial photography, or remote sensing.

The Basic Requirements of a Sensitivity Map

Sensitivity maps which are of most benefit to users are those which permit a precise determination of the vulnerable resources; facilitate an accurate determination of ecologically sensitive zones; provide useful data for decision-making, and enhance the ability to specify areas that require special monitoring. In order to be useful and effective therefore, sensitivity maps must meet certain basic requirements. They should:

- **convey an instant message.** To be of real assistance to the end user the map must convey information which is immediately obvious. In an emergency situation, the locations and relative sensitivities of potentially affected resources should be clear so that valuable time is not lost trying to interpret the map.

- **not be so cluttered with information that they are confusing to the user.** There are definite benefits associated with the layering capability of most sensitivity mapping systems. Since only a specific amount of information is recorded on each sheet or layer, users can access the data they need and eliminate unnecessary and/or irrelevant details.

- **use suitable symbols which don't conflict with each other.** The end user shouldn't have to struggle to understand the information on the sensitivity maps. The base map and associated layers should provide just enough information to convey the message in a clear and organized fashion, depicting the various classes of data in the correct order and maintaining their relative degree of importance. Symbols should be easily understandable pictographic characters.

The Status of Sensitivity Mapping in Canada

Oil spills from the NESTUCCA off Washington State in December 1988 and the EXXON VALDEX in the Alaskan panhandle in March 1989 highlighted the need to evaluate and improve the state of marine preparedness in Canada. In 1989 the Premier of British Columbia commissioned a study into the

transportation of oil and oil spills in the waters off the province's coast. In the same year the Prime Minister of Canada commissioned a Public Review on Tanker Safety and Marine Spill Response Capability. The B.C. study determined that the sensitivity maps which were available during the response to the NESTUCCA spill contained complex and detailed inventories of biological resources which were difficult to interpret and of limited use. The report recommended that provincial and federal authorities collaborate on a focussed effort to improve mapping programs in the province and across the country.

The report of the national Public Review Panel on Tanker Safety and Marine Spill Response concluded that Canada and Canadian waters and coastlines were at serious risk from oil pollution, and that the capability to adequately respond to oil spills was lacking. It identified sensitivity mapping as an important objective and one which should receive government support.

As a result, the federal government made a commitment to improve Canada's overall response capability, and assigned resources for the development of an improved national sensitivity mapping program.

The objectives of the National Program are to:

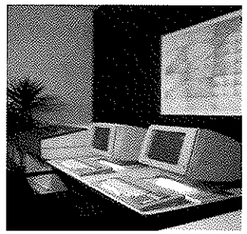
- establish the content of and develop a national protocol for sensitivity maps
- develop appropriate standards to guide sensitivity mapping efforts
- develop plans to produce sensitivity maps for high priority areas
- evaluate and recommend user-friendly computer systems and software for use in the sensitivity mapping program

Environment Canada, the lead agency for the national program, has developed an approach that establishes and enhances partnerships with other groups within Environment Canada (e.g. the Canadian Wildlife Service); federal and provincial government resource agencies; the oil industry, and international agencies involved in similar efforts.

To date, sensitivity mapping systems have been prepared for much of Canada's coastal zone through efforts led by each Environment Canada region in partnership with other agencies. Significant progress has been realized in establishing coastal protection priorities and mapping protocols; in evaluating and selecting computer aids to mapping projects, and in implementing regional mapping efforts.

In order to avoid duplication in efforts, existing data is compiled and entered into the system. Where information does not exist, data is collected and digitized.

In meeting its sensitivity mapping responsibilities, Environment Canada employs a computerized mapping system to fully



realize the many advantages that this technology has. Scale is flexible and it is possible to update information as required.

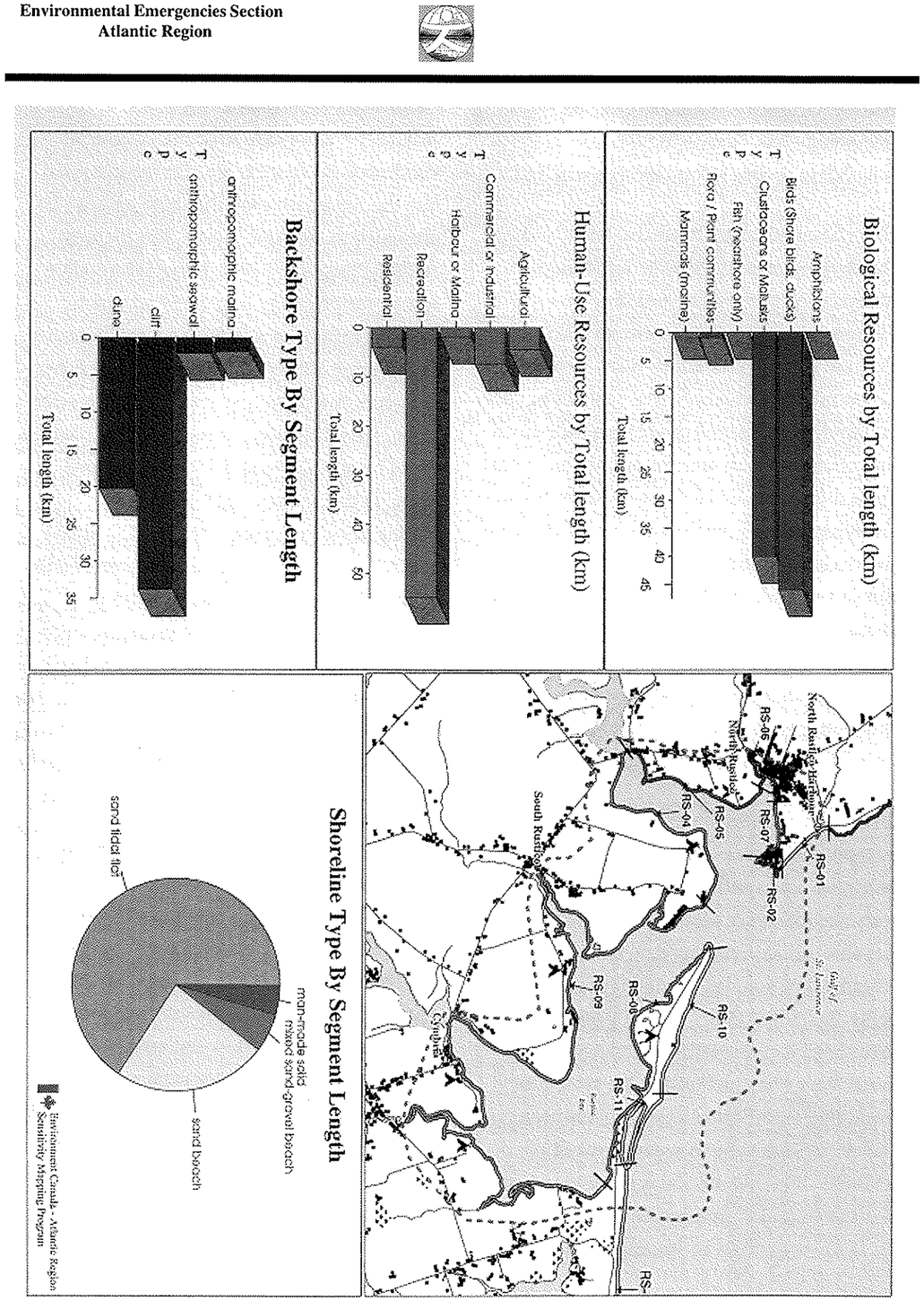
Significant advances have also been made in the development of software for storage, analysis and retrieval of data. For example, Geographic Information Systems (GIS) and desktop mapping packages allow a more rapid, powerful and comprehensive analysis of data; an iterative evaluation of changing scenarios and circumstances, and the overlaying of data from different sources. In an oil spill situation, for example, a responder may be interested in the fishery resource in a particular area, and the software allows that information to be retrieved and displayed along with other relevant features in that area. GIS is a powerful tool in the development and use of an interactive management system. It is, however, only as useful as the data it contains.

In the Atlantic Region, the MapInfo/MapBasic computer software was chosen as the desktop mapping package because it was judged to be very flexible, very user-friendly and was capable of incorporating data from a number of other data sources. Digital topographic base maps at 1;1,000,000, 1:250,000 and 1: 50,000 have been incorporated and a range of data bases have been included in the system as well. Each segment of shoreline has been classified according to a standardized classification scheme and is represented on the map by a colored line and/or code which is linked to records in an associated data base.

Other types of sensitivity data such as natural, cultural or man-made structures which are vulnerable to oil spills are also incorporated into the Atlantic region data base and can be presented as thematic layers. Any element could be linked to a descriptive information source which can be accessed and which includes information useful in a spill situation. For example, for a map which showed fishery resources in a particular area, data on species name, spawning time, expert resource contacts could be accessed and displayed. In some cases, in the Atlantic regional system, photographs have been stored on CD-ROM and can be readily accessed from icons on the computer screen as can videos taken of selected shoreline areas. A typical printout showing the capabilities of the system is shown on Page 12.

Summary

In the event of an environmental emergency which threatens coastal habitats and resources, spill responders use a variety of tools and technologies to ameliorate the potential for adverse impacts. Sensitivity maps are one important element in a comprehensive spill prevention, preparedness and response program. They incorporate catalogues of ecologically sensitive areas and seasonal vulnerabilities of various physical, biological and cultural resources. Sensitivity maps provide users with an important and dynamic tool to aid them in making vital decisions for the protection of our priority coastal resources.



FOR FURTHER INFORMATION CONTACT:

IN THE ATLANTIC REGION

Regional Environmental Emergencies Coordinator
Environmental Protection Branch
Environment Canada
4th Floor, Queen Square, 45 Alderney Drive
Dartmouth NS B2Y 2N6
Phone 902 - 426 - 2576
Fax 902 - 426 - 9709

IN NEW BRUNSWICK

New Brunswick Provincial Manager
New Brunswick Environmental Protection Office
Environment Canada
77 Westmorland Street, Suite 450
Fredericton NB E3B 6Z3
Phone 506 - 452 - 3286
Fax 506 - 452 - 3003

IN NOVA SCOTIA

Nova Scotial Provincial Manager
Nova Scotia Environmental Protection Office
Environment Canada
5th Floor, Queen Square
45 Alderney Drive, Dartmouth, NS B2Y 2N6
Phone 902 - 426- 5601
Fax 902- 426- 3654

IN PRINCE EDWARD ISLAND

Prince Edward Island Provincial Manager
Prince Edward Island Environmental Protection Office
Environment Canada
97 Queen Street
Charlottetown PEI C1A 4A9
Phone 902 - 566 - 7042
Fax 902 - 566 - 7279

IN NEWFOUNDLAND AND LABRADOR

Newfoundland and Labrador Provincial Manager
Newfoundland and Labrador Environmental Protection Office
Environment Canada
P.O. Box 5037
St. John's NL A1C 5V3
Phone 709 - 772 - 5488
Fax 709 - 772 - 5097

Credits: This booklet was prepared by Duerden & Keane Consultants Inc.
for Environmental Emergencies Section, Environment Canada, Atlantic Region.

Published by the Authority of the Federal Minister of the Environment.