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## THE TRANSPETRO EMERGENCY RESPONSE SYSTEM

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### ABSTRACT

This paper describes the TRANSPETRO Emergency Response System, developed by PETROBRAS / TRANSPETRO, which is applicable to oils terminals, mostly located in sea or river harbor areas, and a large oil pipeline mesh that spans the Brazilian territory. The engine of the system consists of a distributed workflow management software, called InfoPAE. The software runs locally at each major installation, all connected to a central site. The deployment of the TRANSPETRO Emergency Response System is part of a larger effort to achieve a standard of excellence in the response to emergency situations at each operational unity, including full compliance with environmental regulations set by the federal government.

### 1. INTRODUCTION

This paper introduces the TRANSPETRO Emergency Response System, developed by PETROBRAS / TRANSPETRO. The system covers oil terminals, located mostly in sea or river harbor areas, a large oil pipeline mesh that spans the Brazilian territory and navigation lines along the Brazilian coast and rivers crossed by oil tankers. The deployment of the system is part of a larger effort to achieve a standard of excellence in the response to emergency situations at each operational unity, including full compliance with environmental regulations set by the federal government.

The engine of the system consists of a distributed workflow management software, which works with plans,

defined as structured collections of actions, coupled with geographic as well as conventional data.

When detecting an accident, the emergency response team will start the appropriate plan, characterize one or more scenarios and delegate combat procedures to specific sub-teams. Each sub-team has access to geographic data about the region where an emergency occurred and will follow the combat procedure it was assigned to.

Development of the InfoPAE system [3,4] begun in 1998 and the first prototype was installed in 1999. In 2000, InfoPAE was in operation at TRANSPETRO and the exploration and production areas of PETROBRAS. In 2001, the use of the system was expanded to oil refineries and natural gas installations. InfoPAE is currently operational in nearly 80 installations.

A preliminary version of the plan specification language can be found in [3] and a much revised version in [5]. The language is similar to other workflow specification languages [12,13], such as that adopted in the WIDE Project [6]. FRIEND [2], INCA [7] and MokSAF [8] are examples of emergency management systems. In particular, the MokSAF system supports route planning by combining AI techniques with GIS. Other examples of multi-agent systems with internal planning components are RETSINA [10] and HIPaP [11]. A survey of cooperative multi-agent systems appears in [9].

The paper is organized as follows. Section 2 focuses on the deployment strategy. Section 3 details the software infrastructure. Section 4 addresses how the database is

populated. Finally, Section 5 contains the conclusions and suggests possible extensions to the system.

## 2. DEPLOYMENT STRATEGY

The TRANSPETRO Emergency Response System was developed to improve the response to emergency situations through the organized deployment of pre-defined combat procedures, and ancillary information. The combat procedures were defined based on an evaluation of: the organization of the emergency teams; the communication procedures; characterization of the installations; definition of accidental scenarios; environmental sensitivity maps; simulation of oil spill trajectories and dispersion behavior; geographical data of the area surrounding the installations; other conventional data related to the installations, including equipment available, etc.

The deployment of the system involved four major steps:

1. Assessment of the environmental sensitivity of the regions near the installations, taking into account environmental and socio-economic aspects. The result takes the form of sensitivity maps that cover about 108,000km<sup>2</sup> of pipeline stripes and 8,000km of coastal line. These maps were used to prioritize the actions during emergencies.
2. Simulation of the trajectories and dispersion patterns of oil spills, obtained through simulation using hydrodynamic models of the water bodies near the oil terminals.
3. Definition of emergency plans and sizing of the equipment needed, based on a detailed risk assessment of accidental scenarios. These scenarios take into account: the type of the accident (fire, explosion, etc.); the estimated volume of oil involved; the oil type; characteristics of the installation affected; sensitivity maps of the region; and simulation results.
4. Implementation of the system, by:
  - a. Translating the (paper) emergency plans into an executable format.
  - b. Collecting conventional and geographical data about the installations and the surrounding regions.
  - c. Deploying the hardware and software infrastructure.
  - d. Training the users of the system and the emergency teams.

Section 3 describes in more detail the software infrastructure, while Section 4 focuses on questions pertaining to the data infrastructure.

## 3. THE SOFTWARE INFRASTRUCTURE

### 3.1 ARCHITECTURE OF THE SYSTEM

The TRANSPETRO Emergency Response System is a distributed collection of independent sites, connected to a central site. Each site runs a copy of InfoPAE on top of a standard relational database management system. Each site controls one or more installations, which can be oil terminals, mostly located in sea or river harbor areas, and oil pipelines, spanning the Brazilian territory. The system also includes a site that controls the TRANSPETRO fleet, that is, it contains data about the navigation lines along the Brazilian coast and rivers and about the oil tankers.

InfoPAE is an automated system designed to improve the response to emergency situations. The system offers sophisticated action plans, easy access to vital information and

tight control over the resources allocated to face an emergency.

InfoPAE works with emergency plans, which are structured collections of actions, coupled with information stored in geographical as well as conventional databases. During an emergency, the team follows a previously stored plan, backed up by its ancillary information. The team registers the actions taken and documents eventual difficulties. Later on, upper level management may use the system to generate reports that are useful to detect eventual problems with the plan or to assess the performance of the team.

InfoPAE has the following major components:

- a database storing plans and conventional and geographical data;
- a data editor to maintain the database;
- a plan editor to create new plans and to relate them to persistent data;
- a plan interpreter to control the execution of a plan during an emergency and to access its associated data. It interacts with the human agents to register the progress of actions contained in the plan, who took the action and any observation pertaining to the action. It also helps the upper management staff keep track of the current scenario: the current assessment of the situation (as reported by the emergency teams), what has been accomplished, what remains to be done, etc.
- a geographic data browser that offers a variety of tools to browse the database, including some typical of geographical information systems;
- a report generator to prepare reports based on plan execution traces;
- a plan publisher that maps plans and ancillary data into printable documents, with a predefined organization.

### 3.2 EMERGENCY PLANS

An emergency plan defines:

- a structured collection of actions to be followed during the emergency.
- a description of the teams required to execute the actions.
- a list of the resources, documents and information in general that will help carry out the actions.

In its simplest conception, a plan is just an ordered list of actions. However, in general, a plan will indicate which groups of actions can be executed concurrently, and which groups must be executed serially.

A plan also depends on a characterization of the emergency conditions, such as the type of product and the estimated amount that spilled and environmental conditions (direction of the wind, tide conditions, etc...). Therefore, the plan will contain groups of actions that apply only under certain conditions.

The term "user" designates the person who is interacting with the tool, and "team" to designate any group of people that actually executes a sub-plan of the emergency plan.

Plans implemented for the TRANSPETRO Emergency Response System are structured into well determined phases, which are: (1) emergency identification and immediate actions; (2) mobilization of the emergency teams; (3) characterization of the accidental scenario; (4) combat procedure; and (5) closing procedure

In general, an accidental scenario or simply, a scenario is characterized by well-defined attributes, usually indicating the

nature of the accident, the product involved (if applicable), the site where the accident occurred and the environmental conditions under which the accident took place. An example of a scenario would be “spill of oil type II at the pier, with high tide and south wind”.

Each scenario is associated with a combat procedure, consisting of elementary actions, structured according to a specific combat logic. Each action, or group of actions, may in turn be associated with people or institutions to be contacted, types of resources required to perform the action, emergency teams to be mobilized and general documentation to be used.

There also is considerable similarity, if not redundancy, between combat procedures for scenarios of the same plan. In fact, they frequently differ only on the associated information.

Users also strongly suggested that it should be possible to invoke combat procedures by clicking on the location of the accident, visualized on the user interface. This can be achieved indirectly by georeferencing the scenarios and creating a scenario information layer. Since combat procedures are always linked to scenarios, they also become georeferenced objects that can be activated from the scenario information layer.

In view of these observations, the plan definition language, XPAE [5], includes elements to:

- define sub-plans
- define classes of (geo-referenced) scenarios
- associate methods to scenarios
- structure elementary actions
- hyperlink actions, and other parts of a plan, to objects and documents in a database
- help reduce plan redundancy

Finally, the semantics of the XPAE language is defined with the help of Petri nets, as suggested in [1].

### 3.3 EXECUTING EMERGENCY PLANS

When an emergency occurs, the user must invoke the plan interpreter to control the execution of the appropriate plan. The interpreter will then guide the teams throughout plan execution, tracing the actions taken, and collecting additional data about plan execution.

Once the execution of a plan starts, the plan interpreter maintains the list of current actions, questions and tests (that is, of those elementary sub-plans) that are ready to execute. Note that this list may contain more than one element if the plan contains parallel groups.

For each current action, the user may access any data element associated with the action. This includes both the data directly associated with the action and the data associated with a group that contains the action.

The user may choose one of the current actions and flag it as executed, thereby transforming into current any elementary sub-plan that depends on it.

The user may also defer the execution of a current action, if the action was flagged as deferrable when the plan was defined. This also transforms into current any elementary sub-plan that depends on the deferred action.

When the user selects a current question, the plan interpreter prompts the user to choose one of the alternatives associated with the question. The module stores the alternative in the question's parameter and then it proceeds to analyze the sub-plan associated with the alternative chosen.

The plan interpreter automatically executes a test based on the value currently associated with its parameter, that is, the module proceeds to analyze the sub-plan associated with the alternative stored in the sub-plan.

The user also has the option to undo the last action executed. He may also, at any time, change the alternative chosen for a question. In both cases, the module re-computes the list of current elementary sub-plans.

If necessary, the user may register an unpredicted action, which becomes part of the current execution of the plan, but not of the plan itself.

Finally, the user may request a report of the actions already executed, based on the trace the plan interpreter maintains. This facility allows post-emergency evaluation of the plan, which may help detect flaws in the plan, or inadequate team behavior.

When an emergency occurs, the user also has access to the geographic data browser that allows browsing conventional as well as geographical data related to the location where an emergency occurred.

The browser offers a variety of tools, typical of a geographical information system. In particular, the browser offers three search interfaces:

- a conventional search interface just to browse the database for conventional data describing, for example, material resources and internal or external contacts;
- a search interface to retrieve geo-referenced data from the database, filtered by type or by name, and to display them using the appropriate tool;
- a point-and-click interface that helps the user retrieve data based on their location over a map or geo-referenced image.

## 4. THE DATA INFRASTRUCTURE

### 4.1 DATA ALLOCATION STRATEGY

The TRANSPETRO Emergency Response System operates as a federated collection of databases, with a designated central database, stored in the headquarters, and a collection of local databases, stored at each site of the system.

Each local database stores:

- emergency plans pertaining to the installations the site controls;
- conventional data that are valuable to the deployment of the emergency plans and that must be readily available during plan execution;
- geographical data that are relevant to the execution of the emergency plans.

As a basic requirement, each local site must be autonomous, in the sense that it must operate disconnected from the rest of the corporate network. Therefore, each local database must store all operational data required by the emergency plans pertaining to the local installations.

In particular, each local database must replicate – and synchronize – all data from external data sources that are relevant to the emergency plans it stores. For example, PETROBRAS maintains a corporate database to control emergency equipment. The relevant data from this database is first replicated to the TRANSPETRO Emergency Response System central database and then partitioned and replicated to each local database. In fact, this simple strategy is adopted for all external data sources.

This strategy also considerably simplifies the maintenance of the hyperlinks connecting actions, and other parts of a plan, to objects and documents. Indeed, all hyperlinks involve only objects in the same local database, and not across distinct databases.

#### 4.2 PLAN AND CONVENTIONAL DATA PREPARATION

Emergency plans first exist on paper. For each installation, an independent team, composed of emergency response experts, prepared the emergency plans and collected most of the ancillary data and documentation. The result was an often a voluminous documentation, organized around a (paper) emergency plan.

A second team then processed the documentation to feed the database with:

- conventional data, such as lists of contacts and authorities that must be aware of the emergencies (their names, position, phone numbers, etc.);
- descriptions of the resources that are necessary to carry out the actions, including the emergency teams;
- documents, such as state and federal environmental regulations, photos of the installation, equipment manuals, installation blueprints and other engineering data;
- executable emergency plans, written in XPAE, the workflow definition language.

This process is tedious and error prone, specially the last step, since XPAE has many features typical of a programming language.

Simple measures were taken to alleviate the problem. First, the (paper) emergency plans are highly structured and follow a rigid style. Second, the (paper) emergency plans are fairly generic and are specified by combining high level descriptions of elementary emergency procedures. For example, to some extent, the emergency plans for most oil terminals are just variations of one basic plan. The specificities of the oil terminal and the surrounding environment are captured mostly by the conventional and geographic data.

These two measures imply that processing the (paper) emergency plans is a fairly repetitive and regular task and that there is considerable re-use of workflow fragments from one plan to the other, at least when both refer to the same installation type.

In fact, we are currently experimenting with a combination of form-based data input with information extraction techniques to automate the preparation of (executable) emergency plans. The goal is to design a simple software tool that can be directly used by the emergency response experts, with almost no computer background. The tool would incorporate plan templates that facilitate conventional data acquisition, using forms, and automated compilation of the workflow definition. Since the work of the emergency response experts requires frequent visits to the installations, the tool will run on a notebook, disconnected from the databases.

#### 4.3 GEOGRAPHICAL DATA PREPARATION

Geographic data include:

- the familiar feature collections that represent economic and environmental aspects of the area near the installations, such as vegetation coverage and soil type, terrain slope and elevation, coastal line, etc.

- geo-referenced data about the installations themselves, such as the location of pipelines, pumping stations, etc.
- sensitivity maps of the surrounding areas of an installation, that carry important information for the decision maker during an emergency;
- maps of the anticipated trajectories and dispersion patterns of oil spills.

Figure 1, at the end of the paper, illustrates an environmental sensitivity map, Figure 2 an oil spill trajectory and dispersion map and Figure 3 the resulting combat procedures.

As mentioned in Section 2, the sensitivity maps cover the areas near the installations and take into account environmental and socio-economic aspects. Possible trajectories and dispersion patterns of oil spills were obtained through simulation, using hydrodynamic models of the water bodies near the oil terminals. This information, combined with the sensitivity maps, was used to determine vulnerable areas, prioritize combat strategies and size the equipment needed.

#### 5. CONCLUSIONS

This paper outlined the basic concepts and functionality of the TRANSPETRO Emergency Response System, developed by PETROBRAS / TRANSPETRO. The engine of the system consists of a distributed workflow management software, called InfoPAE. The system allows users to execute comprehensive emergency plans, hyperlinked to conventional as well as geographical data.

The development of the system involved the following partnerships:

- TecGraf/PUC-Rio, responsible for developing the software and for deploying the databases;
- CENPES/PETROBRAS, responsible for the environmental sensitivity maps of the areas near the oil terminals located in sea or river harbor areas, and for the simulation of oil spill trajectories and dispersion patterns;
- EAMB/EGE/PETROBRAS, responsible for the environmental sensitivity maps of the areas near the pipelines;
- DPH Consulting, responsible for defining the combat strategies and for determining the accidental hypothesis for the oil terminals and pipeline stripes.

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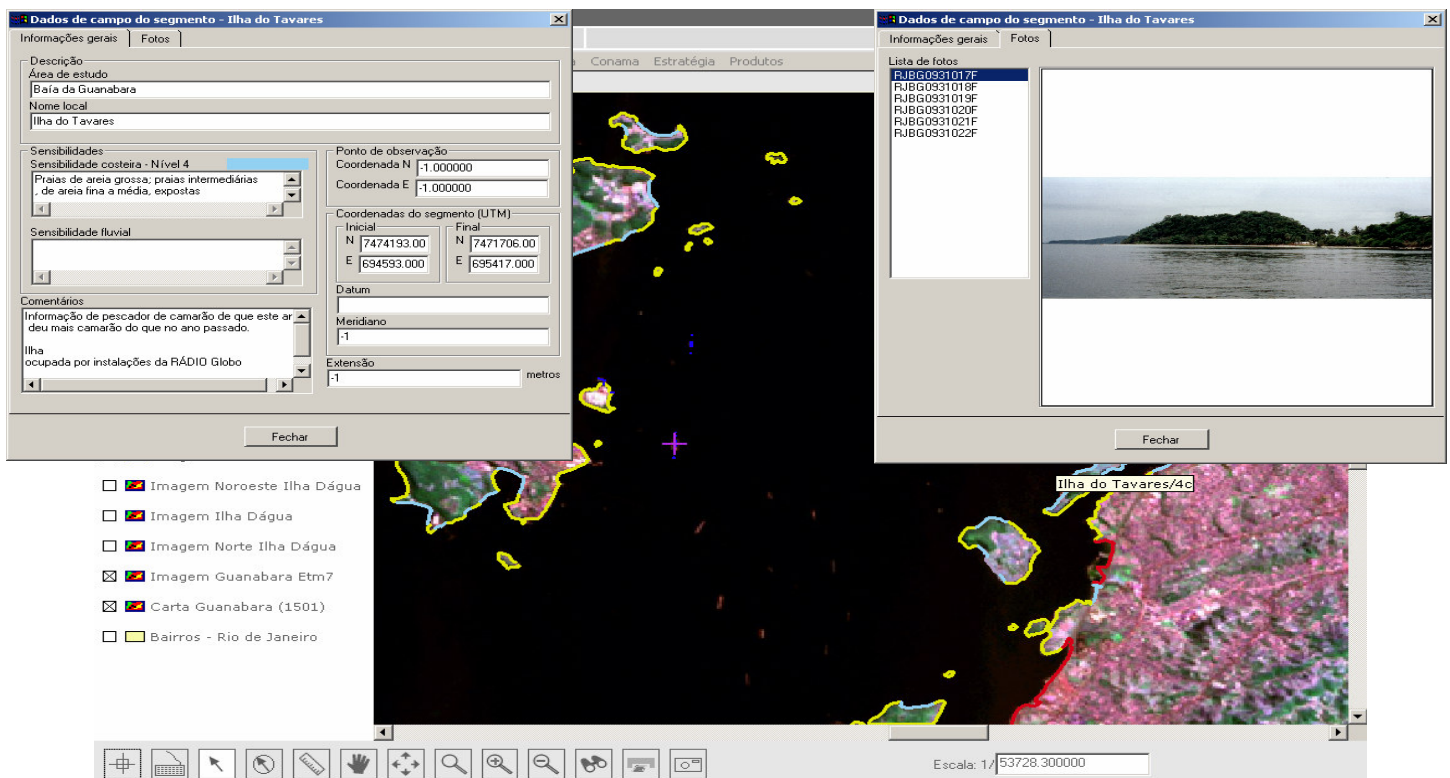


Figure 1– Guanabara Bay: Example of senvironmental sensitivity map.

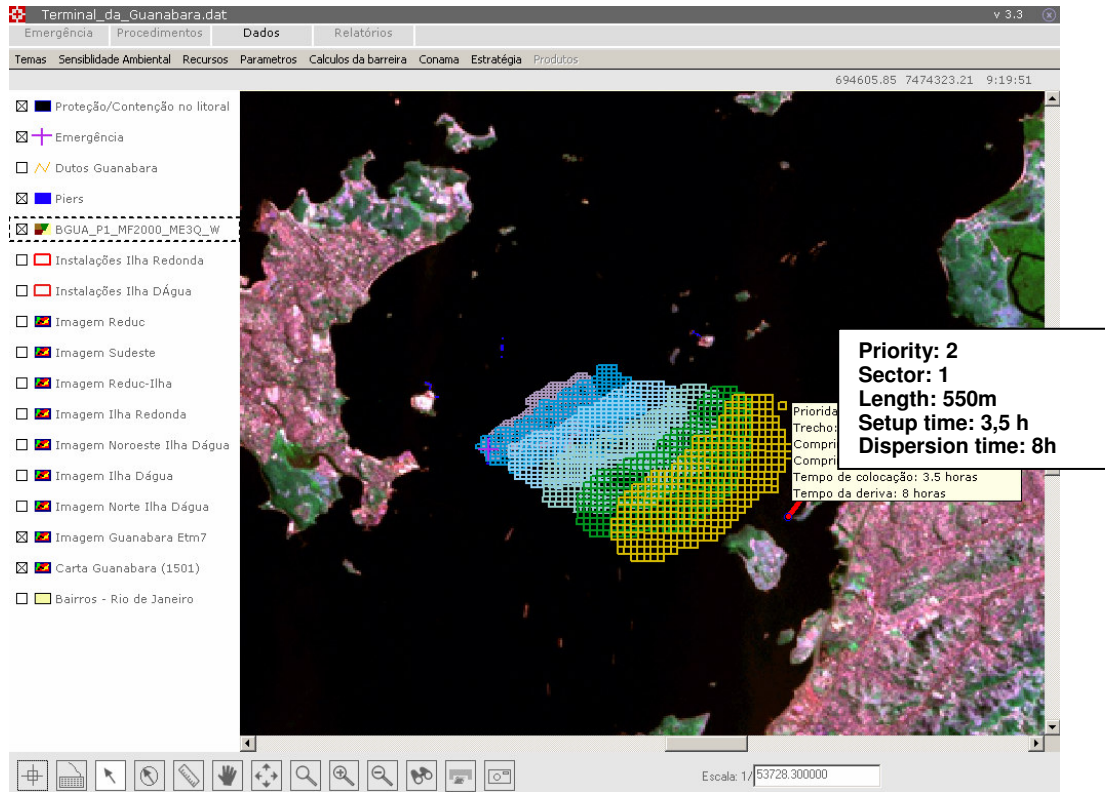


Figure 2 – Guanabara Bay: Example of oil spill trajectory and dispersion pattern, obtained by simulation.

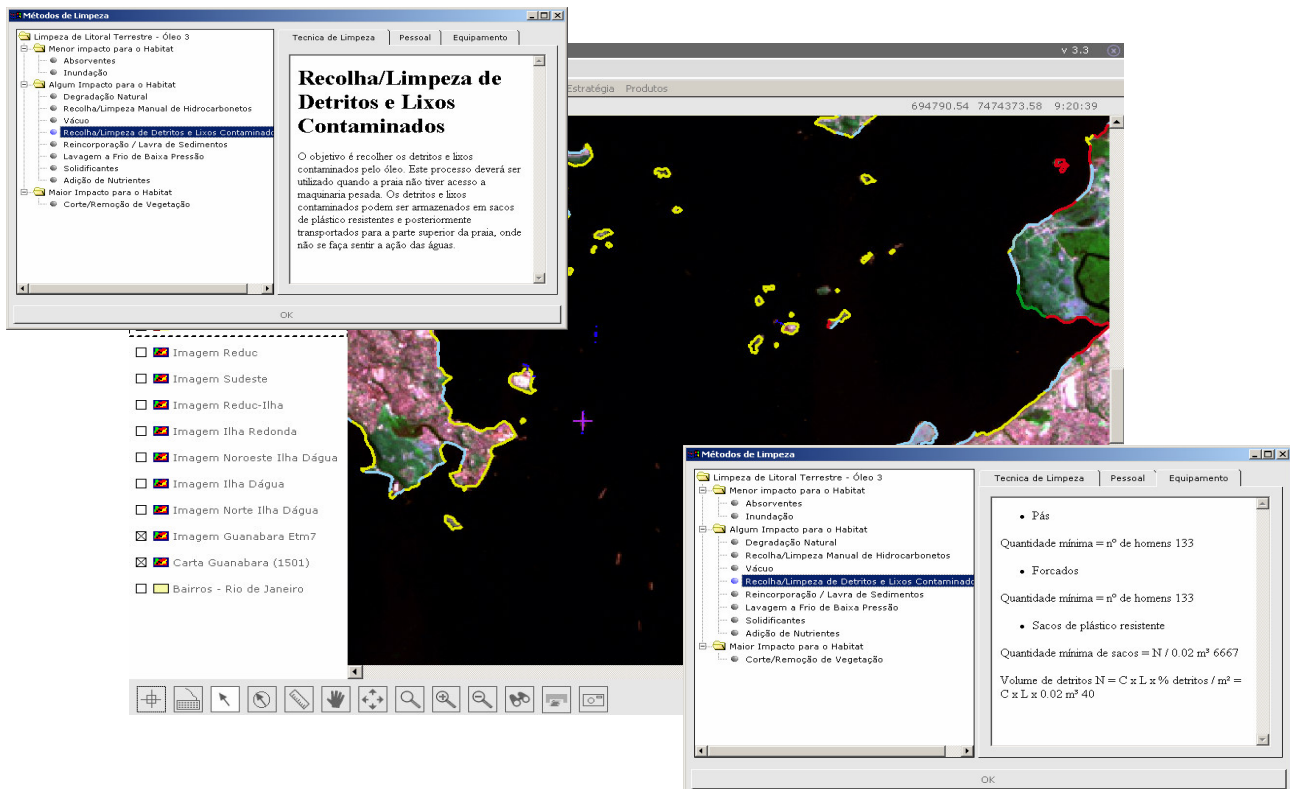


Figure 3 – Guanabara Bay: Example of combat procedure (in Portuguese).