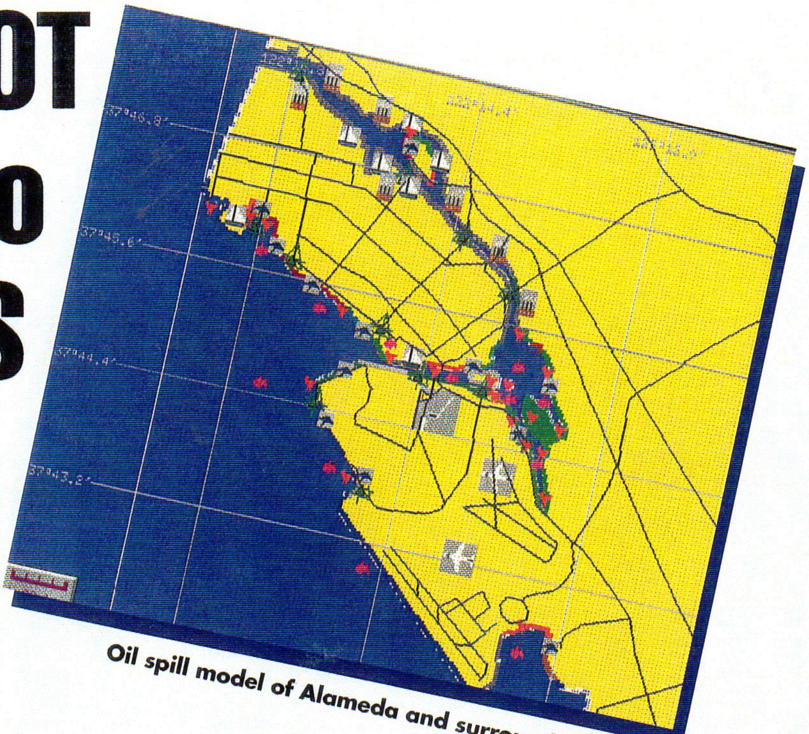
Use of SPOT Imagery to Obtain GIS Input for OIL SPILL MODELS



Oil spill model of Alameda and surrounding areas.

By H.H. Davis, P.D. Caldwell, P.B. Goodwin and Eric Karver

Satellite imagery is a cost-effective tool for creating and updating basemaps of coastal zones, especially where existing maps and aerial photographs are unavailable, are out-of-date, or provide limited information. Reliable maps of coastal zones are particularly important for oil spill modelling programs. Digitally merging same-day SPOT panchromatic and multispectral imagery provides maximum spatial resolution and permits excellent color differentiation of coastal zone features. This combination adequately discriminates individual features, including pipelines, offshore platforms, storage tanks, jetties, and shoreline type. The SPOT images can be interpreted within a workstation or PC environment and the digital vector map downloaded into a sophisticated oil spill modelling program. This program resides on a PC and is designed to facilitate oil spill simulations, spill response contingency planning, and actual spill incident response. A GIS capability within the modelling program incorporates the SPOT interpretation, information gathered in the field, and geographical data of a specific area (location of production platforms, pipelines, marine terminals, lease boundaries, sensitive environmental areas, etc.). Chevron is using the nearby San Francisco Bay as a convenient site for evaluating our interpretations, accomplishing field work, and streamlining our computer processes. This procedure can then be utilized in Chevron's overseas operations.

Published hydrographic charts and maps typically display out-of-date information concerning the geographic extent and location of both natural and man-made features in coastal zones, thus degrading the usefulness and validity of an oil spill model. We have found that SPOT panchromatic and multispectral images are well suited for discriminating individual coastal zone features, including pipelines, offshore platforms, storage tanks, jetties, and shoreline type. These images are interpreted, classified and the resultant digital map is loaded into an oil spill modelling program (the Worldwide Oil Spill Model - WOSM - developed and owned by a consortium of government agencies and international and domestic private companies). In addition, maps of facilities and infrastructure, lease boundaries, environmentally sensitive areas, etc. are routinely loaded into WOSM. A GIS capability integrates this geographical information with other algorithms that model characteristics of the petroleum product, weather conditions, and oceanographic conditions.

In most areas where Chevron operates, verification of field conditions is difficult and expensive. Chevron is using the Alameda Estuary located on the eastern shore of San Francisco Bay, as a convenient area to help correlate coastal zone signatures and patterns as seen on SPOT images with actual field conditions. We hope that this will improve the confidence we have in our interpretations of SPOT images overseas.

Figure 1: SPOT panchromatic merged with SPOT multispectral imagery, 10m resolution. Rotated into map space using U.S. Tiger data and GPS points. Initial interpretation of physical features (i.e. marshes, sandy beaches, mud flats, deep water channels). (SPOT © 1991 CNES)

THE STUDY AREA

Immediately west of the city of Oakland in San Francisco Bay is the island community of Alameda. This heavily urbanized island has a wide variety of shoreline types and utilizations. Along the southwest shore are a marina and more than 4 km of beaches. On the northeast side are marinas and industrial water front. Arrowhead Marsh and associated mud flats to the southeast is one of three wildlife and bird sanctuaries along the shore. The southern portion of the study area is the edge of Oakland International Airport. The runways are protected by rock seawalls. Less than 200 years ago Alameda was a largely uninhabited marshy sandbar surrounded by oyster beds. For the purposes of this study, we have interpreted the 80 km^2 study area as having nine of the 10 different shoreline types which the oil spill model incorporates (Table 1).

The study area has shoreline types of sufficient extent (>50 m^2 cells), to permit isolating each type into a training site. Tidal shoreline types are most common. The three sand types were defined in the field by sight and not rigorous sieve size. The source of the fine sand is local, however, coarse sand has been imported, and in some areas, has mixed with the fine sand. The term "marsh" is so generic in our oil modelling program that almost any wet-footed plant community within a fresh/salt water environment qualifies.

Our classification of shoreline into exposed rocky, tidal and wavecut types is tenuous because these features are within San Francisco Bay and not facing open ocean. The rocky shorelines are all man-made and are exclusively of the seawall type. Some are more exposed to wave action than others. Engineers claim that the seawalls have a minimum life of 50 years. We have interpreted an exposed wavecut shore where the bathymetric topography is comprised of man-made compacted dirt and debris rising some 30 feet at a 45 degree angle. This wavecut shore abuts an estuarian channel with a 1-2 knot tidal flow. During storms this shoreface shows signs of active wave or bank cutting.

Aerial view of Alameda Island.

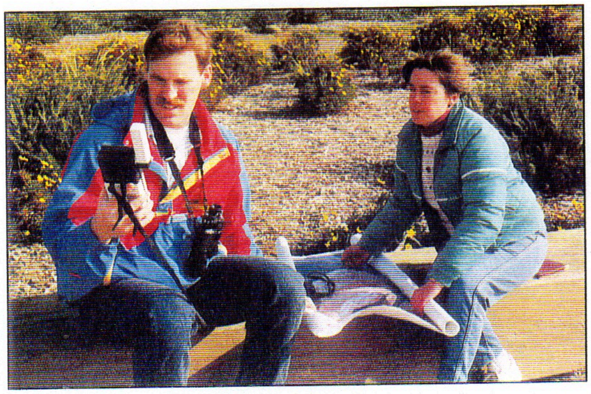
METHODOLOGY

SPOT panchromatic and multispectral imagery were acquired on Jan. 24, 1991 over the eastern San Francisco Bay. Ground control points (GCPs) were identified and the images were rectified to a specified map projection. Chevron used USGS 1:24,000 topographic maps (Oakland East, Oakland West and San Leandro) and U.S. Census Bureau Tiger digital data files to obtain the GCPs. The two files were then merged and the resulting 10 meter data was processed to enhance the coastal zone features.

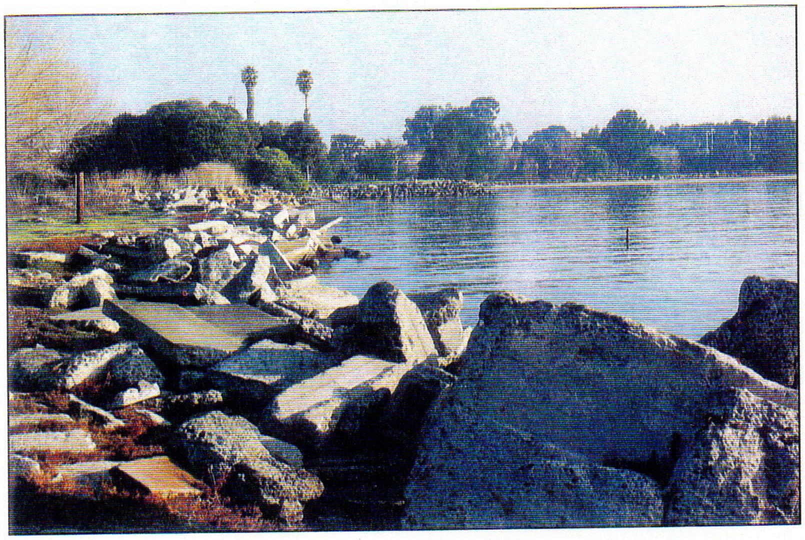
Enhancement techniques were varied in order to discriminate specific coastal zone features. For example, edge filtering and grayscale inversion were done to highlight offshore obstructions, followed by brightening contrast on the raw data to enhance sediment plumes. The infrared band of the multispectral data was used by itself to provide an image with maximum clarity (in some hazy areas the IR band, after being merged with the spatially high resolution panchromatic image, had better resolution than the panchromatic image). These multiple, co-registered enhancements were loaded into a computer-aided drafting (CAD) workstation and alternately displayed while the interpretation was digitized directly from the monitor.

The interpretation and other vector map files were organized into separate CAD layers that were suitable for transfer into the oil spill modelling program as a base for its GIS. (For example, in foreign oil producing regions, facility and infrastructure maps, production platforms, pipelines, lease boundaries, etc.)

A parallelpiped classification produced a land water boundary which was vectorized, exported as a .DXF file and imported into the WOSM spill model. This coastline file was used as a boundary to constrain the area extent of any water-borne spill. The water area was gridded to a 50m cell size. The cell size is a critical parameter that affects the model's efficiency and accuracy. It is important to realize that the model's output is coarser than the input SPOT data. Often model grids have cells that are on the order of 250 and 500m. Landforms that are interpreted on the SPOT imagery may be too insignificant for the model if the grid cell is excessively large. In order to remember this modelling limitation when verifying coastal zone features in the field, we embedded the grid file into the SPOT imagery and printed large-scale color paper plots for field mapping. Each coastal cell of the grid was assigned one of the shoreline classifications. To assist in comparing satellite interpretation with field evidence, this classification was also embedded into the SPOT image.



Top: **Chevron members take GPS measurements on Alameda Island.** ***Below:*** **Alameda Island's exposed rocky shoreline.**



We took the color SPOT prints to the field in January 1994 (three years after the SPOT images were acquired), along with a portable GPS receiver, topographic maps, and documentation for the model's definition of shoreline types. In a half day, we obtained enough ground truth to reliably classify the image in terms of shoreline types. The resolution of the imagery was excellent. Marinas were clearly visible, showing the docks with boats in their slips and the dark water between each dock (10 feet in width). Clumps of pampas grass, local trees, inland lagoons, golf course waterways, the grassy in-field of the Oakland Coliseum stadium, and deep water channels in the estuary were also clearly visible on the SPOT imagery. Comparison with our independent workstation interpretation was favorable.

Soft shorelines such as the Alameda Estuary are dynamic. When the shore is composed of mud, soil, sand, marsh, reeds, mangrove and other easily eroded material, it can change faster than maps can be updated or even satellite images can be acquired. Depending on the scale of the modelling effort, soft shorelines should be field checked if the concern exists with the accuracy of maps or images. Field work using a portable GPS receiver, available basemaps, a camera, and a color plot of the image map (for annotation) has proven to be effective for updating existing maps and images. If a portable computer with integrated image display/vector mapping software is available, then efficiency in the field is further increased. Observations concerning shoreline, roads, marine access, equipment staging areas, development, etc. would be entered into the vector map with location provided by GPS. Appropriate field information would be used to improve the classification of the image into shoreline types. The updated image and existing maps would be transferred into the oil modelling program and its GIS.

CONCLUSIONS

SPOT has proven to be an excellent source of GIS data for this model because it provides:

1. global coverage
2. a digital format
3. ease of geo-referencing
4. favorable costs compared to aerial photographs
5. the ability to acquire up-to-date images
6. sufficient resolution for most oil spill mapping applications
7. resolution is greater than the spatial validity of the model's algorithms.

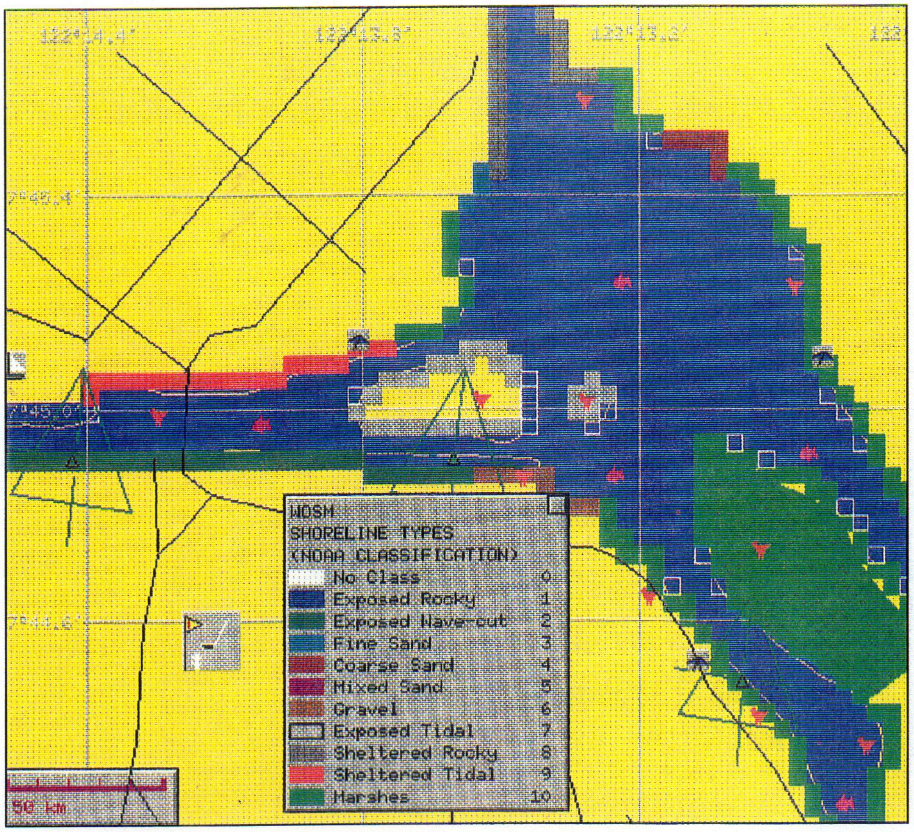
The problems and limitations of using remote sensing images for constructing the basemap and GIS of an oil spill model include:

1. Timely acquisition of cloud-free imagery. One must first determine if the coastal area has undergone excessive modification since the date of acquisition. A three year old image may not adequately represent the current environment and conditions necessary to support emergency response action.

2. Some shoreline types cannot be consistently discriminated by imagery alone. The three sand types are the most difficult to distinguish.

3. Tidal conditions during image acquisition must be known. To optimize the model, the shoreline composition throughout the tidal range should be considered.

4. Ground truth should be acquired. If the model is being used as part of an emergency spill response program, the shoreline types and all the other environmental data should be field checked.



Example of a final oil spill model showing various GIS layers and coastal shoreline types.

ACKNOWLEDGEMENTS

J.M. Ellis, M.B. Quinn, M.R. Choiniere were instrumental in field checking, mapping and direction. More information about the "World Oil Spill Model" (WOSM) may be obtained from Eric Anderson, Applied Science Associates Inc., 70 Dean Kanauss Dr., Narrakansett, RI 02882-1143, telephone (401) 789-6224.

This paper was originally presented at the Tenth Thematic Conference on Geologic Remote Sensing, San Antonio, Texas, May 9-12, 1994.

EOM

Table 1.

Ten types of NOAA shoreline classifications used in the oil spill model.

exposed rocky	exposed wavecut
fine sand	coarse sand
mixed sand	gravel*
exposed tidal	sheltered rocky
sheltered tidal	marsh

*The study area did not contain a purely gravel shoreline with sufficient extent so as to have a unique signature. The gravel shorelines are a mix of sand and gravel.

About the authors:

H.H. Davis, P.D. Caldwell and P.B. Goodwin all work for Chevron's Remote Sensing Group in San Ramon, Calif. Davis is a remote sensing technician, Caldwell is a remote sensing analyst, and Goodwin is a remote sensing geologist. Eric Karver serves as the western sales representative for SPOT Image Corp. in Reston, Va.