Environmental Monitoring after *Nakhodka* Oil Spill and Utilization of GIS/GPS and Hi-resolution Satellite Images

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ABSTRACT

One main purpose of environmental monitoring after oil spill is developing ESI (Environmental Sensitivity) Maps. Environmental impacts caused by the spilt oil are strongly depending upon the coastal topology and geology. Monitoring all impacted shorelines is almost impossible; using high-resolution satellite images such as IKONOS greatly contributes to improve the efficiency of on-site researches, at the same time, reliability of ESI maps.

KEYWORDS: Oil Spill, Environmental Monitoring, Satellite Image, ESI map, GIS

INTRODUCTION

The Russian tanker "Nakhodka" spilled some 8,600kL of heavy C oil and polluted more than 2,000 kilometers of shoreline facing the East Sea (the sea of Japan). This includes fishing areas where local people rely on marine resources for sightseeing and fishery.

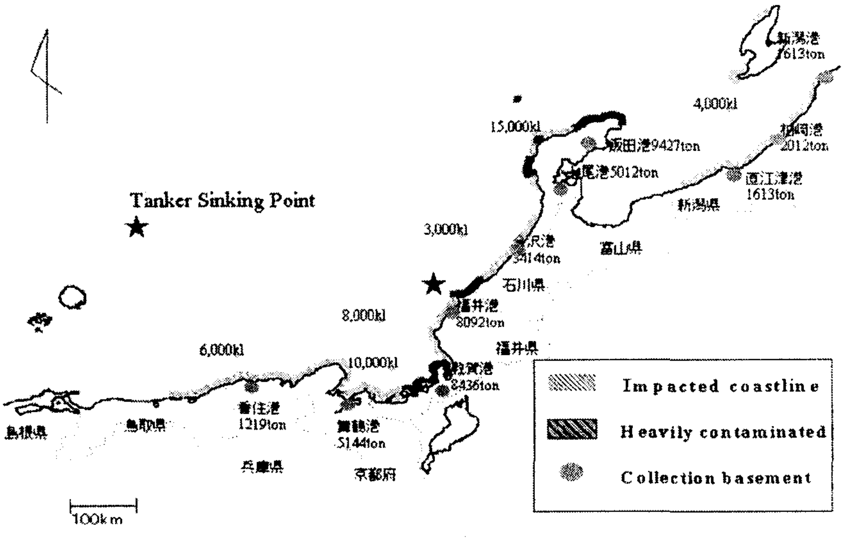

Fig. 1. Location of contaminated area

This accident was happened on January 1997, soon after the spill, Japanese local and central government started environmental monitoring researches for examining the oil-impacted shorelines. Those research projects has already finished and concluded "conspicuous impacts were not detected", only two years after the accident. In these situations, our environmental monitoring researches were set up six months after the spill and still continue till today. Main purposes of our researches are 1) observing oil residue and examining the relation between shoreline topology, sediment and geology 2) monitoring environmental impacts toward coastal ecosystem 3) land measurement for detecting the influences of oil recovery works. Our final goal is to develop ESI maps covering Japanese all shorelines based on our research.

OIL RESIDUE AND SHORELINE TYPES

As Glundlach and Hays (1978) have pointed out that oil residue and intensity of environmental impacts are strongly depending upon the shoreline topology, geology and sediment. Figure 2 shows geological type of shoreline for our study sites.

Table 1. ESI Guideline developed by NOAA

ESI RANK	SHORELINE TYPE
1A	Exposed Rocky Shore
2A	Exposed Wave-cut Platform
3A	Fine-to Medium Grained Sand
4	Coarse-grained Sand Beaches
5	Mixed Sand and Gravel Beaches
6A	Gravel Beaches
7	Exposed Tidal Flats
8A	Sheltered Rocky Shores
9A	Sheltered Tidal Flats
10A	Salt-and Brackish Water Marshes

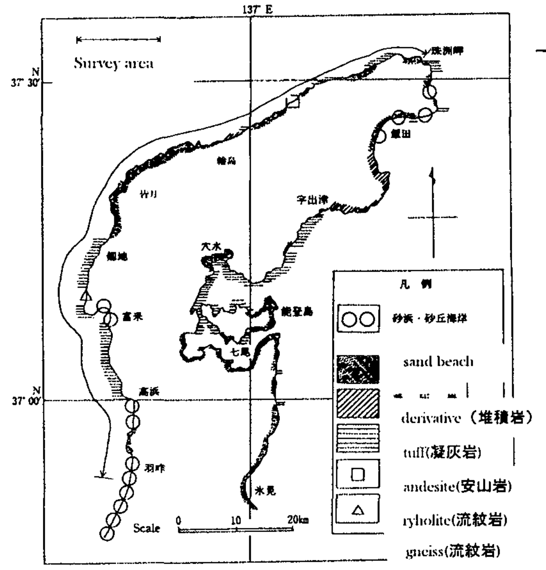

Fig. 2. Geological type of shoreline of NOTO Peninsular

Following Glundlach's concepts, NOAA (National Oceanic and Atmospheric Administration of the United States) developed ESI (Environmental Sensitivity Index) guidelines for classifying the types of shorelines. Table 1 shows the current guideline shown by their web site. In this table, shorelines with larger number tend to be more damaged because oil stays longer on these beaches.

Environmental Monitoring Research

Since September 1997, six month after all recovery works done by the government were finished, we set up on-site environmental monitoring research. SOS (Shoreline Oiling Summary) form developed by Environmental Canada is introduced to this research. This form is developed for describing and recording oil residue, distribution and intensity with "standardized abbreviation".

SHORELINE OILING SUMMARY (SOS) FORM

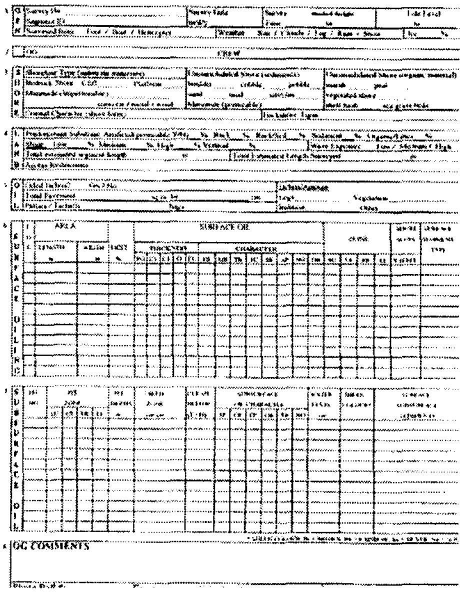

Fig. 3 SOS Form (Owens & Sergy, 1994)

Table 2. Shoreline Oil Terminology/Codes

Std. Abbr.	Description
SAP	Subsurface asphalt pavement (cohesive)
OP	Oil-Filled Pores (pore spaces are completely filled with oil, to the extent that the oil flows out of the sediments when disturbed). May also consist of weathered oil such as a buried lens of asphalt pavement
PP	Partially Filled Pores (pore spaces partially filled with oil, but the oil does not flow out of the sediments when disturbed)
OR	Oil Residue (sediments are visibly oiled with black/brown coat or cover on the clasts, but little or no accumulation of oil within the pore spaces)

SOS forms are helpful for recoding the status of oil residue, and keeping these recodes, we can know the changing of the status with time series. But the purpose of judging relative intensity of each oiled site, SOS form seems to be insufficient. For compensating this inconvenience, scores are allotted to each code for both surface and subsurface oil residue. Then the maximum score 80 gives the severest status of oil residue. For judging intensity and density of oil residue, a template shown by Fig. 4 is used.

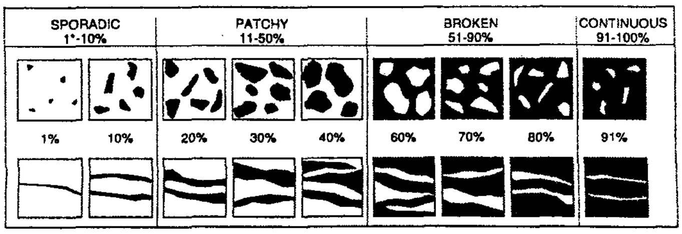

Fig. 4. Template used for evaluating oil residue (Michel et al., 1998)

Table. 3. Scores for each stage of oil residue

Surface Oil residue/coverage	Score	Subsurface	Score
Sporadic	10	Trace/Stain	10
Patchy	20	Cover / Coat	20
Broken	30	Partially filled pores	30
Continuous	40	Oil filled pores	40
		Asphalt pavement	20-40

USING GPS/GIS FOR MONITORING RESERCH

For carrying out on-site researches periodically, each time we came across the some difficulties. The biggest problem is how we identify the monitoring point at the research sites. First, we set the stakes for gardening as landmarks on the monitoring point. But most stakes were lost because of drift sand. We started use GPS and GPS for dealing with this problem. In April 1998, Japan coast guard has started mid-wave differential beacon broadcast, then the accuracy of positioning has exceedingly improved.

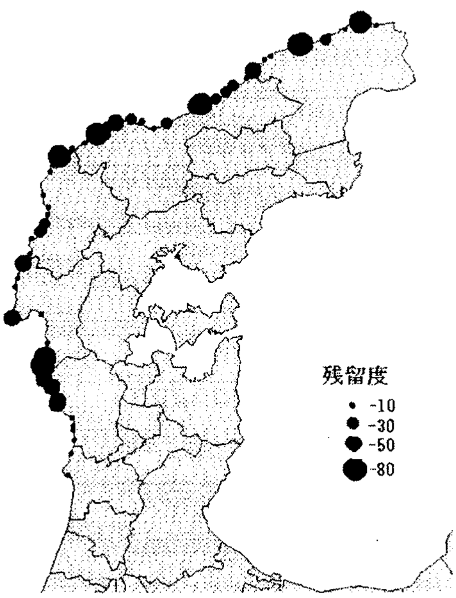

Fig. 4. Intensity of oil residue in 2001 at Noto Peninsular

GPS/GIS can also improve the efficiency and reliability of environmental monitoring research. Carrying dGPS equipment connected to the mobile computer, study points and lines at the beach are found quickly and easily. As well as precise positioning, GIS can also manage research results with high efficiency.

DEVELOPING ESI MAP BASED ON RESEARCH RESULT

When a shoreline is threatened by an approaching oil spill, responders must quickly decide which locations along a shoreline to protect from the spill. That is, they must set their protection priorities. To do this, they first identify the places that are most important to protect, and then determine which of those locations they can protect. ESI map has been developed for supporting these decisions.

Putting monitoring research data onto GIS, we can clearly know the relation between shoreline types and the intensity of the environmental impacts. This information, in itself, means ESI.

ESI map has three "layers" of information shown by Fig. 5., 1) base map 2) shoreline environmental sensitivity index line 3) location for important manmade structure such as water intake, endangered wild animal habitats, so on.

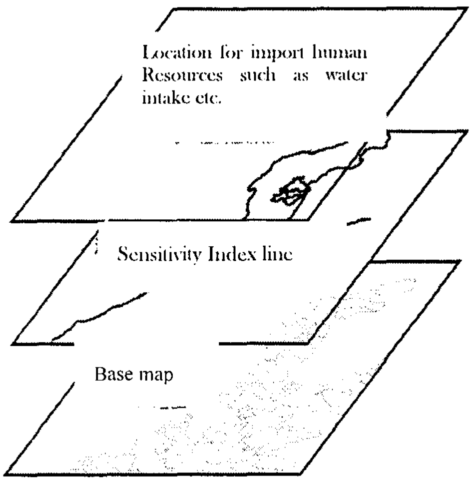

Fig. 5. Structure of ESI map

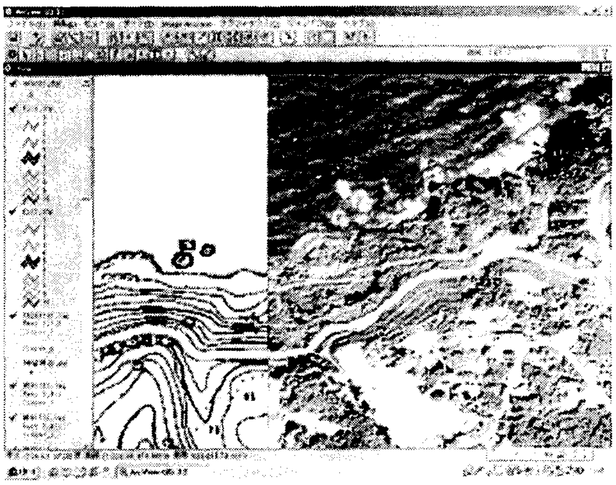

Fig. 6. ESI map and satellite image (IKONOS).

For constituting these three layers, hi-resolution satellite image such IKONOS is highly available. Some shorelines cannot be accessible because all of them may not have approach roads or sometimes they are too steep to approach. Hi-resolution images are good enough to identify the shoreline type for classifying the shoreline following NOAA's ESI guideline. Using geo-corrected images on GIS; it is possible to raise the convenience (see Fig.6. right part of this figure is shown base map image and right side is geo-corrected IKONOS image put on the base map).

CONCLUSION

ESI map is indispensable for decision makers to plan effective oil recovery works. These works are to be selected carefully taking account of shoreline type, natural condition including wild animals and plant vegetation, human resources and fishery. Moreover, these decisions have to be done soon after the spill event occur. Considering these conditions, ESI map should be prepared in the times of peace based on the lessons of actual oil spills. From our experience of Nakhodka, GIS/GPS, hi-resolution satellite images and their multiple use surely contribute to improve the reliability of ESI map.

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