# ENVIRONMENTAL PORT MANAGEMENT: DREDGING BRAZILIAN PORTS – AN EXAMPLE OF THE PORT OF RIO GRANDE

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## ABSTRACT

This work deals with the problems that concern the dredging processes on the Port of Rio Grande, RS (southern most State of Brazil). The subject is presented in such a way that it stands the major problems related to the dredging process itself and spoil disposal options. The data gathered from a bibliographic review and from the dredging works on 1998, 2000 and 2003 were used to develop a preliminary systematic model of this process. The model elaborated consists of technical, ecological and economical aspects. An analysis of the major points to be considered when dealing with dredging projects on the port of Rio Grande makes clear the importance of environmental monitoring of these activities. The main points to be considered are: selecting the type of dredge and the method of management and disposal of the sediments; the monitoring of the impacts over the environment (plants, animals, water and sediment quality); and the operational costs and monitoring costs of these activities. Another point that should be considered is about the choice of disposal options or beneficial reuse of the dredged material.

**Keywords:** Brazil, environmental impacts, modeling, monitoring

## INTRODUCTION

One important research field on developing and developed countries is the improvement of ports and channels by the use of dredging activities. These activities produce a certain level of impacts and a monitoring program should always be considered to evaluate their environmental impacts.

Most of the ports worldwide have been settled on rivers, estuaries and lagoons and evolved into industrial centers highly populated. The navigation channels on the entrance of these ports and estuaries have suffered shallowing processes needing frequent dredging to maintain its depth. However, the sediments present on the bottom of industrialized ports are usually contaminated with heavy metals and organic compounds. This way, the dredged material must be carefully handled and placed on proper sites. Therefore, the dredging activities demand correct planning and decision taking on the process itself, as well as on the handling and disposal of the dredged material.

On developing countries such as Brazil, there is a lack of information related to dredging works (Torres and Calliari 2004). In many cases, existing information are not presented to the community, being held by the port administration they belong to or research institutes that do not publish them. In a worse situation, very few of the ports and channels that require dredging have any kind of environmental monitoring and evaluation. The first Brazilian legislation dealing with the dredging process has been approved on March 2004 and regards only the previous characterization of the sediment in order to decide the disposal on the coast (CONAMA 2004).

Therefore, there is a necessity to develop monitoring techniques of these activities aiming secure projects in accordance with the existing policy, which can be complemented by international laws on dredging and disposal. The evaluation of the techniques used in projects outside Brazil could help implementing the mechanisms that better represent the reality of the Brazilian ports.

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We must consider the multidisciplinarity that evolves the dredging activities which include port, naval and ocean engineering, oceanographic processes (comprising physical, chemical, geological and biological oceanography) and environmental, ecological, economical, social and legal aspects to which the dredging operations are closely related and offer background for detailed studies.

## STUDY AREA

The port of Rio Grande is the southernmost port of Brazil (figure 1) and is located on the west margin of the North Channel (considered the natural drainage of the Patos Lagoon Hydrographic Basin). It presents great geographic condition and structure for the flow of the production of the Rio Grande State and the North of Argentina, presenting great importance to the economy of the region. Also, it is the third most important Brazilian port, after the ports of Santos and Rio de Janeiro (Torres 2000).

The city of Rio Grande is located on the margins of the estuarine region of the Patos Lagoon, in a peninsula limited to the south and northeast by shallow bays ("Saco da Mangueira, do Martins and do Justino"); to the north by the North Channel; and to the east by the Access Channel to the Patos Lagoon and the Atlantic Ocean ("Canal do Rio Grande"; figure 2).

The estuarine region comprehends the transition area that has some influence from salt water and the lagoon. The Patos Lagoon estuary is classified as a Coastal Plain Estuary or Bar Estuary according to Fairbridge (1980 in Hartmann 1996). Kjerfve (1994) also denotes this estuary as choked (strangled) because it is a narrow and long lagoon, composed of elliptic cells connected with each other and with a long and narrow channel linking to the ocean.

With the increasing importance of the port of Rio Grande during the last decades, the improvements on the navigation conditions on the Patos Lagoon inlet took place with the construction of the "Molhes da Barra" (two 2 miles long jetties on the entrance of the Lagoon). This construction, started on 1898 and finished on 1915, is one of the biggest coastal engineering works on Brazil. These jetties fixed the bar, allowing a natural deepening of the channel from 2.5m to 6m. Lately, with the dredging works to open the Rio Grande Canal, in 1972, ships with a greater draft were allowed to enter the estuary. The main depth of this channel is about 14m and is maintained through periodic dredging every two to three years (Hartmann 1996).

Mainly suspended matter makes up the sediment contribution to the Patos Lagoon and estuarine area. Baisch (1994) estimated that the solid discharge from the Guaíba system and Camaquã River are about 5.3 million $m^3$ per year, in which about 82% are from the Guaíba and 18% from the Camaquã. According to this author, only 25% from this volume reaches the estuarine region, in a total of 1.2 million $m^3$. Adding to it the amount of sediment exported from the Mirim Lagoon through the São Gonçalo Channel, this volume comes to about 2 million $m^3$ of suspended matter arrive the estuarine area and is responsible for the shoaling process on the navigation channels.

According to the available data about the maintenance dredging of the Rio Grande Port, the shoaling tax of the port region is about 1.4 milllion $m^3$ per year, divided on three distinct areas: Rio Grande Canal, approximately 1,040,000 $m^3$/year; Access Channel to Porto Novo, 75,000 $m^3$/year, and; Evolution Basin of Porto Novo, 285,000 $m^3$/year (Portobrás 1979).

## METHODOLOGY

A detailed survey of the dredging operation of the port of Rio Grande that took place from March to August, 1998, has been carried out along with the biological, physical, chemical and geological evaluation of the area. From the information gathered, we looked toward the environmental and socio-economic aspects, as well as the information on the technology that is used. These information were used to develop a thematic model that will help future planning in order to prevent the impacts that dredging activities cause on the port of Rio Grande as well as on the other Brazilian ports that require dredging to maintain their channels in condition to navigation. Also, the two following dredging works and their environmental monitoring program were analyzed.

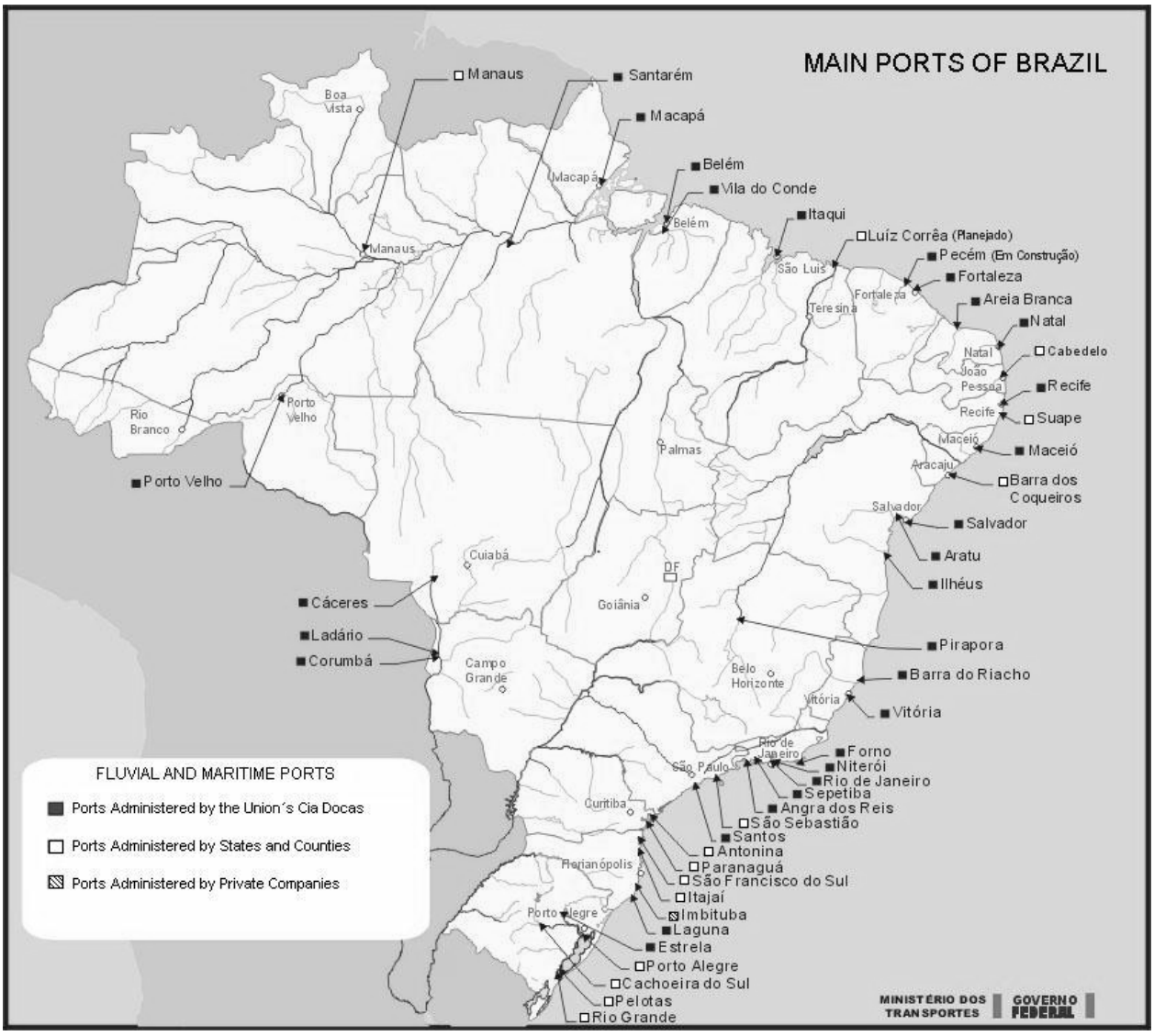


**Figure 1. Main ports of Brazil according to Brazilian Ministry of Transport in Torres and Calliari (2004).**

## RESULTS AND DISCUSSION

The total amount dredged from the Rio Grande Port on the dredging operation in 1998 was approximately 2,940,000 $m^3$ with a total cost of US$ 4.4 million. The individual costs varied from US$ 1.44 to US$ 1.97 per $m^3$ depending on the part of the port that should be dredged (Rio Grande Channel, Access Channel to Porto Novo and Evolution Basin of Porto Novo) and its distance to the disposal site (table 1). The disposal site was located offshore, in front of the Mar Grosso beach in São José do Norte - Rio Grande's neighbor town - about 5 nautical miles from the east jetty, at a depth of about 13 m.

The schematic model shown in figure 3 was elaborated through a bibliographic review and by observing the dredging operation that took place in 1998 and takes into account the following major aspects: technical, environmental/ecological and socio-economics. These aspects can be applied on the model in order to generate a great number of useful information to be used on the design of new dredging projects (Torres 2000).

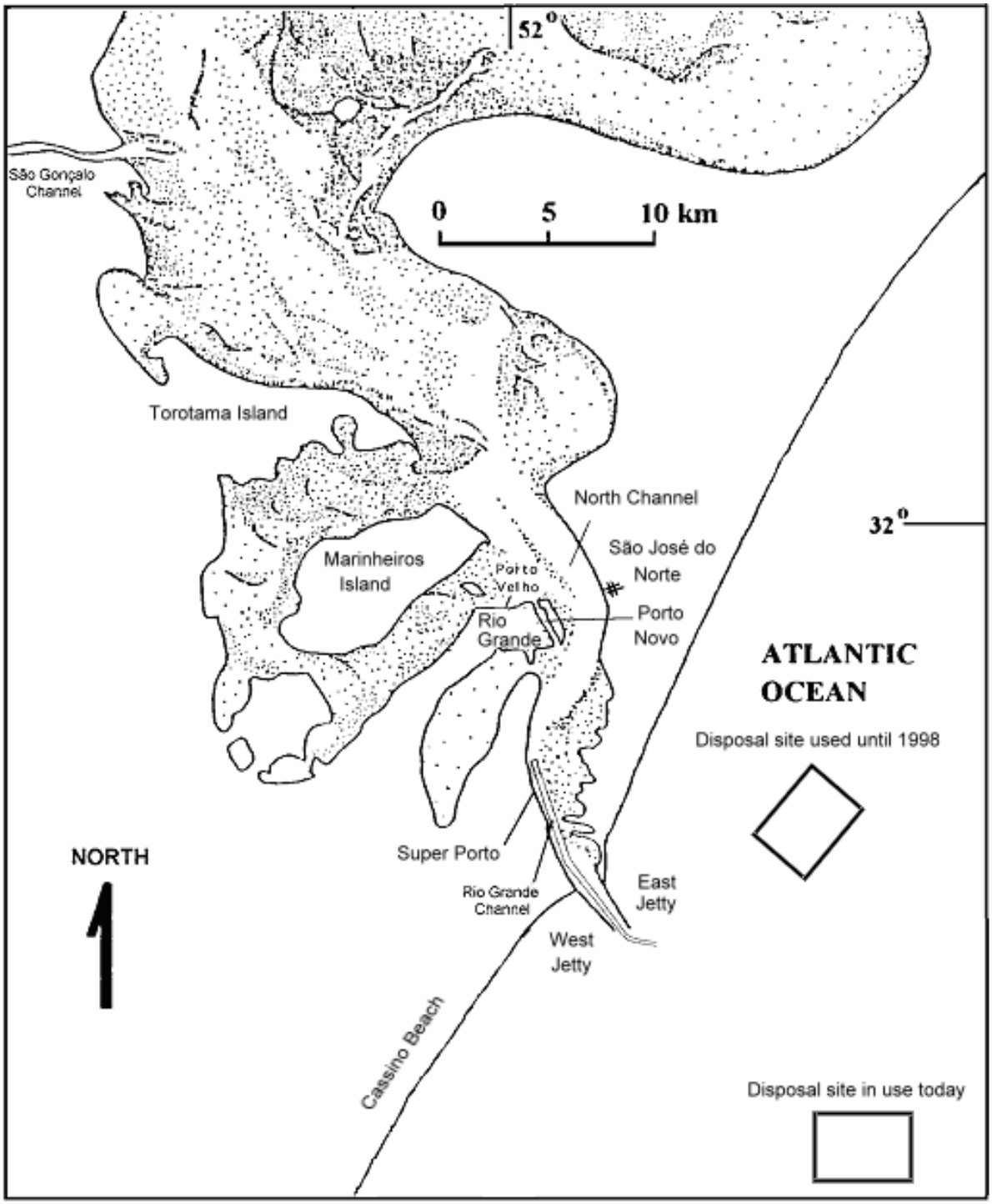


**Figure 2. Rio Grande region map showing the port areas, the navigation channels and the disposal site used until 1998 and the current site (modified from Hartmann 1996).**

It's known from prior projects that the sediments from the Rio Grande channel are contaminated by heavy metals and organic matter from the port area, from the effluents of the industries based on the Industrial District, specially from the fertilizer industries and adjacent to the sewage effluent from the city although these levels are not so high (Baisch 1997). As dredging resuspends this sediment allowing these contaminants to get back to the water column,

it is advisable that these activities should be monitored before it is started, during the operations and after it is concluded. On the port of Rio Grande, this monitoring was done by the first time during the dredging activities of 2000/2001, being ignored on the other dredging operations that took place since 1972.

**Table 1. Dredging costs and volumes related to each port area.**

| Port Area | Volume Dredged ($m^3$) | Cost per $m^3$ (US$) | Total Cost (US$) |
|---|---|---|---|
| Access Channel | 2.300.000 | 1,44 | 3.750.000,00 |
| Access Channel to Porto Novo Basin | 265.000 | 1,97 | 220.000,00 |
| Evolution Basin of Porto Novo | 375.000 | 1,87 | 430.000,00 |

The disposal site used on the 1998 operation was considered unsuitable because it could form sand bars on the beach area, affecting on the incidence of waves on the root of the east jetty, and it could cause its rupture (Calliari and Tagliani 1997). This problem has been solved on the 2000/2001 dredging operation, on which another disposal site, located about 13 miles offshore, with an approximate depth of 20 m (figure 2), and out of the navigation roots as proposed by Torres (2000).

Using the model presented here, we are able to verify which points of the dredging process can be optimized and the model gives a background for future studies on the dredging operations of the Rio Grande port and estuarine area. The main points to be considered are: selecting the type of dredge and the method of management and disposal of the sediments; the monitoring of the impacts over the environment (plants, animals, water and sediment quality); and the operational costs and monitoring costs of these activities (Torres 2000). One aspect that should be emphasized is the volume to be dredged, which in many cases can be influenced by geological and climatic cycles of the region, raising or reducing the volume of sediments that reach the estuarine area.

Another point that should be considered is the choice of disposal options or reuse of the dredged material. Some of the techniques used can be dangerous to the environment while others can be beneficial as the use of these sediments for beach nourishment, landfill or construction material, as well as the geotechnical properties of the dredged material. A pilot project is being conducted in order to use the contaminated sediments from the area of the Porto Novo as material for blocks and cement to be used on buildings (Dias et al. 2004).

On the monitoring activities of the 2000/2001 dredging (emergencial: 11/07 - 26/10/2000 and maintenance: 16/11/2000 - 24/05/2001; Asmus and Zamboni 2001 and Asmus et al. 2002) were also observed the influence of dredging over the benthic organisms, plankton, fish and fishing resources, vegetation, water and sediment quality, and the overflow activity (discharge of the exceeding water from the interior of the hopper dredge, and which contains fine grained sediments), on the dredging site and on the disposal site.

From this monitoring it was possible to determine that the dredging activities should be done on the periods that the outflow regime can carry the resuspended matter to the ocean, preventing it to re-settle on the channel. Also, once it is contaminated with heavy metals and organic compounds, it required careful management and placement. The main toxic compounds are organic compounds, sulphur and nitrogen from the city sewage outlets, phosphorus (P), lead (Pb), copper (Cu), cadmium (Cd), zinc (Zn), chromium (Cr) and nickel (Ni) from the fertilizer industries on the industrial district adjacent to the port area. These compounds, when resuspended, can allow seafood resources to be poisoned and bioaccumulate on their organisms, representing some harm to human health.

The environmental effects over the plants and animals of the estuarine area of the lagoon and nearby coastal zone are mainly the increase of turbidity (with normal concentration of about 50mg/kg of suspended sediments reaching up to 15,000mg/kg on the plume behind the dredge; figure 4), reducing light and influencing the plant growth and

fisheries life cycles. Also, sediment settlement on the channel and disposal site can affect benthic organisms, suffocating them.

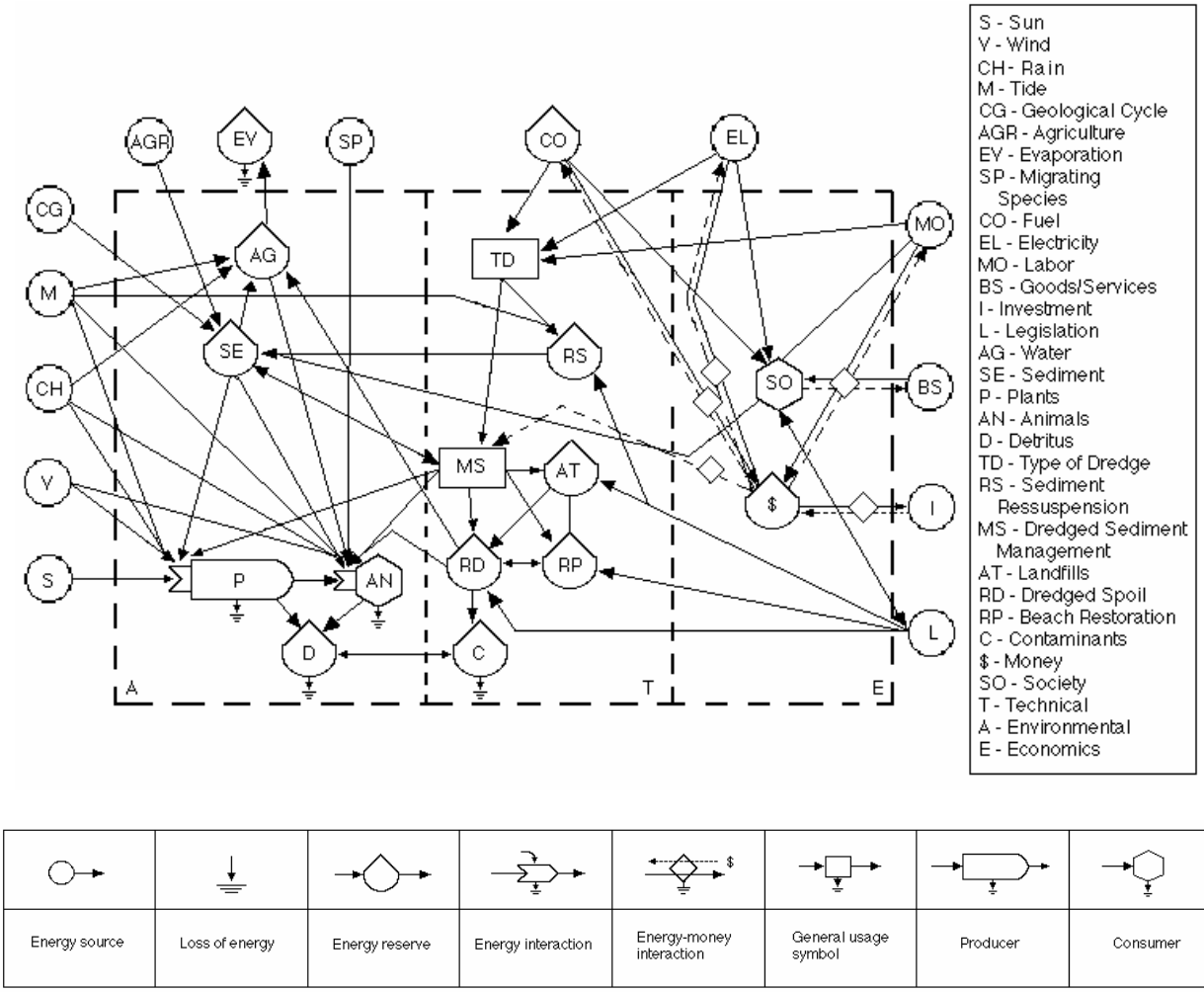


**Figure 3. Schematic model showing the relationship between the various processes related to the dredging activities (Modified from Torres 2000).**

During the dredging work of 2003/2004 a monitoring program was also carried on (Asmus & Granato 2004). On this particular project, the overflow was controlled. This way, the suspended matter on the plume behind the dredge did not reach the same values as on the previous dredging, staying below the 500mg/kg level. Also, another action that was taken was related to conducting most of the work during the periods when the discharge from the lagoon to the ocean is larger, pushing the turbidity plume to the sea and preventing the settlement of the sediments back on the channel. This showed up a good practice to improve the overall conditions of the estuarine area.

It is suggested that the sediment could be used to create artificial islands and salt marshes in order to promote a beneficial use of the sediment inside the estuary when the sediment does not show contamination and on civil engineering projects when it shows some contamination.

**Figure 4. Picture of the dredge working on the Porto Novo in 2000 showing the turbidity plume behind the dredge (Asmus and Zamboni 2001).**

## CONCLUSIONS

From the information obtained, it was possible to draw the following conclusions and recommendations for future dredging projects and other scientific works:

- the port of Rio Grande has great importance on the shipping activities of Brazil and South America and maintaining the navigation channels to proper depth is of considerable importance;
- the knowledge of the natural and anthropogenic shoaling of the navigation channels is the first step to understand the processes that occur on the port area;
- the volume of sediments that reach the estuarine area is greater than the volume of sediments that is dredged over certain period, so part of it is exported to the ocean and part settles on the channels;
- it is known that the sediments on the bottom of the channels is contaminated by organic matters and some metals from the industries adjacent to the port and from the sewage discharge from the city of Rio Grande and that the dredging processes can resuspend these contaminants;
- the dredging works should be conduced on periods of large water discharge from the lagoon so the resuspended sediment would be carried out with the outflow;
- monitoring the quality of the water and the sediment as well as the influence of the dredging operations on the biological, chemical and physical processes on the estuarine area should be conducted before, during and after the dredging work takes place and it should be carried by major environmental agencies of Brazil such as the National Institute of the Environment (IBAMA) that belongs to the Environmental Ministry (MMA) but it has never done such monitoring;
- monitoring activity should comprise the aspects presented on the schematic model and includes the choice of dredging equipment and the best disposal management techniques, volume to be dredged, water and sediment quality, as well as the biological cycles on the port area as has been done by the first time on the 2000/2001 and on the 2003/2004 dredging works by the port administration and the University of Rio Grande (a joint work by the Departments of Oceanography, Geosciences, Chemistry and Physics).

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