CONF-9510262--1

BNL-61909

# Ecological Risk Screen for PAHs in Sediments Near Two Produced Water Discharges at Coastal Production Platforms in the Gulf of Mexico

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## Abstract

Preliminary screens for risks to biota, were done on PAHs in sediments associated with produced waters from platforms at Delacroix Island and at Bay de Chene, in open bays of the Louisiana coast. Sediment samples were taken in Spring 1993 at the discharge sites, along three transects at Delacroix Island and along four transects at Bay de Chene (at intervals of 100, 300, 500 and 1000 ft), and at two reference locations for each discharge site. A screen for deleterious effects on biota was done by comparing concentrations to the Effects Range-Median (ERM) and Effects Range-Low (ERL) criteria of Long et al. 1995. Only sediment samples from the discharge site at Bay de Chene exceeded ERM concentrations for either total PAH, or individual and total high molecular weight PAHs. The ERL criteria for total and individual PAH concentrations were exceeded at, and 100 m from the discharge at Delacroix Island. At Bay de Chene the ERL criteria for total and individual PAH concentrations were exceeded at the discharge, as well as at 100 and 300 m stations.

One U.S. Department of Energy (USDOE) mission is cost-effective development of domestic oil and gas resources with proper concern for the environment. This includes the potential costs of compliance with regulations and effects on domestic oil and gas supplies. Most of the current (and projected future) oil and gas platforms in the U.S. are located in the central and western Gulf of Mexico. This area supports economically important commercial and recreational fisheries, as well as unique, socially valued ecosystems and several endangered and threatened species. Oil and gas production are often accompanied by a saline wastewater, called produced water. In offshore and coastal areas, this wastewater may be discharged to surface water. Produced water may contain a number of contaminants, including oil and grease, organic compounds, heavy metals and radionuclides. Many of these contaminants are toxic to marine organisms at high concentrations.

Potential human health and environmental impact in the Gulf of Mexico, from discharge of produced water, concern regulators at state and federal levels, environmental interest groups, industry and the public. Current regulations in the United States require or propose a zero discharge limit for coastal facilities based primarily on studies performed in low energy, poorly flushed environments. Produced water discharges in coastal Louisiana, however, include a number located in open bays, where potential impacts are likely to be larger than the minimal impacts associated with offshore discharges, but smaller than those demonstrated in low-energy canal environments.

The USDOE program in the Gulf of Mexico consists of two interactive ongoing projects. One project, "Environmental and Economic Assessment of Discharges from Gulf of Mexico Region Oil and Gas Operations" (the USDOE field study), is done by Continental Shelf Associates, Inc. and their subcontractors, one of which, Steimle & Associates, Inc. supplied the data for this report. The objectives include:

- assessment of the fate and environmental effects of contaminants in produced water;
- assessment of the catch, consumption, and human use patterns of seafood species collected from coastal and offshore waters;
- assessment of the economic effects of issued and proposed regulations on offshore oil and gas producers in the Gulf of Mexico Region.

The other project, "Produced Water Risk Assessment and Programmatic Support", was assigned to the authors at the Biomedical and Environmental Assessment Group at Brookhaven National Laboratory (BEAG/BNL). Our objectives are to:

- provide technical and programmatic support to USDOE in its research effort to characterize health and environmental impacts of produced water discharges;
- perform human health and ecological risk assessments for contaminants discharged in produced water;
- provide scientific bases for risk management actions by State and Federal agencies.

The state of Louisiana planned to allow open bay discharges to continue through January 1997. To provide technical support for this decision, BEAG/BNL did a preliminary ecological assessment of the potential impact of pre-termination data from sites (Fig. 1, Table 1) that were to be studied for recovery from produced water discharges. These sites fell within the output of 90% of the Louisiana discharges, which are low volume, less than 5,000 bbl/d (Boesch and Rabalais 1989). They are typically found in shallow water depths: Delacroix ~1.5 m; and Bay de Chene ~2.3 m.

## Materials and Methods

Benthos, sediment and core samples were collected at discharges, stations, and reference stations on the transects shown in Fig. 2 and 3. Methods of handling, treatment and analyses of the samples have been described elsewhere by Mullino et al. (1995).

### Delacroix Island

The Delacroix Island Oil and Gas field, approximately 30 miles (48 km) southeast of New Orleans, was in constant production since 1940. Eleven wells were in production in the field at the time of pre-termination sampling (April 1993).

The field contains numerous canals and their remnants, in an area that is a subsiding delta with broken marsh, numerous small water bodies, and a few large open bays. This area is highly influenced by the Mississippi River because of the Caernarvon diversion, about 15 miles (24 km) northwest of the field. The purposes of this diversion

are to bring sediment-rich Mississippi River water to the subsiding delta, and reduce saltwater intrusion.

At Delacroix Island (Fig. 2), samples were taken on three transects (NW, NE & S), with stations at the discharge 100, 300 and 500 m from the discharge, and at two reference sites on the NW and NE transects. Because of land formations only the NW and SW transects had 1000 m stations.

Bay de Chene

The Bay de Chene Oil and Gas Field lies in the Barataria Basin, approximately 42 miles (67 km) south of New Orleans. The field was in constant production since 1942, with four producing wells at the time of the pre-termination sampling (May 1993).

The sampled tank battery is located in Hackberry Bay, a large open bay that is typical of the Barataria system. The area is influenced seasonally by the Mississippi River, but to a lesser extent than the Delacroix Island Area.

At Bay de Chene (Fig. 3), the collection stations were on 4 transects (NW, NE, SW & SE), with a reference station for each of the two northern transects. Only 500 m and 100 m stations were sampled on the SE transect, because of the presence of field facilities. The 100 m station along the NE transect was an abandoned fuel dock, located in a channel.

Risk Assessment

A screening analysis was done as a preliminary assessment of the pre-termination sediment sample data to comply with the urgent needs of USDOE, related to the State of Louisiana's permits for continued operations. More-detailed analyses of the ecological risks from produced waters at these two sites are being done by others.

The screening analysis used a recent update by Long et al. (1995) of the Long and Morgan (1990) ERL and ERM criteria for potential adverse ecological effects of sediment contaminants. (ERL = effects range low, adverse effects at the 10th percentile of tests in a Biological Effects Data Base; ERM = effects range median, effects at the 50th percentile of the tests.) Sediment values of a contaminant that are less than the contaminant's ERL value were defined as a minimal effects range, where effects "...would rarely be observed" (Long et al. 1995). Concentrations at and above the ERL value, but less than the ERM value, "...represent a possible-effects range within which effects would occasionally occur". Concentrations at or above the ERM value "...represent a probable effects range within which effects would frequently occur".

This presentation concentrates on PAHs. A report on screening of naturally occurring radioactive materials, inorganic and other chemical pollutants was presented elsewhere (Meinhold et al. 1995).

## Results

At Delacroix Island total and individual PAH concentrations exceeded ERL criteria at the discharge and 100 m stations (Table 2). Acenapthene exceeded the ERL Value at the 300 m and 500 m stations of the northwest transect. No criteria values were exceeded at 1000 m and reference stations, and no PAHs exceeded ERM values at any stations.

At Bay de Chene only the discharge station samples exceeded ERM criteria for total and individual PAHs (Table 3). Total and individual PAH concentrations exceeded ERL criteria at the discharge, 100 m, and 300 m stations (Table 4). High concentrations at 100 m NE probably reflect the influence of the abandoned loading dock.

## Discussion

Before cessation of operations, PAH levels in surface sediments were generally elevated above ERL criteria, up to 100 m in radius around the two discharges. At Bay de Chene, ERL criteria were also exceeded at 300 m, particularly on the NE transect. This could reflect a combination of factors: a rate of produced water discharge that was approximately double the rate at Delacroix Island (Table 1); greater chance for distribution of the discharge because of turbulence (see discussion below); and the presence of a channel; and residual sediment contamination from the abandoned dock at the 100 m station in that channel. Nevertheless, sediment samples from the Bay de Chene discharge station were the only ones that exceeded ERM criteria for PAHs.

If sediment PAH concentrations are a determining factor, one could predict from our screening results that benthic biota would be adversely affected within a 100 m radius from open bay discharges of produced waters. The pre-termination sediment PAH concentration data were supplied to us by Steimle & Associates, Inc. These data are part of a report by Mullino et al. 1995 on the USDOE field study. They reported depressions of numbers of species (amphipod, gastropod, bivalve, and polychaete) and/or individuals at less than 100 m from the discharges. These field observations agree with other observations on open coastal bays off Louisiana (Neff et al. 1992; Rabalais et al. 1992).

The pre-termination benthic effects were greater at the Delacroix Island discharge station than at the comparable Bay de Chene station. Mullino et al. explained this as a result of hydrology of the environment. Although the Delacroix discharge was approximately half that at Bay de Chene, there was less opportunity for turbulent mixing and dilution of the discharge, because the Delacroix environment was semi-enclosed. It was suggested that the Delacroix discharge was more likely to produce a hypersaline nonoxygenated layer on the bottom, as supported by data, from the 2 sites, on the chlorinity of pore water (Mullino et al. 1995).

The effects of hypersalinity and other contaminants can't be separated from those of PAHs. Mullino et al. 1995 reported that multiple regression analyses identified sediment concentrations of dibenzothiophenes (not listed in the criteria values) at the stations as negatively correlated to numbers of individuals around both sites. Dibenzothiophenes and fluoranthenes were negatively correlated with numbers of individuals and numbers of species at Bay de Chene.

For stations beyond 100 m, predictions of detrimental effects, based on the comparisons to the criteria of Long et al. 1995, do not appear to be matched by the benthic data. Published letters (Chapman 1995a,b) indicate that there is no reason to expect such a relationship. Comparisons to standard criteria based upon biological testing, and field observations each have their own role in the analysis of ecological risk: "...numerical environmental quality criteria are useful generically for screening purposes, but not for definitive assessments of, in particular, areas of the environment that fall between 'very clean' and 'very polluted'."

## Acknowledgements

This work was supported by the United States Department of Energy, Office of Fossil Energy, through the Metaire Site Office, with guidance from Dr. Brent Smith as project officer. The primary contractor for the field study described in the text was Continental Shelf Associates, Inc., Jupiter, Florida. Steimle and Associates, Inc., Metaire, Louisiana supplied the data used the analysis. Work performed under Contract No. DE-AC02-76CH00016 with the U.S. Department of Energy (A.F. Meinhold, P.I.).

## References

Boesch, D.F. and N.N. Rabalais [ed.]. 1989. Produced Waters in Sensitive Coastal Habitats: An Analysis of Impacts, Central Coastal Gulf of Mexico. OCS Report/MMS 89-0031, U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, LA.

Chapman, P.M. 1995a. Extrapolating laboratory toxicity results to the field. Environ. Toxicol. Chem. 14: 927-930.

Chapman, P.M. 1995b. Do sediment toxicity tests require field validation. Environ. Toxicol. Chem. 14:1451-1453.

Long, E. R., D. D. Macdonald, S. L. Smith and F. D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19: 81-97.

Long, E.R. and L.G. Morgan. 1990. The Potential for Biological Effects of Sediment-sorbed Contaminants Tested in the National Status and Trends Program. NOAA Tech. Memo. NOS OMA 52, U.S. National Oceanic and Atmospheric Administration, Seattle, WA.

Meinhold, A.F., S. Holtzman and M.P. DePhillips. 1995. Risk assessment for produced water discharges. Proceedings of the 1995 International Seminar on Produced Water and Environmental Aspects, September 25-28, 1995, Tronheim, Norway, In Press.

Mullino, M.M., M.F. Rayle, J.C. Francis and M.A. Poirrier. 1995. Delineation of Benthic Impact and Recovery at Two Produced Water Discharge Sites in Inshore Louisiana. Proceedings of the 1995 International Seminar on Produced Water and Environmental Aspects, September 25-28, 1995, Tronheim, Norway, In Press.

Neff, J.M., T.C. Sauer, Jr. and N. Maciolek. 1992. Composition, fate and effects of produced water discharges to nearshore marine environments. *In* J.P. Ray and F.R. Engelhart [ed.] Produced Water Technological/Environmental Issues and Solutions, Plenum Press, NY.

Rabalais, N.N., B.A. McKee, D.J. Reed and J.C. Means. 1992. Fate and effects of produced water discharges in coastal Louisiana, Gulf of Mexico, USA. *In* J.P. Ray and F.R. Engelhart [ed.] Produced Water Technological/Environmental Issues and Solutions, Plenum Press, NY.

Table 1. Open bay study sites

| Site | Termination of Discharge | Environment | Discharge (bbl/day) |
|---|---|---|---|
| Delacroix Island Tank Battery #1 | 1 May 1993 | Saline, Open-Water | 1,970 |
| Bay de Chene Tank Battery #5 | 1 July 1993 | Saline, Open-Water | 3,825 |

Table 2. Concentrations of PAHs in Sediment Samples (0 to 5 cm) at Delacroix Island that Exceeded ERL Criteria (Discharge values are the averages from three core samples).

| Contaminant | ERL (ppb) | Measured (ppb) | Station |
|---|---|---|---|
| Total PAH | 4,022 | 12,871 | Discharge |
| | | 6,056 | 100 m NW |
| Acenaphthene | 16 | 32 | Discharge |
| | | 99 | 100 m NW |
| | | 180 | 300 m NW |
| | | 69 | 500 m NW |
| | | 210 | 100 m NE |
| | | 71 | 300 m NE |
| | | 140 | 500 m NE |
| Anthracene | 85 | 200 | 100 m NW |
| Fluorene | 19 | 68 | Discharge |
| Naphthalene | 160 | 173 | Discharge |
| Benzo(a)anthracene | 261 | 350 | 100 m NW |
| Fluoranthene | 600 | 900 | 100 m NW |

Table 3. Concentrations of PAHs in Sediment Samples (0 to 5 cm) at Bay de Chene that Exceeded ERM Criteria (Discharge values are the averages from three core samples).

| Contaminant | ERM (ppb) | Measured (ppb) | Location |
|---|---|---|---|
| Total PAH | 44,792 | 162,152 | Discharge |
| Benzo(a)anthracene | 1,600 | 12,000 | Discharge |
| Benzo(a)pyrene | 1,600 | 9,000 | Discharge |
| Chrysene | 2,800 | 11,000 | Discharge |
| Dibenzo(a,h)anthracene | 260 | 1,700 | Discharge |
| Fluoranthene | 5,100 | 8,100 | Discharge |
| Pyrene | 2,600 | 6,100 | Discharge |
| High Molecular Weight PAH | 9,600 | 47,900 | Discharge |

Table 4. Concentrations of PAHs in Sediment Samples (0 to 5 cm) at Bay de Chene that Exceeded ERL Criteria (Discharge values are the averages from three core samples).

| Contaminant | ERL (ppb) | Measured (ppb) | Location |
|---|---|---|---|
| Total PAH | 4022 | 72685 | Discharge |
| | | 5370 | 100 m NW |
| | | 4075 | 300 m NW |
| | | 11577 | 100 m NE |
| | | 6336 | 300 m NE |
| Acenaphthene | 16 | 213 | Discharge |
| | | 48 | 100 m NE |
| | | 20 | 300 m NE |
| Anthracene | 85.3 | 573 | Discharge |
| | | 86 | 100 m NE |
| Fluorene | 19 | 320 | Discharge |
| | | 22 | 100 m NW |
| | | 33 | 300 m NW |
| | | 67 | 100 m NE |
| Naphthalene | 160 | 160 | Discharge |
| Phenanthrene | 240 | 1363 | Discharge |
| | | 250 | 100 m NE |
| | | 260 | 300 m NE |
| Benzo(a)anthracene | 261 | 4787 | Discharge |
| | | 340 | 100 m NE |
| | | 350 | 300 m NE |
| Benzo(a)pyrene | 430 | 3683 | Discharge |
| Chrysene | 384 | 4433 | Discharge |
| | | 470 | 100 m NE |
| Dibenzo(a,h)anthracene | 63.4 | 687 | Discharge |
| | | 70 | 100 m NE |
| Fluoranthene | 600 | 4300 | Discharge |
| | | 910 | 100 m NE |
| | | 650 | 300 m NE |
| Pyrene | 665 | 3167 | Discharge |
| | | 730 | 100 m NE |

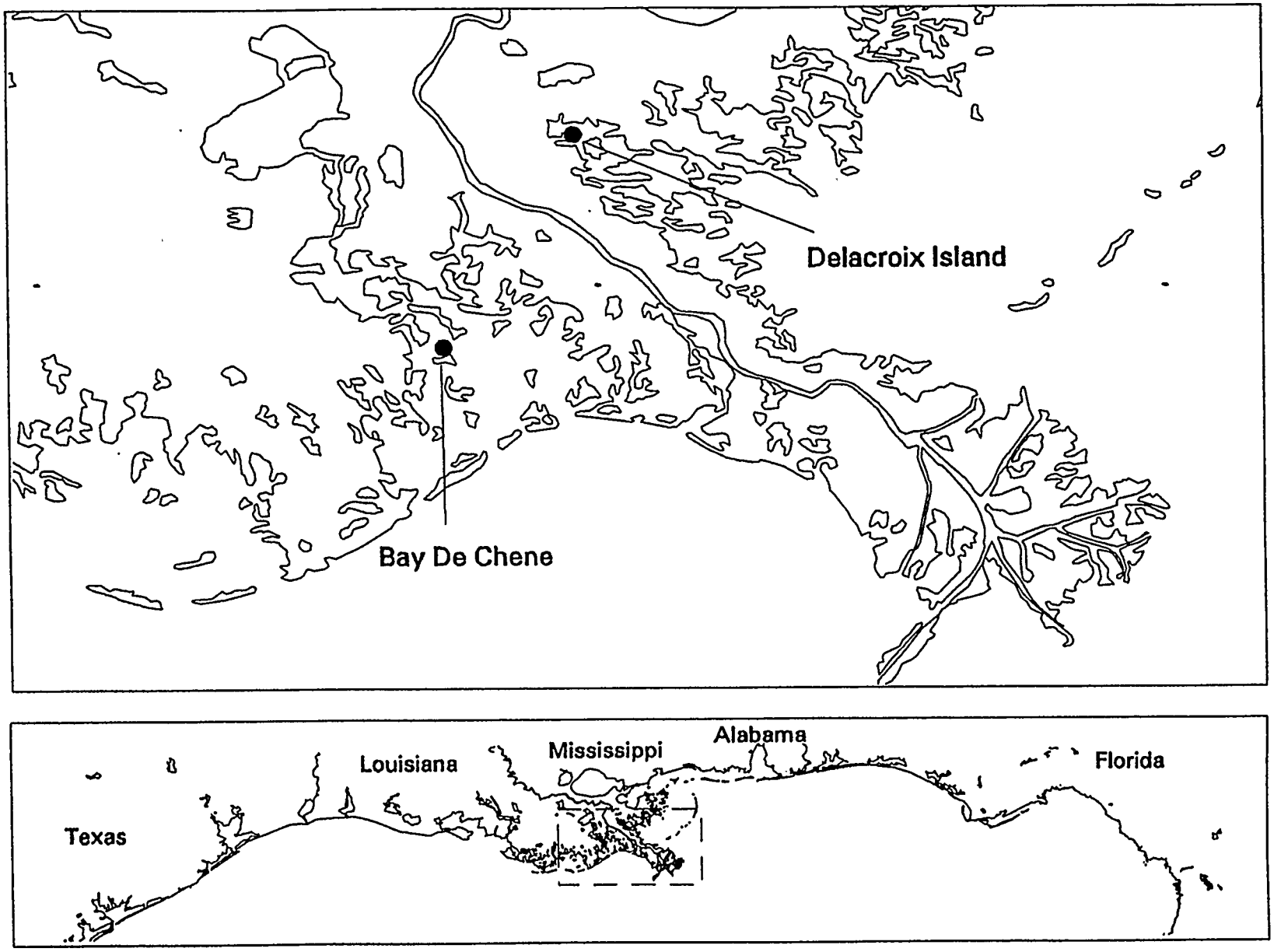


Fig. 1. Locations of sediment sample sites for produced water discharges in open bays in the Gulf of Mexico

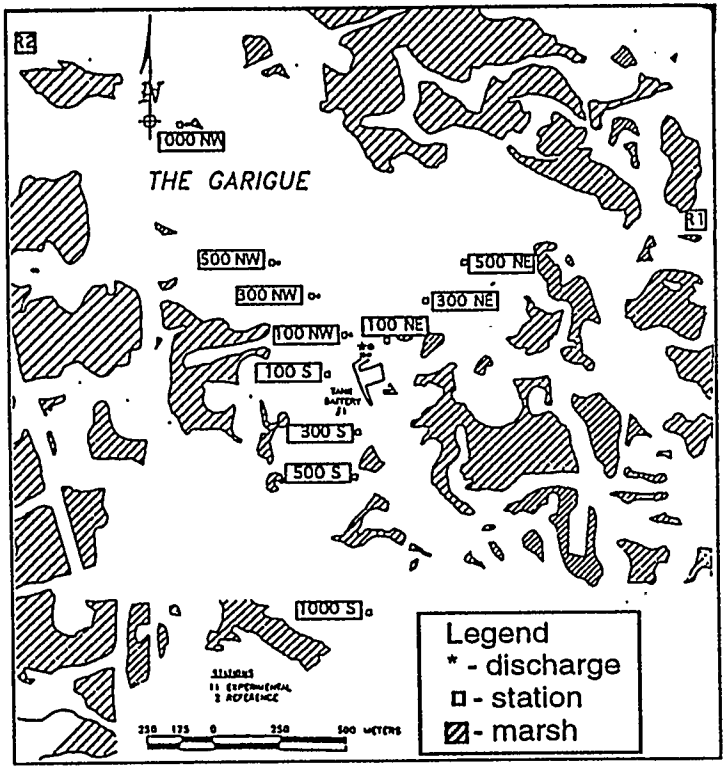


Fig. 2. Sediment sampling stations at and around the Delacroix Island production platforms.

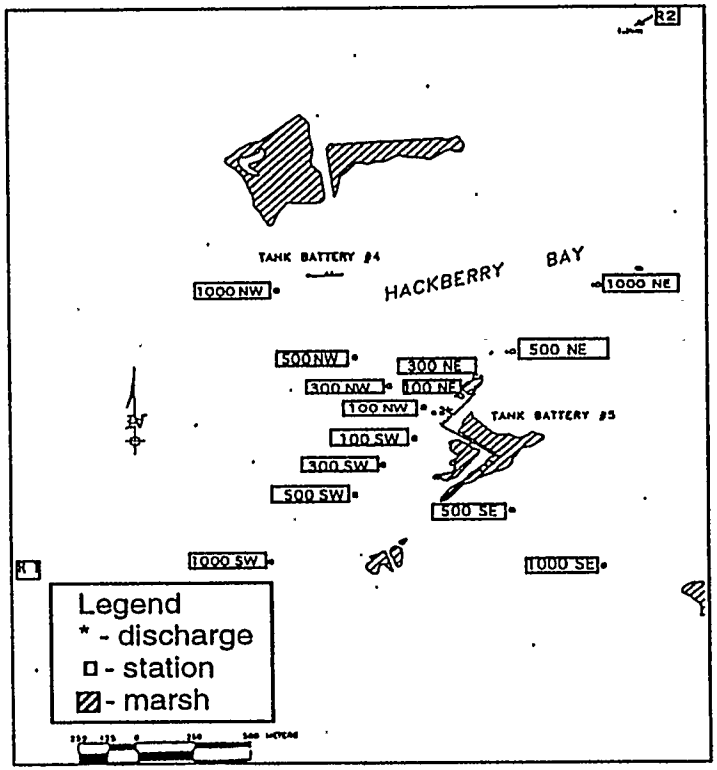


Fig. 3. Sediment sampling stations at and around the Bay de Chene production platforms.

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