

FLORIDA COASTAL SEDIMENT CONTAMINANTS ATLAS

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1994

EXECUTIVE SUMMARY

Sediment quality is a useful indicator of aquatic environmental conditions. Sediments are the major repository of contaminants in surface water systems, and play a significant part in influencing the fate and effects of potentially toxic substances. The purpose of the *Florida Coastal Sediment Contaminants Atlas* is to describe the spatial extent of chemical contamination in Florida's coastal waterbodies, and to assist in comparing contaminant levels and distributions between waterbodies. Most of the highest concentrations for any particular contaminant are found at sites near Tampa, Pensacola, Miami, and Jacksonville. However, high contaminant concentrations are occasionally found near other cities, and low to moderate levels of contaminants are common adjacent to many less developed coastal areas. Sediment chemistry data indicate the most common metal contaminants are lead, zinc, cadmium, and mercury, and the most common class of organic contaminant is the polynuclear aromatic hydrocarbons. Stormwater runoff appears to be the major cause of contamination of sites identified in the *Atlas*. Regional monitoring of contaminants in living resources and sediments, augmented by other assessments, is strongly recommended to keep a finger on the pulse of Florida's coastal ecosystems.

Sediment information is used by local, state, and federal regulatory agencies for many purposes, including trend monitoring, permitting, and restoration. To improve the use of this information, the FDEP initiated a series of coastal sediment contaminants surveys in 1982. The *Atlas* provides the results of the surveys through 1991. In addition to FDEP data, the *Atlas* has been strengthened by inclusion of statewide sediment data from the National Oceanic and Atmospheric Administration's (NOAA) National Status and Trends Program, as well as sediment data produced by the Mote Marine Laboratory, an independent marine research facility located in Sarasota, Florida.

Sediment chemical data, presented on *Atlas* maps as barcharts, allow comparison of sediment contaminants levels within coastal areas, and between estuarine systems. The *Atlas* includes information on eight trace metals (arsenic, cadmium, chromium, copper, mercury, lead, nickel, and zinc), and five classes of organic compounds - chlorinated hydrocarbons, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), phenolic hydrocarbons, and aliphatic hydrocarbons. To interpret metals contamination, individual metal concentrations are reported using an interpretive statistical approach developed by the Department. The total concentration of each class of organic compound is normalized to total organic carbon to help account for differences in the tendency of sediments to accumulate organic contaminants. A Technical Volume accompanies this *Atlas* and provides ancillary information for users of this document.

The *Atlas* qualitatively presents the extent of contamination of estuarine and marine habitats; however, it should not be used without additional information to predict biological effects of contaminants.

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ACKNOWLEDGEMENTS

The *Florida Coastal Sediment Contaminants Atlas* is the product of considerable effort by many individuals concerned with improving information on the condition of Florida's coastal environment. In particular, Lou Burney, Kathleen Swanson and Graham Lewis made significant contributions in collecting and interpreting statewide sediment chemistry data. Appreciation is extended to the following individuals and their respective government agencies: Dana Morton and Betsy Deuerling of the City of Jacksonville Water Quality Division; Gary Molina of the Dade County Department of Environmental Resource Management; Rick Alleman of the South Florida Water Management District; and Paul Davis and Carmen Vare of the Palm Beach County Department of Environmental Resources Management.

The Center for Spatial and Environmental Analysis in the University of South Florida Department of Geography produced the maps included in this atlas. The Center's faculty, especially Dr. Mark Lindberg and graduate students, went beyond contract requirements to ensure the quality of the maps and data presentation. We appreciate the assistance of the Marine Research Institute and the Stormwater and Nonpoint Source Section of the Florida Department of Environmental Protection in funding a major portion of the first printing. NOAA provided funding for contaminant surveys through the Office of Ocean and Coastal Resource Management, under the Coastal Zone Management Act of 1972, as amended.

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SECTION 1: PURPOSE OF THE FLORIDA COASTAL SEDIMENT CONTAMINANTS ATLAS

1.0 Introduction

The purpose of this atlas is to describe the spatial extent of chemical contamination in sediments of Florida's coastal waterbodies, and to assist in comparing contaminant levels and distributions between these waterbodies. Sediments are the major repository of contaminants in aquatic environments, and sediment quality data, as a direct indicator of the health of coastal aquatic habitats, are increasingly relied on by federal, state, and local agencies to support resource management programs.

The *Florida Coastal Sediment Contaminants Atlas* summarizes results of coastal sediment contaminants surveys conducted from 1982 to 1991 by the Florida Department of Environmental Protection (FDEP). The *Atlas* also includes sediment chemistry data from surveys conducted by the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Programs, and a survey in the Lower St. Johns River estuary by the Mote Marine Laboratory. The *Atlas* permits a broader use of data gathered by these surveys in environmental management decisions. Presented in an easy-to-interpret map and graphical format, information in the *Atlas* can be employed by many users, including urban planning and regulatory agencies, industries (e.g. permit applicants), and scientists. The public may find this document useful in assessing impacts of development in coastal areas.

In a 1990 report entitled *Managing Troubled Waters: The Role of Marine Environmental Monitoring*, the United States National Research Council emphasized that localized permit compliance monitoring, while meeting limited objectives, does not address public concerns about environmental degradation in the coastal environment. The report recommended that regional monitoring programs are needed to define the extent and severity of coastal contamination, determine the effectiveness of regulations, and help guide policies and programs in protecting the marine and estuarine environment. This recommendation clearly reflects the objectives of the *Florida Coastal Sediment Contaminants Atlas*.

1.1 How to Use the *Florida Coastal Sediment Contaminants Atlas*

The *Atlas* contains sediment contaminants data placed in a spatial reference framework. An

attempt has been made to present map areas that display complete hydrographic regions defined by coastal water circulation patterns. Coastal areas are subdivided into nine geographic regions: 1) the panhandle, which includes Pensacola Bay, Choctawhatchee Bay, St. Andrews Bay, St. Joseph Bay, and Apalachicola Bay; 2) the Big Bend region, which covers the area between Apalachee Bay and Tarpon Springs; 3) Tampa Bay; 4) Charlotte Harbor and Caloosahatchee River; 5) the Everglades; 6) the Florida Keys; 7) the southeast region (Biscayne Bay to Jupiter); 8) the east-central region (Indian River Lagoon); and 9) the northeast region (Daytona Beach to Fernandina Beach). In intensively sampled areas, such as Tampa Bay or the Lower St. Johns River, inset maps provide more detail on individual sediment sampling locations.

Different site symbols are employed to indicate which group of researchers (FDEP, red triangle; NOAA, green star; Mote Marine Laboratory, blue flag) produced the sediment chemistry data. The barchart format allows for quick discernment of trace metal enrichment or the presence of organic contaminants at individual sites. A color-coded legend for the barcharts is included on the first map of each region. Trace metal barcharts present enrichment values between 1 and 10 times the expected background value. If the concentration of a trace metal in sediment at a site falls within the expected natural range, no bar is plotted. A bar is plotted if the trace metal enrichment factor is greater than 1.0. If a sediment sample is enriched by a factor of 10 times above expected natural levels, a "+" sign above the bar indicates this condition.

As with the metals data, organic contaminants data are normalized; however, the organic concentration is normalized to total organic carbon (TOC) to account for possible biological effects. The resulting normalized values are plotted on barcharts which use a logarithmic scale. The larger the bar representing a class of organic contaminants, the more likely the impact on benthic organisms at the site.

If a particular trace metal or class of organic contaminants was not analyzed, an open circle is placed under the barchart in the appropriate column. For explanations of the trace metal enrichment factors and organic contaminants normalization procedure, please see Sections 4.1 and 5.1, as well as the Technical Volume that accompanies this publication.

SECTION 2: SEDIMENT QUALITY ISSUES

2.0 Introduction

Florida is the fourth most populous state, with a growing population of nearly 14 million. Most residents live near the coast, and population density in these regions is expected to increase by over 30 percent in the next twenty years (Culliton *et al.* 1990). This growth may result in increased discharges of contaminants and nutrients into coastal systems despite pollution control efforts. The state's nearly 11,000 miles of tidal shoreline, combined with the rate of coastal development, complicates the process of monitoring the health of Florida's coastal ecosystems, and makes it difficult to measure the progress of pollution control efforts. Florida coastal waters receive trace (heavy) metals and various toxic organic compounds from a variety of sources, including natural contributions from rivers and streams, direct discharges of treated effluent from sewage treatment facilities, industrial sources, and non-point sources such as urban stormwater, agricultural runoff, and atmospheric deposition.

2.1 Sediment Quality: An Indicator of Ecosystem Health

Coastal monitoring programs based solely on water column measurements do not effectively indicate coastal and estuarine contamination. Sediment quality information is useful as an indicator of ecosystem health, as sediments play a significant role in influencing the fate and effects of many toxic substances. Many trace metals and toxic organic compounds rapidly adsorb (attach) to suspended particles. The particles settle in estuarine and marine ecosystems and become incorporated in sediments. Measurements of contaminants in the water column often show that contaminant concentrations are within state water quality standards, while concurrent measurements of sediments may show the site to be highly contaminated. As such, sediments integrate contaminant inputs over time and may become sources of contamination long after original discharges cease.

Sediments link chemical and biological processes in benthic (sediment-dwelling) communities. Sediments provide essential habitat for spawning, incubation, and other biological processes. Direct contact with or ingestion of contaminated sediments may affect the health and behavior (feeding/burrowing) of benthic organisms. As contaminants accumulate in these organisms, subsequent bioconcentration may occur if the contaminants are transferred to consumer organisms such as fish,

birds, and humans. Elevated levels of toxic contaminants have been observed in fish and wildlife from many locations in the United States, and concern over the risk of consuming contaminated seafood and fish has increased public awareness of the issues of sediment contamination and coastal pollution.

The protection of unimpacted sediments and management of contaminated sediments is critical to maintaining marine and estuarine ecosystem health. The presentation of sediment quality in this document not only provides a statewide perspective on contaminants levels, but also provides a context for local assessment of sediment quality conditions.

SECTION 3: COASTAL SEDIMENT CONTAMINANTS SURVEYS

3.0 Introduction

This section describes the objectives of the Florida coastal sediment contaminants surveys and summarizes computer mapping procedures, sampling procedures, laboratory analyses, and the sediment chemistry database. Detailed information on these topics is included in a separate Technical Volume. In addition to the FDEP coastal sediment contaminants surveys, other agencies and research groups have collected Florida sediment chemistry data (Section One, Technical Volume). In evaluating and comparing such databases, a principle concern is to ensure that sampling and analytical methods are comparable (Section Two, Technical Volume). The *Atlas* includes data from two additional sediment chemistry databases which are comparable to the FDEP database. Insufficient funds were available to evaluate and include additional sediment data sets.

3.1 FDEP Coastal Sediment Contaminants Surveys

Results presented in the *Atlas* do not represent a spatially unbiased view of sediment contamination. The majority of the sampling locations in the *Atlas* represent areas adjacent to highly developed coastal areas. However, the *Atlas* also includes sediment information on areas likely to experience growth and areas likely to remain isolated from development.

The FDEP surveys contributing data for the *Atlas* were conducted under different projects (Section One, Technical Volume). For the Deepwater Ports Project (1983-1984), most sites were located to assess commercial navigation channels and berths. These sites are near densely developed areas and are located in areas likely to accumulate contami-

nants. A second type of survey (1985-1991) focused on parts of estuaries likely to be contaminated based on tributary inflow and land use patterns or likely to receive contaminants due to future development. In a third type of survey conducted to develop data on unperturbed sediments, sites were located in remote areas removed from known or suspected contaminant sources. These reference or "clean" sites represent the wide variety of coastal sediment types in Florida. Given the above site selection objectives, the results presented in the *Atlas* do not represent a spatially unbiased view of sediment contamination. Thus, the proportion of coastal contamination cannot be estimated. Rather, the database represents a statewide overview of sediment conditions in areas ranging from pristine to highly contaminated.

3.2 The FDEP Coastal Sediment Contaminants Database

The FDEP sediment contaminants database used in the *Atlas* includes information on nearly 700 sites visited between 1983 and 1992. Some sites were resampled. Sediment samples were analyzed using comparable techniques (Section Two, Technical Volume). Although the *Atlas* reports data for arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc, the FDEP sediment database also contains concentration data on other metallic and nonmetallic elements (barium, iron, lithium, manganese, silver, titanium, and vanadium). The FDEP sediment database also includes measurements of grain size, nutrients (total Kjeldahl nitrogen, total phosphorous, and total organic carbon), and toxic organic contaminants, such as polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), phenolic and aliphatic hydrocarbons, and chlorinated pesticides (e.g. DDT).

Measurement of trace metal concentrations is standard in sediment surveys because of the prevalence of processes which can result in metals contamination. Section Four of the Technical Volume lists common uses and sources of metal contaminants examined in the *Atlas*. Most metals examined in the FDEP sediment surveys are present in the microgram per gram (parts per million, ppm) range. However, mercury occurs in the nanogram per gram (parts per billion, ppb) range in virtually all pristine estuarine sediments. State-of-the-art analytical techniques are therefore required for mercury measurements to obtain meaningful detection limits and accurate concentration values. Near urban centers, the presence of high levels of metals often signals

the presence of organic contaminants but, due to high analytical costs, not every site measured for metals was analyzed for organic contaminants. Virtually all of the organic contaminants occur in the ppb concentration range.

All sediment chemistry data are stored in the FDEP sediment database in DBASE IV format. Station coordinates, water column parameters (conductivity, dissolved oxygen, temperature, and salinity), and visual sediment descriptions are also entered in the FDEP sediment database. Metals, toxic organic compounds, and water column parameters in the FDEP database are listed in Section Three of the Technical Volume.

3.3 NOAA and MOTE Marine Laboratory Sediment Contaminants Surveys

Data from two sediment chemistry databases besides FDEP have been incorporated into the *Florida Coastal Sediment Contaminants Atlas*. Since 1984, the National Status and Trends Program of the National Oceanic and Atmospheric Administration (NOAA) has monitored the concentrations of metals and toxic organic contaminants in bottom-feeding fish, shellfish and sediments at United States coastal sites. Forty-two NOAA sites are located in Florida coastal waters. NOAA analyzed a suite of metals and toxic organic compounds similar to those in the FDEP surveys and employed comparable analytical methods (NOAA 1991).

The Mote Marine Laboratory (MML), based in Sarasota, Florida, conducted a sediment quality study of the Lower St. Johns River estuary in 1987 and 1988. The project, entitled *Characterization of Baseline Conditions of the Physical, Chemical, and Microbiological Environments in the St. Johns River Estuary*, produced sediment metals and toxic organic contaminants data for 33 sites, as well as other environmental data. The MML sampling and analytical methods were consistent with FDEP methods.

3.4 Spatial Analysis of Site Locations

Atlas maps were prepared by the Center for Spatial and Environmental Analysis in the University of South Florida Department of Geography. The sediment contaminants data and station notation information were plotted with the ARC-INFO program on base maps taken from a Geographical Information Systems (GIS) database. Station notation information and metal and organic contaminants data of the FDEP, NOAA, and MML were graphically expressed

through the use of ARC-INFO software. Coordinates for sampling locations were rectified with original chart-plotted station locations to ensure accurate identification.

SECTION 4: FLORIDA SEDIMENT TRACE METALS DATA

4.0 Mineralogy and Trace Metals of Florida Coastal Sediments

Florida coastal sediments are composed of sand, silt, clay, carbonate minerals, and organic debris. Metals are natural components of these diverse sediments, and their concentration varies significantly. Therefore, interpretation of sediment trace metals data is not straightforward. To identify metal contamination, anthropogenic trace metal enrichment must be distinguished from a variable natural background.

Florida estuarine sediments are produced primarily by three sedimentation processes: 1) erosion and redeposition of coastal and upland sediments deposited during previous high sea level stands; 2) *in situ* production and weathering of plant and animal material (e.g. shell material and reef fragments); and 3) inshore movement of fine-grained sediment from the open ocean. In Florida, the sediments formed by these processes span a significant geochemical range, from the silica- and aluminum-rich sediments of northern and central Florida to the carbonate-rich, aluminum-poor sediments of southern Florida and the Florida Keys.

Coastal sediments in northern and central Florida consist of the weathering debris of exposed rocks of the southeastern United States, as well as unconsolidated sediments of the Gulf and Atlantic Coastal Plain in Alabama, Georgia, and Florida. These sedimentary (clastic) materials contain aluminosilicate minerals transported to estuaries by rivers such as the Perdido, Choctawhatchee, Apalachicola, Ochlockonee, Suwannee, and St. Johns. Sediments in the northern part of the state, except for the Tarpon Springs to Big Bend area discussed below, consist mainly of a mixture of quartz sand and silt, and variable proportions of clay and organic matter. The aluminum-rich clay minerals represent weathering products of other aluminosilicate mineral groups, such as feldspar, micas, pyroxene, and amphibole. Because of the weathering of these metal-bearing minerals, trace metal and aluminum concentrations in sediments are much higher in

northern Florida than in the southern part of the state.

Sediments along the Gulf of Mexico coast from the Tarpon Springs area north to the Big Bend area receive material transported by numerous spring-fed rivers. Much of this part of Florida is a low-relief karstic plain, with limestone and dolostone comprising most of the exposed geologic formations. The average aluminum concentration of sediments in this region is lower than in other North Florida coastal regions, reflecting the influence of carbonate rocks in these drainage basins.

Sediments of Florida Bay and the Florida Keys contain significant quantities of calcium carbonate. These sediments have slowly formed from the remains of the subtropical and tropical marine flora and fauna. Modern and ancient coral reefs provide a source of carbonate sedimentary material, but a minor amount of quartz and clay material is contributed by riverine and salt marsh systems. South Florida is the only coastal sedimentary province of the conterminous United States that is dominated by carbonate sediments. In contrast to North Florida sediments, south Florida estuarine sediments usually contain low levels of metals.

4.1 The Metal to Aluminum Normalization Method for Identifying Metal Enrichment in Florida Sediments

Interpretation of sediment metal data is complicated by the fact that natural metal concentrations in sediments vary by orders of magnitude depending on the sediment source region. Thus it is impossible to quantify the amount of anthropogenic contamination based solely on absolute metal concentrations. This observation is important because the lack of accounting for natural metals burdens often has led to incorrect interpretation of contamination. In the past, large variations in metal concentrations were incorrectly interpreted as reflecting anthropogenic inputs.

To distinguish natural variability from variability induced by contamination and to compare Florida's diverse coastal areas described above, the FDEP developed an interpretive statistical tool based on normalization of metal concentrations to the concentration of aluminum in Florida sediments (Schropp and Windom 1988; Windom *et al.* 1989; Schropp *et al.* 1990). The interpretive tool corrects for natural metal background levels in sediments. The barchart presentation method in the *Atlas* identifying metal

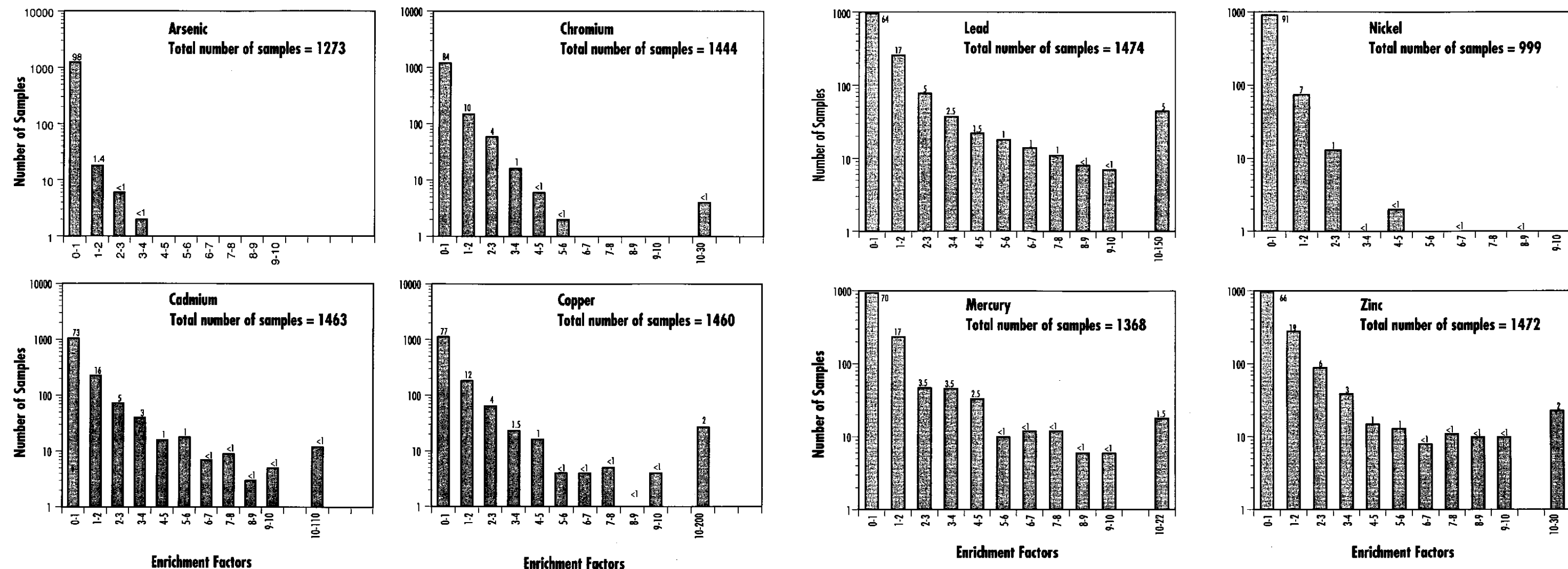


Figure 1 - Statewide comparison of FDEP sediment samples that contain metals levels above expected natural background. Bars are expressed as enrichment factors above background (e.g. a factor of 3 to 4 represents metals concentration 3 to 4 times above expected background). The number above each bar is the percentage of samples analyzed for that element that fall in that enrichment factor range.

contamination is based on the metal to aluminum normalization method. The bars indicate the amount of metal present above expected natural concentrations for each location.

At present the FDEP does not have confidence that mercury enrichment can be identified through a relationship with aluminum. To present mercury enrichment information, a maximum mercury concentration associated with uncontaminated estuarine areas is assumed typical of natural sediments. Interpretation of the barcharts was discussed in Section One of the *Atlas*. Section 2.3 of the Technical Volume contains a detailed explanation of the aluminum normalization method and trace metal barchart presentations.

SECTION 5: FLORIDA SEDIMENT TOXIC ORGANIC CONTAMINANTS DATA

5.0 Introduction

Toxic organic contaminants can be classified based on their chemical structure and presence or absence of certain elements (e.g. chlorine). The FDEP database contains five separate classes of toxic organic contaminants: pesticides (e.g. DDT, dieldrin), polychlorinated biphenyls (PCBs), polynuclear (sometimes referred to as polycyclic) aromatic hydrocarbons (PAHs), phenolic compounds, and aliphatic petroleum hydrocarbons. Section Five of the Technical Volume summarizes potential sources of the five toxic organic compound classes. Chlorinated organic and phenolic compounds are man-made, therefore detection of these compounds

indicates anthropogenic input or contamination. Certain PAHs and aliphatic petroleum hydrocarbons are produced by natural processes such as forest fires and underwater petroleum seeps. However, the presence of these compounds in Florida coastal sediments can be attributed almost entirely to human activities such as the use of petroleum derivatives in asphalt road construction or crude oil and fuel spills (Eisler 1987; NOAA 1991). Careful consideration is needed concerning laboratory preparation of sediment samples. Since some organic contaminants are toxic in the parts per billion range (MacDonald 1993), laboratory methods must have adequate detection limits to produce useful sediment data.

5.1 Interpretation of Organic Contaminants Data

As with the sediment metal data, organic contaminants data also are normalized, in this case to the concentration of total organic carbon (TOC) in the sample (see Section 2.4, Technical Volume). Naturally occurring organic molecules on sediment particle surfaces enhance adsorption of organic contaminants, thus sediments with elevated TOC levels have a greater capacity to chemically bond with organic contaminants. Thus, high TOC concentrations tend to reduce the bioavailability of organic toxicants. The concentration of organic contaminants is normalized to account for the influence of organic carbon upon bioavailability, and, therefore, the potential for toxicity. High concentrations of organic toxicants may not pose toxicity problems if they are effectively sequestered by the TOC of the

sediment. On the other hand, relatively sandy sediments with moderate to low concentrations of TOC may be toxic.

The concentrations of all analyzed compounds in an organic contaminants class are summed together for plotting purposes. For example, individual chlorinated pesticides are first measured as separate compounds. Then the individual pesticides are summed into a single category, which is normalized to the TOC concentration in the sample. Similar procedures are performed for the other organic contaminants classes. In the *Atlas*, the larger the bar representing a certain category of organic contaminants the greater the potential impact on the benthic organisms at that site. An important point to realize is that even extremely low concentrations of organic contaminants therefore plot on these barcharts.

SECTION 6: STATEWIDE COASTAL CONTAMINANTS OVERVIEW AND DISCUSSION OF ESTUARIES

6.0 Introduction

This section provides a statewide summary of coastal sediment quality, as well as a synopsis of sediment quality of selected estuarine systems. The discussions, based on information shown in the trace metals and organic contaminants maps, do not provide detailed analysis of estuarine water quality, watershed features, or land use practices. However, general physical characteristics such as mean water depth, estuarine surface area, and estuarine drainage area (EDA), are listed for each estuarine system. The EDA is the land and water component of the watershed that directly affects an estuary (NOAA 1985).

6.1 Statewide Summary of Coastal Sediment Contaminants

The coastal contaminants surveys primarily were established to help identify contaminated sites. For this reason, the sample survey strategies were biased, with the majority of samples collected from sites adjacent to or near developed areas. Therefore, the sites do not represent a spatially unbiased view, and we cannot make estimates of the proportion of the coast as a whole that may be contaminated. Nevertheless, in our opinion, the surveys provide a useful picture of estuaries affected by development, and in that vein, allow a qualitative statewide coastal summary.

With respect to the eight metals measured (arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc), enrichment above expected natural levels of these elements was most frequently observed for cadmium, mercury, lead and zinc (Figure 1, page 6). At least one of the five classes of organic contaminants is present in measurable concentrations in almost 75 percent of the sites evaluated for organic contaminants (Figure 2). As might be expected, sites closer to shore tend to have higher contaminants levels and, for both metals and organic contaminants, stormwater runoff appears to be the major cause of contamination of sites identified in the *Atlas*. However, organic contaminants occasionally are detected at locations far from urban areas, and this type of contamination may be due to agricultural and atmospheric inputs.

6.2 Estuaries of the Florida Panhandle Region

In the *Atlas*, the Panhandle of Florida consists of the area that extends west from the Ochlockonee River drainage basin to the Florida-Alabama boundary (Map 1). Sediments of Florida Panhandle estuaries consist mostly of quartz sand and silt, clay minerals, and organic debris. The rivers which form these estuaries arise in drainage basins in southern Alabama and southern Georgia, as well as west Florida counties.

6.2.1 Perdido Bay

Located at the boundary of Florida and Alabama, Perdido Bay has an estuarine surface area of 86 mi² and an average depth of just over seven feet. The Perdido Bay estuarine drainage area (EDA) encompasses 1205 mi² in the Coastal Plain in parts of Baldwin and Escambia Counties in Alabama, and western Escambia County in Florida (NOAA 1985). Streams in the upper basin feed the Perdido River and its two major tributaries, the Styx and Blackwater Rivers. Lower in the watershed, Elevenmile Creek and numerous small streams enter the bay. Several facilities, including wastewater treatment facilities and a paper mill (Champion International), are located in the Perdido Bay watershed.

Slight lead and zinc enrichment has been observed in sediments of Bayou Marcus, with slight zinc enrichment in sediments of Elevenmile Creek (Map 2). Stormwater runoff from urban areas may be the source of lead and zinc contamination in Bayou Marcus (Schropp *et al.* 1991). PAHs are present at every FDEP site within the Perdido Bay sys-

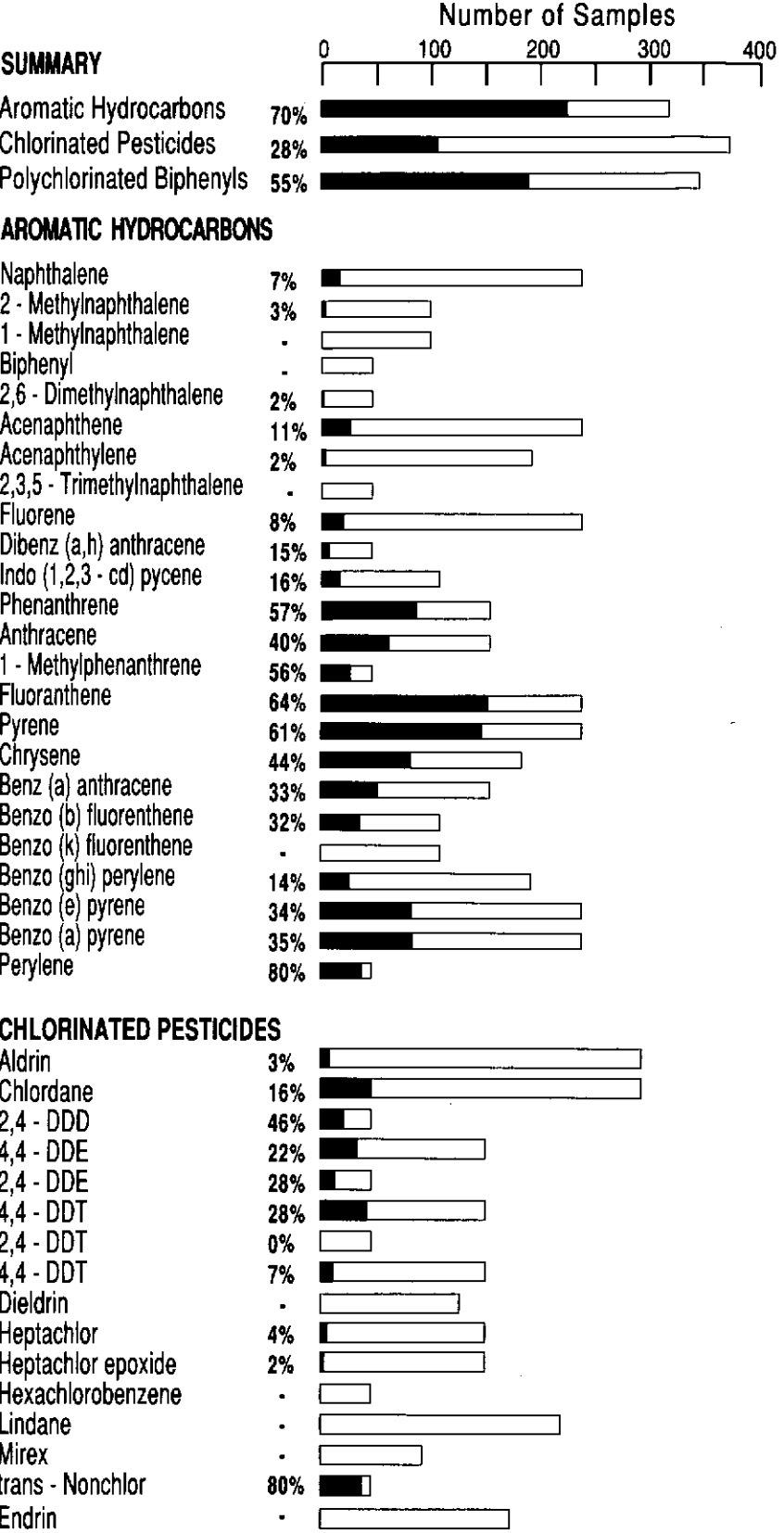
tem, PCBs are present at three sites, and aliphatic hydrocarbon compounds are present at four sites (Map 65).

6.2.2 Pensacola Bay

The four major subdivisions of the Pensacola Bay estuarine system are Escambia Bay, Pensacola Bay, Blackwater Bay, and East Bay. Together these waterbodies form one of the largest estuarine systems of Florida, encompassing over 152 mi² of estuarine surface water area. The EDA of these four bays covers 3480 mi² of Escambia, Santa Rosa, Okaloosa and Walton Counties, and parts of some southern Alabama counties. Average water depth in the estuary is 19 feet (NOAA 1985). Major tributaries of the estuary include the Yellow, Blackwater and Escambia Rivers as well as several smaller streams. Santa Rosa Sound, located north of Santa Rosa barrier island, provides a hydrologic connection between the Pensacola Bay and the Choctawhatchee Bay estuaries.

The Pensacola Bay System is one of the more heavily impacted estuarine systems of Florida. Escambia Bay and East Bay have experienced extreme submerged vegetation losses, and there have been widespread fluctuations in fish and shellfish harvests (Pensacola Bay SWIM Plan 1990). Land uses within the system's watershed include urban development, recreation, conservation, silviculture and agriculture. The western part of the Pensacola Bay system is predominantly urban whereas the eastern portion is mostly undeveloped. The urban center of Pensacola contains extensive industrial, commercial, and residential development. Industrial facilities are located along Bayou Chico, the Escambia River, and near Escambia Bay.

Slight trace metal contamination is present at many sites throughout the Pensacola Bay area (Maps 2-5). However, high levels of metal contamination have been observed in certain parts of the bay system. Sediments in Bayou Grande show moderate to high enrichment factors in several metals, particularly cadmium, lead and zinc (Map 3). The highest metal



** Numbers left of bars represent the percent of samples having detectable levels of contaminants
Figure 2 - Statewide comparison of FDEP sediment samples that contain detectable levels of toxic organic contaminants. The total number of samples analyzed for each class of organic contaminant is determined using the numbered graph at the top of the figure.

enrichment factors in the Pensacola Bay system are at sites in Bayou Chico (Map 4), where two sites have chromium and zinc enrichment greater than ten times the expected background value. Bayou Chico sediments also are contaminated with PAHs and PCBs (Maps 66 and 67). These FDEP observations in Bayou Chico are supported by sediment data of other research groups (Stone and Morgan 1991). In Pensacola Bay, PAHs and PCBs were detected close to shore and in the central part of the bay. Pesticides were detected at two sites and phenolic compounds were detected at one site near Pensacola Harbor (Maps 65, 66, and 67).

6.2.3 Choctawhatchee Bay

The Choctawhatchee Bay estuary has an estuarine surface area of 123 mi², and an EDA of 2259 mi² located in portions of Okaloosa, Walton, Holmes, Washington and Bay counties, and parts of southern Alabama. The Choctawhatchee River is the major tributary, but several creeks also empty into the estuary. Average water depth is about 22 feet (NOAA 1985). With the exception of a site near Destin and a lead enriched site near Valparaiso, no metal enrichment has been observed in this bay system (Map 6). PAHs were detected at the site near Destin, and PAHs, PCBs and pesticides were detected at NOAA sites near Valparaiso and in eastern Choctawhatchee Bay (Map 68).

6.2.4 St. Andrew Bay and St. Joseph Bay

St. Andrew Bay has an estuarine surface area of 98 mi², and an EDA of 1130 mi² in Bay, Washington, Jackson, Calhoun, and Gulf counties. The average depth of the bay is 27 feet (NOAA 1985). The main source of elevated trace metals appears to be stormwater runoff from urbanized areas in and around Panama City. Lead and zinc enrichment was detected at seven sites. Mercury, cadmium, copper and chromium enrichment was detected (Map 7). Sediments in Watson Bayou, Massalina Bayou, and near Sulphur Point exhibit slight to moderate trace metal enrichment. PAHs, PCBs, and pesticides were detected at three NOAA sites, one in the North Bay and two in St. Andrew Bay (Map 69).

East of St. Andrew Bay, St. Joseph Bay is partly separated from the Gulf of Mexico by the northward-trending St. Joseph Spit. Some of the FDEP sites in this system were located to detect contaminants associated with paper mill operations, urban runoff and marine industries. Slight to moderate mercury, cadmium, copper, lead, and zinc enrichment is pre-

sent in this system (Map 8).

6.2.5 Apalachicola Bay

Formed by the largest river system in Florida, the Apalachicola Bay estuary is unusual in that this system is composed of a river delta developing behind a sequence of barrier islands. This geomorphic situation will eventually eliminate the estuary by sediment infilling (Donoghue 1988). The Apalachicola River is formed by the confluence of the Chattahoochee and Flint Rivers near Bainbridge, Georgia, and water quality of the river has been affected by agricultural and nonpoint source runoff from both Georgia and Alabama, as well as Florida. The estuary is highly productive, providing over 90% of the Florida oyster harvest, as well as supporting shrimp and commercial fishing industries.

The Apalachicola estuarine system covers an area of about 210 mi² and has an average depth of over 27 feet. The EDA of the estuary in Florida covers 2970 mi² and occupies parts of Gulf, Franklin, Liberty, Jackson and Calhoun counties (NOAA 1985). The estuary is bounded by four barrier islands: St. Vincent Island, Cape (or Little) St. George Island, St. George Island, and Dog Island. Apalachicola Bay sediments have the highest average aluminum concentrations observed in Florida estuarine systems and also have the highest trace metals background concentrations in Florida.

Virtually no trace metal enrichment was detected by the FDEP or NOAA surveys (Map 9). However the NOAA survey detected PAHs, PCBs, and pesticides at three sites (Map 70). A recent estuarine sediment study (Livingston 1983) indicated that overall the sediments were relatively free of anthropogenic impact, except in some near-shore areas where cadmium, chromium, and zinc appeared to be slightly enriched above predicted background values.

6.3 Estuaries of the Big Bend Region

For purposes of the *Atlas*, the Big Bend Region extends from Apalachee Bay south along the coast to the area near the Anclote River (Map 10). The estuaries of the Big Bend region appear to be the least impacted systems in the state. With the exception of the Suwannee River, riverine systems in the Big Bend may be classified as spring-fed rivers and even the Suwannee River discharge is greatly increased by contributions from springs. The Big Bend estuaries have developed over an ancient shallow-water carbonate platform (the Floridan

Platform). Geologically the Big Bend coastline is described as a sand-starved, low wave energy system dominated by coastal marshes (Hine *et al.* 1988). Compared to other Florida coastal areas, there is little urban development in this region.

No metal contamination was detected in the FDEP or NOAA sites in Apalachee Bay (Map 11), Steinhatchee River estuary (Map 12), or Suwannee River estuary (Map 13). Very slight cadmium enrichment was present at a site near Cedar Key (Map 13). The NOAA surveys detected PAHs, PCBs, and pesticides at sites in Apalachee Bay, the West Pass of the Suwannee River, and near Cedar Key (Map 71).

Six of the nine FDEP stations in the Crystal River estuary exhibit copper enrichment (Map 14). Copper enrichment is almost certainly due to use of copper-bearing herbicides to control aquatic weed growth in parts of the estuary. The FDEP survey also determined slight to moderate cadmium, chromium, lead and zinc enrichment in the Crystal River-Kings Bay estuarine sediments. The United States Fish and Wildlife Service conducted a sediment survey in the Crystal River area to evaluate metal enrichment by utilizing the metal-to-aluminum normalization method. Copper enrichment was detected at every USFW site, and arsenic and zinc were elevated at some sites. Concern was expressed that high copper concentrations in this system may adversely impact the West Indian manatee population in this area (U.S. Fish and Wildlife Service 1991).

No metal enrichment was detected in the Chassahowitzka River system (Map 14). Four of nine sites in the Anclote River estuary near Tarpon Springs show slight to moderate enrichment in the following metals: cadmium, copper, mercury, lead and zinc (Map 15). No metal enrichment was observed in the Pithlachascotee River estuary.

6.4 Tampa Bay

The Tampa Bay estuarine system, with an estuarine surface area of just over 400 mi², is the largest estuary in Florida. The Y-shaped estuary has an EDA of 1860 mi² which covers parts of Pasco, Polk, Pinellas, Hillsborough, Hardee, Manatee, and Sarasota counties. The bay, with an average depth of just over 16 feet, receives runoff from nine rivers, the largest of which include the Hillsborough, Alafia, Little Manatee, and Manatee Rivers (NOAA 1985). Four major urban centers (Tampa, Clearwater, St. Petersburg, and Bradenton) occupy portions of the

EDA, and agricultural activities occur in the Little Manatee and Manatee River watersheds. Tampa Bay is an highly urbanized estuary which contains three major ports, several ship repair facilities, and numerous marinas.

In the *Atlas* metal contaminants maps, the Tampa Bay region is subdivided into five sections: Hillsborough Bay, Old Tampa Bay, western Tampa Bay and Boca Ciega Bay, southeastern Tampa Bay, and the Manatee River area (Map 16). Hillsborough Bay is itself subdivided into five sections (Map 17). In the organic contaminants maps, the Tampa Bay region is subdivided into three sections (Map 72).

Stormwater runoff from urban and residential areas around the bay is an important non-point source of contaminants. Significant metal contamination is present in parts of Hillsborough Bay. The major source of this contamination is likely stormwater discharges, although atmospheric inputs of contaminants also occurs. In northwestern Hillsborough Bay, numerous sites exhibit metal enrichment (Map 18). Perhaps the most heavily impacted area is the Ybor shipping channel where the lead enrichment factor exceeds ten times the maximum expected background value. Every metal is enriched at one or more of the sites in this map area, and most sites exhibit enrichment of several metals. Metal enrichment is present at many sites along the western shore of the Davis Islands. As is often the case adjacent to urban shorelines, high metal levels signal the presence of toxic organic contaminants. As such, PAHs, PCBs, and pesticides were detected at the NOAA site south of Davis Islands (Map 73). A joint study conducted by NOAA and the FDEP has identified sites toxic to test organisms within the Ybor Channel as well as in other areas of Tampa Bay (Long *et al.* 1991; Long *et al.* in preparation).

In northeastern Hillsborough Bay, including East Bay and McKay Bay, every site exhibits metal enrichment to some degree (Map 19). Enrichment factors are lower in west-central Hillsborough Bay (Map 20) than in northern Hillsborough Bay. In east-central Hillsborough Bay, some sites exhibit moderate enrichment factors while others exhibit no metal enrichment (Map 21). The Alafia River sediments exhibit elevated levels of metals, especially cadmium, lead, and zinc (Map 21), as well as the presence of PAHs, PCBs, and pesticides (Map 73). In southern Hillsborough Bay, one site has extremely high enrichment of cadmium, copper, and lead (Map 22). Slight metal enrichment also occurs at other sites in this part of the bay.

In southern Old Tampa Bay, metal enrichment factors were for the most part fairly low (Map 23). Cadmium is a common metal contaminant at these sites. Sites in Bayboro Harbor near downtown St. Petersburg exhibit enrichment in many metals. The NOAA sediment survey detected PAHs, PCBs, and pesticides at sites close to shore, as well as in the center of Old Tampa Bay (Maps 71 and 74). Slight levels of metal enrichment, as well as PAHs, PCBs and pesticides, were detected at NOAA sites in Boca Ciega Bay (Maps 24 and 72). Slight metal enrichment was detected in southeastern Tampa Bay and in the Little Manatee River sediments (Map 25). PAHs, PCBs, and pesticides were detected in Cockroach Bay (Map 75). Agricultural areas adjacent to Cockroach Bay likely provided the source of pesticides within this waterbody. In the Manatee River area, lead and zinc enrichment is present at several sites near Bradenton (Map 26).

6.5 Charlotte Harbor and Caloosahatchee River

The southwest Florida coast has one of the highest population growth rates in the state. The Charlotte Harbor/Caloosahatchee River estuarine system is the second largest estuary in the state and supports highly productive sport and commercial fisheries. Charlotte Harbor, formed by the marine inundation of the Myakka and Peace Rivers, has an EDA of 5030 mi² which contains all or parts of Sarasota, De Soto, Hardee, Charlotte, and Lee counties. This part of the system has an average depth of over eight feet. The EDA for the Caloosahatchee River estuary, at just over 1400 mi², is located in parts of Charlotte, Glades, Lee and Hendry counties. Average depth is just over six feet (NOAA 1985). Two cities, Port Charlotte and Punta Gorda, are located in the Charlotte Harbor drainage basin, while the cities of Fort Myers and Cape Coral are located in the Caloosahatchee River drainage basin (Maps 27 and 76).

Sites in the Charlotte Harbor and Caloosahatchee River estuaries exhibit slight metal enrichment (Maps 28, 29, and 30). Slight lead and zinc enrichment is present in the Caloosahatchee River near Fort Myers. However, FDEP and NOAA surveys detected PAHs, PCBs, and pesticides in Charlotte Harbor and the Caloosahatchee River (Maps 77 and 78). PCBs were detected at six out of seven sites in San Carlos Bay and the Caloosahatchee River (Map 78).

6.6 Everglades Region

In the *Atlas*, the Everglades region is defined as the geographic area between Naples and Cape Sable (Map 31). Numerous small rivers drain the extensive marshlands of the western Everglades and flow into the Ten Thousand Islands area. Average water depth in the Ten Thousand Islands estuary is extremely shallow, at just over four feet (NOAA 1985). Although limited metal enrichment was detected (Maps 32 and 33), the FDEP and NOAA sediment surveys detected PAHs, PCBs, and pesticides at four of five sites (Map 79). Estuarine and freshwater sediment quality studies by the Collier County Pollution Control Department identified cadmium enrichment at certain sites. Organic contaminants such as pesticides were also identified. These data are not plotted in the *Atlas* but are available from the Collier County Pollution Control Department (Grabe 1991a; 1991b).

6.7 Florida Bay and the Florida Keys

As noted earlier, sediments of Florida Bay and the Florida Keys are mineralogically different from sediments in other parts of Florida. Carbonate minerals such as calcite and aragonite (both CaCO₃) constitute a larger percentage of sediment in this part of Florida. However, clay minerals and fine-grained quartz sand and silt are also present. Although the natural metals burden (background) in these sediments is much lower than sediments in the rest of the state, the metal-to-aluminum geochemical relationship still allows for determination of the degree of anthropogenic contamination. Metal enrichment is present near urbanized areas in the Keys (Map 34), but no metal enrichment was detected in the open areas of Florida Bay. No organic contaminants were detected at FDEP sites evaluated in this region, therefore no map for these substances was generated.

6.8 Southeast Region

In the *Atlas*, the southeast region encompasses the area from the Loxahatchee River estuary near Jupiter south through Biscayne Bay to Barnes Sound (Maps 35 and 80). The Biscayne Bay estuarine drainage area of 1850 mi² is located in Dade and Broward counties. The bay has an average depth of 7.5 feet (NOAA 1985). Numerous sediment types have been identified in Biscayne Bay, indicating the highly variable nature of this bay system. The bay represents the area where predominantly carbonate sedimentary environments of the Florida Keys and Florida Bay meet the predominantly clastic sedimen-

tary environments of eastern Florida. Adjacent to the largest population center in Florida, Biscayne Bay has experienced significant degradation.

The FDEP conducted intensive sediment sampling in the vicinity of Miami, as well as sampling near Fort Lauderdale and in the Card Sound area of southern Biscayne Bay (Maps 36, 38, 81 and 83). Metal enrichment was identified in a marina in Card Sound in southern Biscayne Bay. This is one of the few areas in the state where significant arsenic enrichment is present. Slight lead and zinc enrichment was detected in Biscayne Bay near the mouth of Snapper Creek. The FDEP survey did not detect organic contaminants in sediments of Snapper Creek, which drains a large residential area of central and southern Dade County. The NOAA survey detected PAHs, PCBs, and pesticides at a site in south-central Biscayne Bay (Map 81).

In the FDEP and NOAA surveys, the Miami River contains the most contaminated sediments in the state (Map 39). Every site in the river (canal) system has at least one metal enriched more than ten times the expected background value. Two sites have two metals over ten times the expected background, seven sites have three metals over ten times background, and two sites have four metals over ten times background. One site (MIR-3) has a lead enrichment factor of over 110 times the expected background value. Lead and zinc are commonly ten times above expected background in Miami River sediments, but cadmium, chromium, copper, and mercury are also enriched to concentrations ten times above background. PAHs and PCBs are present at every Miami River site, and pesticides were detected at two sites (Map 84). The FDEP survey detected metal and organic compound contamination at sites south and east of Cloughton Island and near the Port of Miami, as well as in open areas of Biscayne Bay (Maps 40, 41, 85, and 86). Although there are numerous potential sources of contaminants in this area, the FDEP sites appear to show a sediment contaminant "plume" in Biscayne Bay stemming from the Miami River. These findings are significant because these data indicate areas in the Bay well removed from sources of contaminants (e.g. stormwater outfalls) are experiencing encroachment of contaminants.

Sites in the Little River and in adjacent areas of northern Biscayne Bay are enriched in every measured metal. As in the Miami River, some Little River sites have lead and zinc enrichment factors more than ten times above expected background (Map

37). PAHs and PCBs are present at every Little River site and virtually every site in Biscayne Bay near the mouth of the river. Pesticides were detected at one site in the Little River (Map 82). Similar to the Miami River, but to a lesser extent, the Little River appears to be contributing significant contaminants loading to adjacent areas of Biscayne Bay.

Extensive residential and urban development has occurred in the Fort Lauderdale area, resulting in significant degradation of the coastal and estuarine habitats. Metal contamination is present in the New River sediments near Fort Lauderdale, with particularly high levels of lead and zinc. Enrichment of chromium, copper, mercury, and nickel also was detected (Map 36). Some of the highest levels of PAHs and PCBs in the FDEP database are found in the New River sites. Pesticides were also detected in these sediments (Map 81).

Both metal and organic contaminants are ubiquitous north of Fort Lauderdale, but are usually present in much lower levels than at sites near Miami and Fort Lauderdale. Lead and zinc enrichment is present at most sites, and mercury enrichment also occurs at many sites. A few sites in the Lake Worth Lagoon north of the city of Lake Worth have significant enrichment in metals, particularly at a site just north of the entrance of the West Palm Beach Canal to the Lagoon (Maps 42 and 43). PAHs and PCBs also were detected slightly south of West Palm Beach (Map 87).

6.9 East Central Region

The east central region represented in the *Atlas* consists of the Indian River Lagoon (IRL) system, which is composed of three interconnected estuarine lagoons - Mosquito Lagoon, Indian River Lagoon, and Banana River Lagoon - all protected by a series of barrier islands. The lagoonal system extends for a distance of over 150 miles through six counties, from Volusia County in the north to Palm Beach County in the south. It varies in width between 0.5 to 5.5 miles (Maps 44 and 88), and contains both true estuarine subsystems (e.g. St. Lucie estuary) and lagoonal systems (e.g. Mosquito Lagoon). The IRL estuarine drainage area is nearly 1250 mi² and the average depth is just under six feet (NOAA 1985).

Significant alteration of the original water circulation patterns of the IRL system has occurred from construction of bridges, causeways, navigation channels, and upland drainage facilities. Wide fluctua-

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tions in freshwater entering the estuarine system produce biologically undesirable salinity variations and increases in sedimentation. Habitat and species diversity in the IRL system has been adversely affected by declining water and sediment quality, and loss of seagrass habitat. Numerous marinas and boat yards contribute to locally elevated levels of metals and organic contaminants (Indian River SWIM Plan, 1989).

Little metal enrichment has been detected in the northern region of the IRL system (Map 45). In the central part of the lagoon system, near the southern part of Merritt Island, slight to moderate metal enrichment is present (Map 46). Pesticides were detected at two sites near Cocoa (Map 89). Enrichment in cadmium, copper, and zinc was detected in the United States Navy turning basin in the Port Canaveral area (Maps 47 and 90). Pesticides were also detected in the turning basin. Cadmium, copper, mercury, lead, and zinc enrichment was detected at a site near Eau Gallie, and lead and zinc enrichment was detected near Sebastian (Map 48). Slight metal enrichment, usually lead, was detected near Fort Pierce (Map 49). PAHs, PCBs, and pesticides were detected by NOAA in the IRL system north of the city of Sebastian (Map 91).

6.10 Northeast Region

The largest estuarine waterbody in the northeast part of Florida is the St. Johns River system, which extends over a distance of 300 miles from St. Lucie County northward to Duval County. The EDA is over 6500 mi² and the average depth of the estuary is 14 feet. Tidal influence is observed slightly upstream of Lake George, a distance of over 120 miles from the Atlantic Ocean (NOAA 1985). As is the case with Florida estuaries adjacent to urban centers, the St. Johns River estuary is affected by point and non-point source pollution. Deteriorating water and sediment quality are problems which have approached a critical state in certain areas of the estuary (Lower St. Johns River SWIM Plan 1992).

The sampling programs of the FDEP, NOAA, and Mote Marine Laboratory (MML) were located in the portion of the river system referred to as the Lower St. Johns River (LSJR). Site locations of the FDEP and MML extended well into the freshwater zone, with the most inland site located in the northern end of Lake George in Putnam County (Maps 50 and 92). The high number of sampling sites in the LSJR system in Duval County required separate index

maps for metal and organic contaminants (Maps 52 and 93).

Slight metal enrichment was detected in five of twelve sites in the Blount Island/Mill Cove area downstream of Jacksonville, but PAHs, PCBs, pesticides, and aliphatic hydrocarbon compounds were detected at many of these sites (Maps 53 and 94). Slight to moderate trace metal enrichment was detected in the LSJR near the City of Jacksonville at the confluence of St. Johns and Trout Rivers, but PAHs, PCBs, and pesticides are present at virtually every site (Maps 54 and 95). The MML site located in the Trout River has elevated levels of cadmium, copper, mercury, lead, and zinc. This tributary to the St. Johns River receives stormwater runoff from parts of northern Jacksonville.

Metal enrichment is present at most sites near downtown Jacksonville (Map 55). Organic contaminants also are present at numerous sites in this area (Map 96). Upstream of downtown Jacksonville, slight metal enrichment was detected in the open river sections of the LSJR, but high levels of metals enrichment were detected in the MML sites in the Ortega River. One or more classes of organic contaminants were detected at every site in this map area (Maps 56 and 97). Slight metal enrichment, usually lead and zinc, was detected in the central part of the LSJR system in Clay and Putnam Counties (Maps 57 and 58), but two or more classes of organic contaminants were detected at every site in this area (Maps 98 and 99). Aliphatic hydrocarbons were detected at five FDEP sites in southern Clay and northern Putnam counties.

Low levels of metal contamination were detected in sites located near the river mouth (Map 59). Slight copper enrichment was detected at sites in Pablo Creek and lead enrichment was detected at a site west of Mayport. PAHs, PCBs, and pesticides were detected at sites near the river mouth by both NOAA and MML. PAHs and PCBs were detected in Pablo Creek, and PAHs were detected in the Tolomato River north of South Ponte Vedra Beach (Map 100).

Metal enrichment was detected occasionally at sites along the Atlantic coastline from the mouth of the SJR in Duval County south to Mosquito Lagoon in northern Brevard County (Maps 60, 61, 62 and 63). Enrichment in copper, lead and zinc occurs frequently in this coastal area. PAHs were detected at every site in the Matanzas or Halifax Rivers in St. Johns, Flagler, and Volusia Counties. PCBs also are present at many of these sites, and pesticides were

detected at one site in St. Johns County (Map 101).

Generally other sites sampled in the northeast region exhibit lower levels of contamination. Virtually no metal contamination was detected at the three sites in the St. Marys River estuary in Nassau County, indicative of the relatively unimpacted nature of this estuarine system (Map 51).

SECTION 7: CONCLUSION

Most of the highest concentrations for any particular contaminant are found at sites near Tampa, Pensacola, Miami, and Jacksonville. However, high contaminant concentrations are occasionally found near other cities. For example, some of the highest organic contaminants levels occur in the New River in Fort Lauderdale. Perhaps surprisingly, contaminants are common in less developed areas. For example, PAHs, PCBs and pesticides have been detected in the Charlotte Harbor-Caloosahatchee River area, and elevated levels of copper occur in sediments of the Crystal River National Wildlife Refuge.

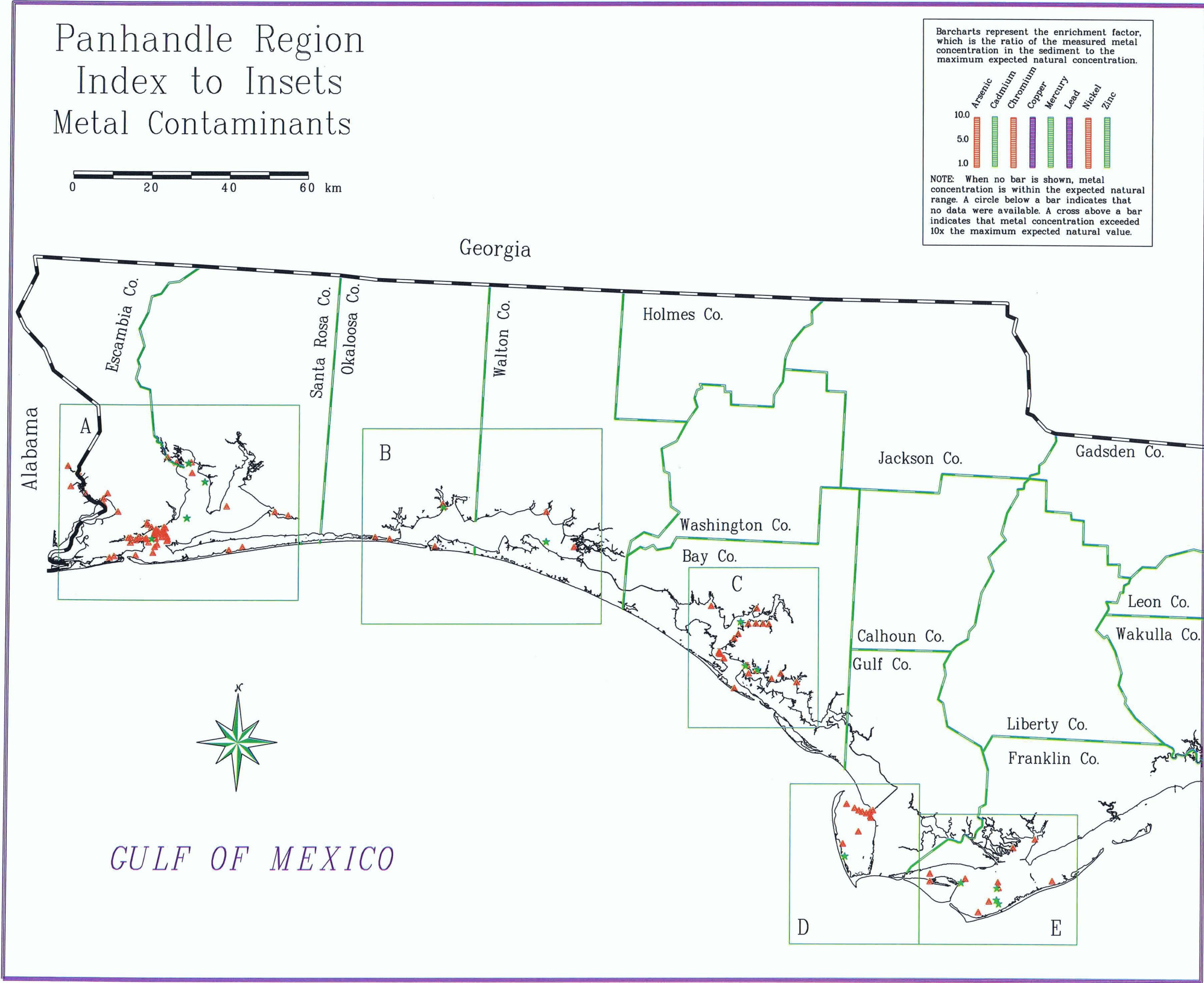
Analysis of the FDEP sediment chemistry database indicates that statewide the most common metal contaminants are (listed in decreasing degree of contamination) lead, zinc, mercury, cadmium, copper, chromium, nickel, and arsenic. The most commonly encountered class of organic contaminant is the polynuclear aromatic hydrocarbons, followed by polychlorinated biphenyls.

Stormwater runoff appears to be the major cause of contamination of sites identified in the *Atlas*. As a result of pollution control efforts by local, county, state, and federal agencies, the practices resulting in coastal contamination may be abating, but they have not stopped. Major accomplishments have been made in controlling point sources of pollution and, more recently, environmental protection programs have increased efforts to control urban stormwater discharges and agricultural land runoff. Monitoring the effectiveness of these controls is a challenge that will face the state for many years. As this document illustrates, sediment monitoring efforts in combination with other assessment activities are essential in keeping a finger on the pulse of coastal ecosystems of Florida.

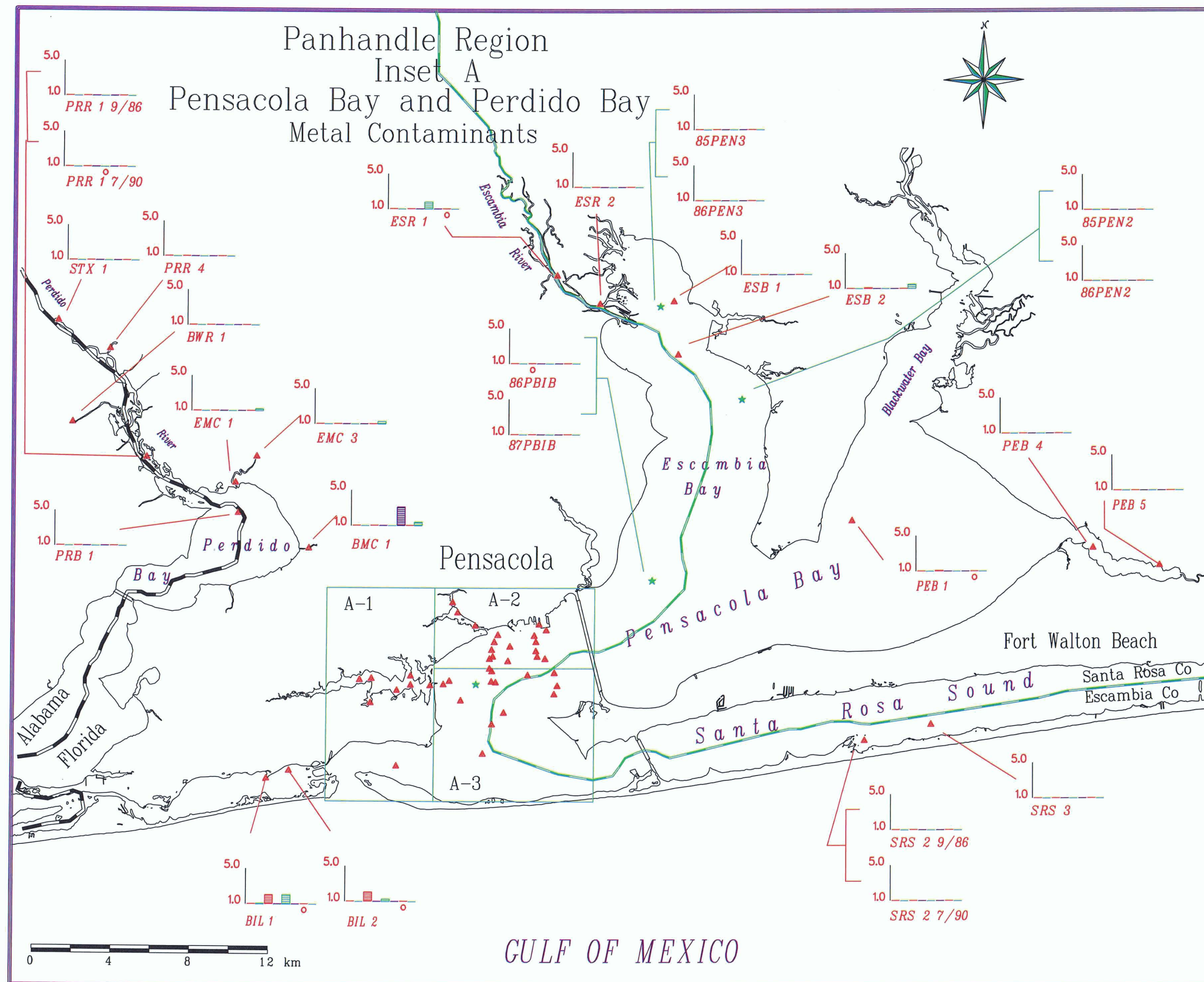
An initial evaluation of the potential for biological effects associated with contaminants levels at sites represented in the *Atlas* is provided in the document *Development of an Approach to the Assessment of Sediment Quality in Florida Coastal Waters* (MacDonald 1993). This report can be obtained from the authors of the *Atlas*.

REFERENCES

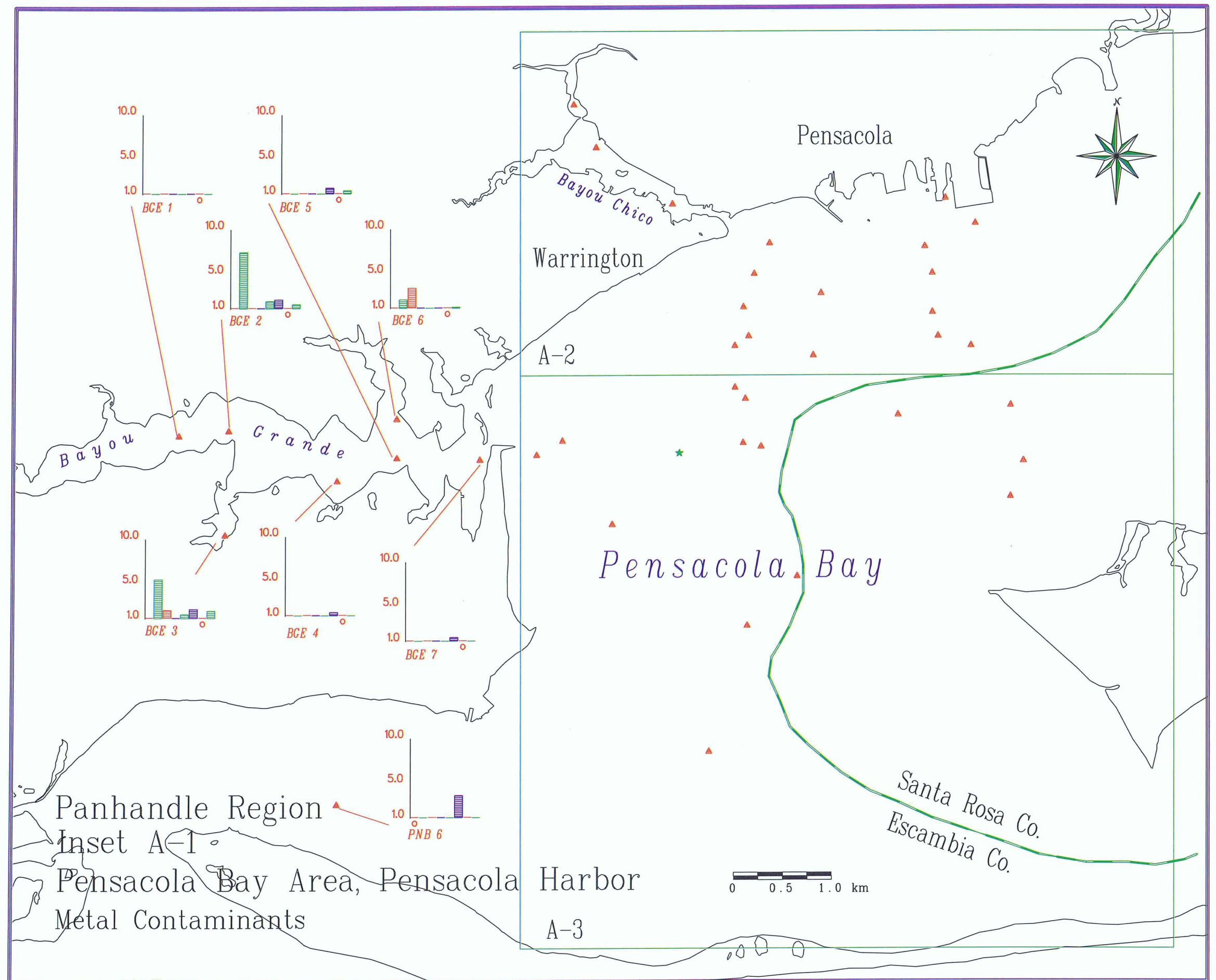
- Culliton, T.J., Warren, T.R., Goodspeed, T.R., Remer, D.R., Blackwell, C.M. and McDonough, J.J., 1990. Fifty years of population change along the nation's coast: 1960-2010. National Oceanic and Atmospheric Administration. Rockville, Maryland. 41 pp.
- Donoghue, J.F., 1988. Evaluation of sediment loading processes in the Apalachicola Bay Estuary. National Oceanic and Atmospheric Administration (NOAA) Technical Memorandum NOS-MEMD, 72 pp.
- Eisler, R., 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.11), 81 pp.
- Grabe, S., 1991a, Sediment quality in estuarine waters of Collier County: April and August 1991. Collier County Pollution Control Department. 14 pp.
- Grabe, S., 1991b. Inland sediment quality annual report, 1991. Collier County Pollution Control Department. 15 pp.
- Hine, A.C., Belknap, D.F., Hutton, J.G., Osking, E.B. and Evans, M.W., 1988. Recent geological history of modern sedimentary processes along an incipient, low-energy, epicontinental-sea coastline: north-west Florida. *Journal of Sedimentary Petrology*, vol. 58, 567-579.
- Indian River Lagoon SWIM Plan, 1989. St. Johns River Water Management District and the South Florida Water Management District. 100 pp.
- Livingston, R.J., 1983. Identification and analysis of sources of pollution in the Apalachicola River and Bay system. As cited in the Apalachicola River and Bay Management Plan, Northwest Florida Water Management District.
- Long, E.R., MacDonald, D. and Cairncross, C., 1991. Status and trends in toxicants and the potential for their biological effects in Tampa Bay, Florida. National Oceanic and Atmospheric Administration Technical Memorandum NOS OMA 58, 77 pp.
- Long, E.R. *et al.*, in preparation. Magnitude and extent of sediment toxicity in Tampa Bay, Florida. National Status and Trends Program, Bioeffects Assessment Program.
- Lower St. Johns River SWIM Plan, 1992. St. Johns River Water Management District.
- MacDonald, D.D., 1993. Development of an approach to the assessment of sediment quality in Florida coastal waters. Prepared for the Department of Environmental Regulation. Two volumes.
- Mote Marine Laboratory Report, 1988. Characterization of Baseline Conditions of the Physical, Chemical, and Microbiological Environments in the St. Johns River Estuary. Prepared by Pierce, R.H., Dixon, L.K., and Brown, R.C. under contract with the Florida Department of Environmental Regulation. 111 pp. plus appendices.
- National Research Council, 1990. Managing troubled waters: the role of marine environmental monitoring. National Academy Press, Washington, D.C. 125 pp.
- NOAA (National Oceanic and Atmospheric Administration), 1985. National Estuarine Inventory Data Atlas. Volume 1. Strategic Assessment Branch, Ocean Assessment Division, NOAA, Washington, D.C.
- NOAA (National Oceanic and Atmospheric Administration), 1991. Second summary of data on chemical contaminant in sediments from the National Status and Trends Program, NOAA Technical Memorandum NOS OMA 59. 148 pp. Rockville, Maryland.
- Pensacola Bay System SWIM Plan, 1990. Northwest Florida Water Management District. 173 pp. plus appendices.
- Schropp, S.J. and Windom, H.L., 1988. A guide to the interpretation of metal concentration in estuarine sediments. Coastal Zone Management Section, Florida Department of Environmental Regulation, 44 pp.
- Schropp, S. J., Calder, F.D., Sloane, G.M. and Windom, H.L., 1990. Interpretation of metal concentration in estuarine sediments of Florida using aluminum as a reference element. *Estuaries*, v. 13, 227-235.
- Schropp, S.J., Calder, F.D., Sloane, G.M., Swanson, K.O., Carlton, J.C., Halcomb, G.L., Windom, H.L., Huan, F., Taylor, R.B., and Hull, T., 1991. A report on physical and chemical processes affecting the management of Perdido Bay: Results of the Perdido Bay Interstate Project. Florida Department of Environmental Regulation, 323 pp.
- Stone, G.W. and Morgan, J.P., 1991. Heavy metal concentrations in subsurface sediments, Bayou Chico, Pensacola, Florida. Report prepared for the Florida Department of Environmental Regulation by the Institute for Coastal and Estuarine Research, The University of West Florida, Pensacola.
- United States Fish and Wildlife Service, 1991. Copper and other contaminants in King's Bay and Crystal River (Florida) sediments: implications for impact on the West Indian Manatee. Prepared by C.F. Facemire. 45 pp, 1 appendix.
- Windom, H.L., Schropp, S.J., Calder, F.D., Ryan, J.D., Smith, R.G., Jr., Burney, L.C., Lewis, F.G., and Rawlinson, C.H., 1989. Natural trace metal concentrations in estuarine and coastal marine sediments of the southeastern United States. *Environmental Science and Technology*, vol. 23, 314-320.



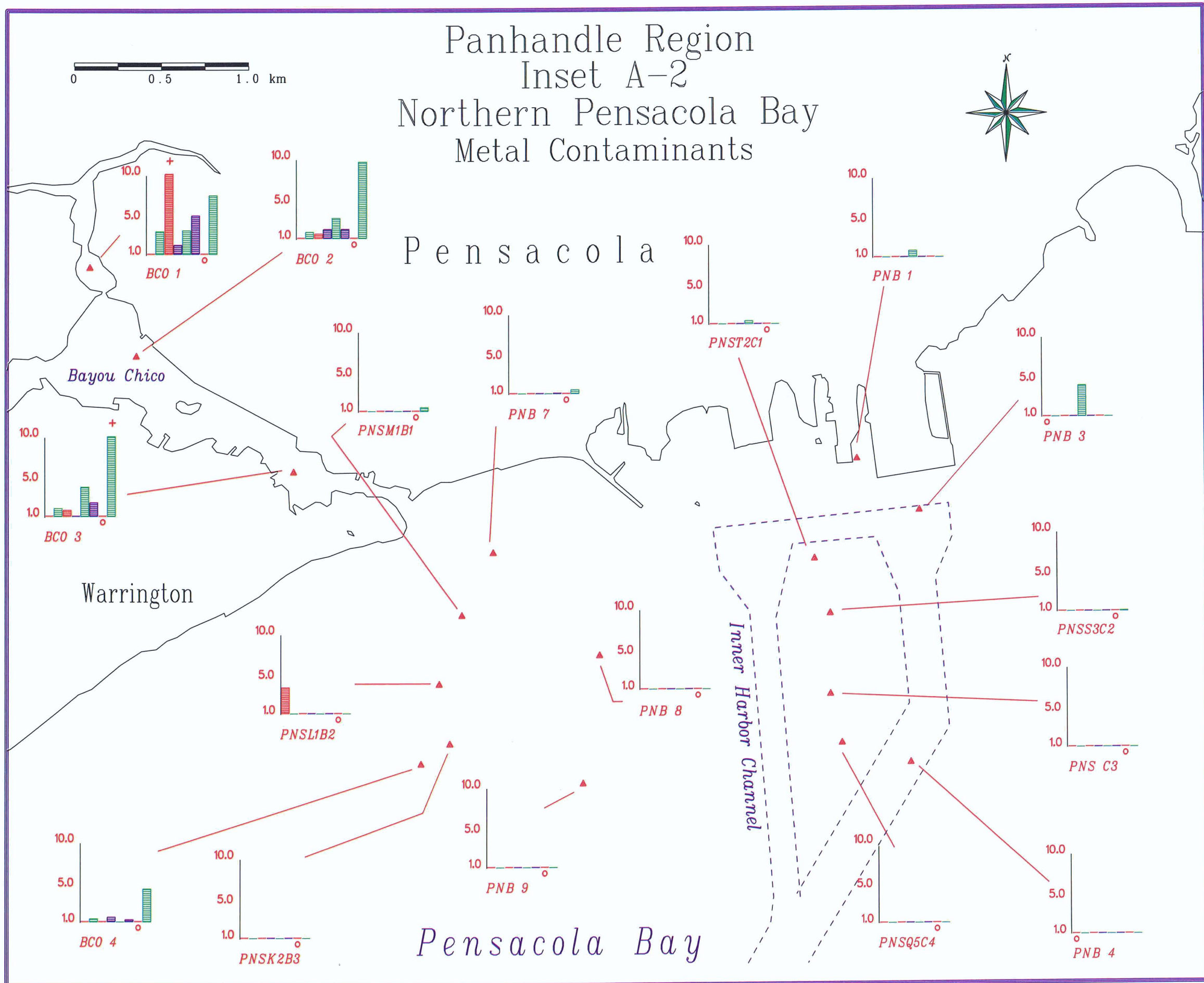
Map 1 - Panhandle Region Index to Insets



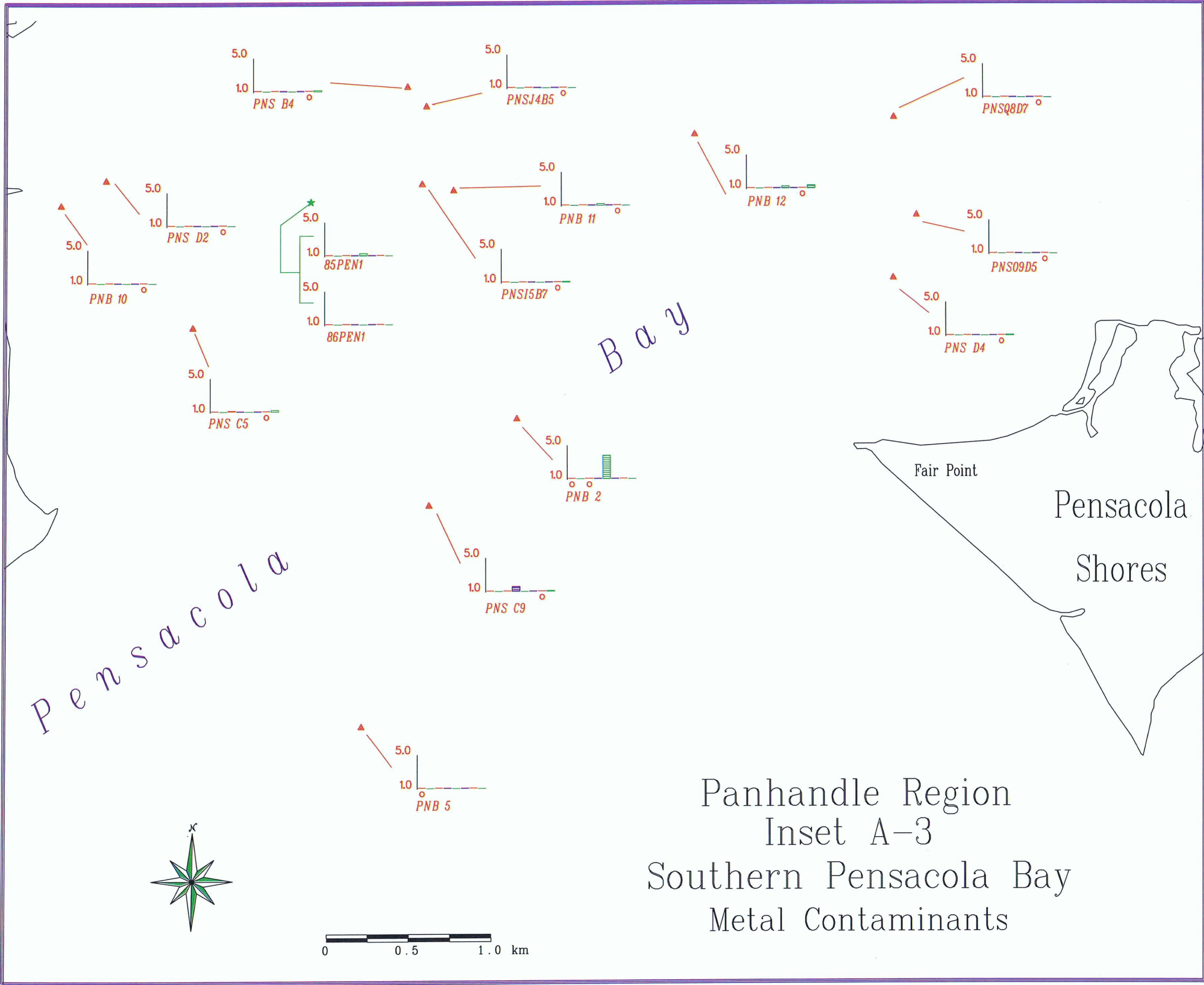
Map 2 - Panhandle Region Inset A -
Pensacola Bay and Perdido Bay



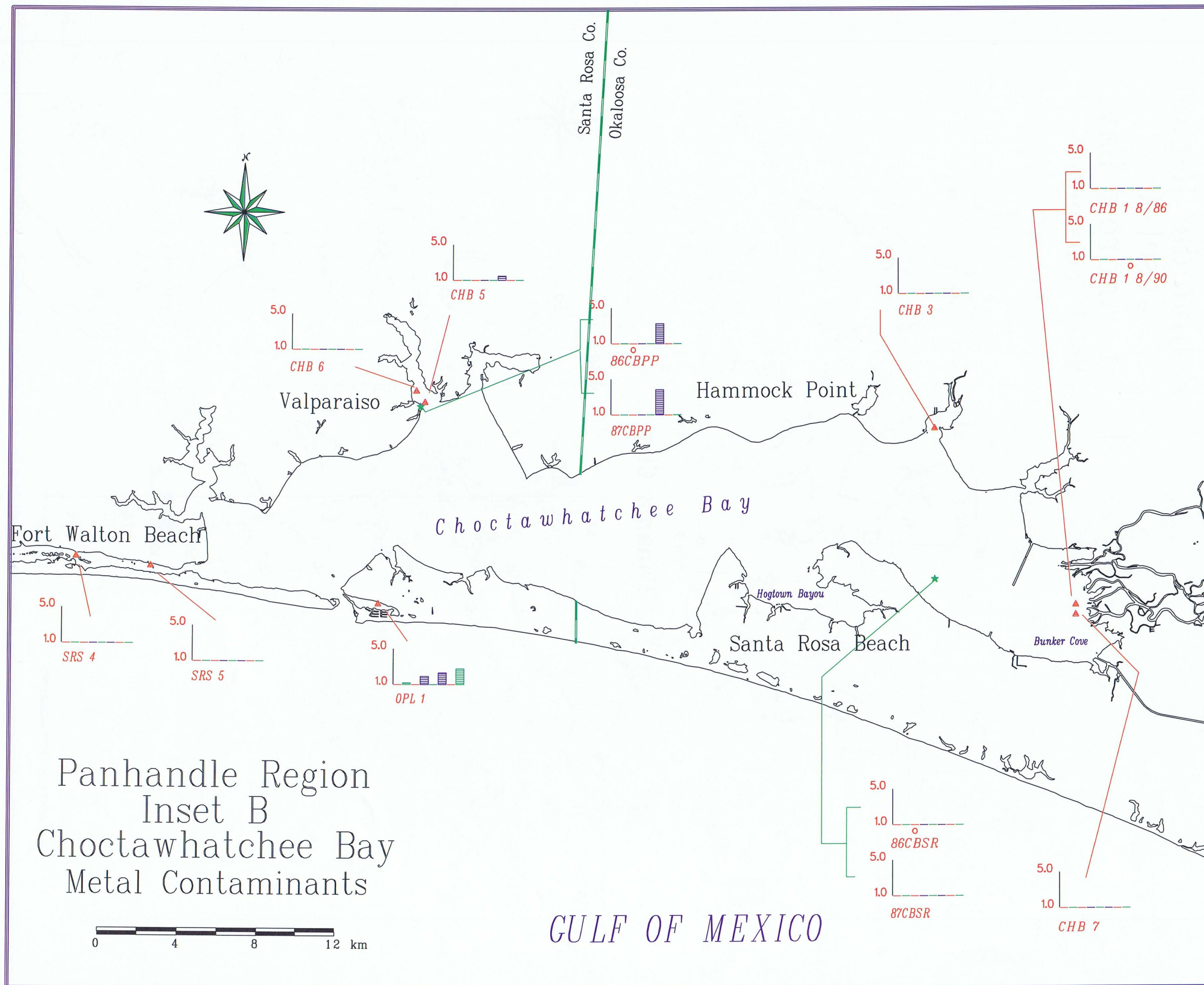
Map 3 - Panhandle Region Inset A-1 - Pensacola Bay Area/Pensacola Harbor



Map 4 - Panhandle Region Inset A-2 -
NorthernPensacola Bay



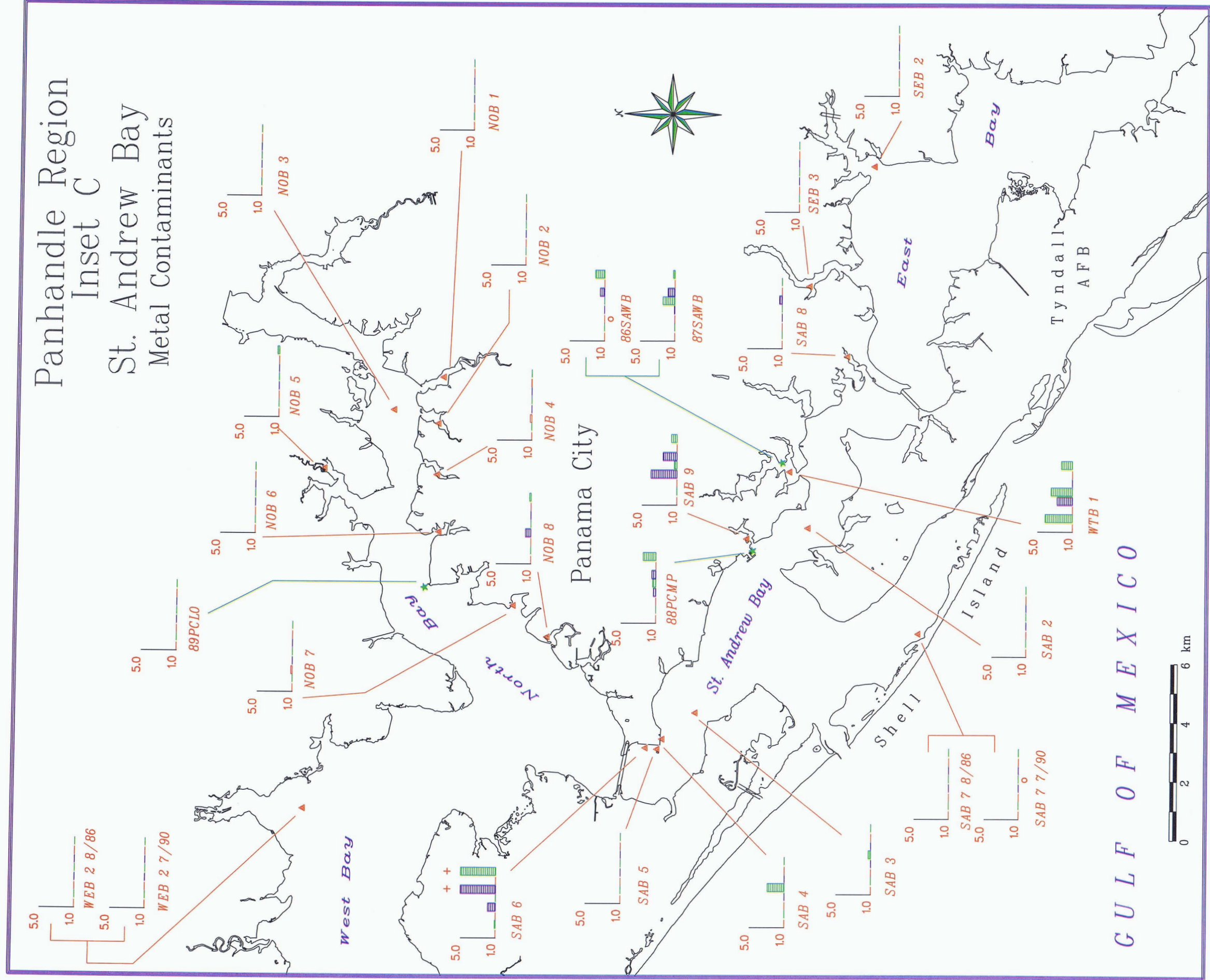
Map 5 - Panhandle Region Inset A-3 -
Southern Pensacola Bay



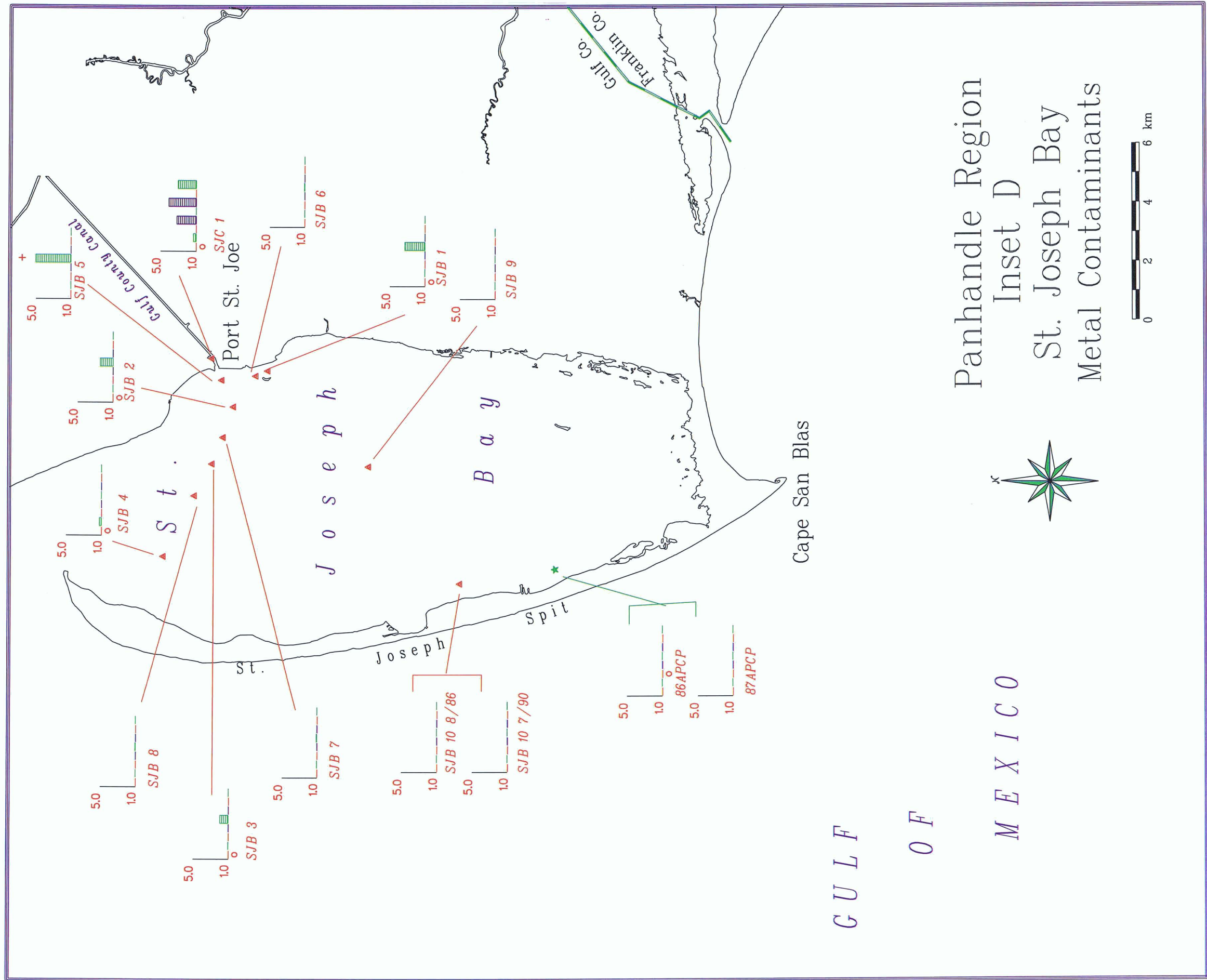
RECEIVED
SUB LANDS & ENV RES
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Map 6 - Panhandle Region Inset B -
Choctawhatchee Bay

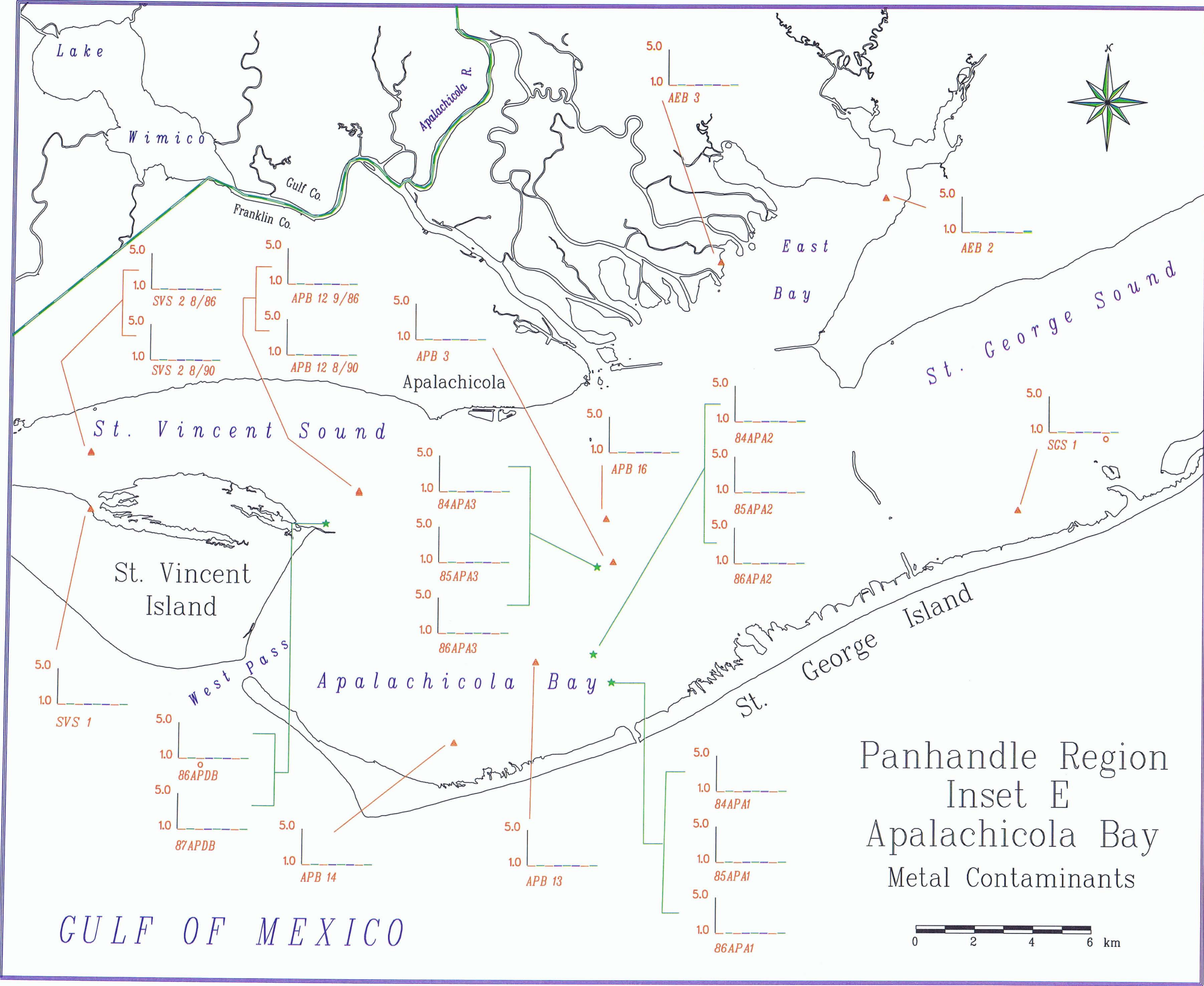
Panhandle Region
Inset C
St. Andrew Bay
Metal Contaminants



Map 7 - Panhandle Region Inset C - St. Andrew Bay

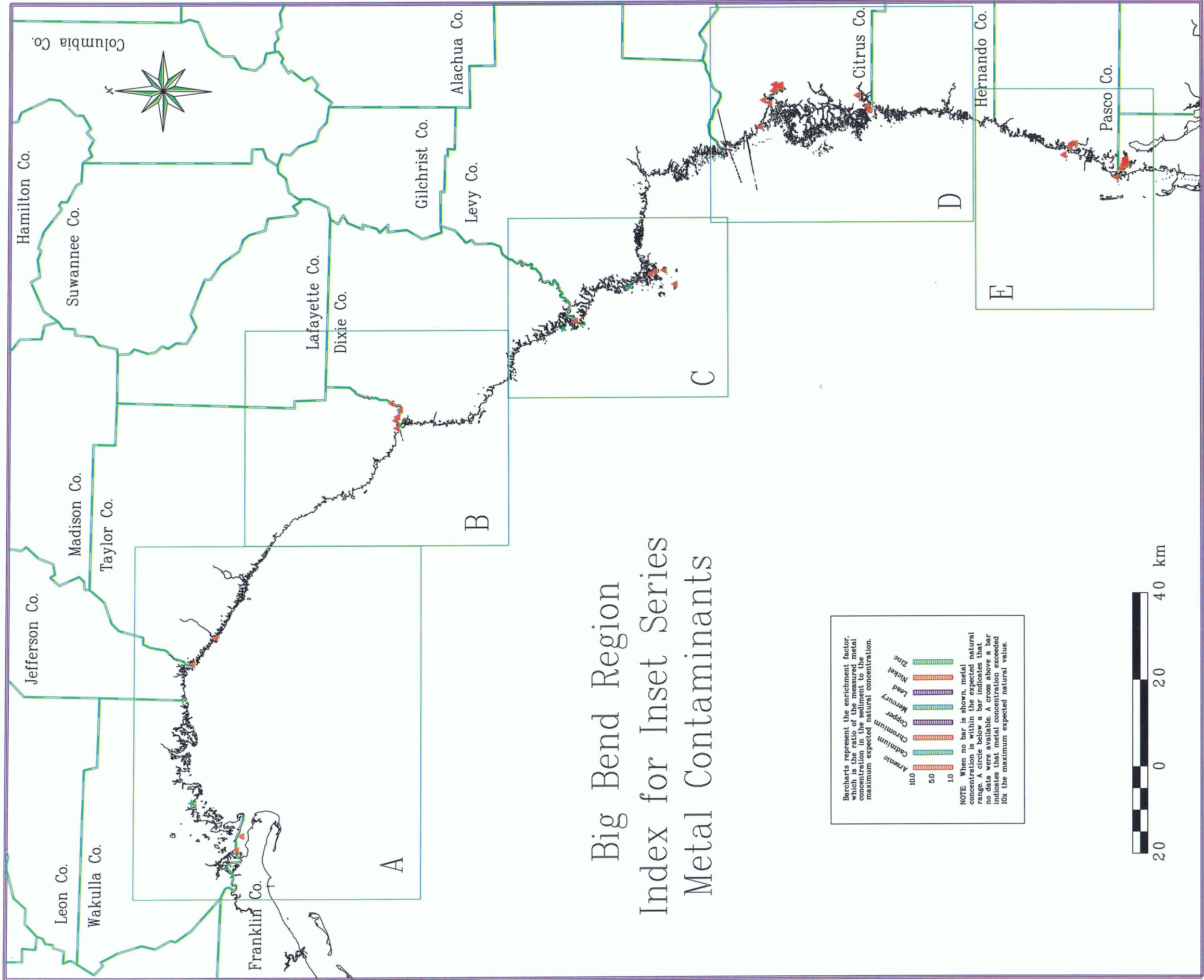


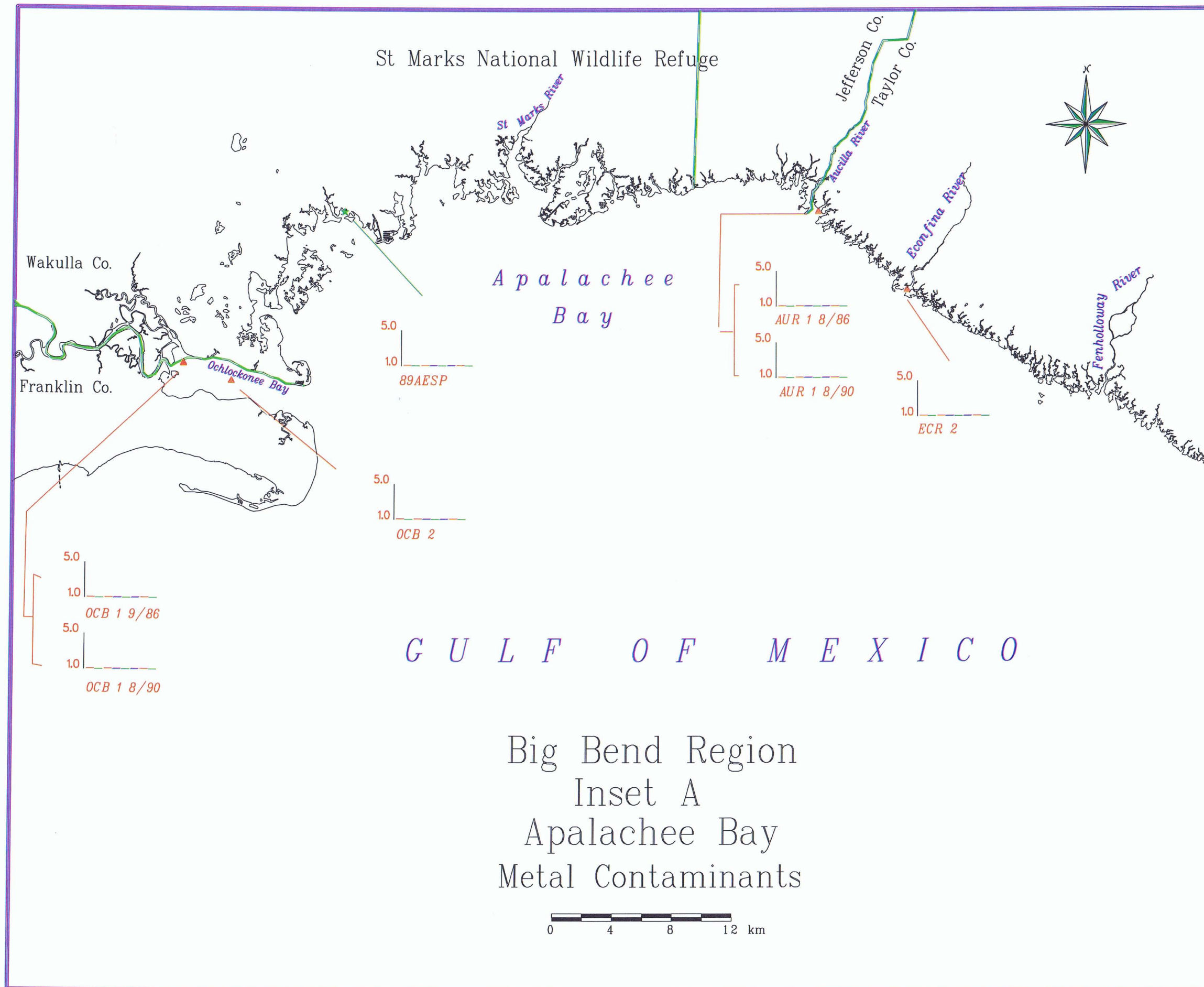
Map 8 - Panhandle Region Inset D - St. Joseph Bay



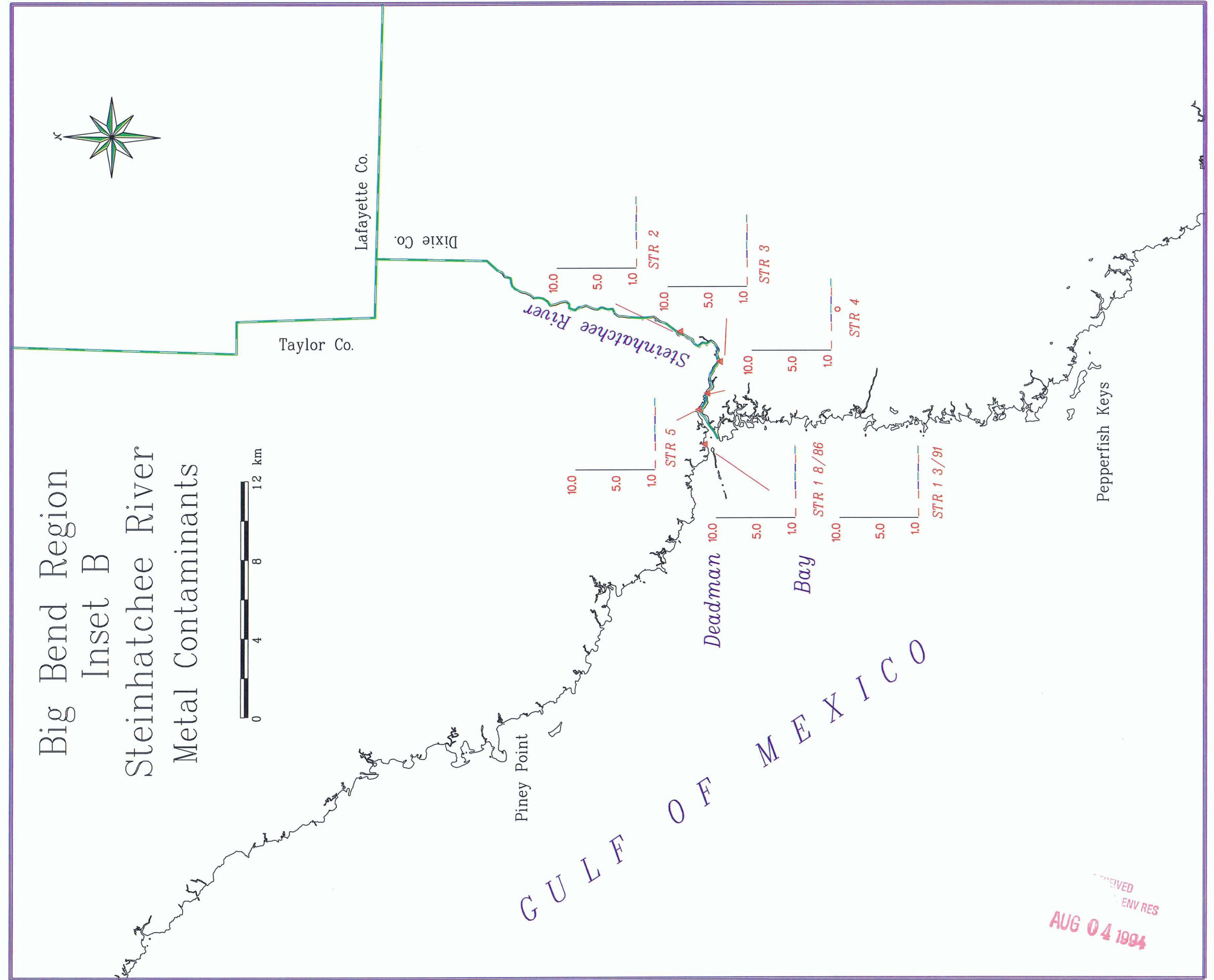
Map 9 - Panhandle Region Inset E -
Apalachicola Bay

Map 10 - Big Bend Region Index to Insets

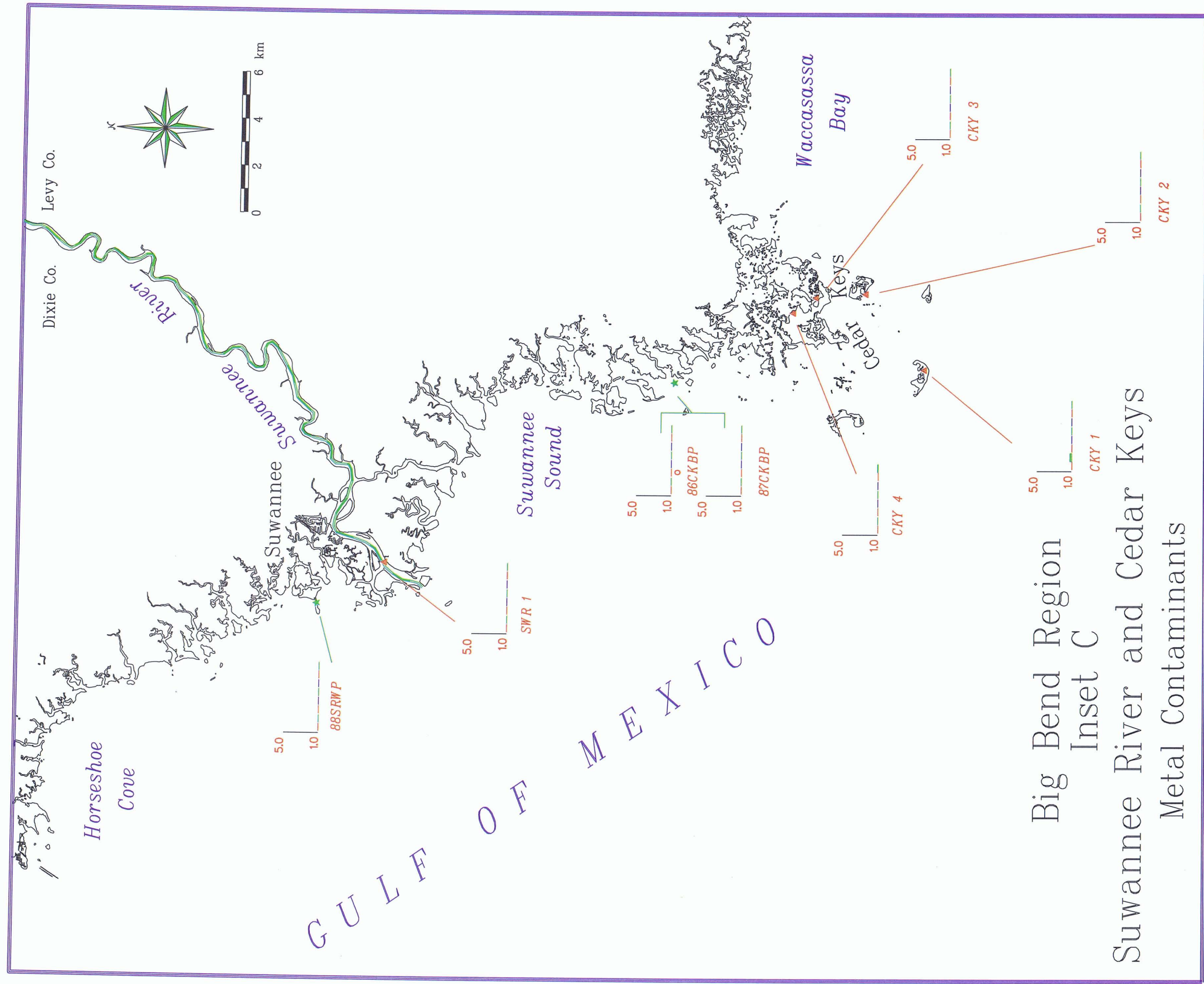




Map 11 - Big Bend Region Inset A -
Apalachee Bay

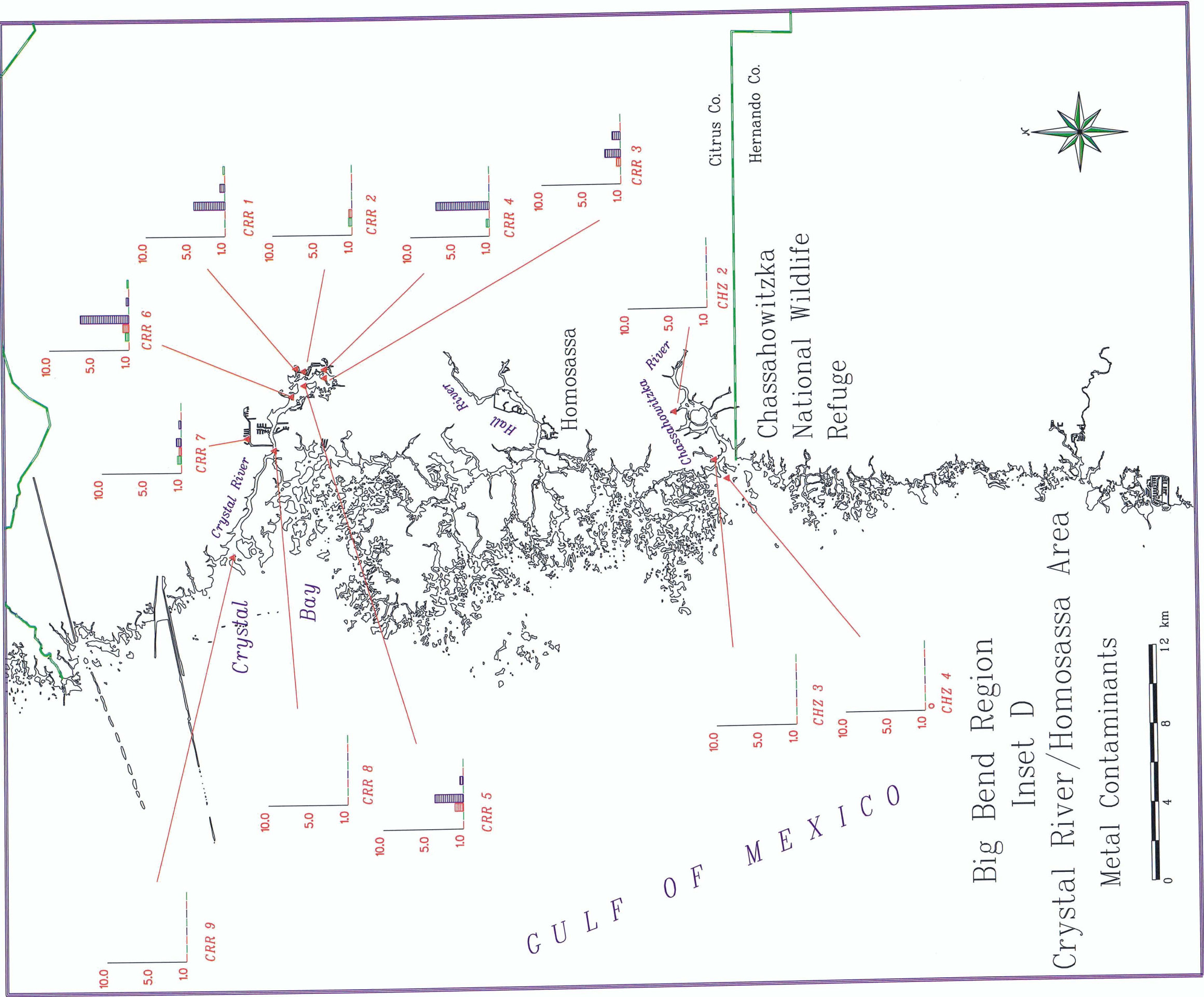


Map 12 - Big Bend Region Inset B -
Steinhatchee River



Big Bend Region Inset C Suwannee River and Cedar Keys Metal Contaminants

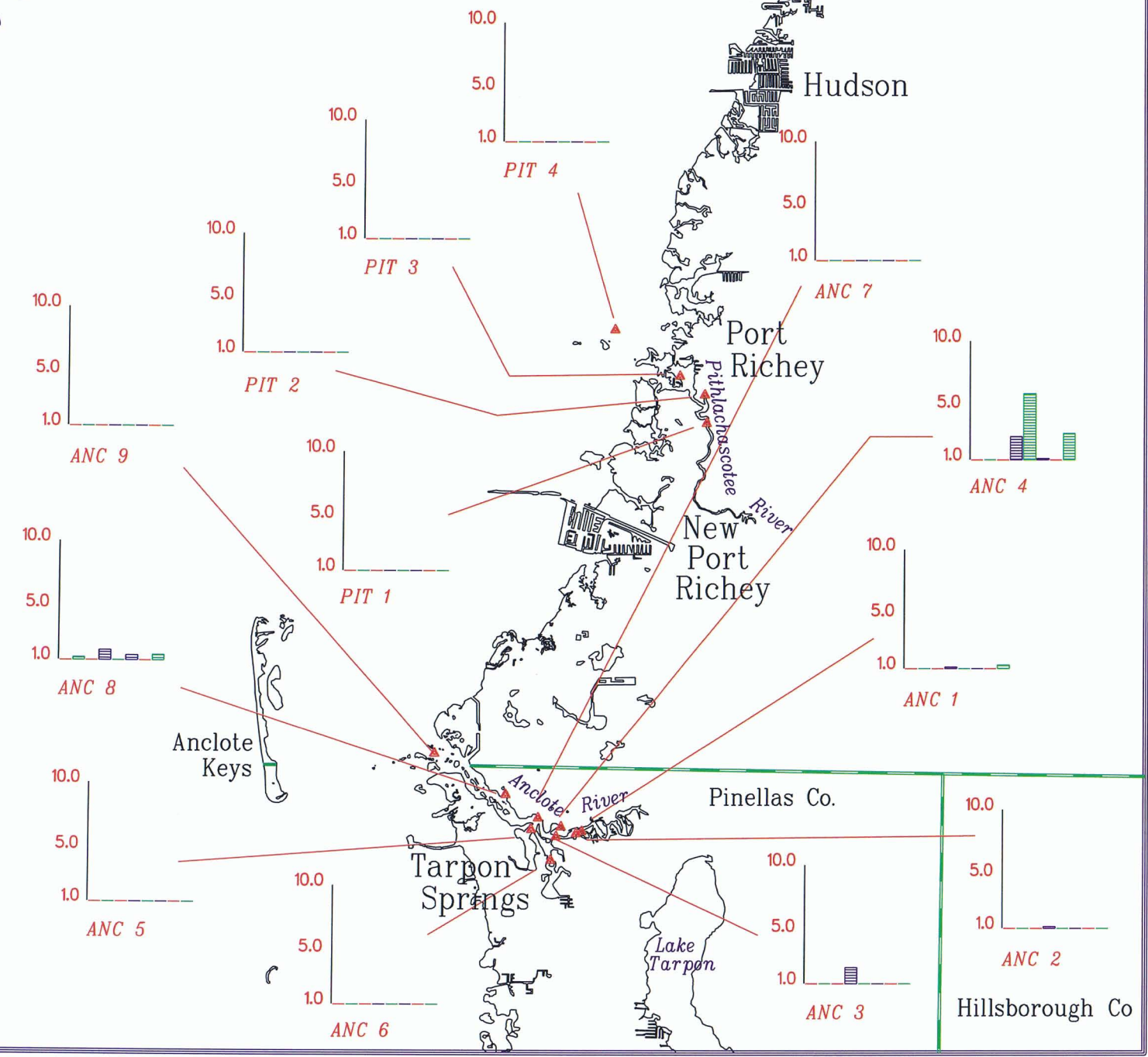
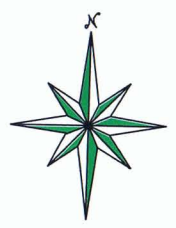
Map 14 - Big Bend Region Inset D - Crystal River/Homosassa Area



Big Bend Region Inset E Anclote River Metal Contaminants

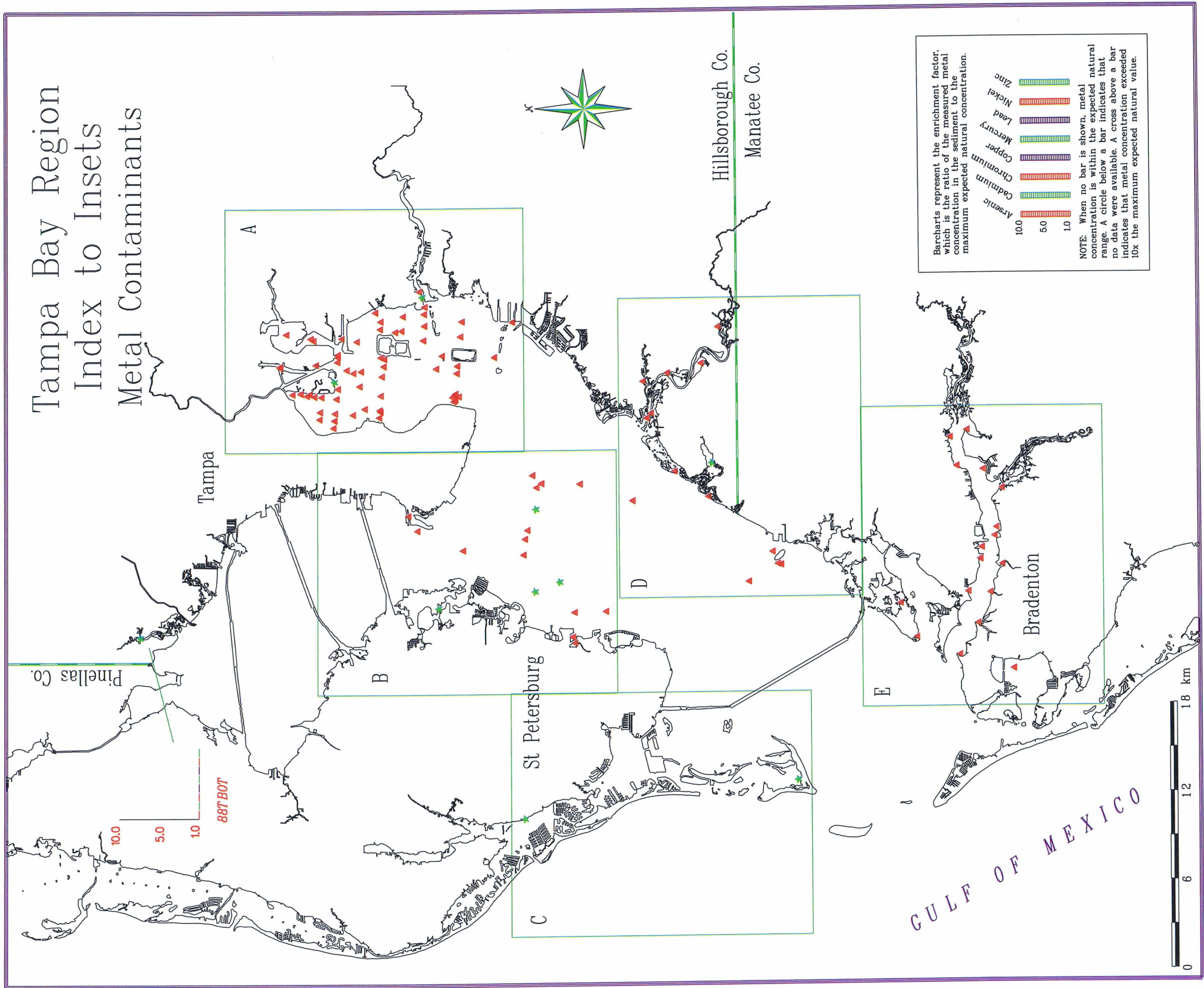


GULF OF MEXICO

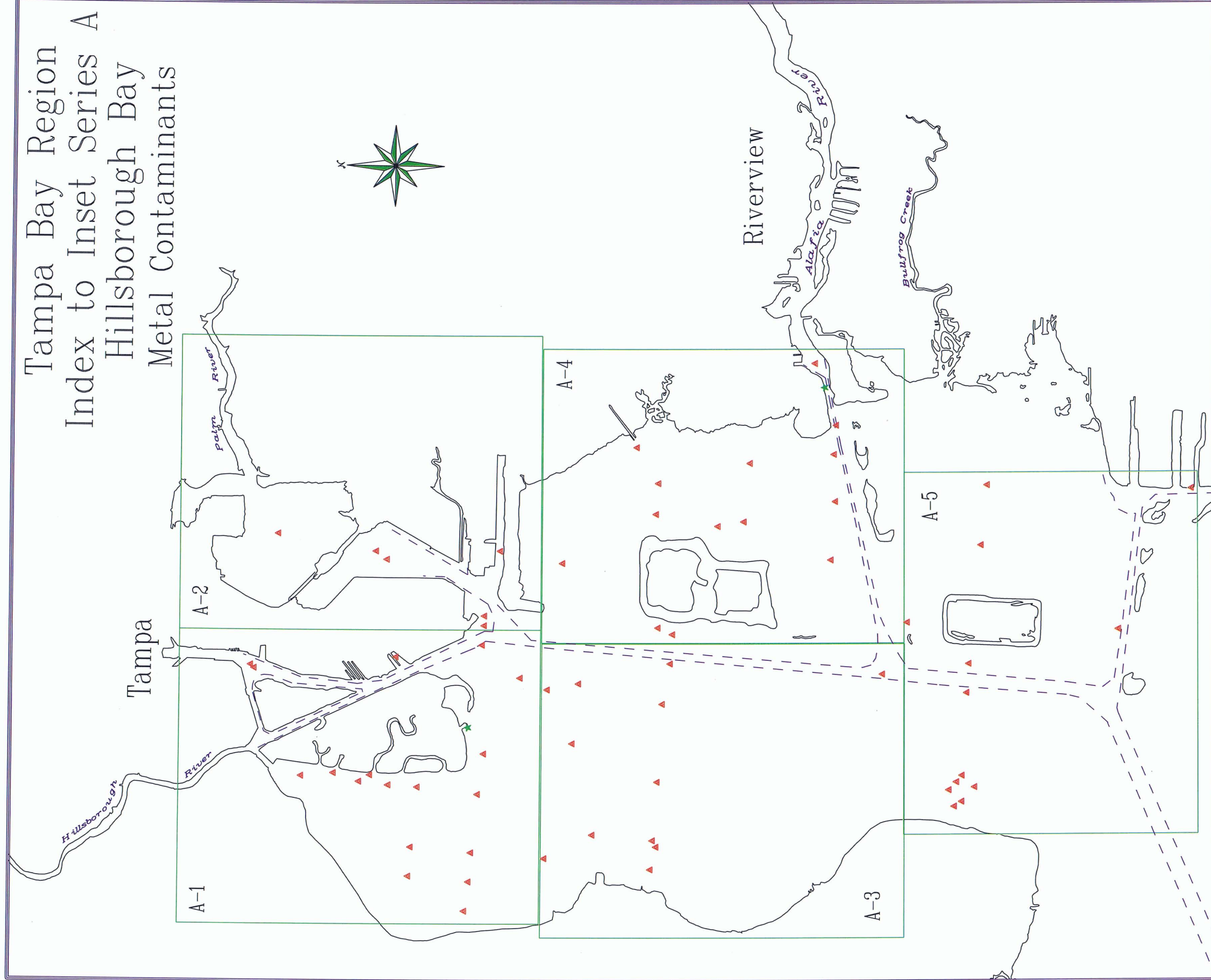


Map 15 - Big Bend Region Inset E -
Anclote River

Map 16 - Tampa Bay Region Index to Insets

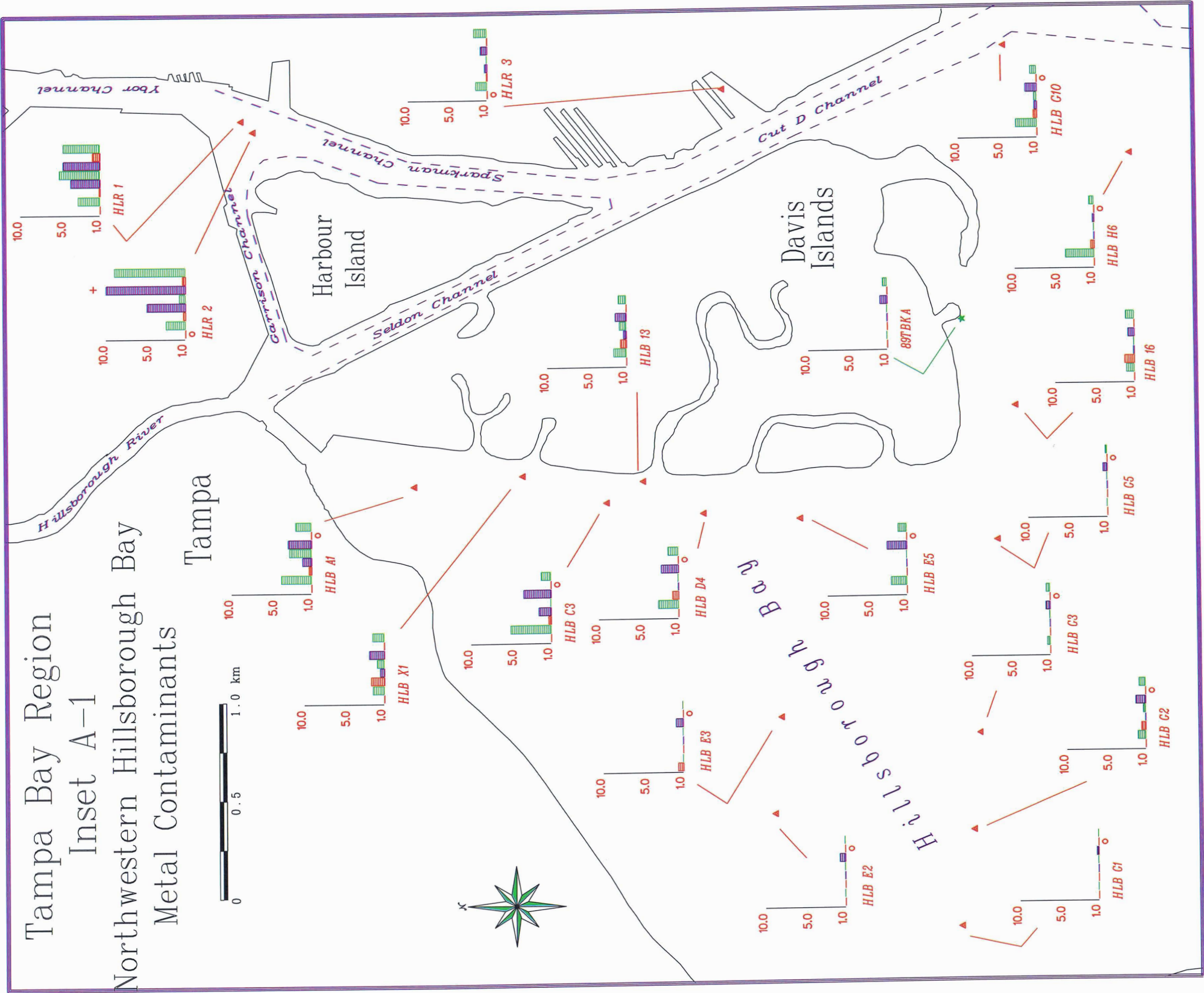


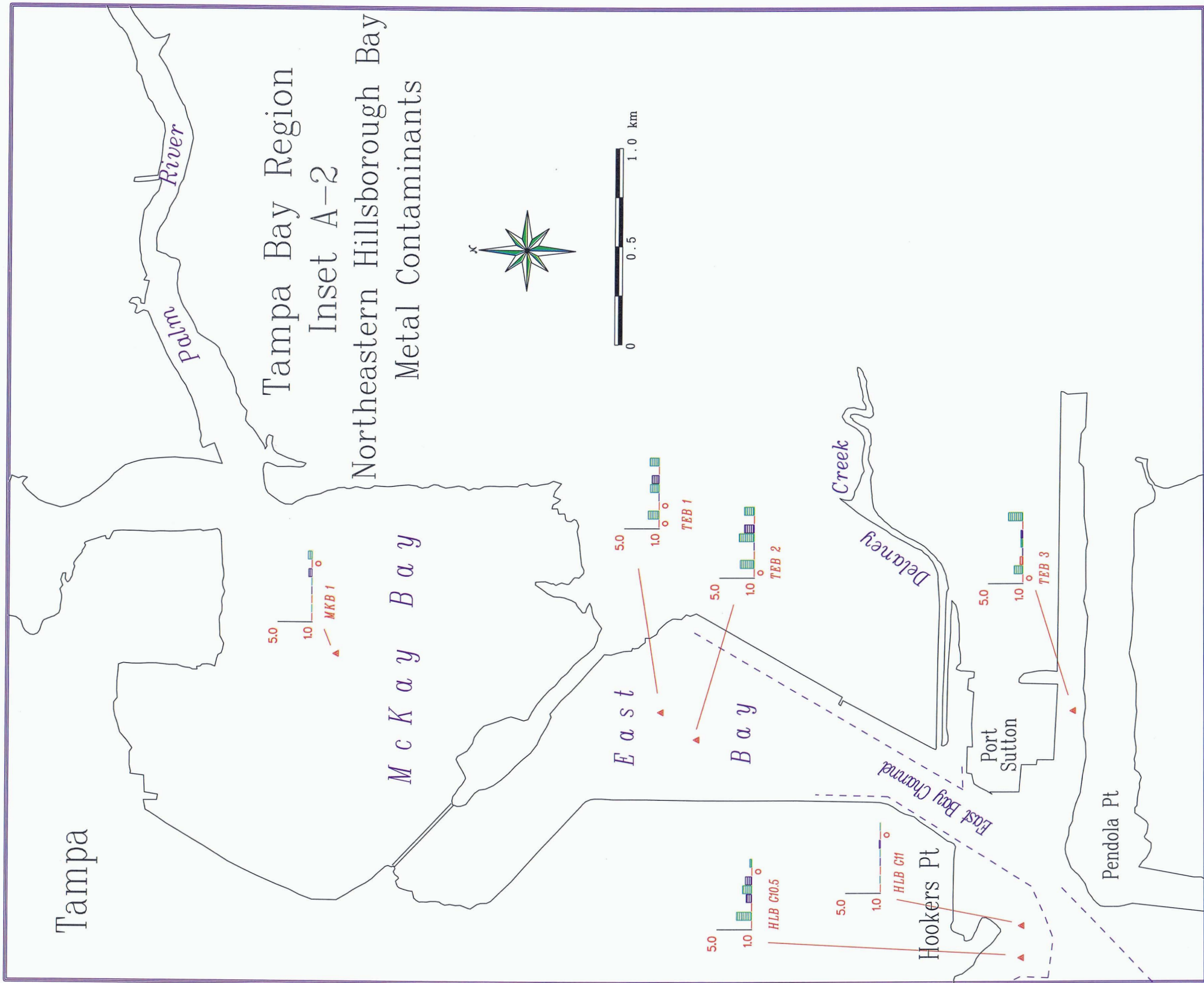
Tampa Bay Region Index to Inset Series A Hillsborough Bay Metal Contaminants



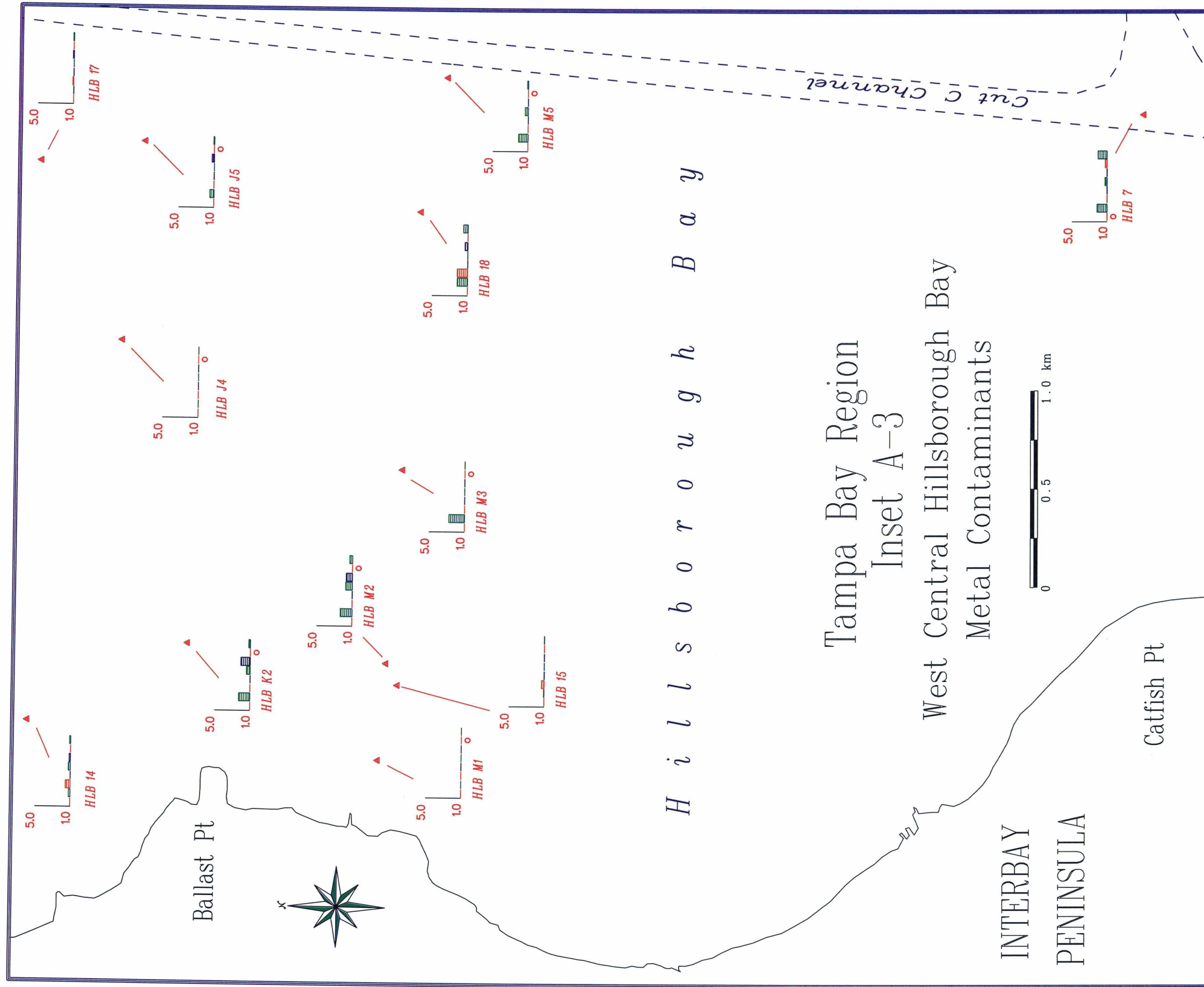
Map 17 - Tampa Bay Region Index to Inset
Series A - Hillsborough Bay

Map 18 - Tampa Bay Region Inset A-1 -
Northwestern Hillsborough Bay

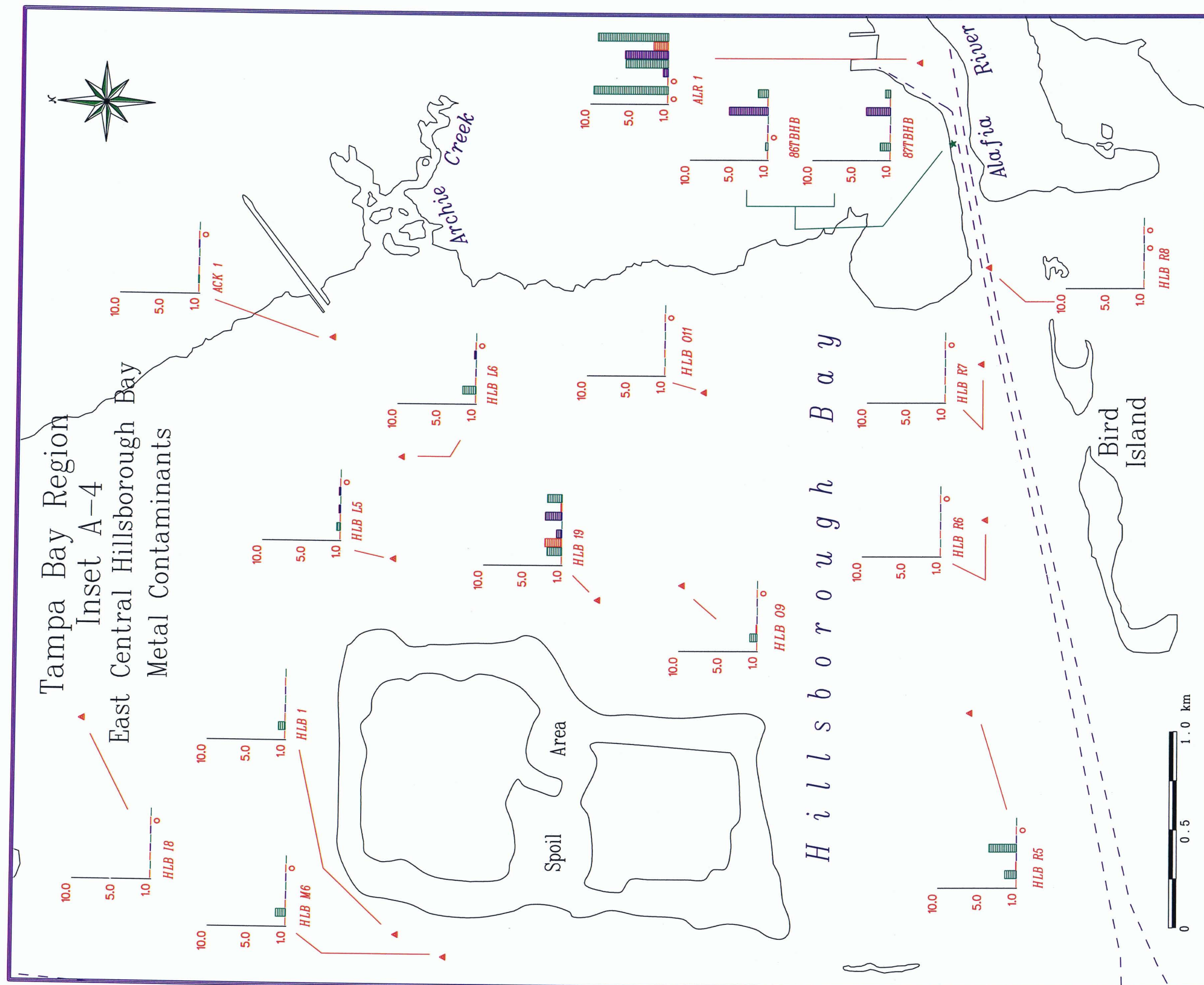


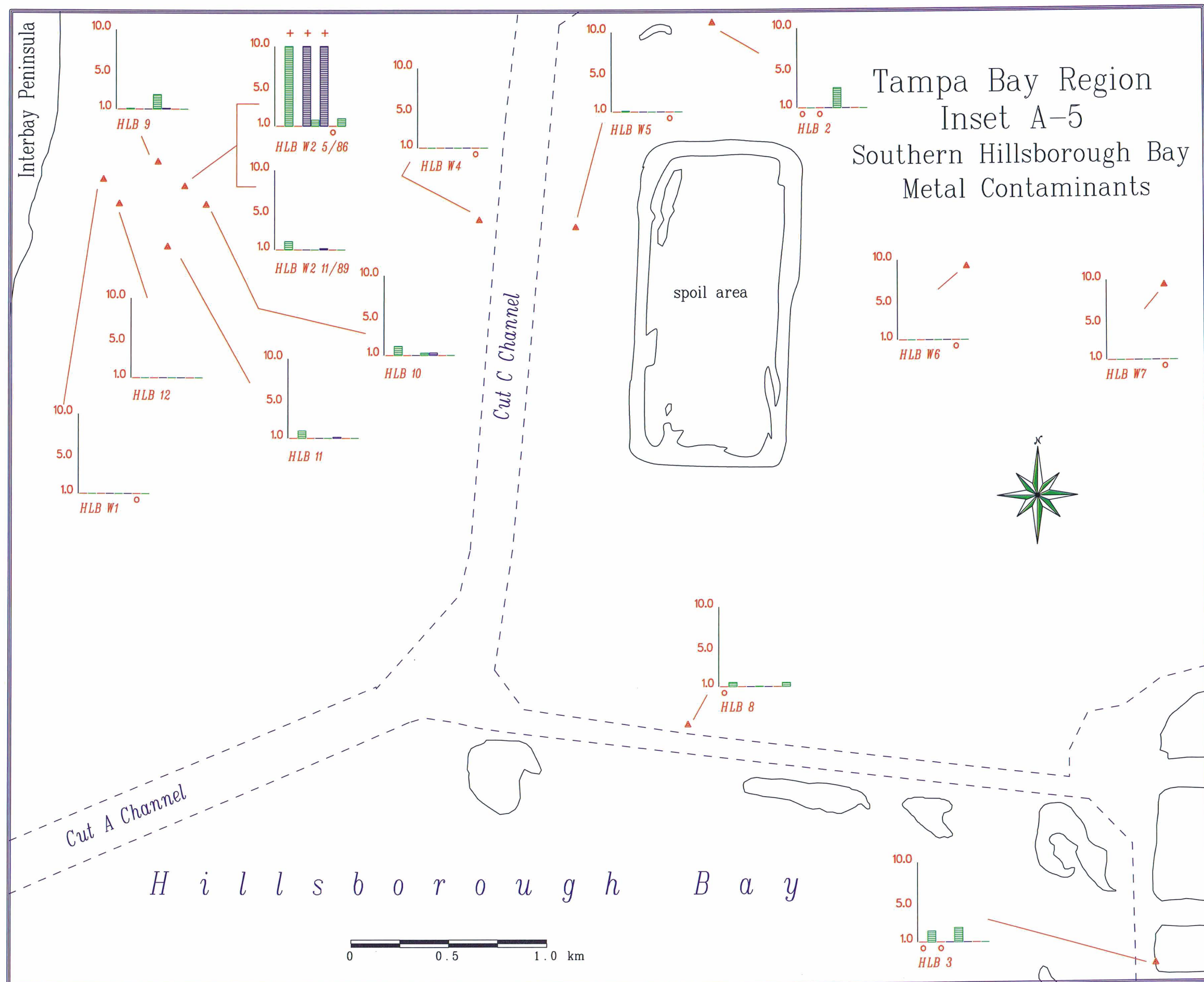


Map 19 - Tampa Bay Region Inset A-2 -
Northeastern Hillsborough Bay

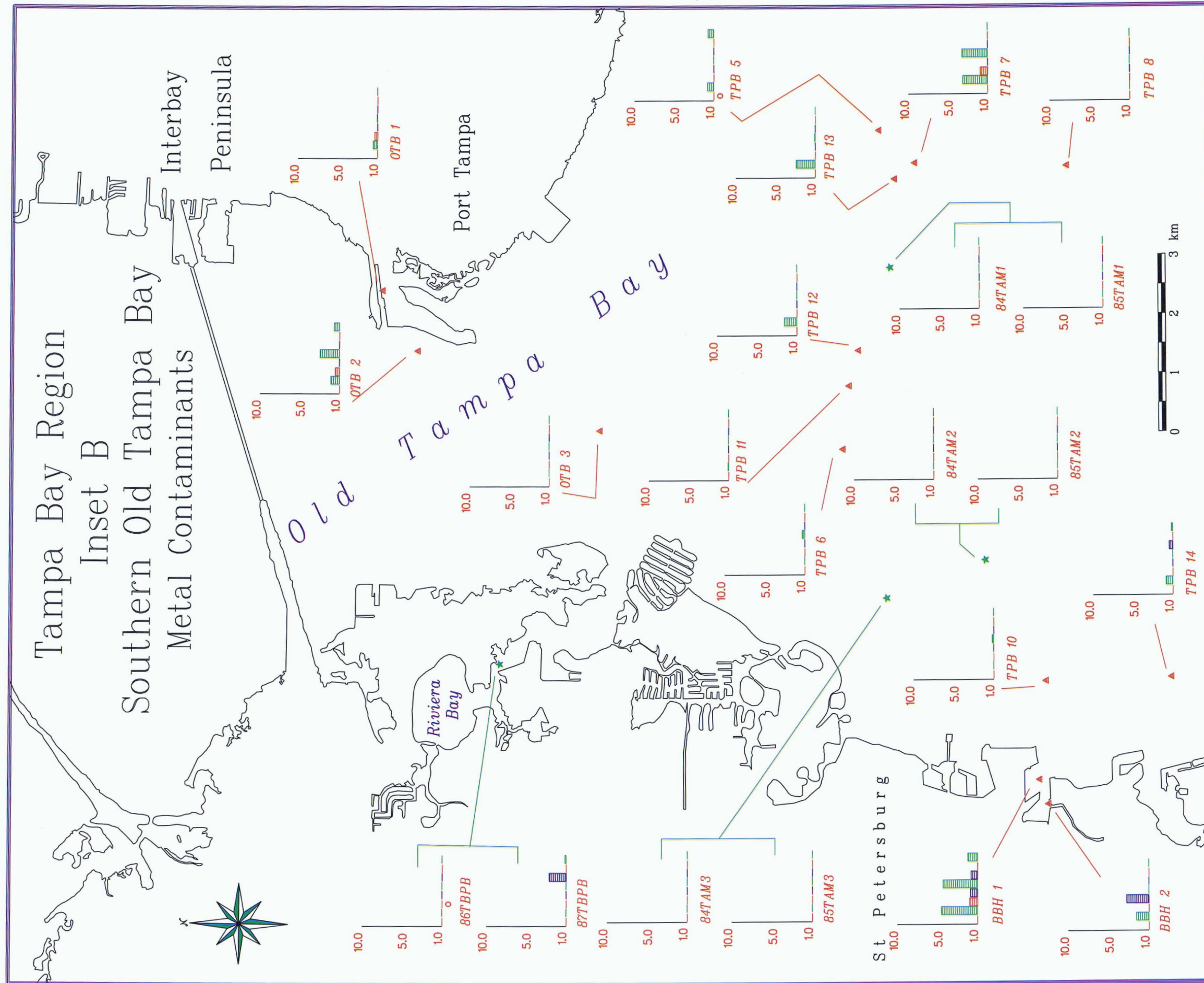


Map 20 - Tampa Bay Region Inset A-3 -
West Central Hillsborough Bay



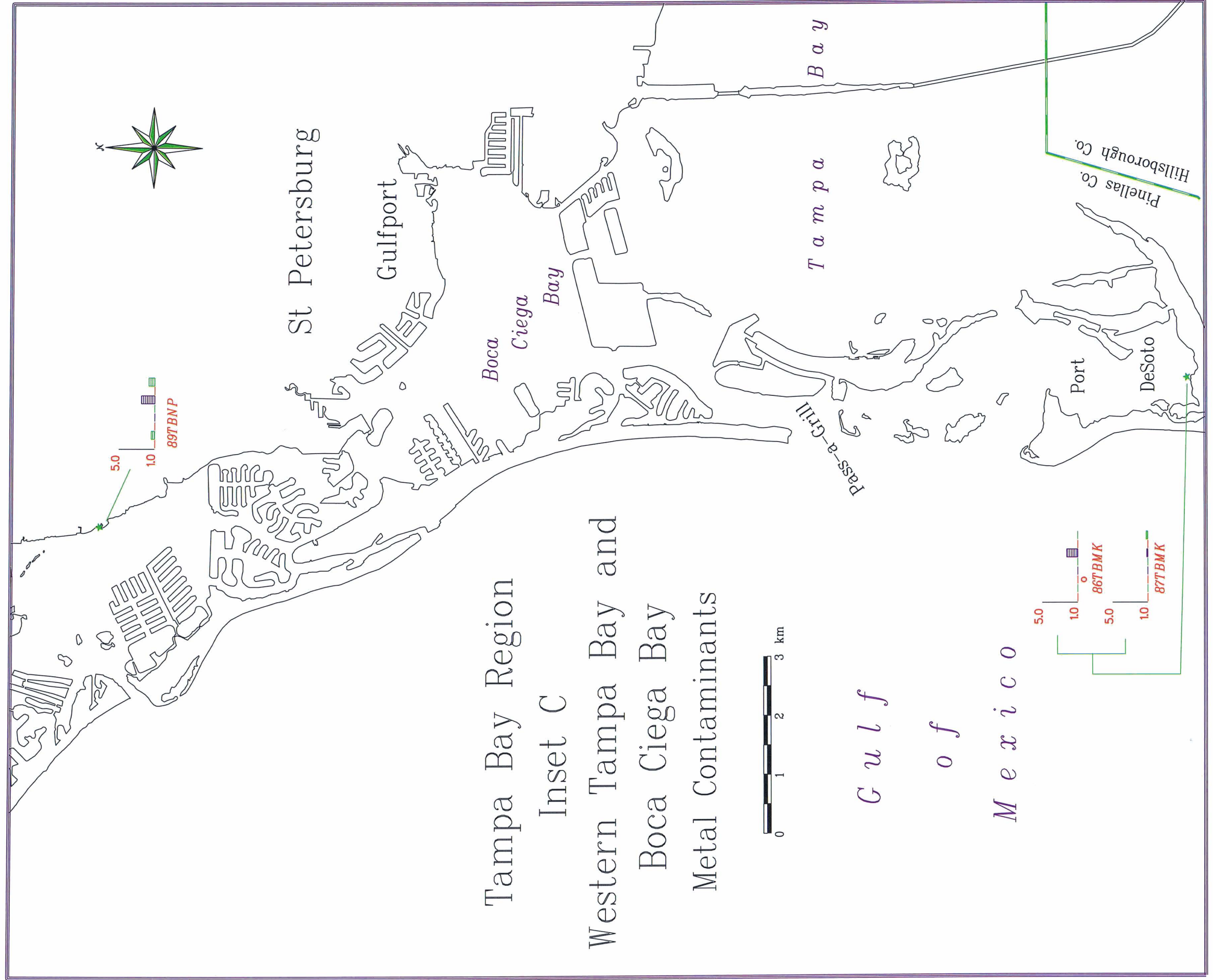


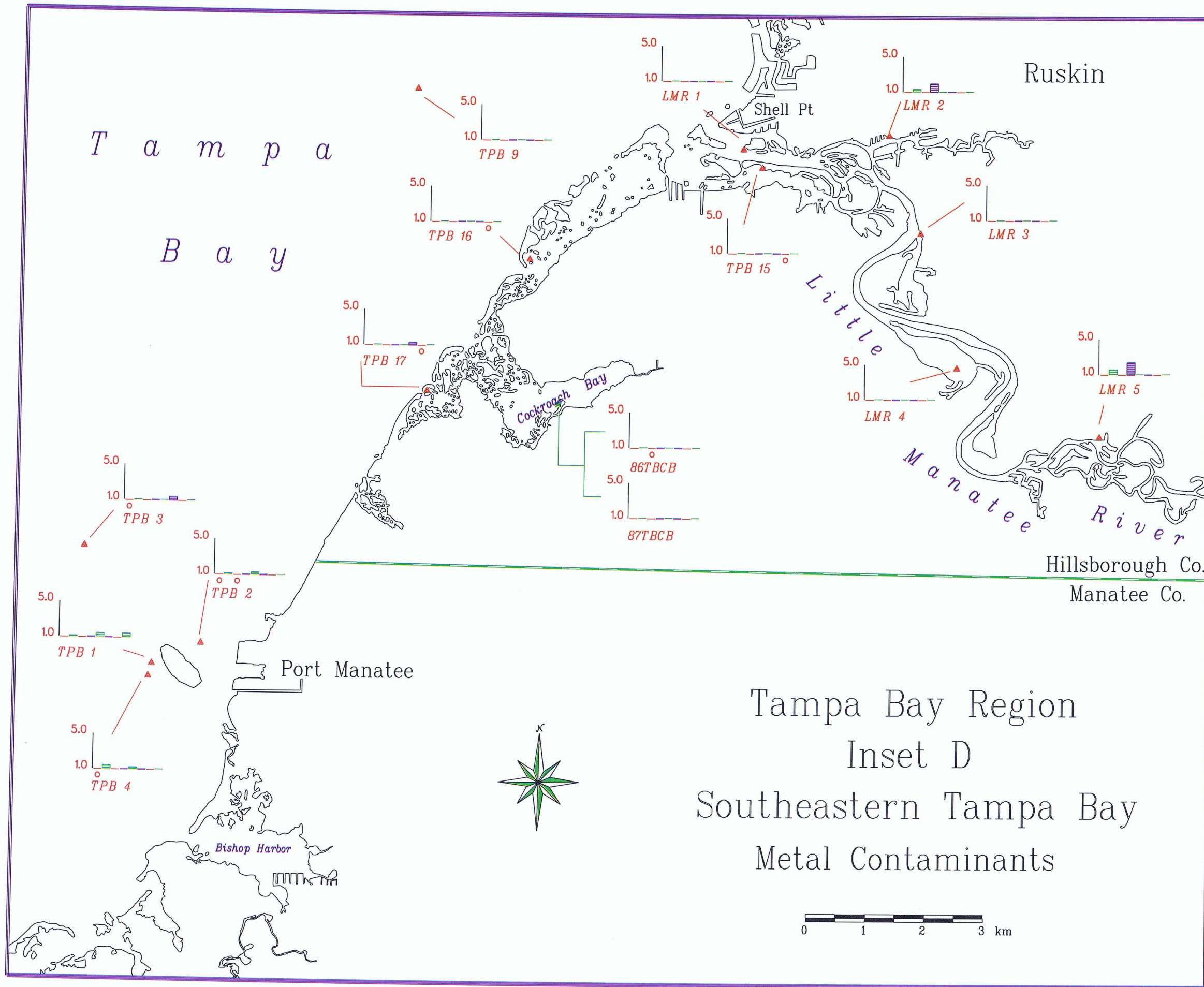
Map 22 - Tampa Bay Region Inset A-5 -
Southern Hillsborough Bay



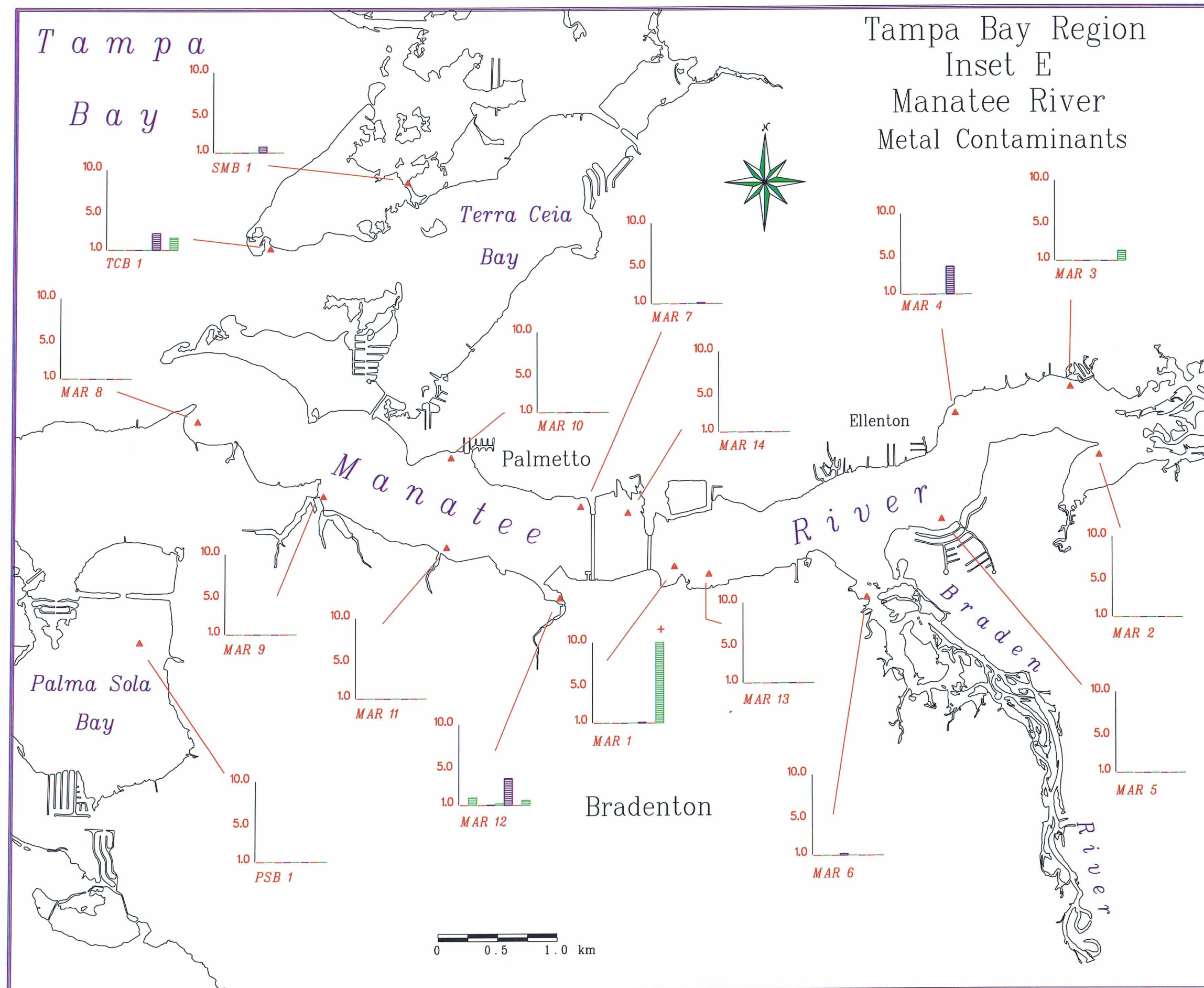
Map 23 - Tampa Bay Region Inset B -
Southern Old Tampa Bay

Map 24 - Tampa Bay Region Inset C - Western
Tampa Bay and Boca Ciega Bay

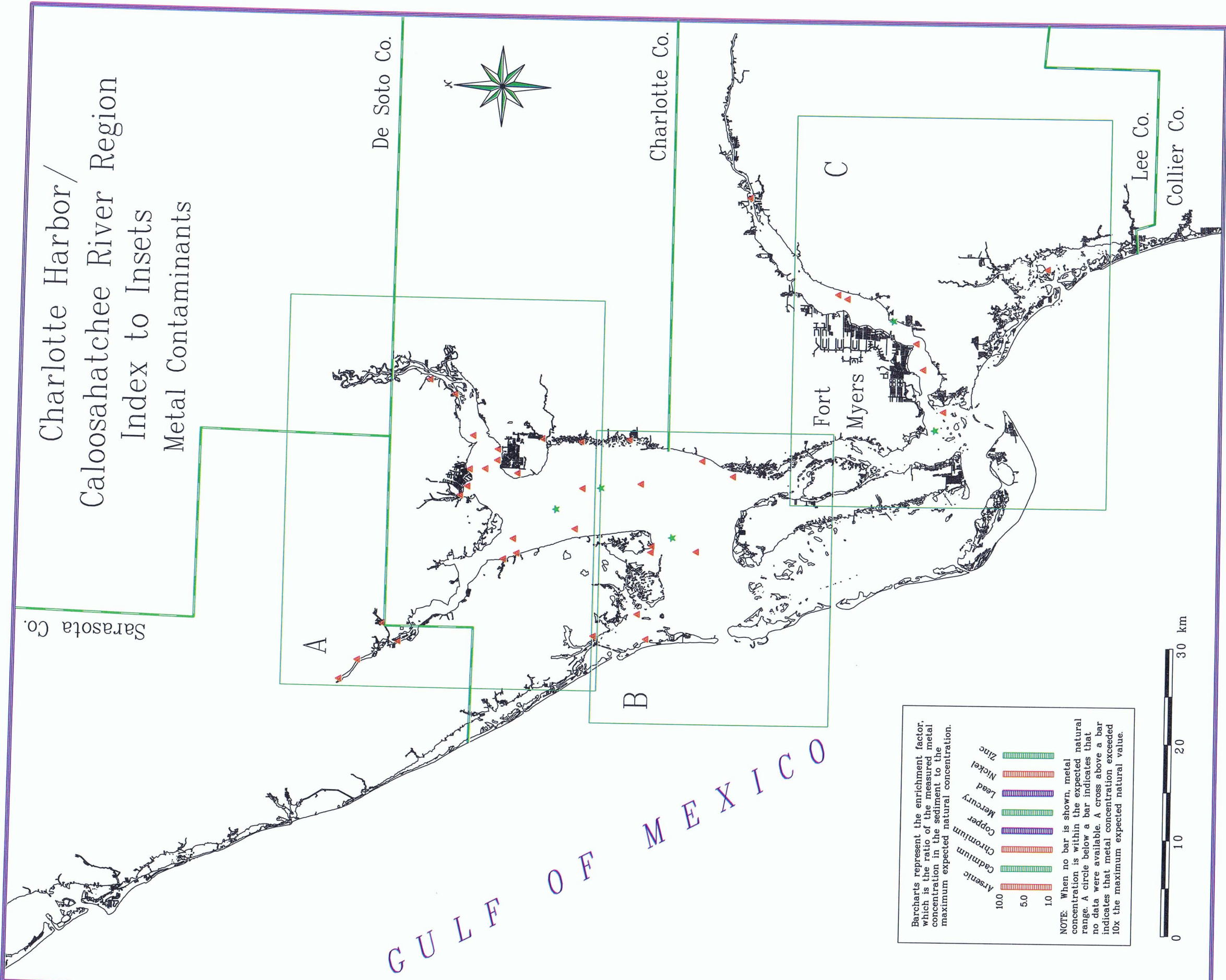




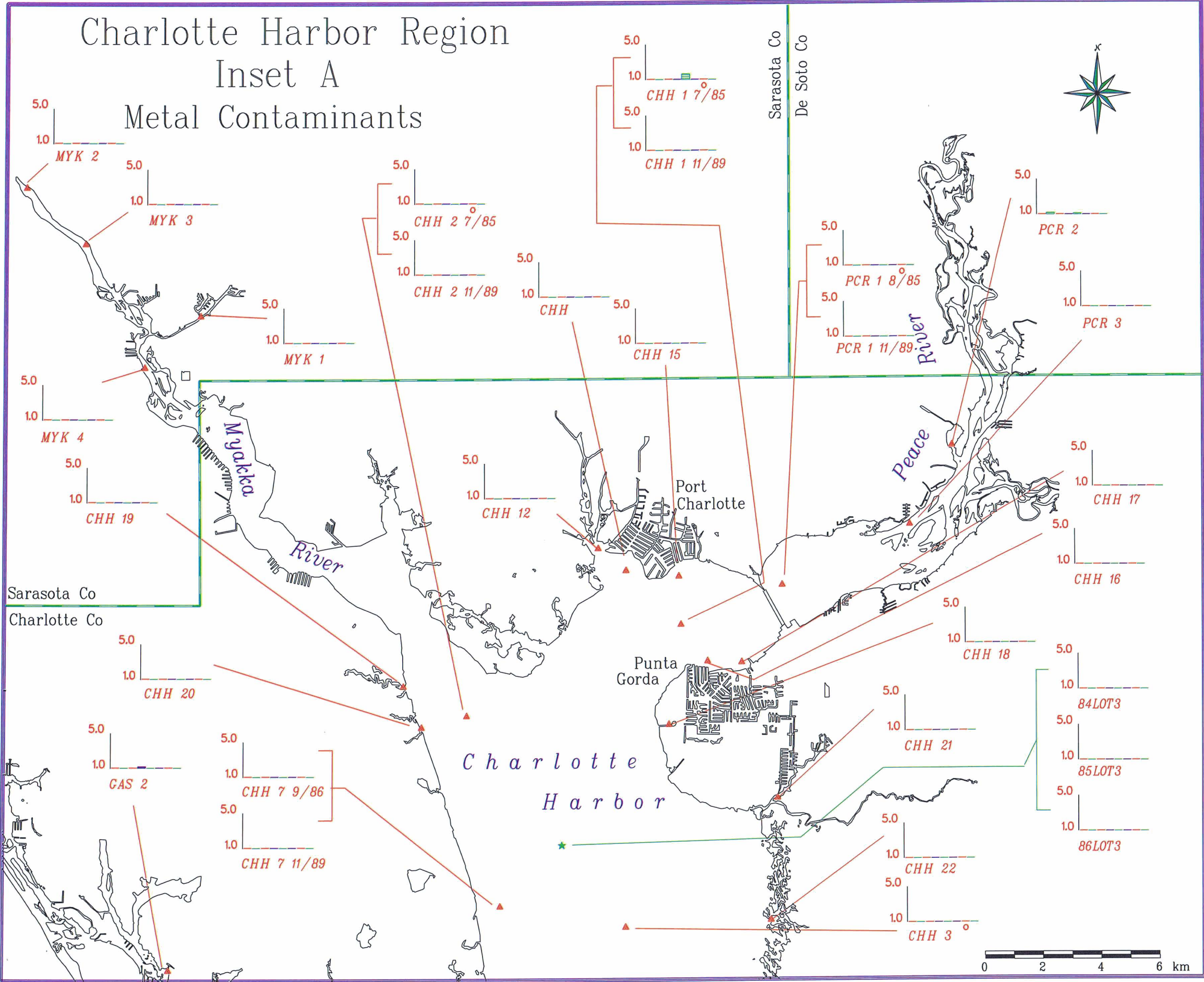
Map 25 - Tampa Bay Region Inset D -
Southeastern Tampa Bay



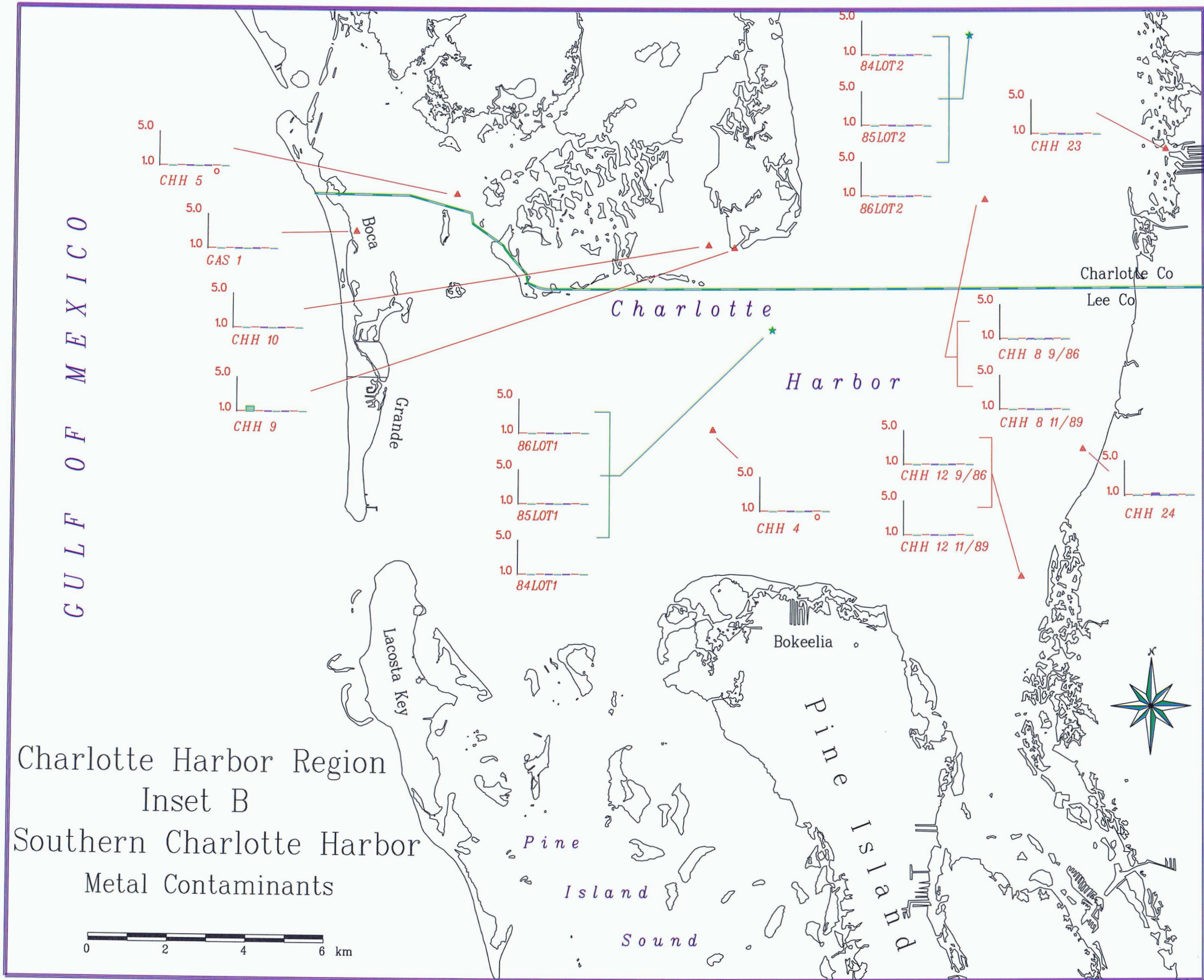
Map 26 - Tampa Bay Region Inset E -
Manatee River



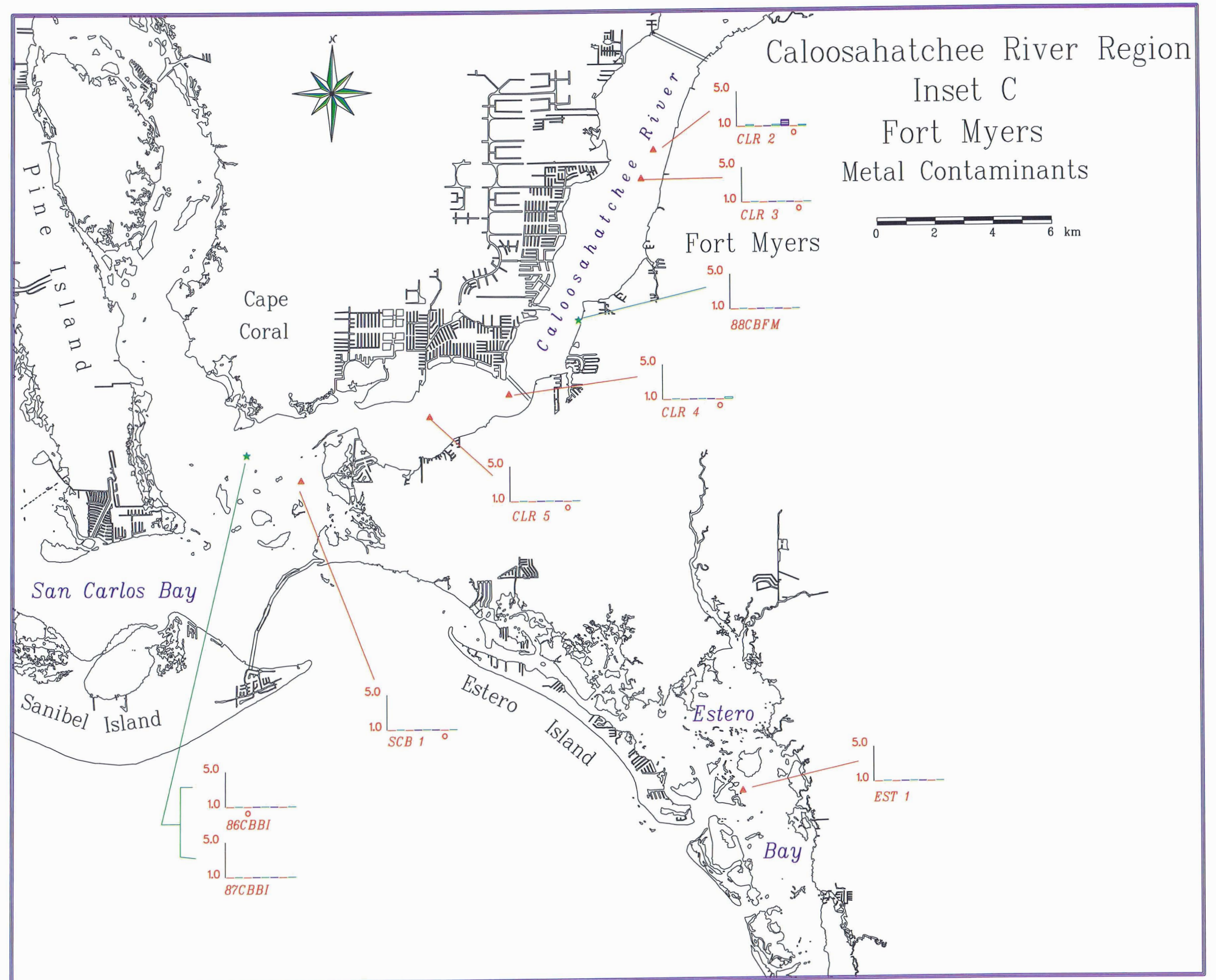
Map 27 - Charlotte Harbor and Caloosahatchee River Region - Index to Insets



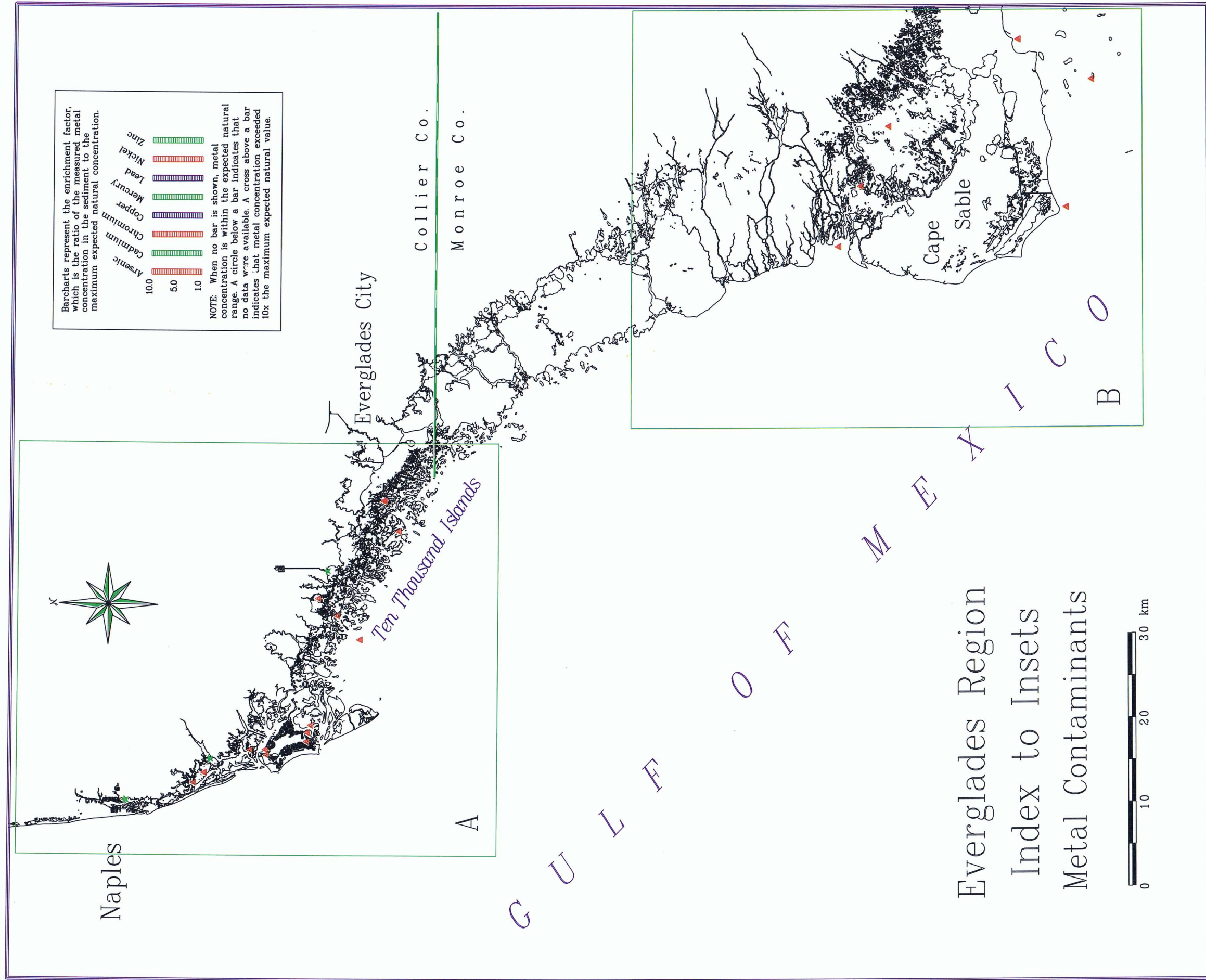
Map 28 - Charlotte Harbor Region Inset A



Map 29 - Charlotte Harbor Region Inset B - Southern Charlotte Harbor

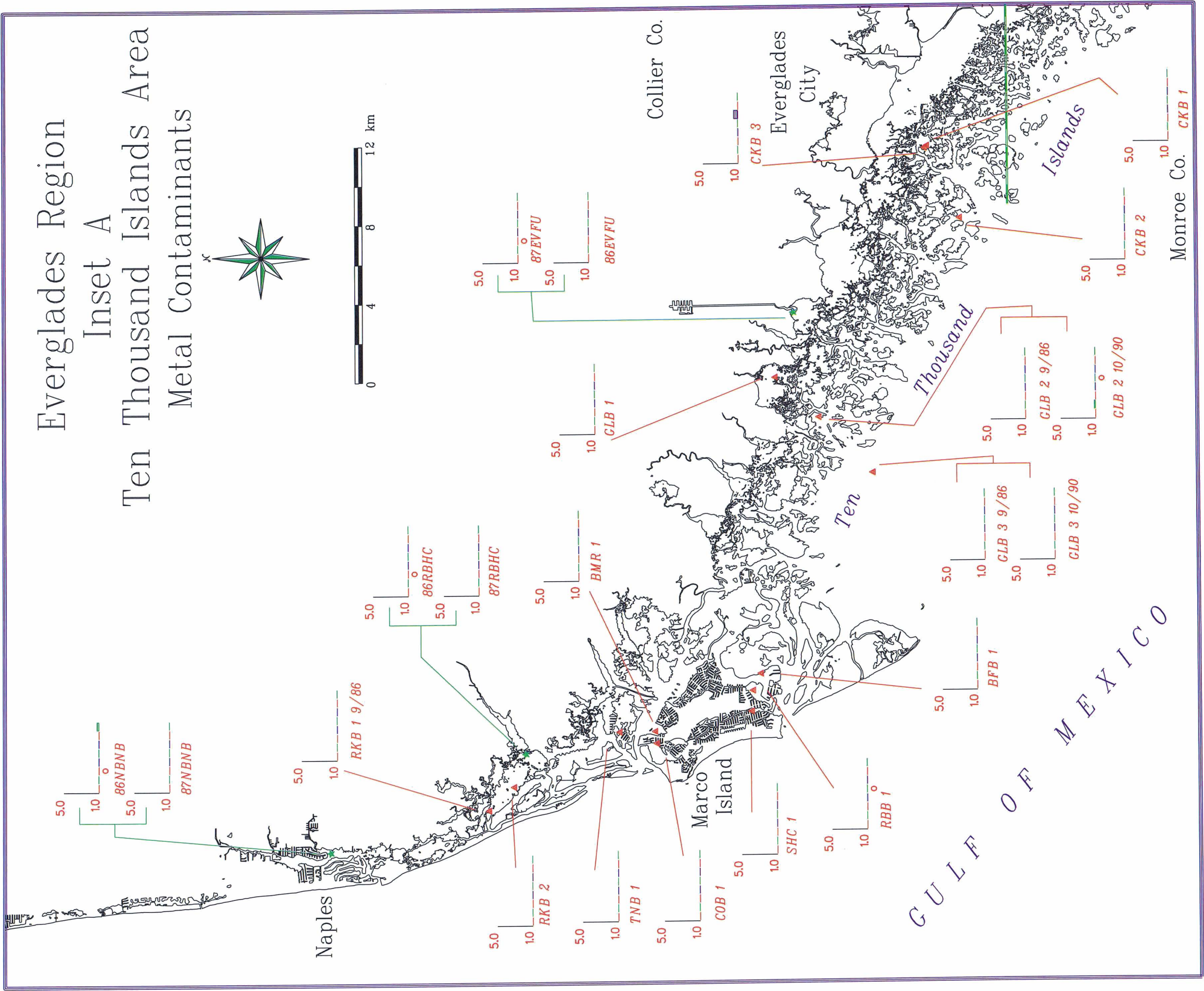


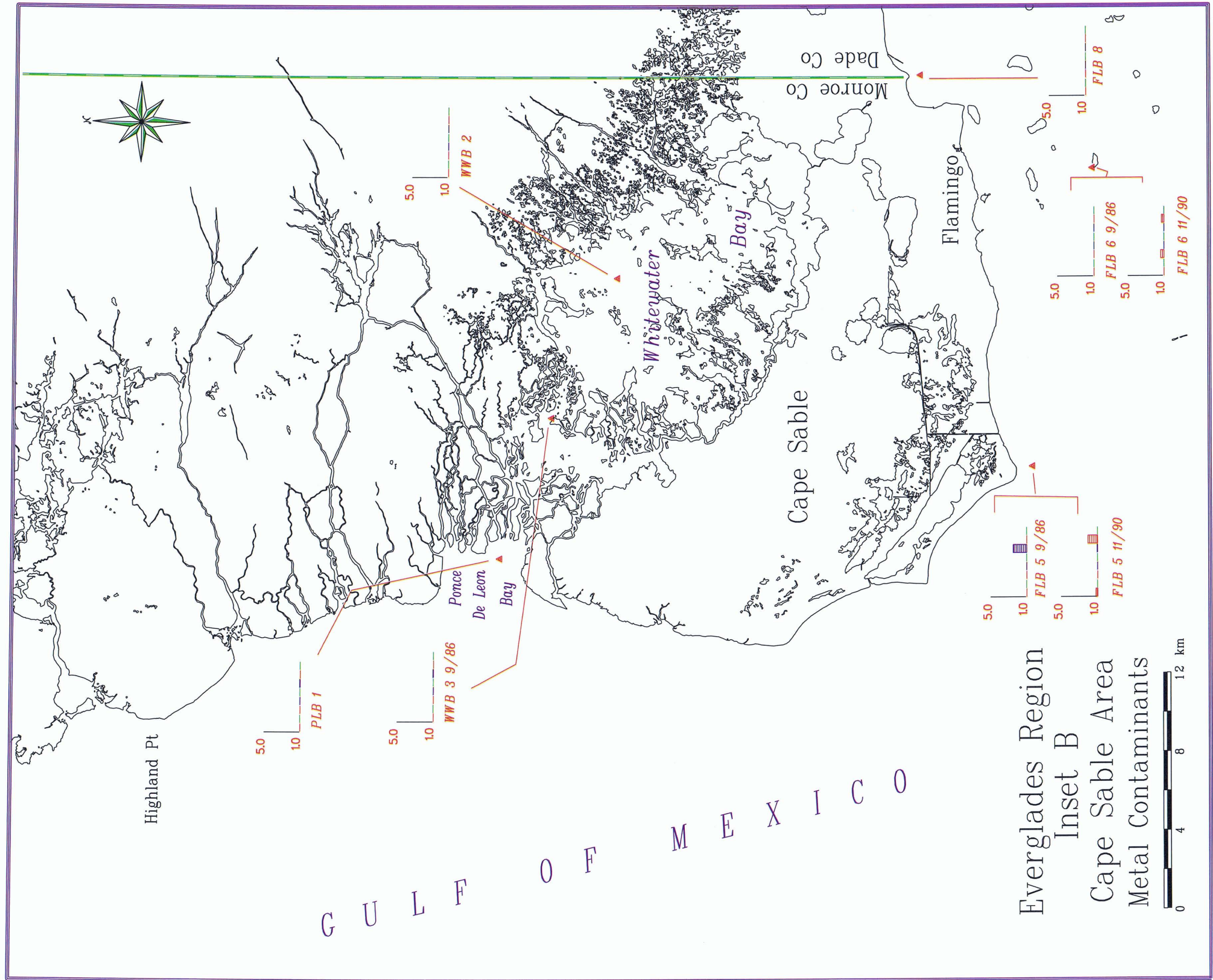
Map 30 - Caloosahatchee River Region
Inset C - Fort Myers



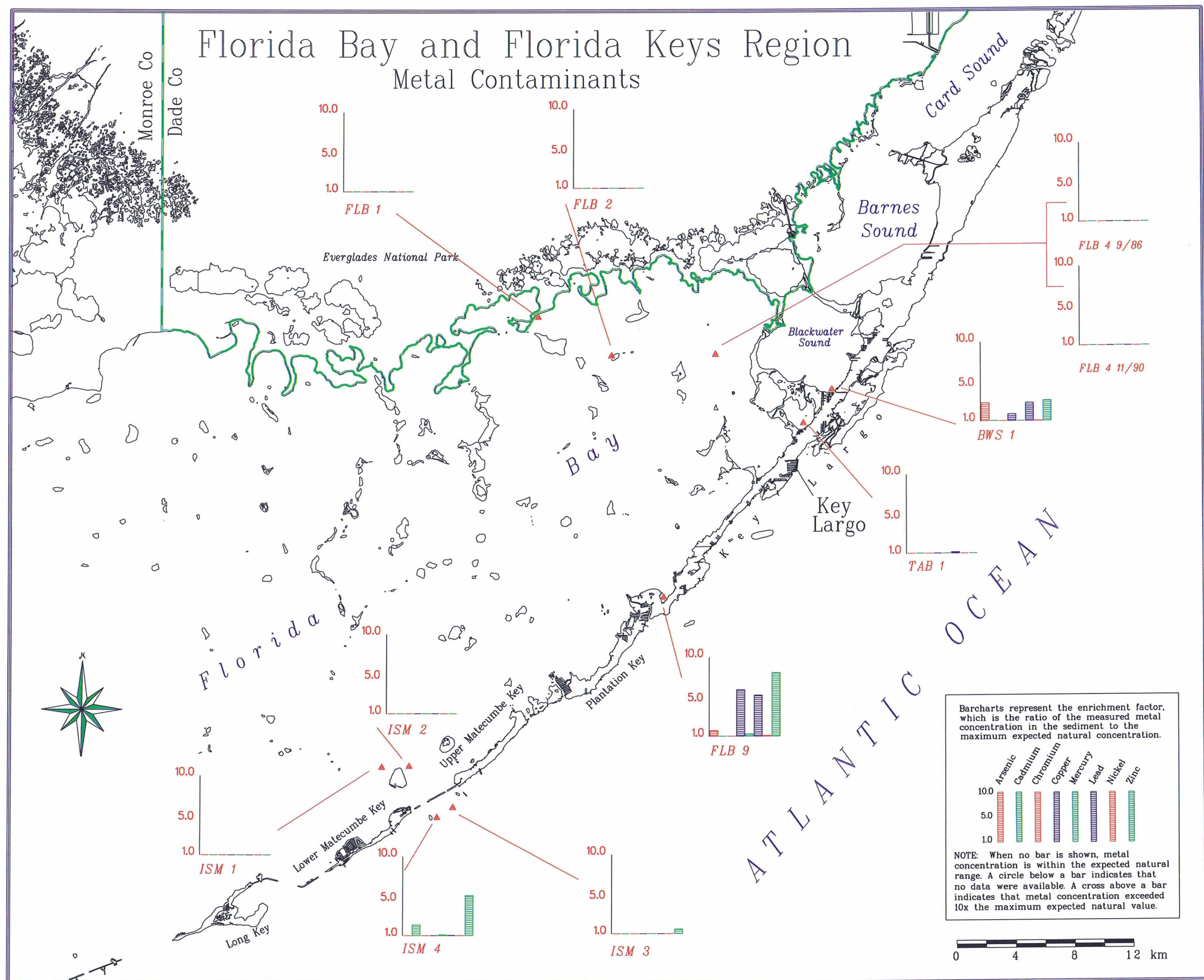
Map 31 - Everglades Region Index to Insets

Map 32 - Everglades Region Inset A -
Ten Thousand Islands Area



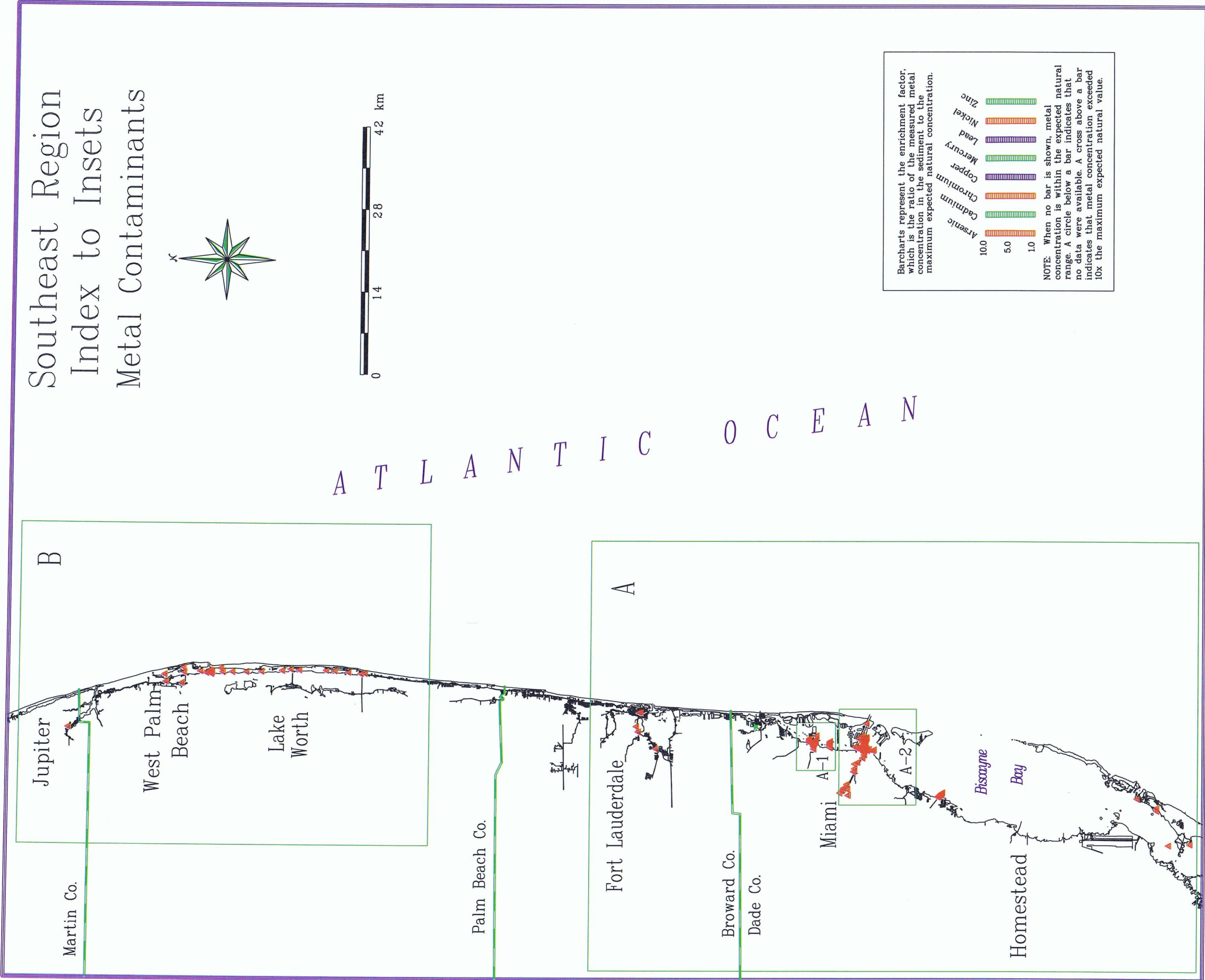


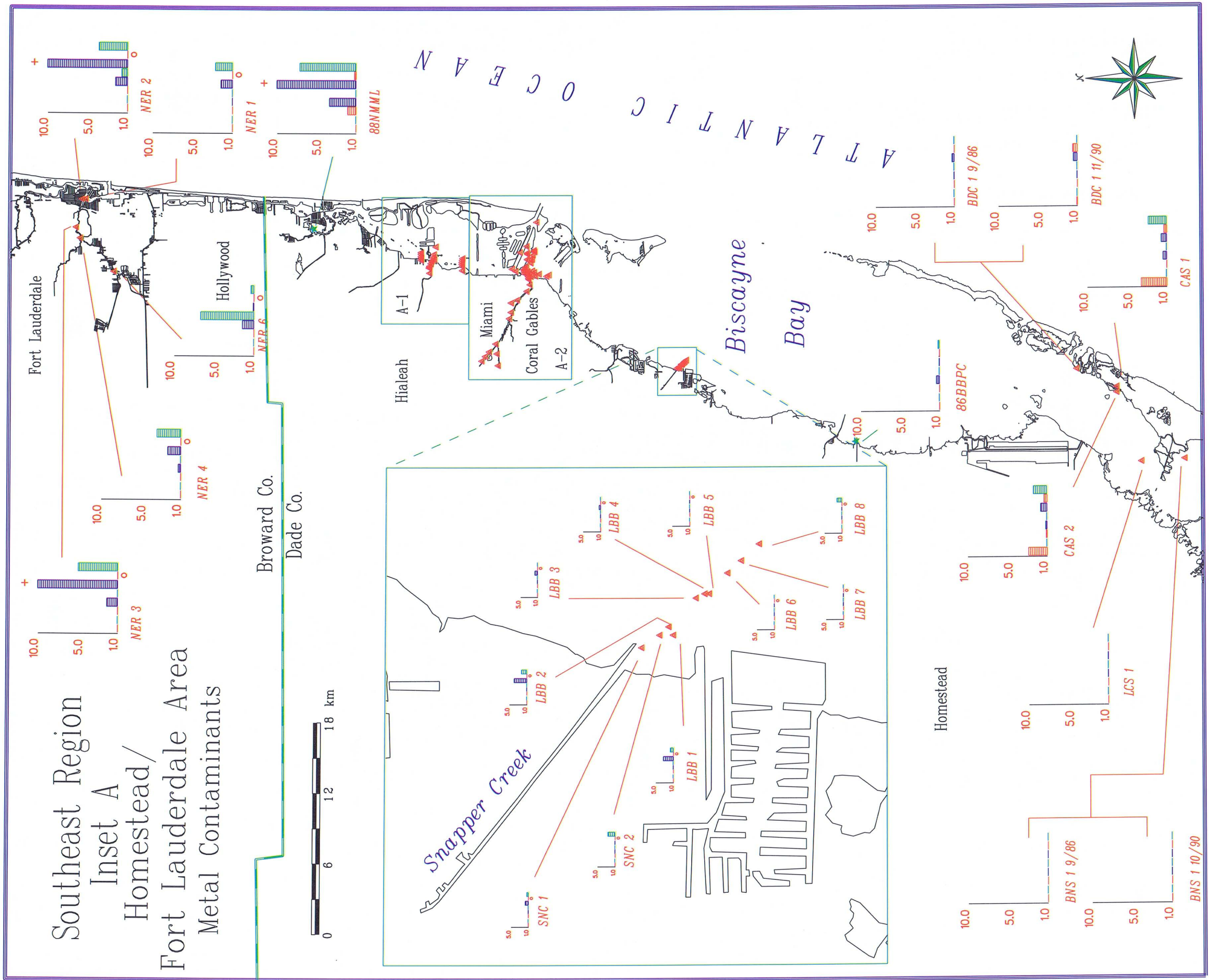
Map 33 - Everglades Region Inset B -
Cape Sable Area



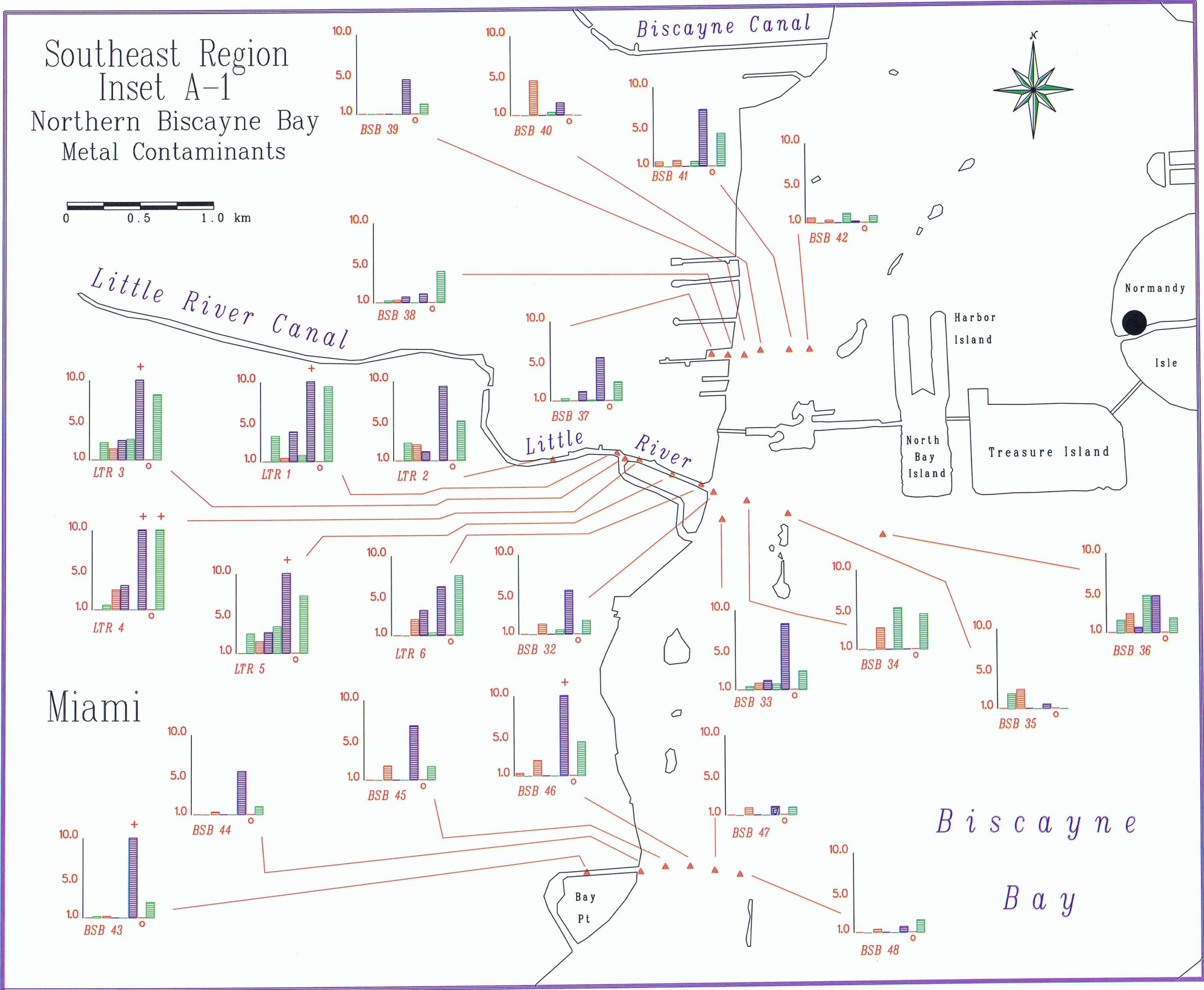
Map 34 - Florida Bay and Florida Keys Region

Map 35 - Southeast Region Index to Insets

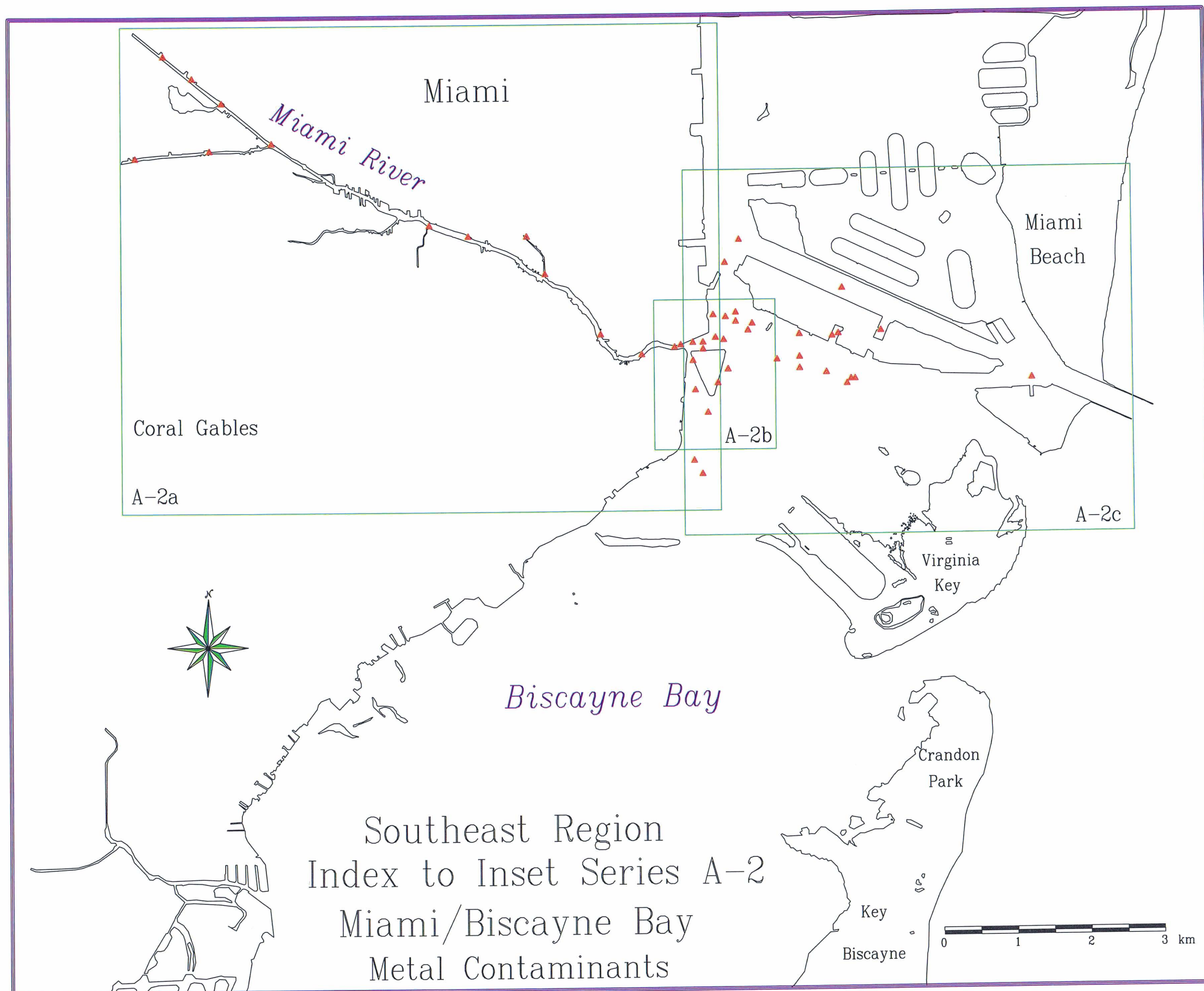




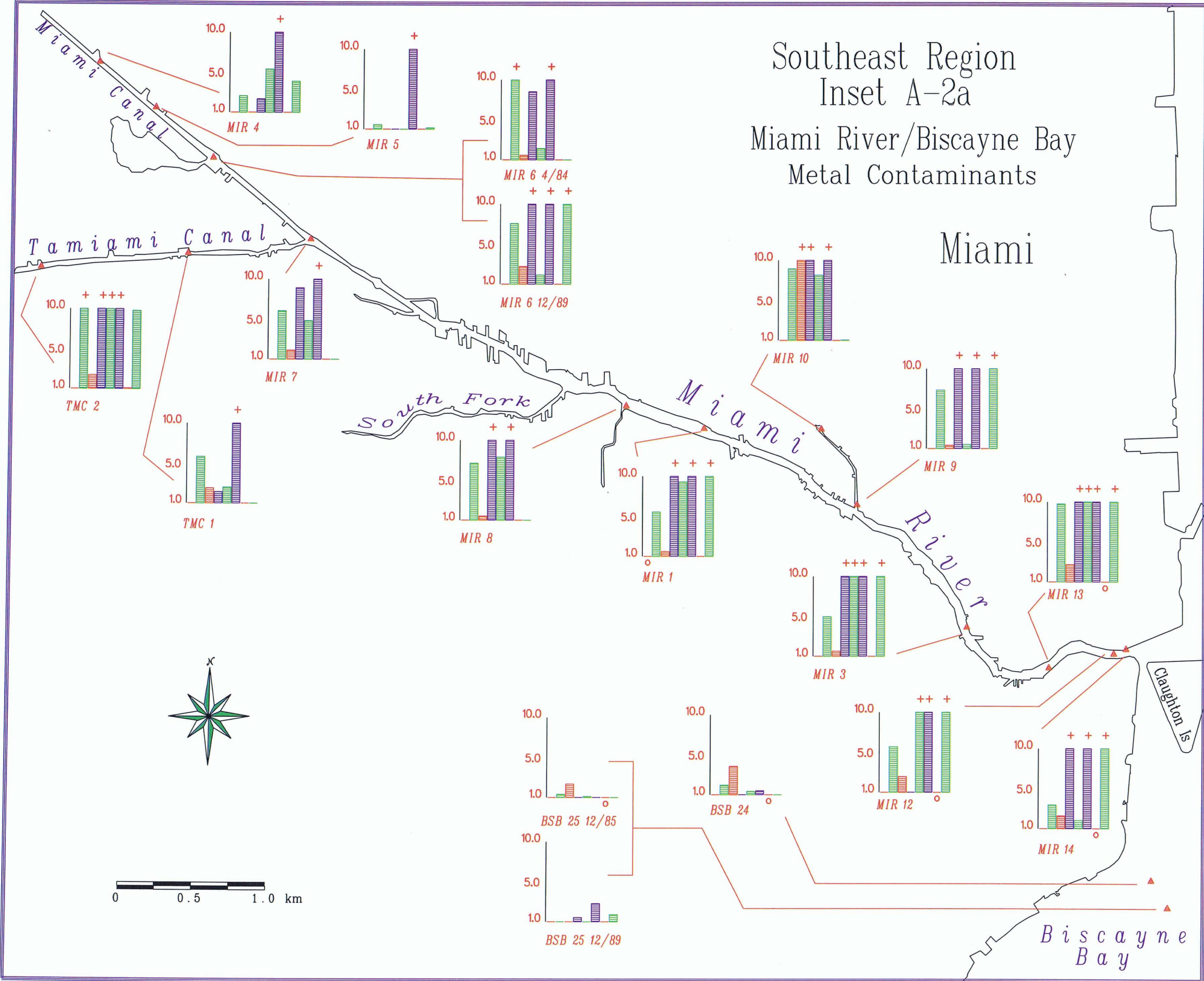
Map 36 - Southeast Region Inset A -
Homestead/ Fort Lauderdale Area



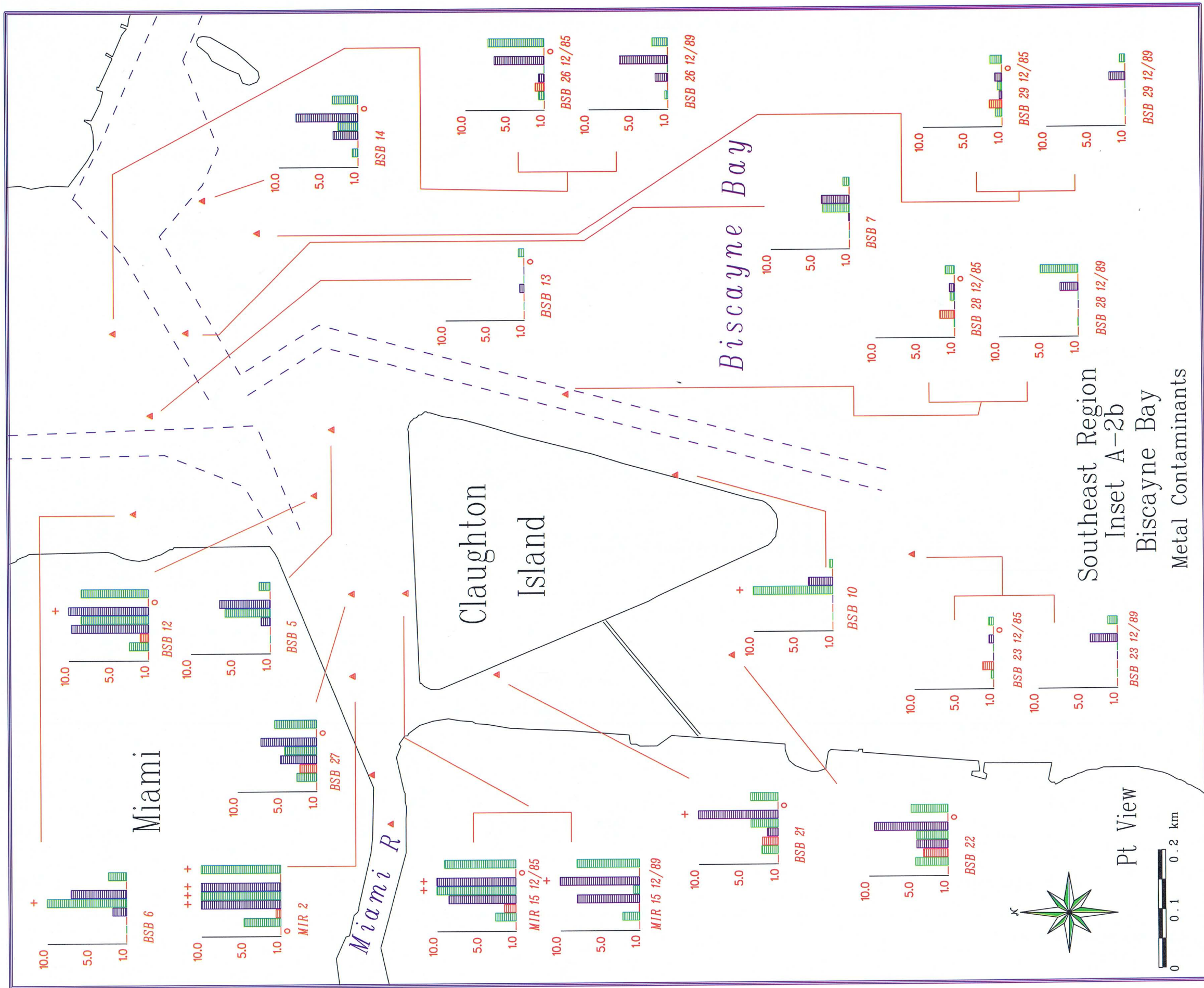
Map 37 - Southeast Region Inset A-1 -
Northern Biscayne Bay



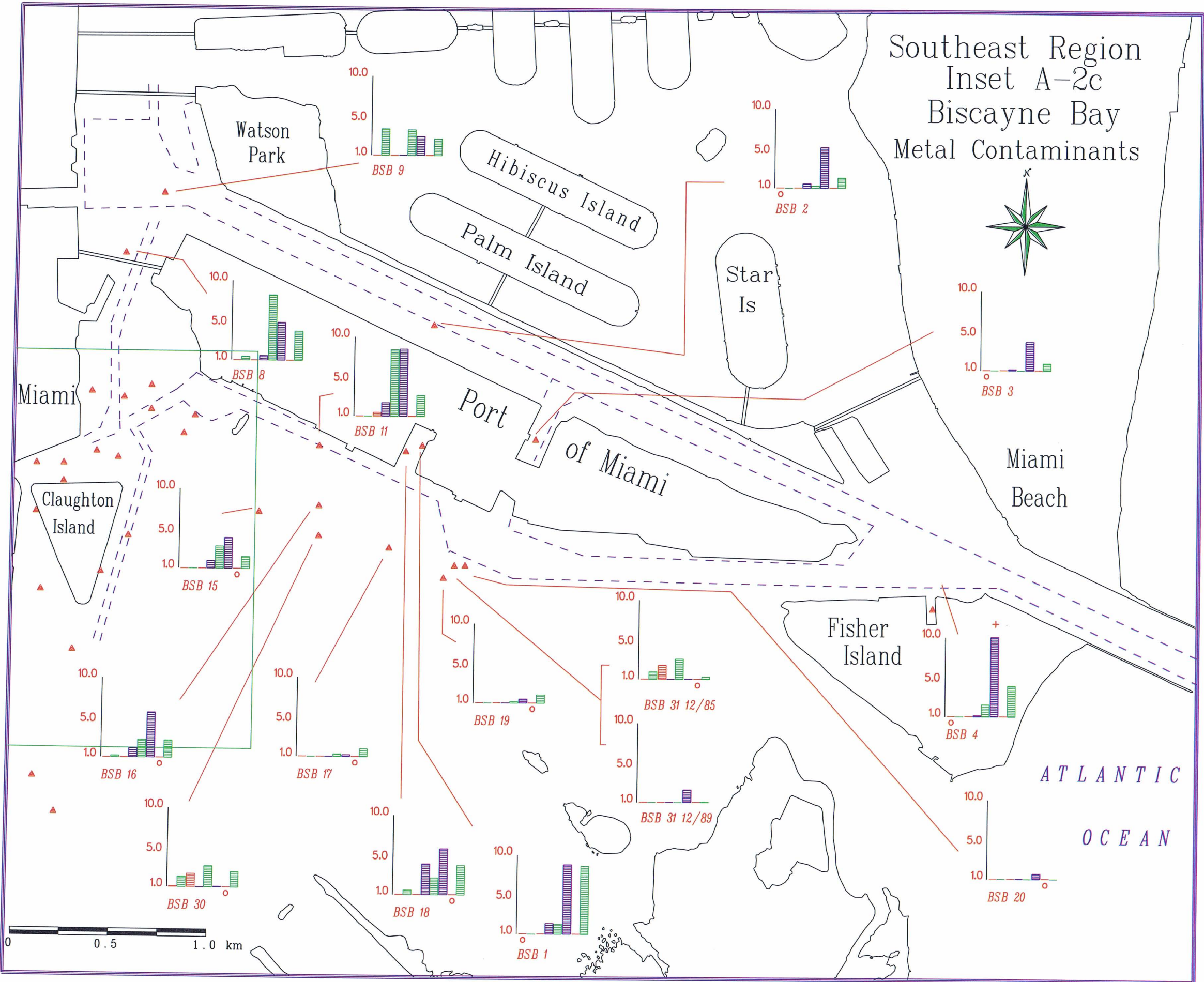
Map 38 - Southeast Region Index to Inset
Series A-2 - Miami/Biscayne Bay



Map 39 - Southeast Region Inset A-2a -
Miami River

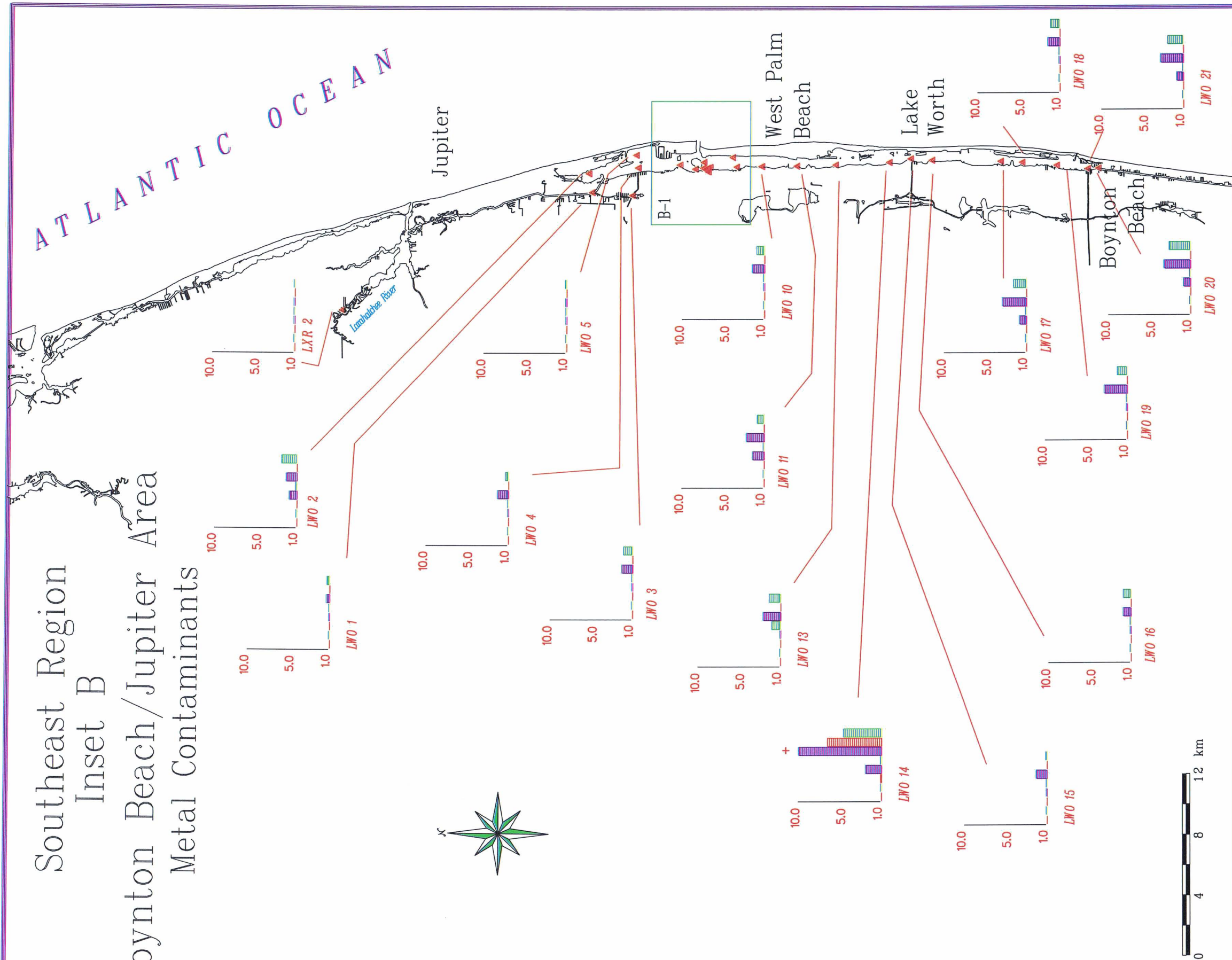


Map 40 - Southeast Region Inset A-2b -
Biscayne Bay

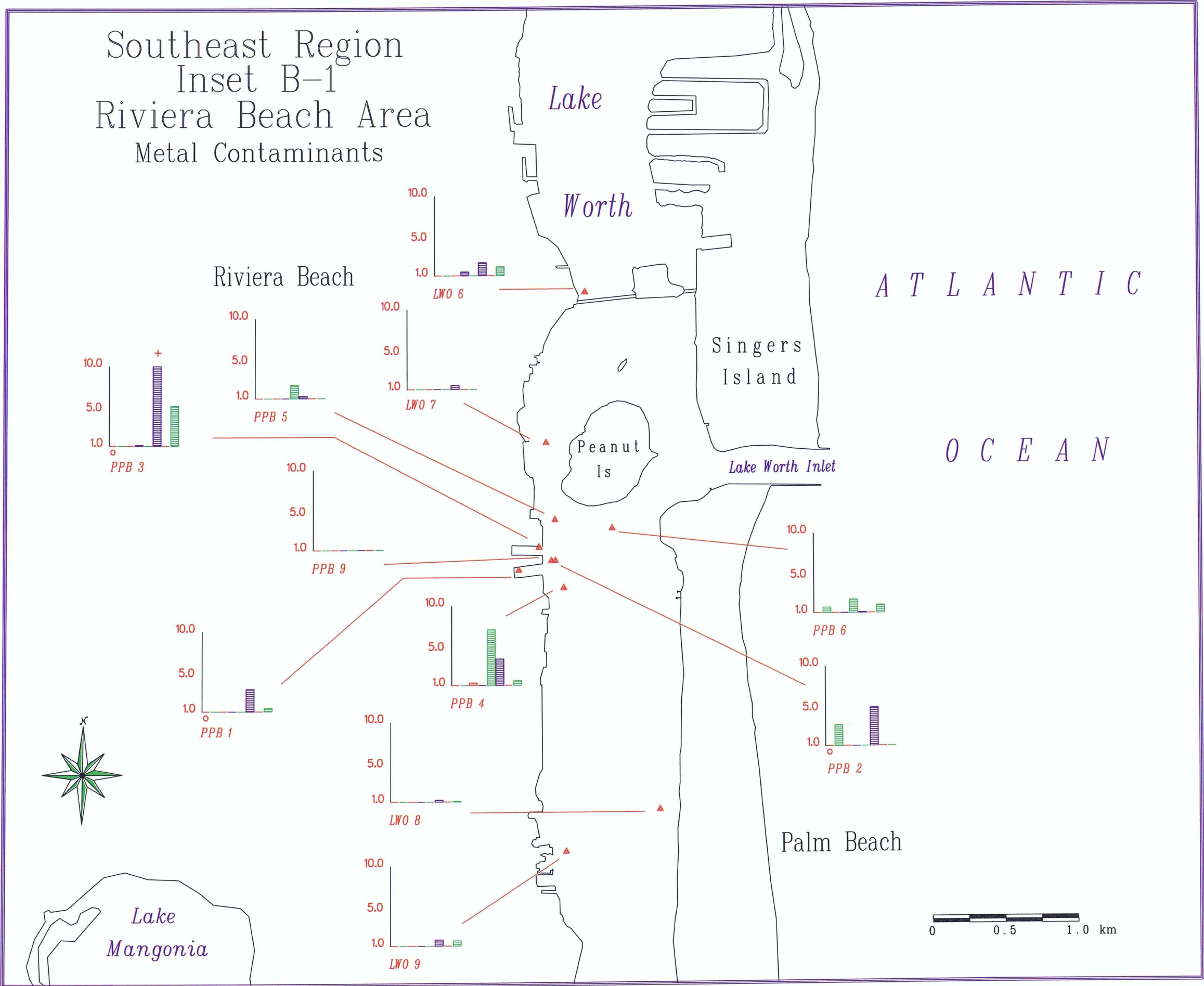


Map 41 - Southeast Region Inset A-2c -
Biscayne Bay

Southeast Region Inset B Boynton Beach/Jupiter Area Metal Contaminants



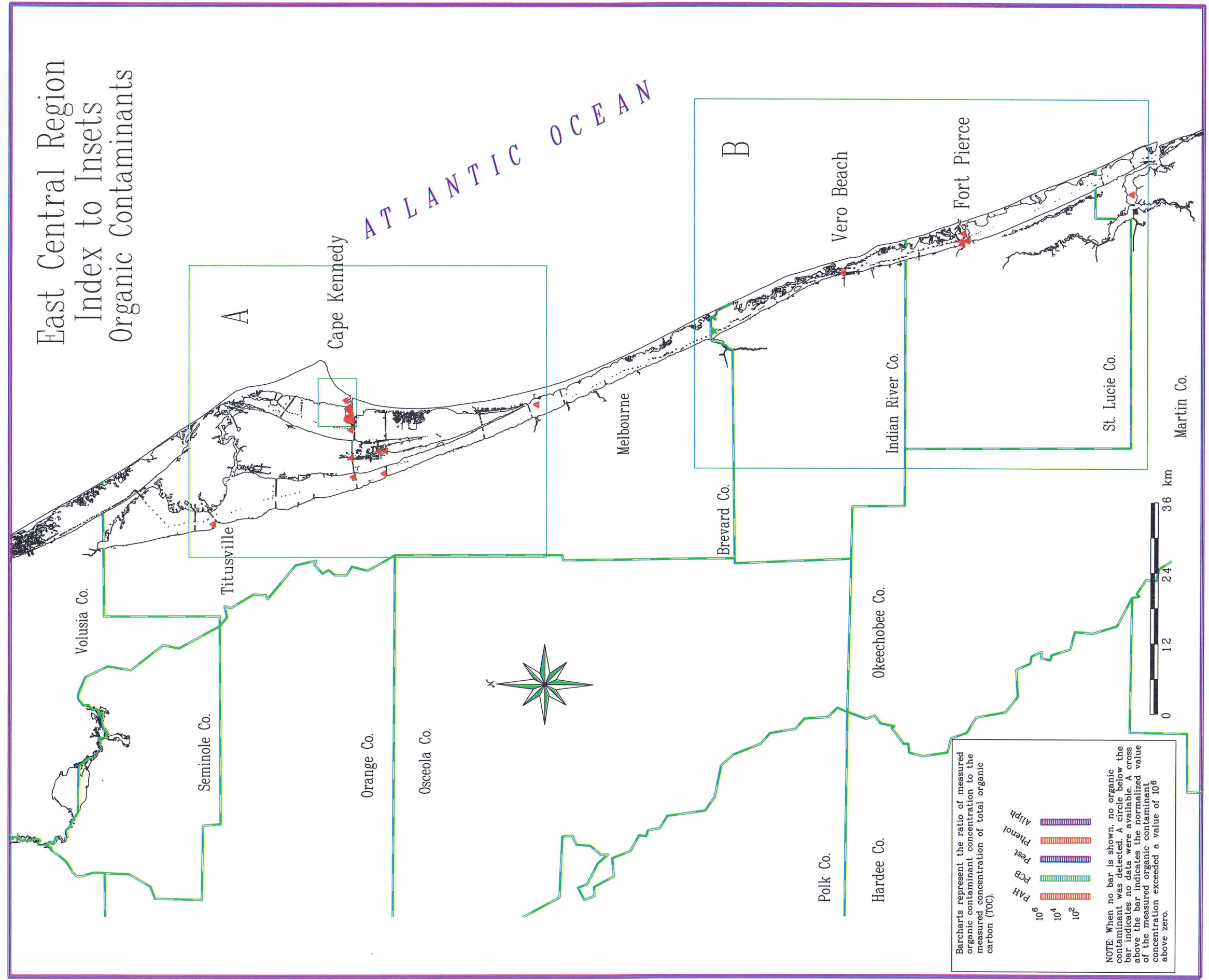
Map 42 - Southeast Region Inset B - Boynton Beach/ Jupiter Area



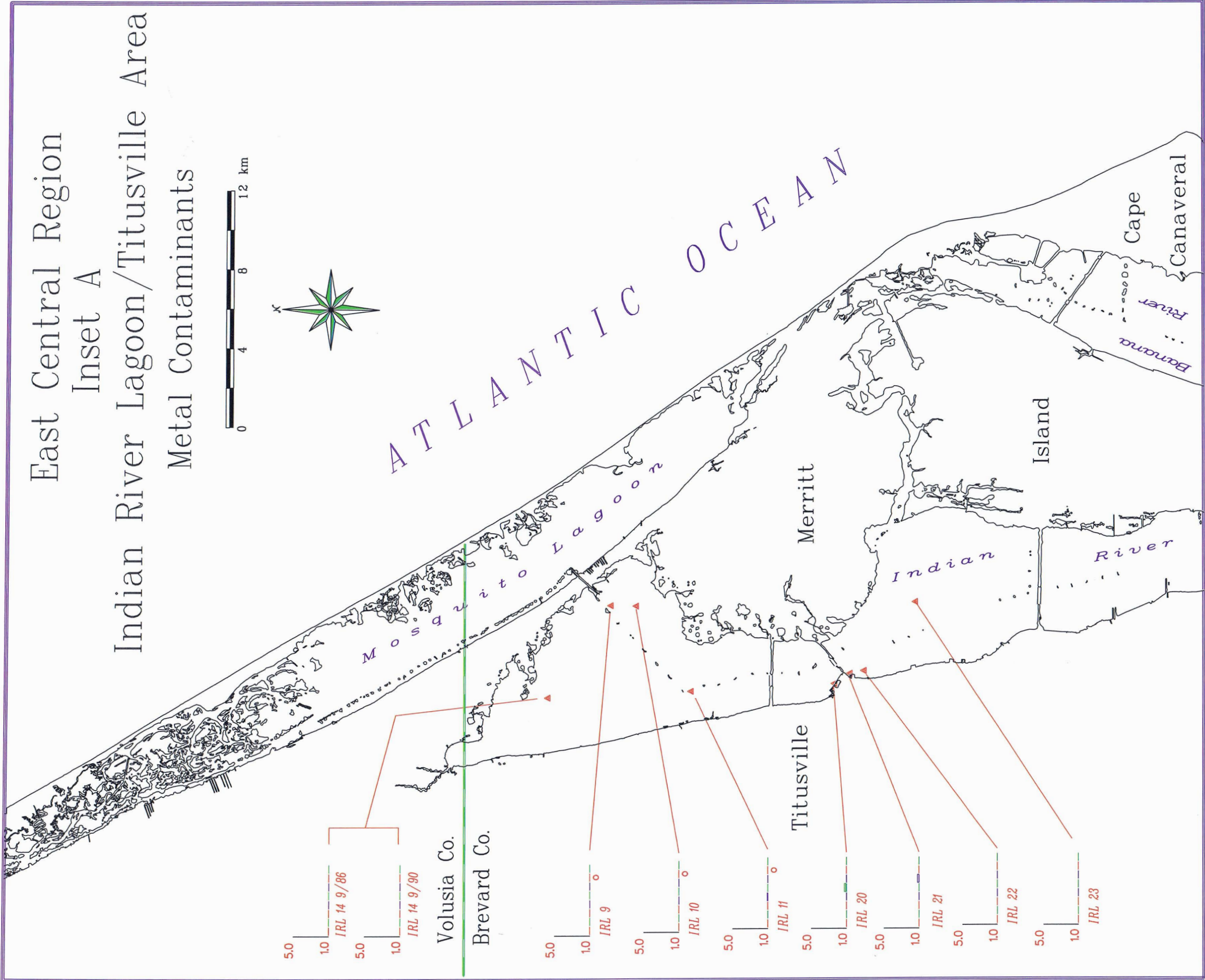
Map 43 - Southeast Region Inset B-1 -
Riviera Beach Area

East Central Region Index to Insets Organic Contaminants

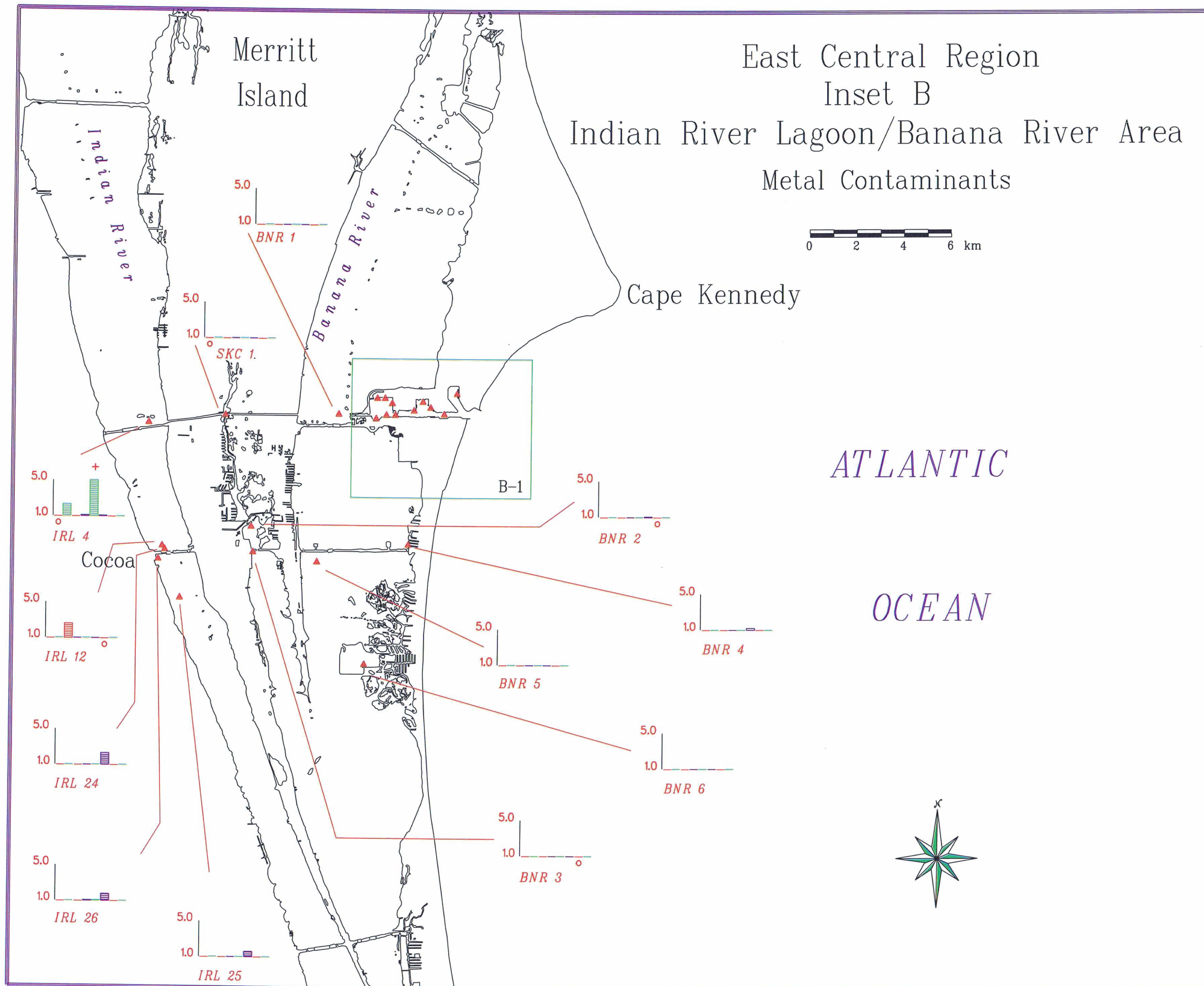
ATLANTIC OCEAN



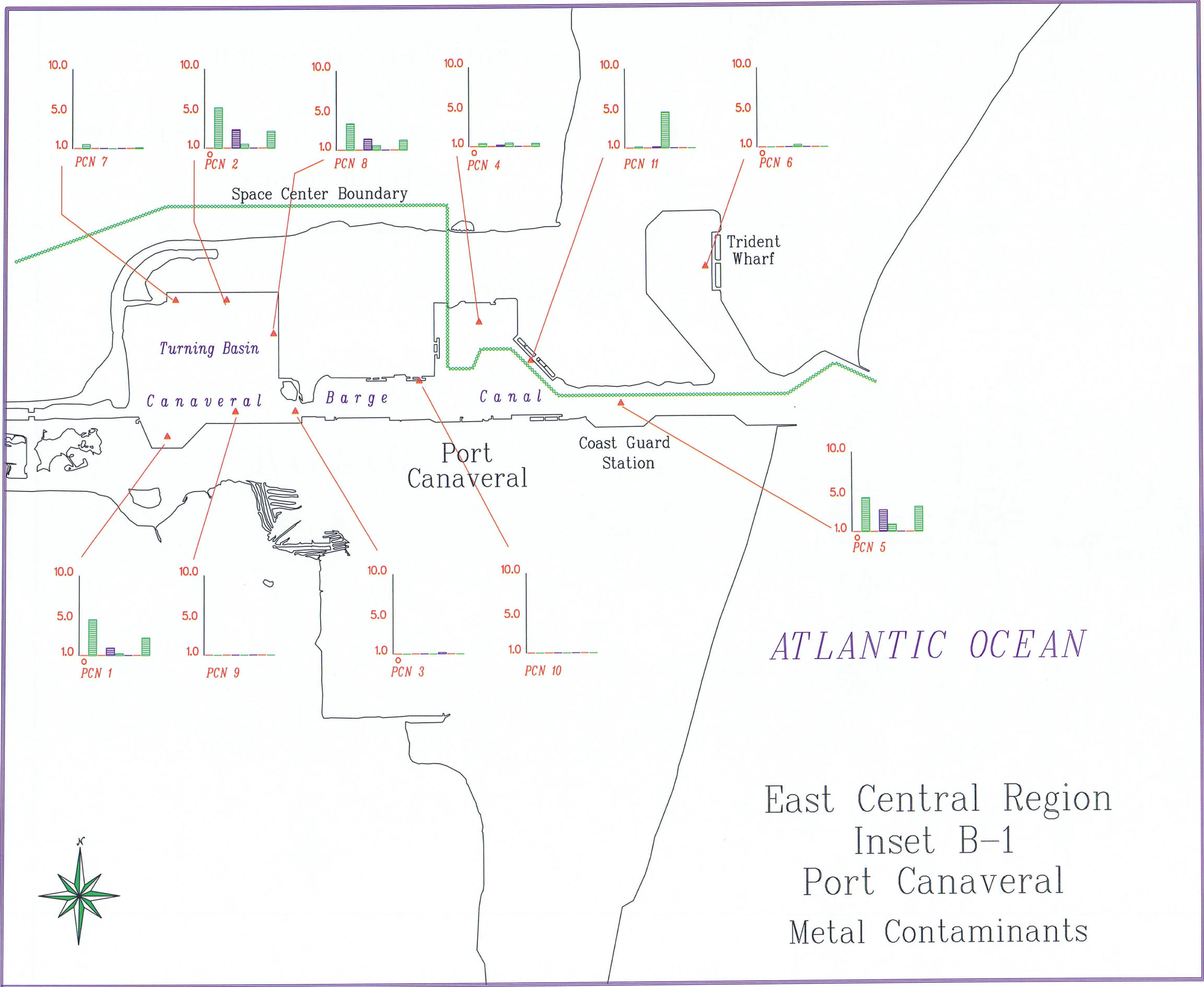
Map 44 - East Central Region Index to Insets



Map 45 - East Central Region Inset A - Indian River Lagoon/Titusville Area



Map 46 - East Central Region Inset B - Indian River Lagoon/Banana River Area



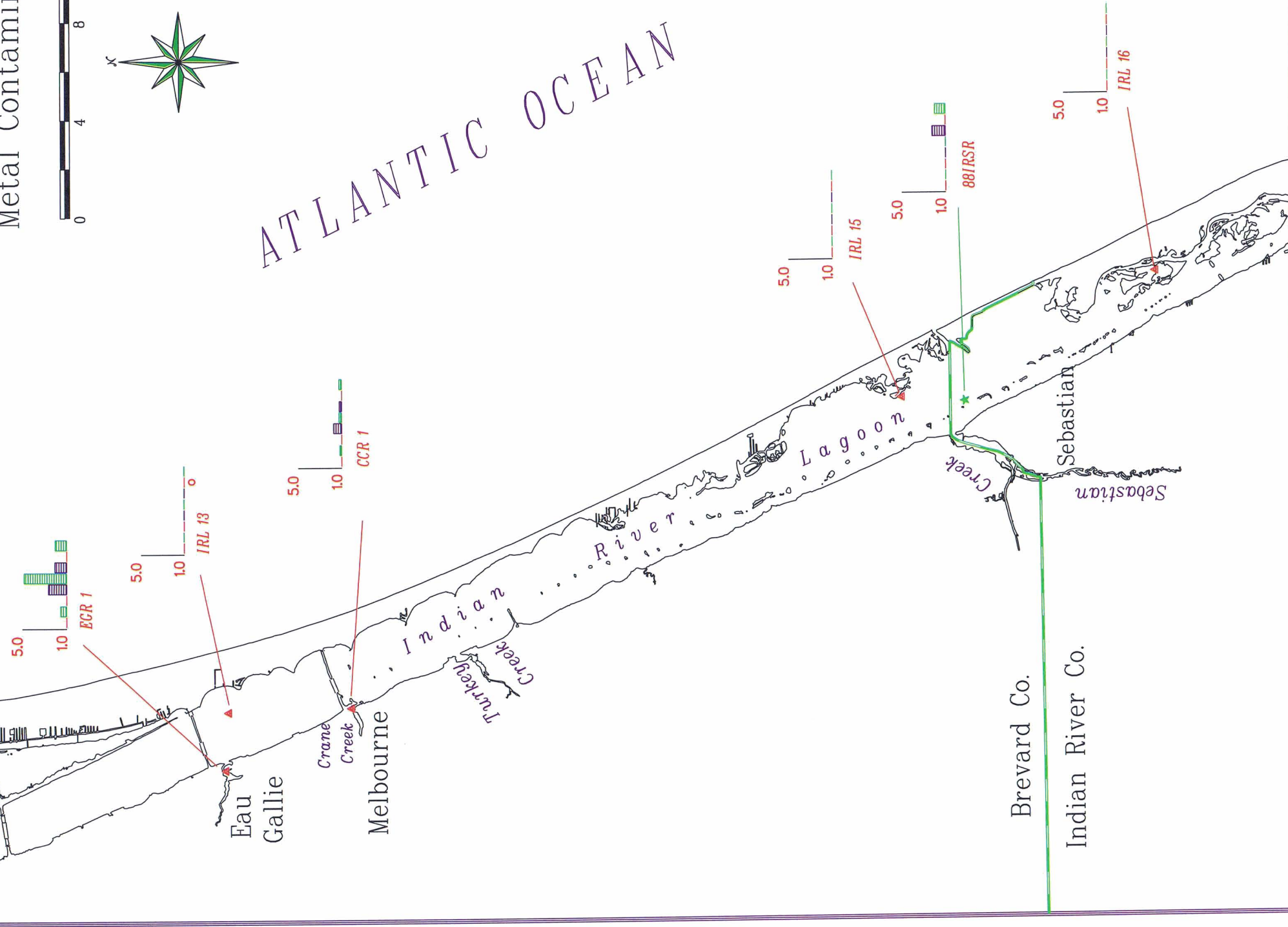
Map 47 - East Central Region Inset B-1 -
Port Canaveral

East Central Region Inset C Indian River Lagoon/Melbourne Area

Metal Contaminants

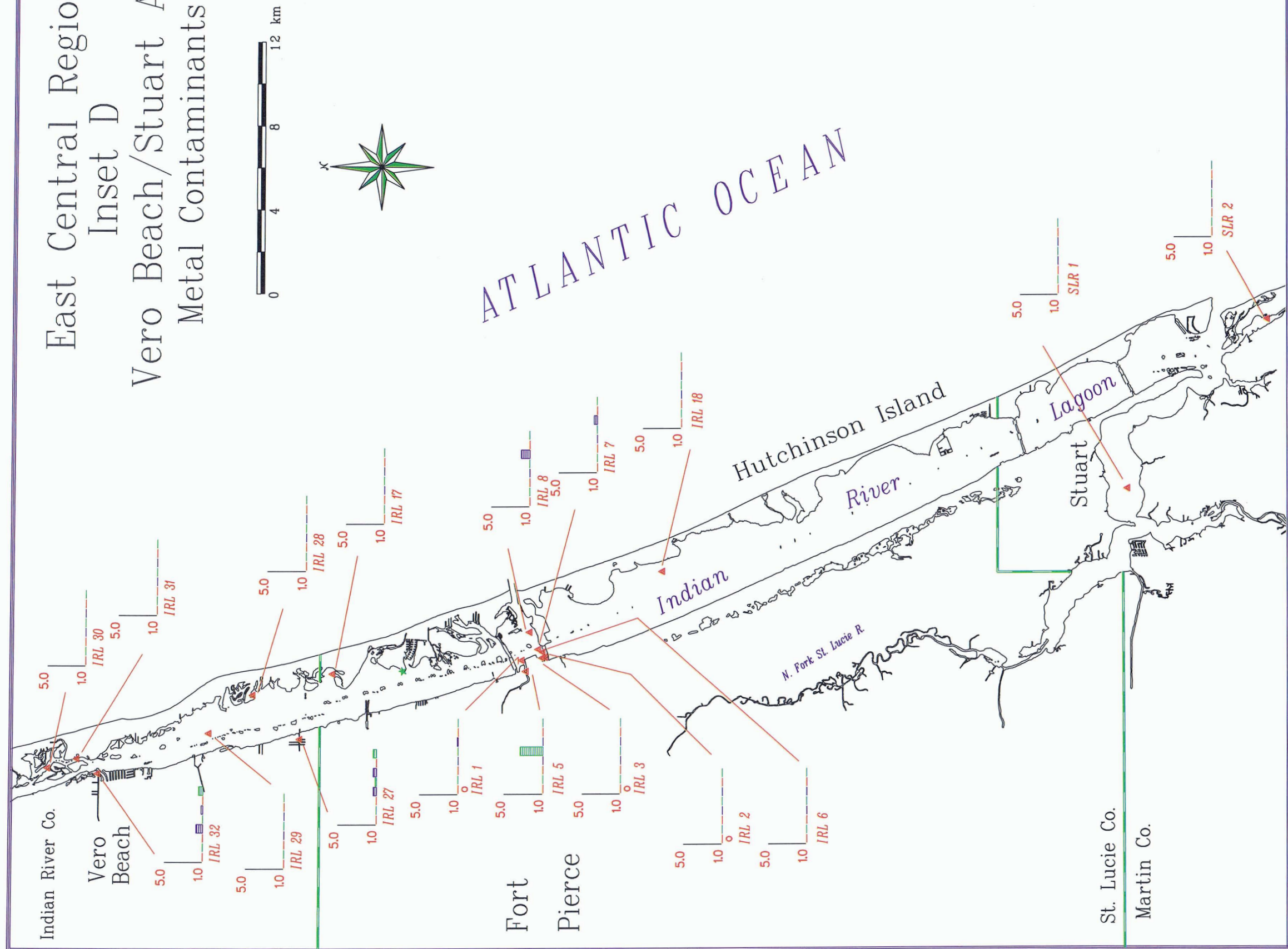


ATLANTIC OCEAN



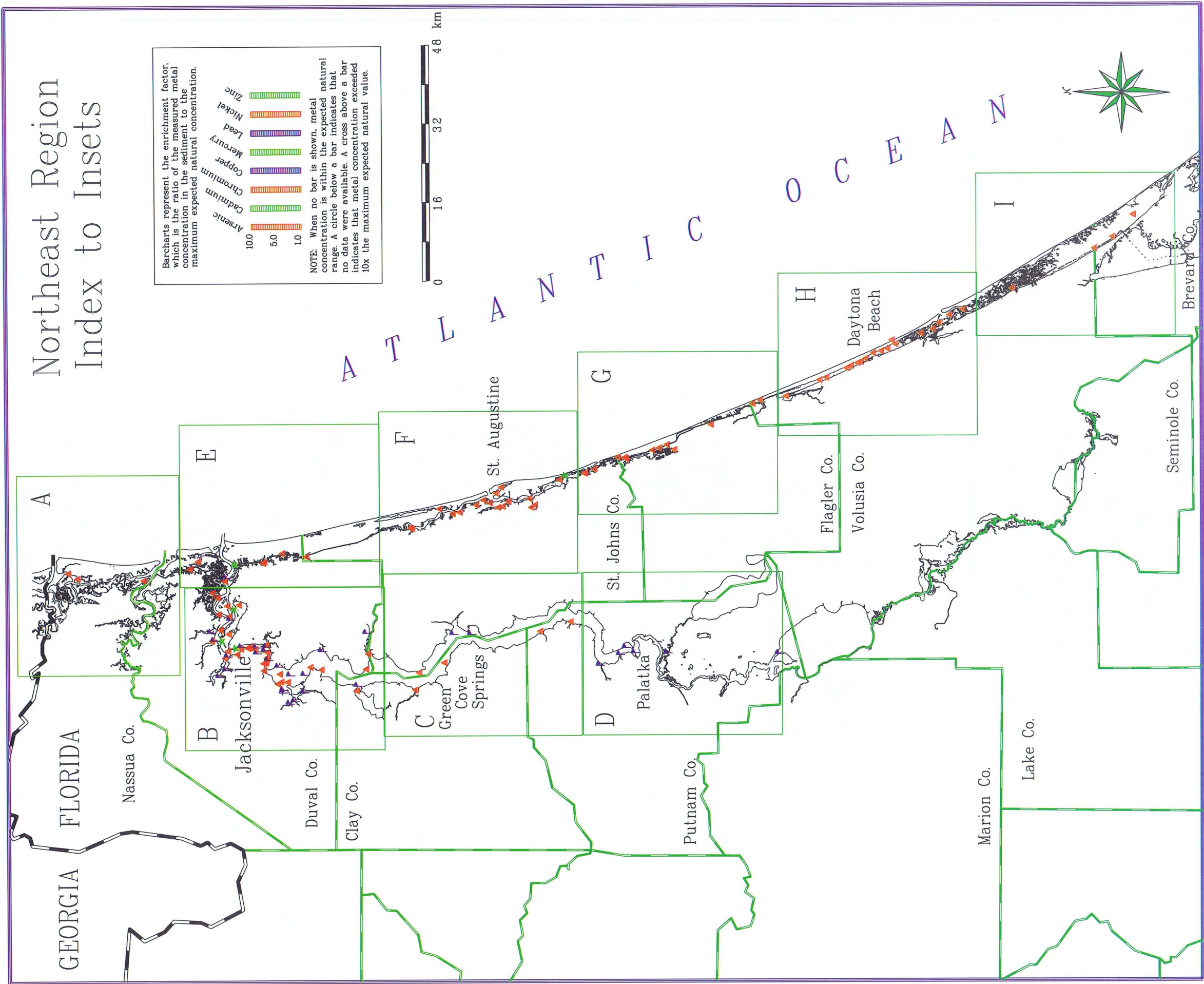
Map 48 - East Central Region Inset C - Indian River Lagoon/Melbourne Area

East Central Region
Inset D
Vero Beach/Stuart Area
Metal Contaminants



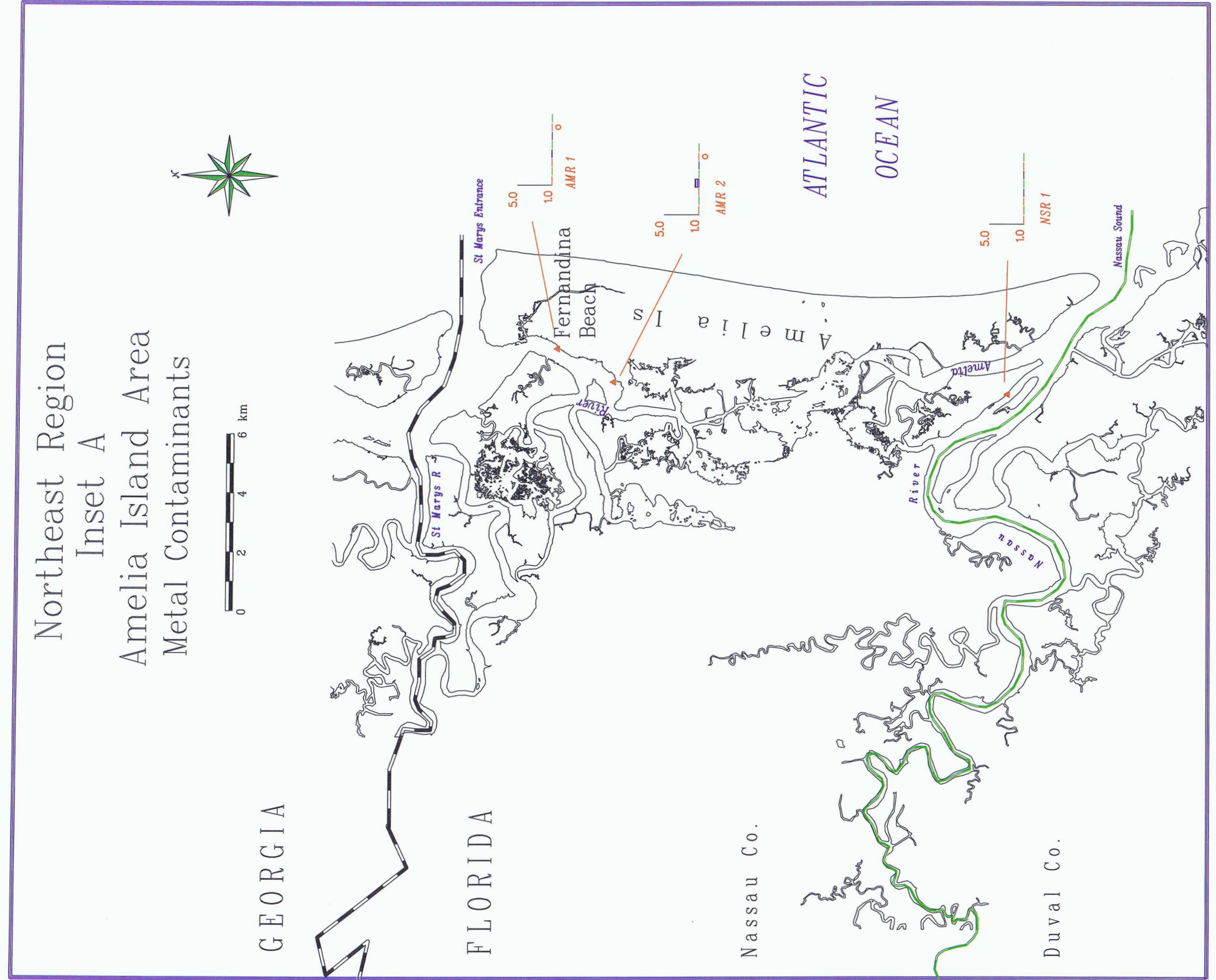
Map 49 - East Central Region Inset D -
Vero Beach/Stuart Area

Northeast Region Index to Insets

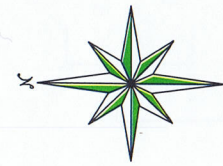


Map 50 - Northeast Region Index to Insets

Map 51 - Northeast Region Inset A -
Amelia Island Area



Northeast Region Index to Inset Series B Lower St. Johns River Metal Contaminants



Jacksonville

B-1

B-2

B-3

B-4

Arlington River

Duval Co.

Clay Co

Orange Park

Doctors Lake

St Johns River

Julington Creek

St Johns Co.

Goodbys Creek

Ortega River

Cedar River

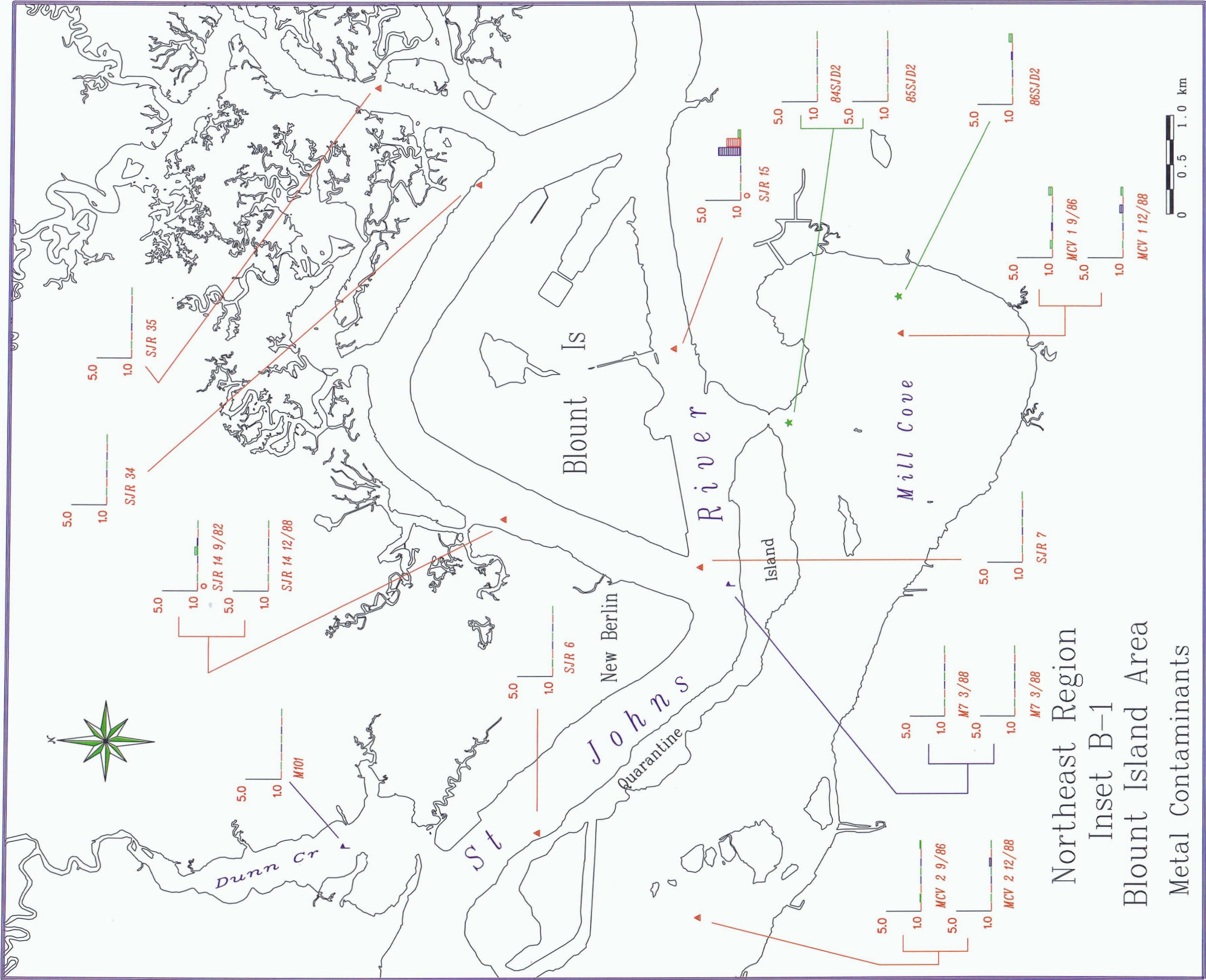
Broward River

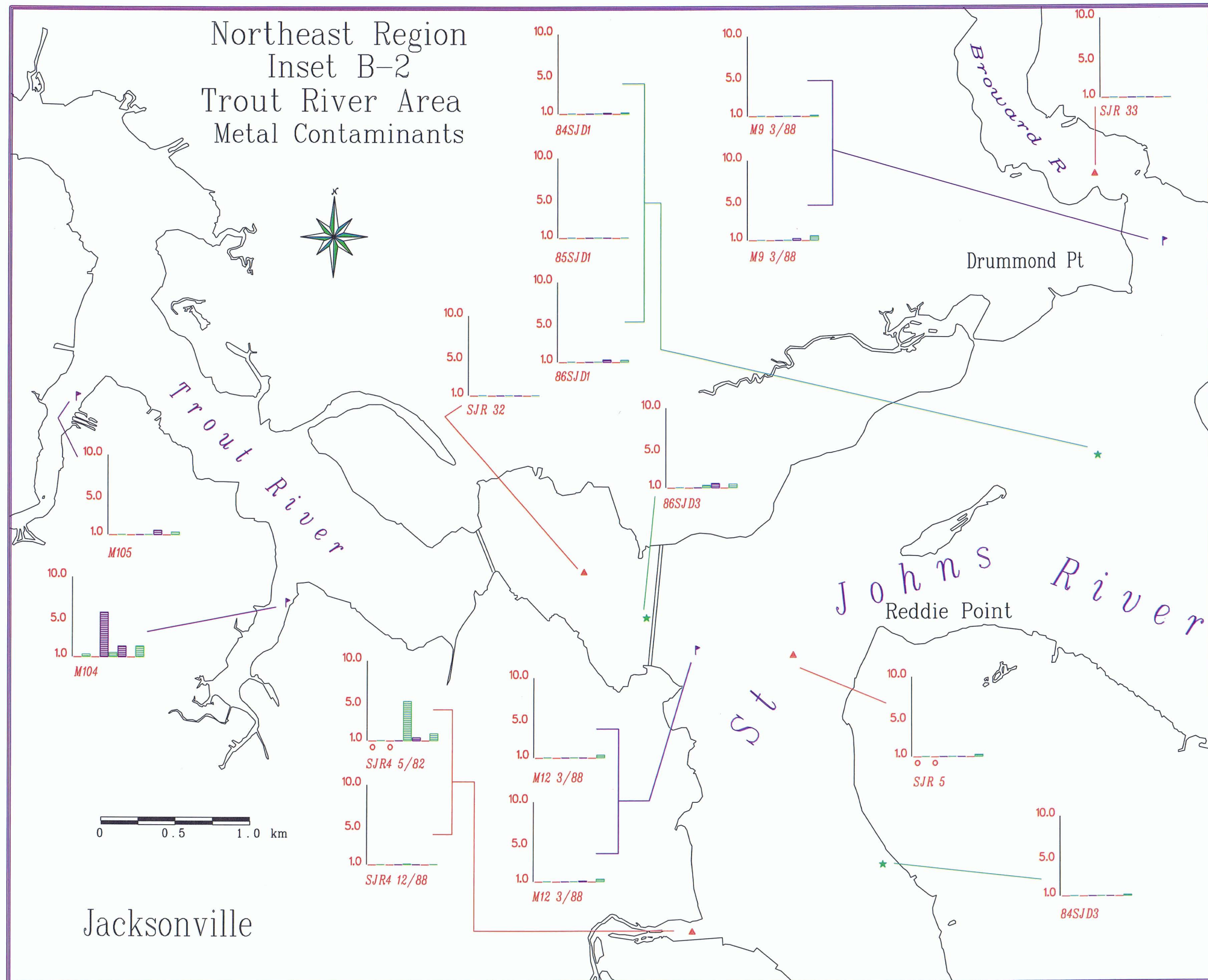
Dunn Creek

Trout River

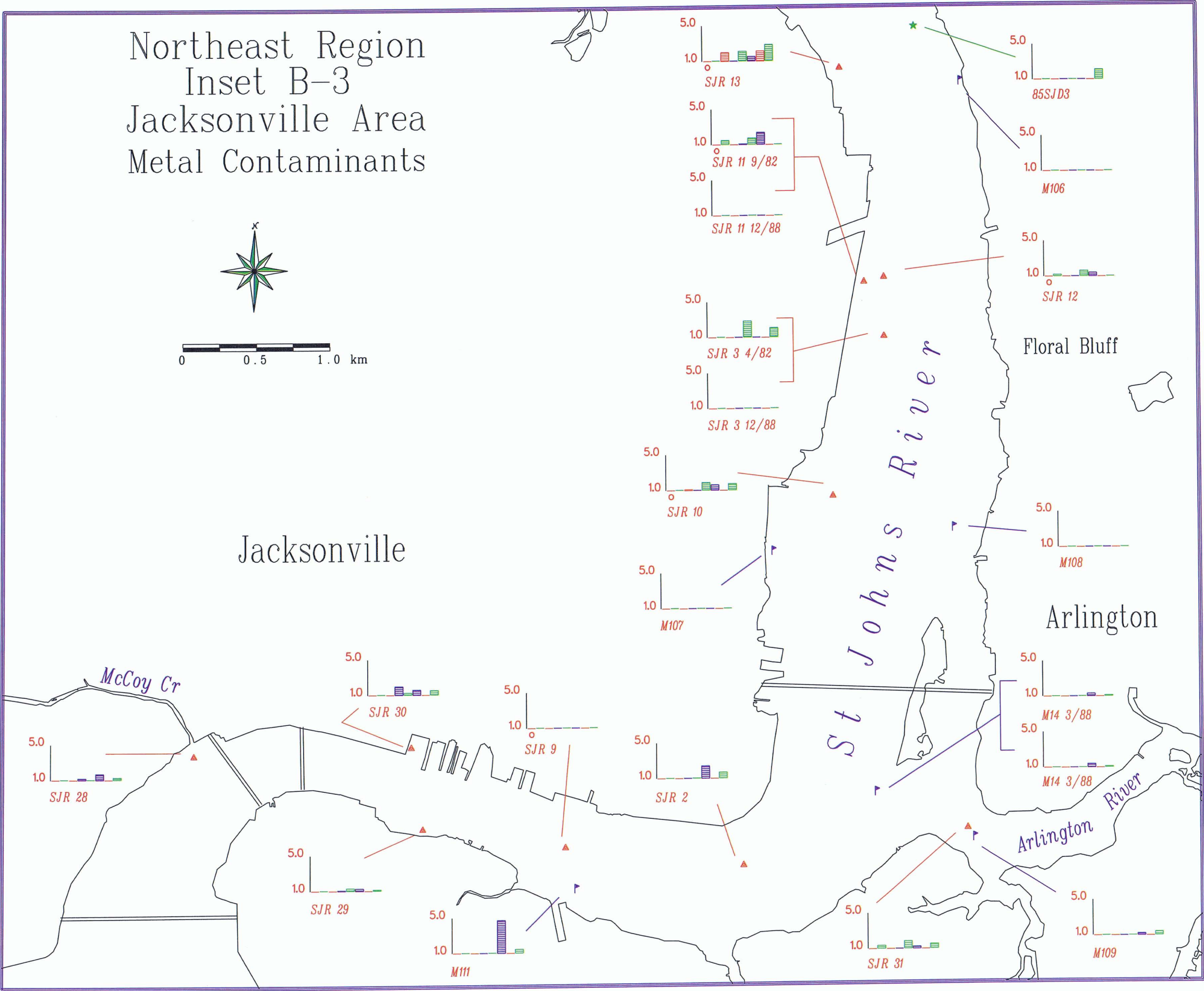
Map 52 - Northeast Region Index to Inset
Series B - Lower St. Johns River

Map 53 - Northeast Region Inset B-1 -
Blount Island Area

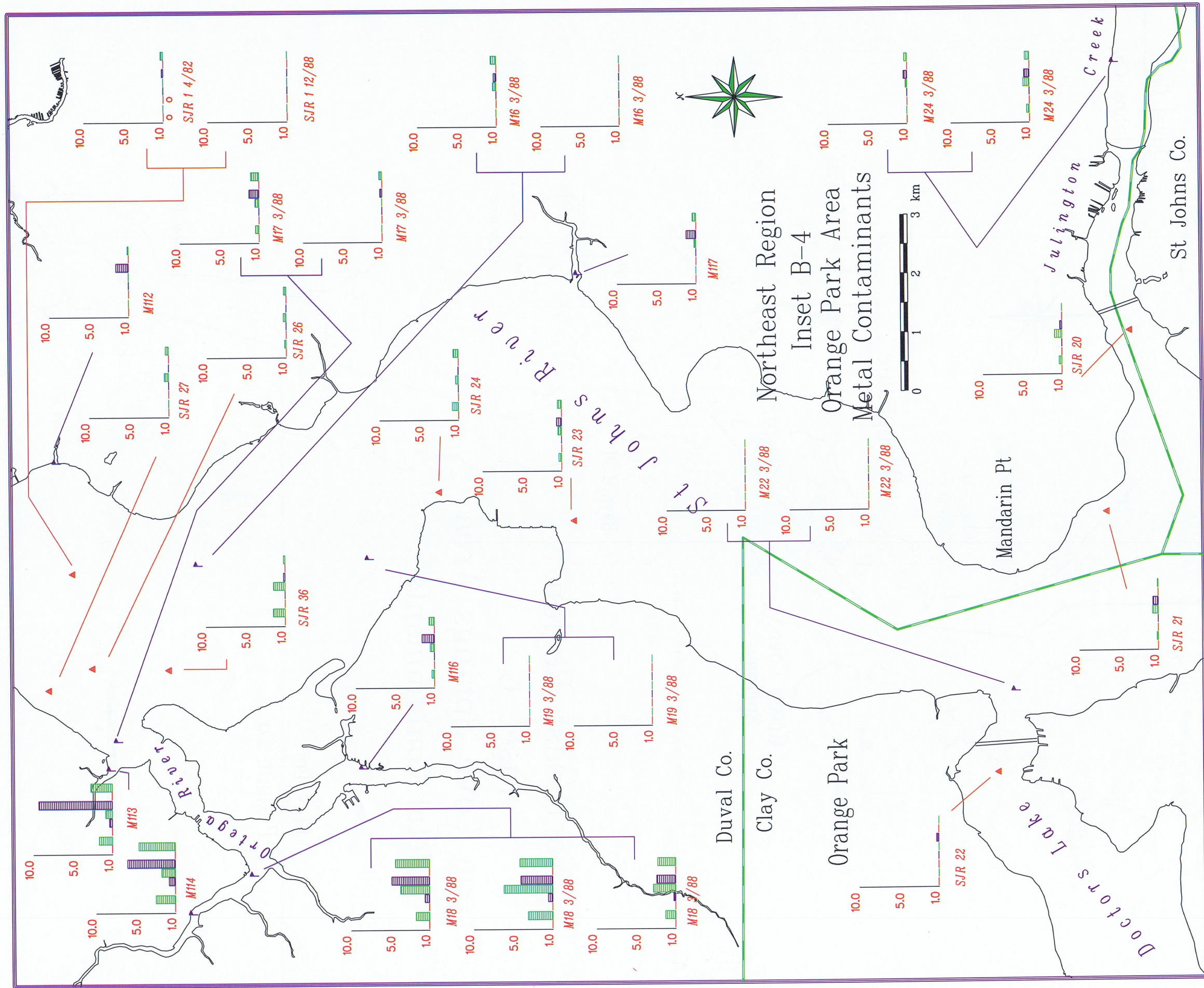




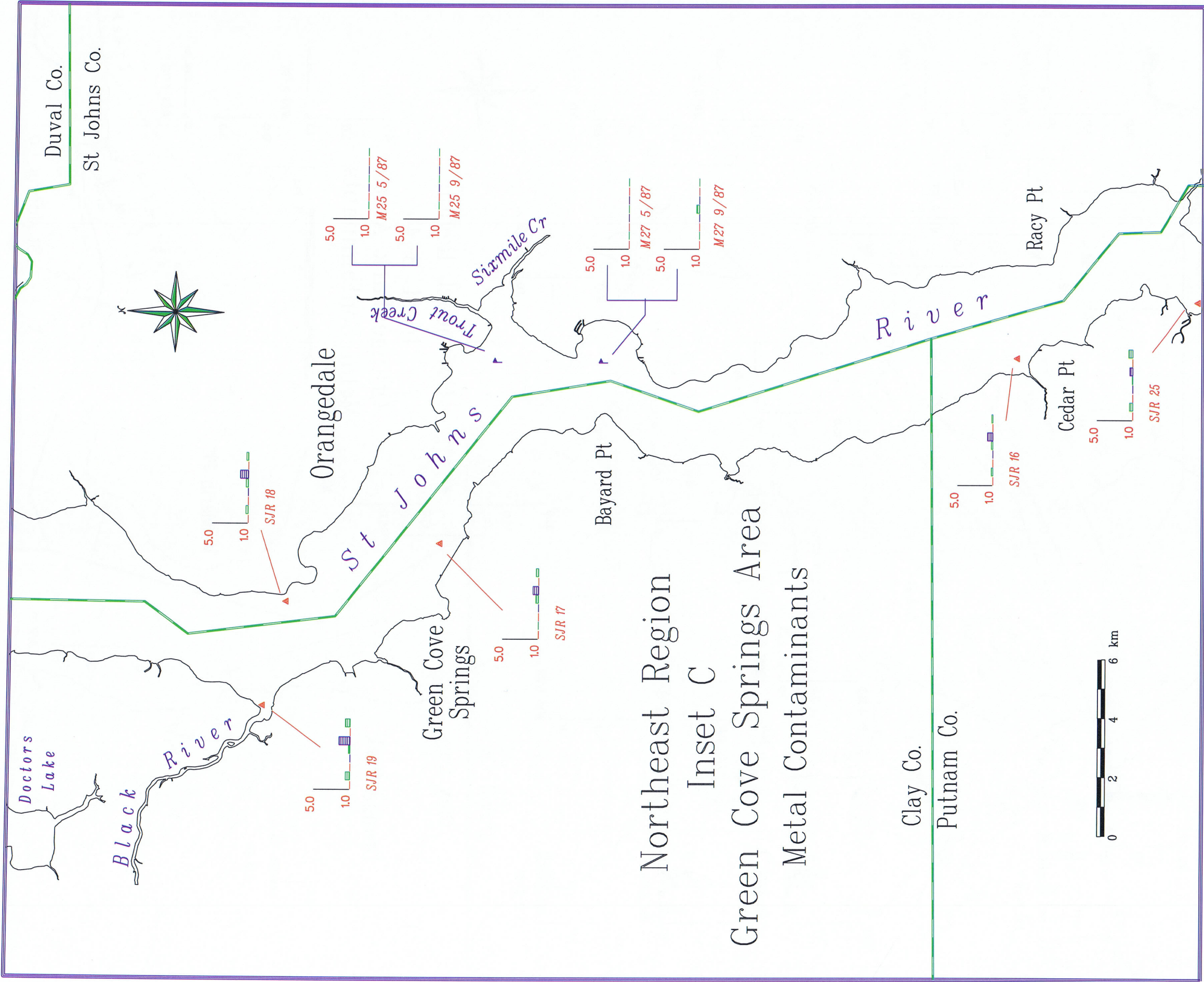
Map 54 - Northeast Region Inset B-2 -
Trout River Area



Map 55 - Northeast Region Inset B-3 -
Jacksonville Area

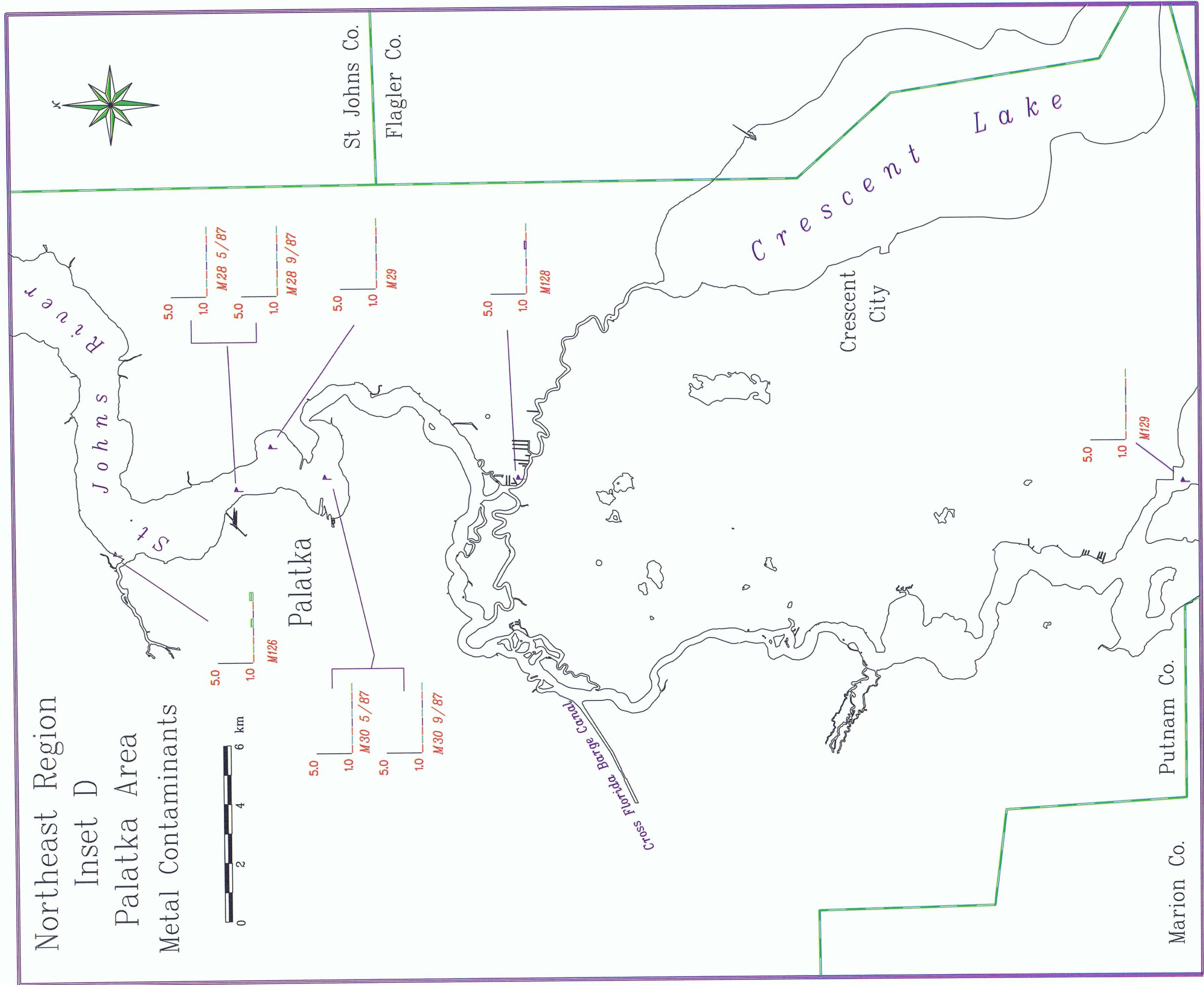


Map 56 - Northeast Region Inset B-4 -
Orange Park Area

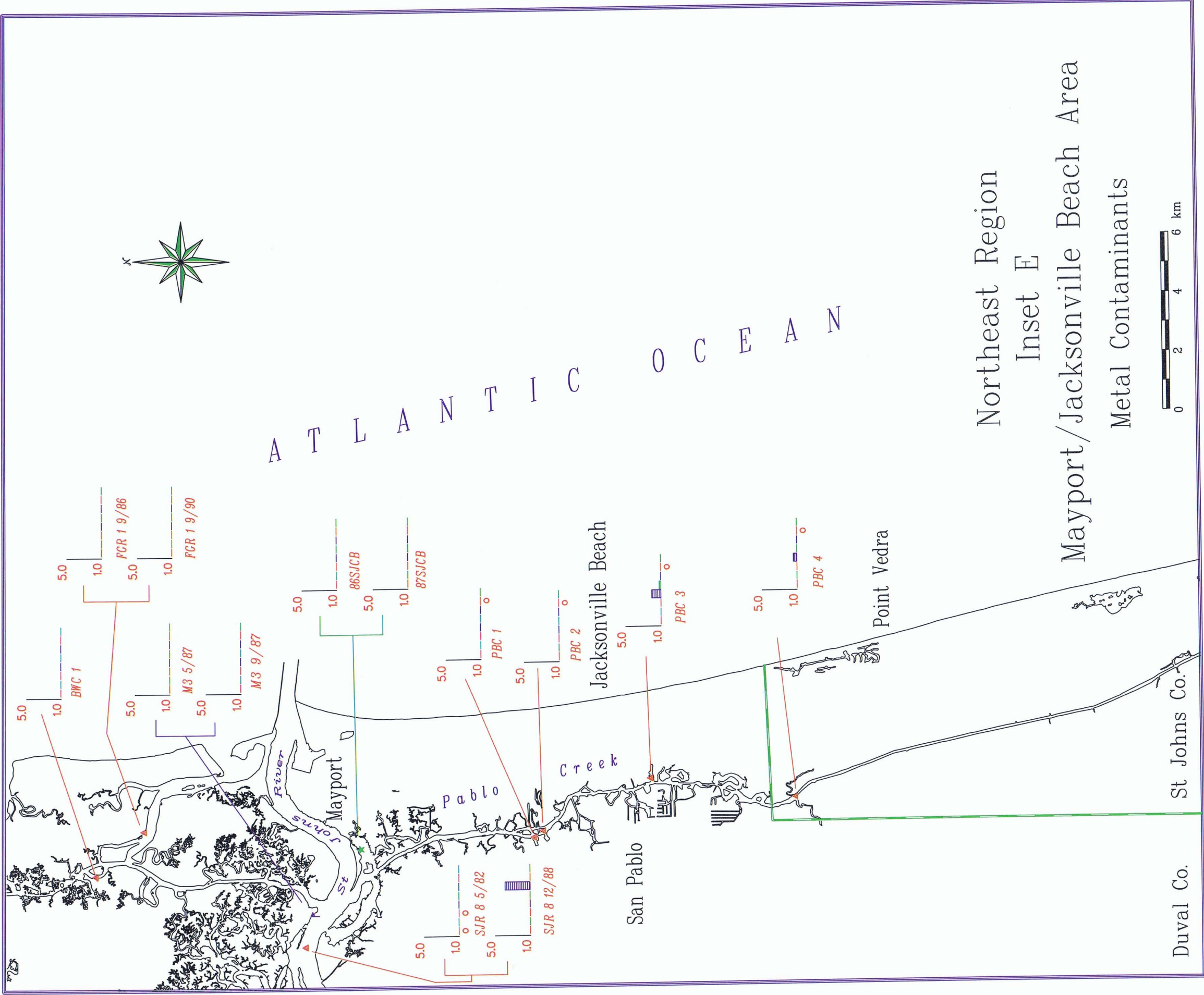


Map 57 - Northeast Region Inset C - Green Cove Springs Area

Map 58 - Northeast Region Inset D - Palatka Area



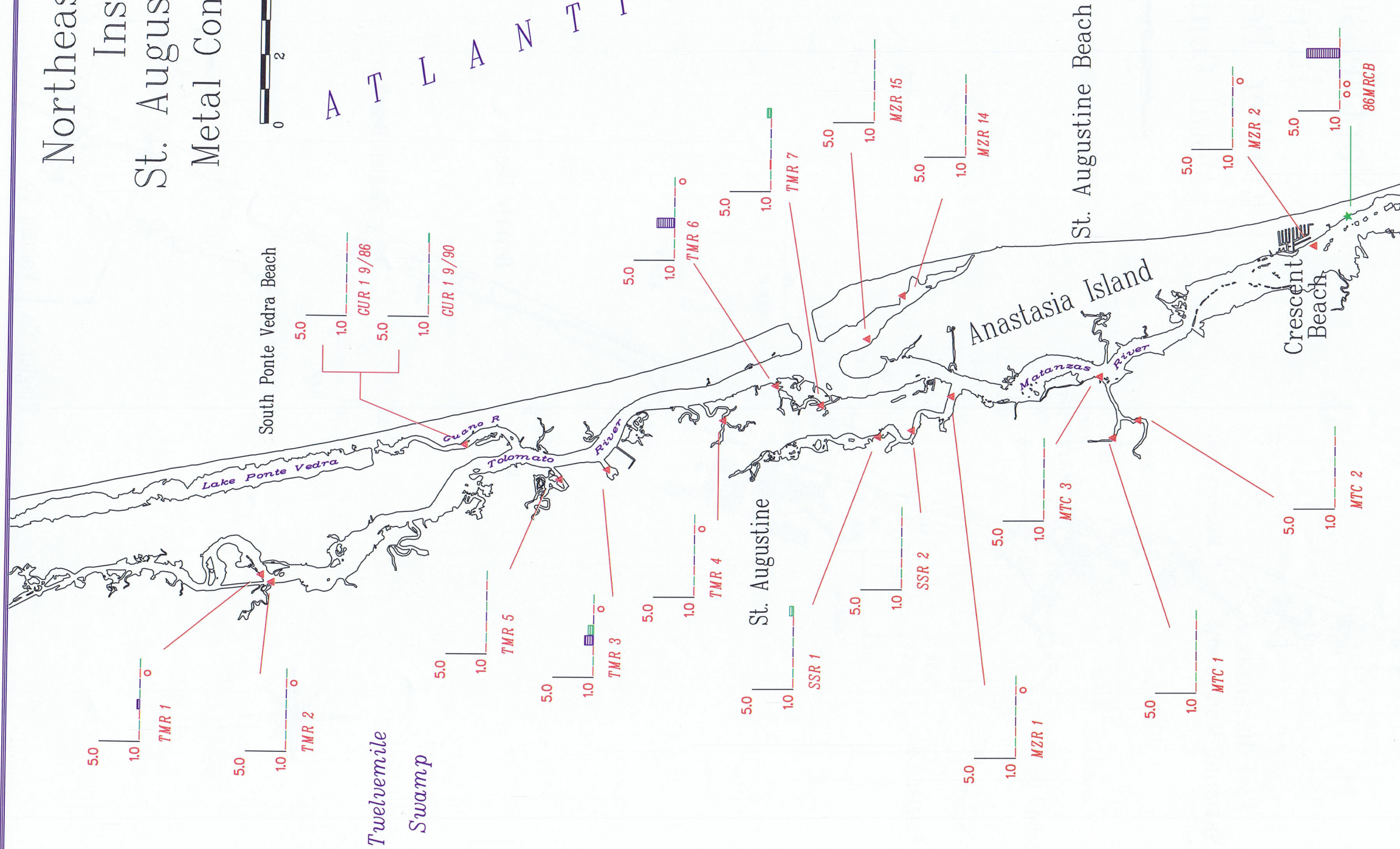
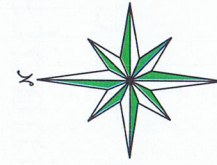
Map 59 - Northeast Region Inset E -
Mayport/Jacksonville Beach Area



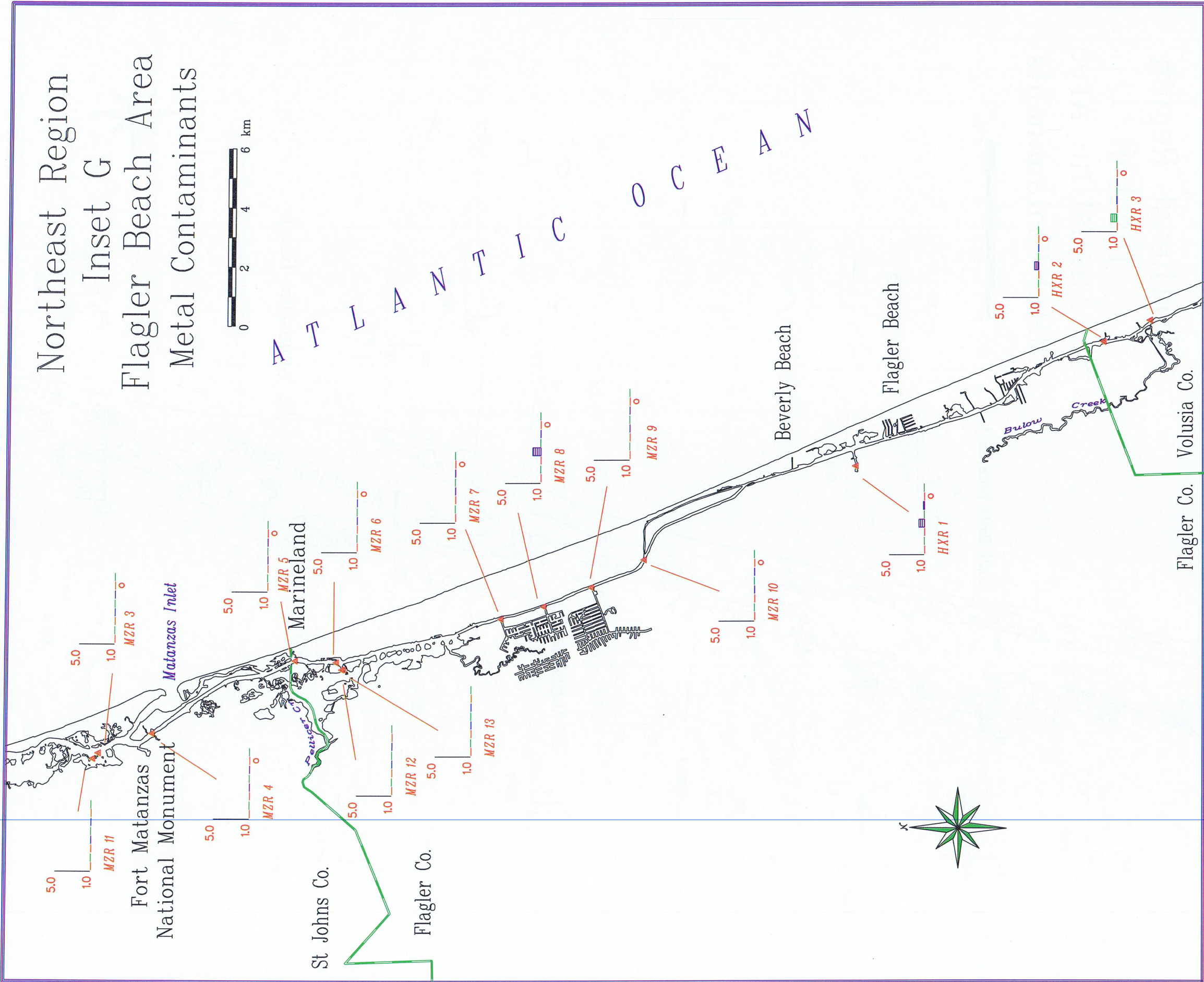
Northeast Region Inset F St. Augustine Area Metal Contaminants



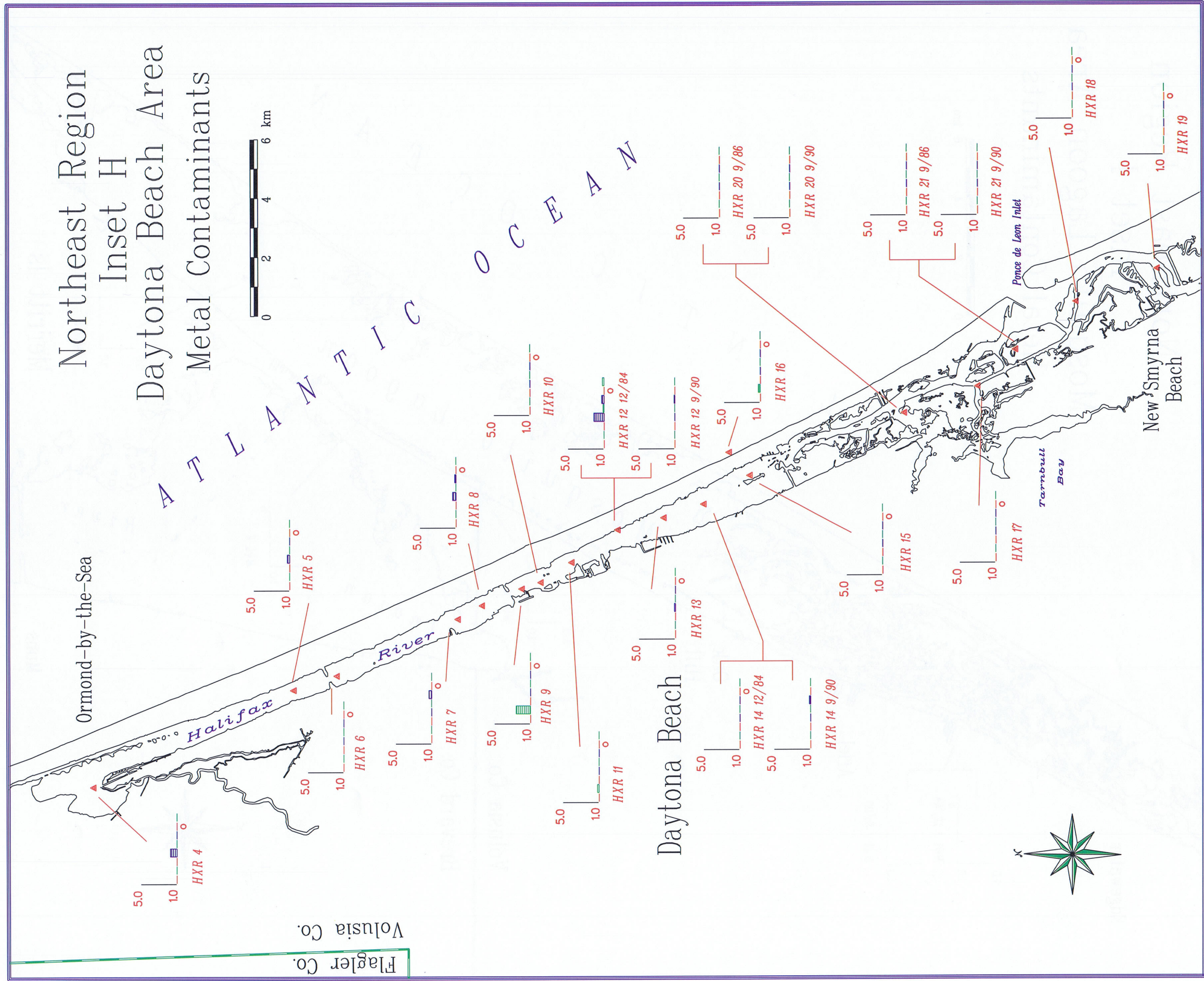
A T L A N T I C O C E A N



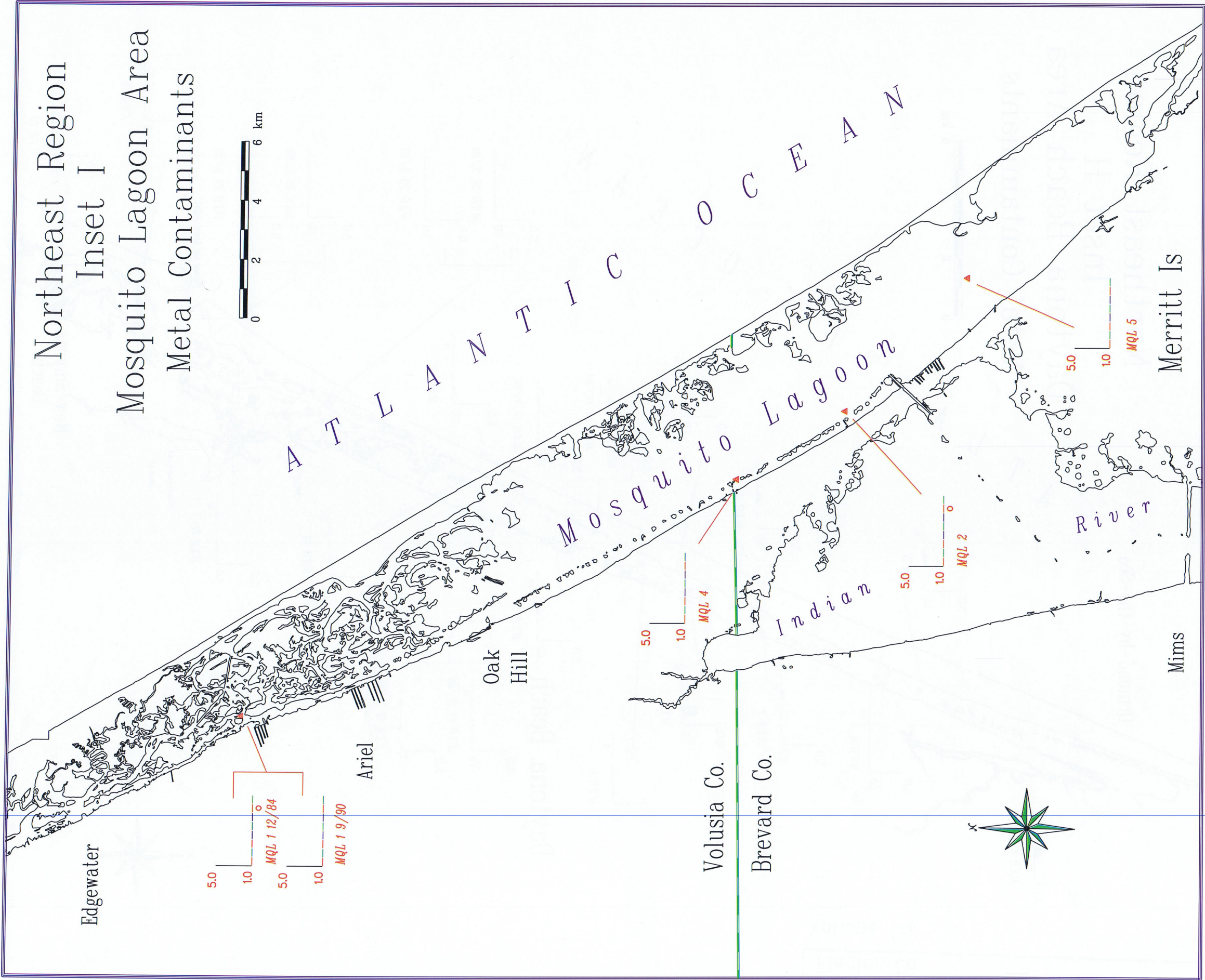
Map 60 - Northeast Region Inset F -
St. Augustine Area



Map 61 - Northeast Region Inset G -
Flagler Beach Area

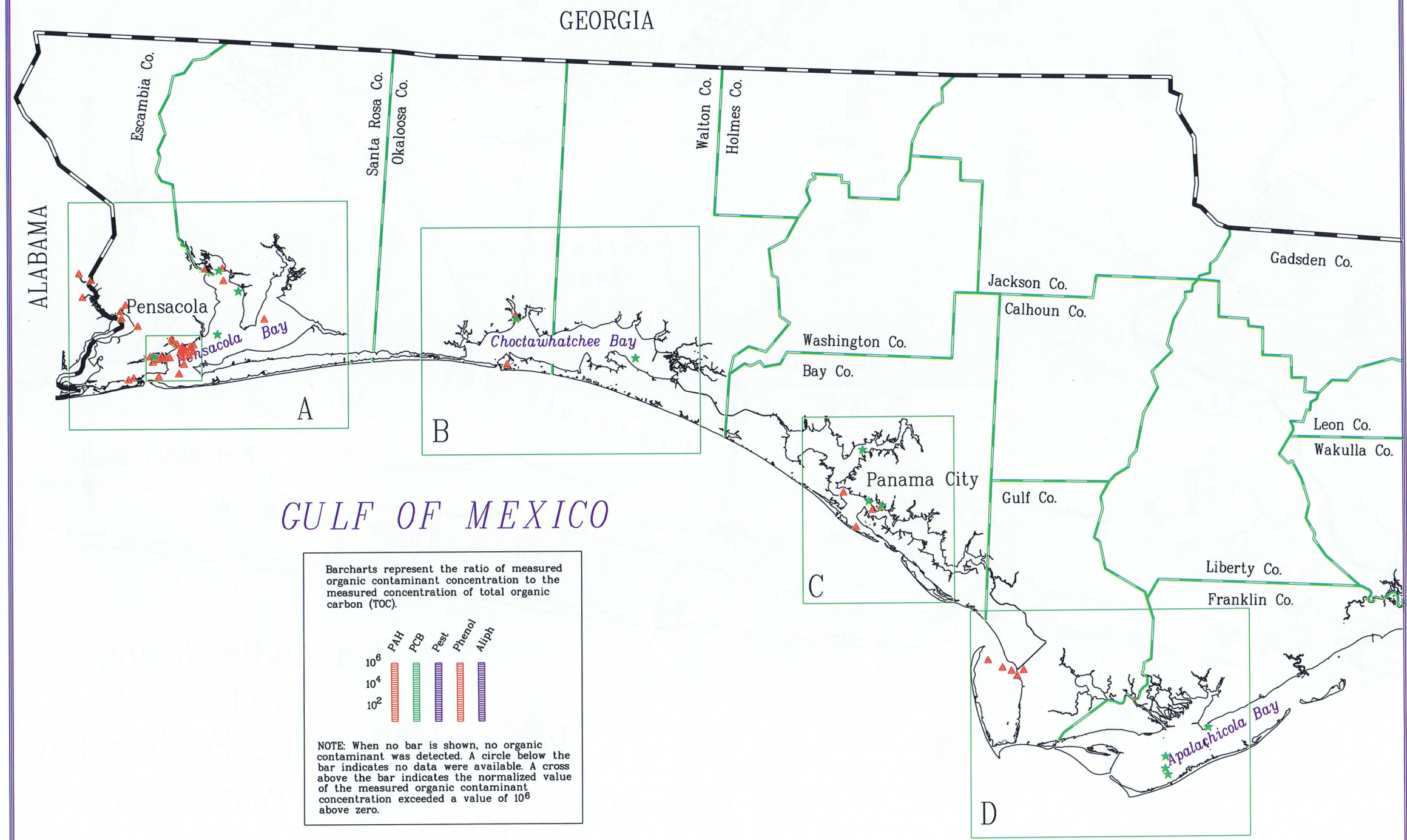


Map 62 - Northeast Region Inset H -
Daytona Beach Area

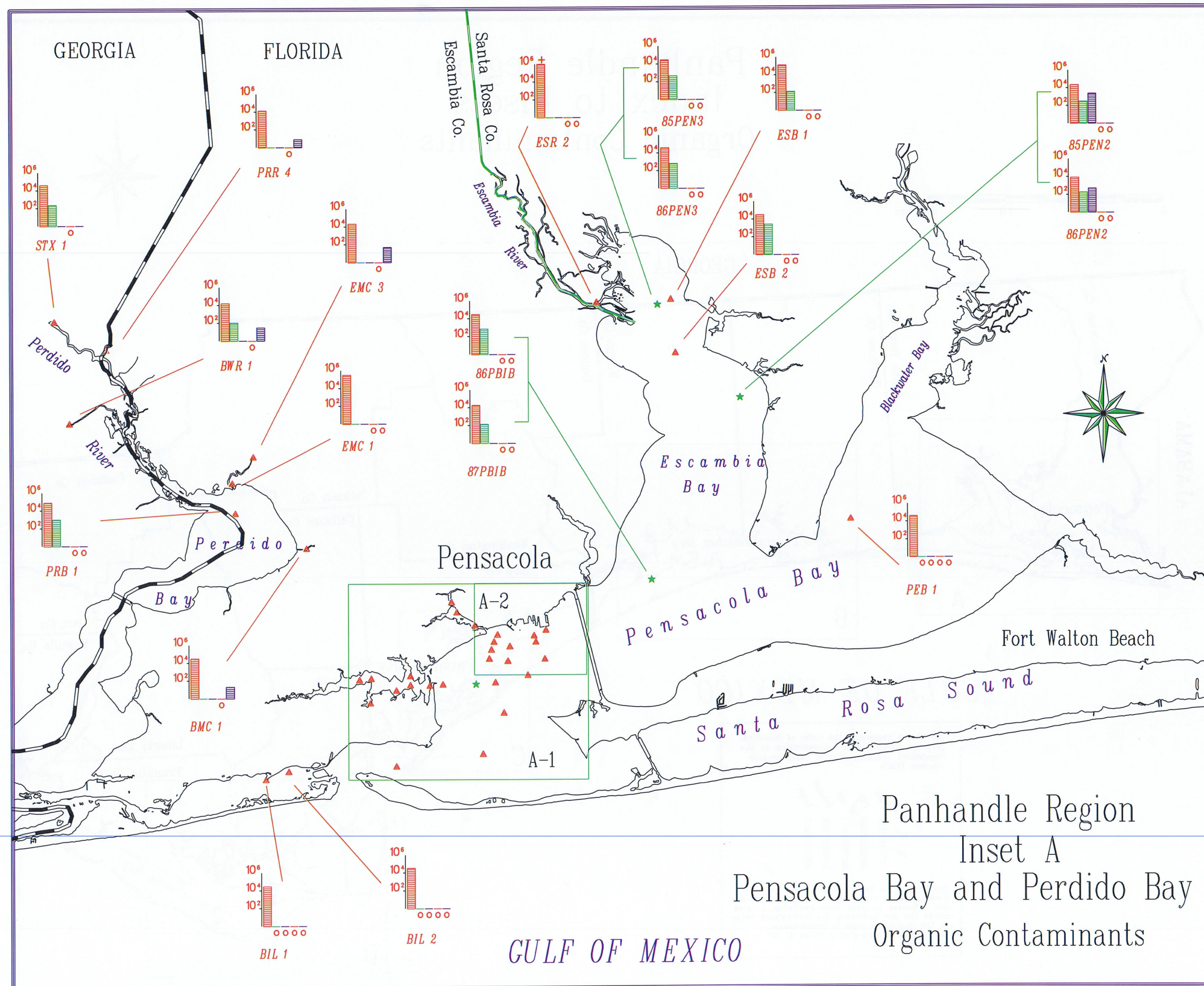


Map 63 - Northeast Region Inset I -
Mosquito Lagoon Area

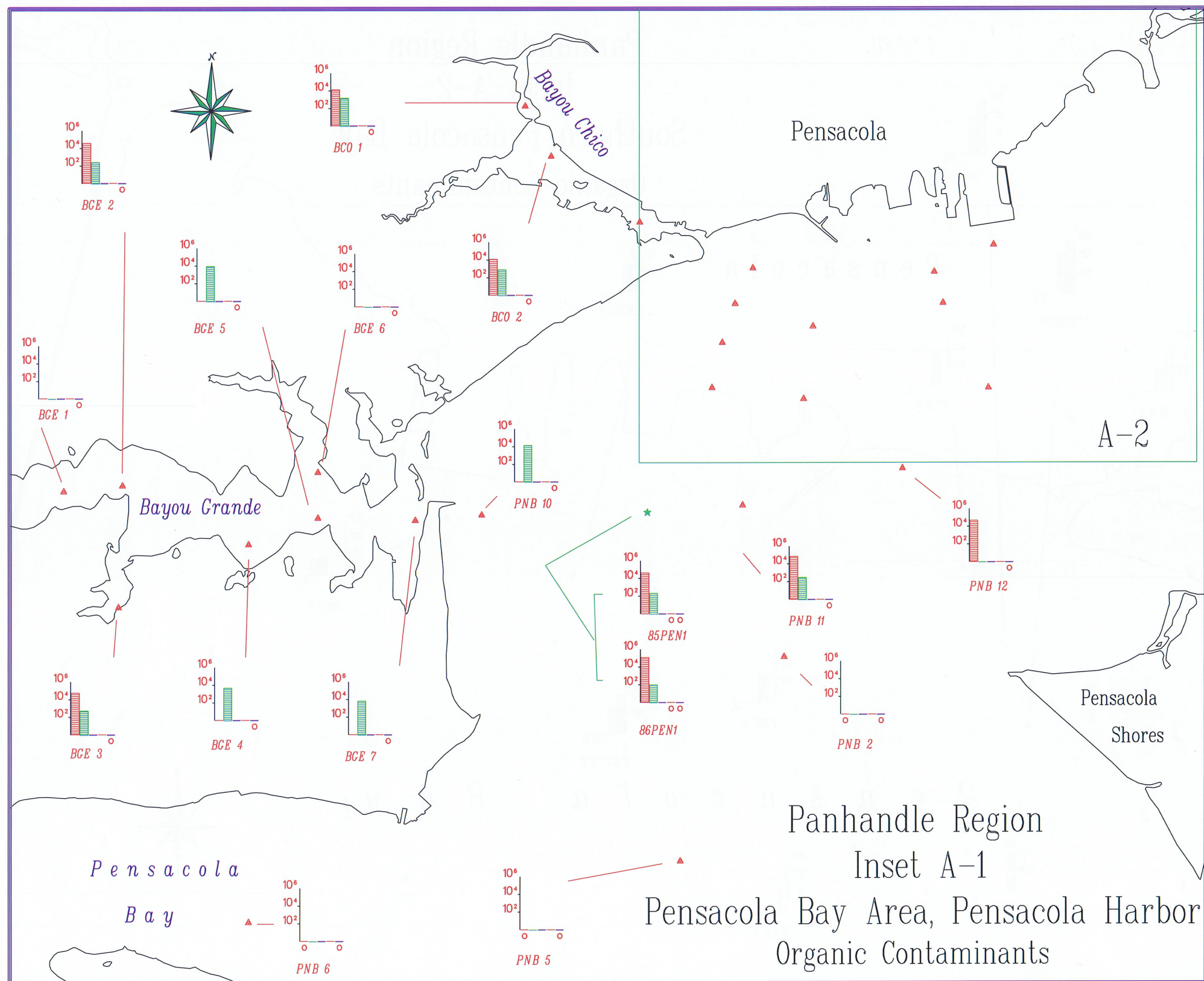
Panhandle Region Index to Insets Organic Contaminants



Map 64 - Panhandle Region Index to Insets

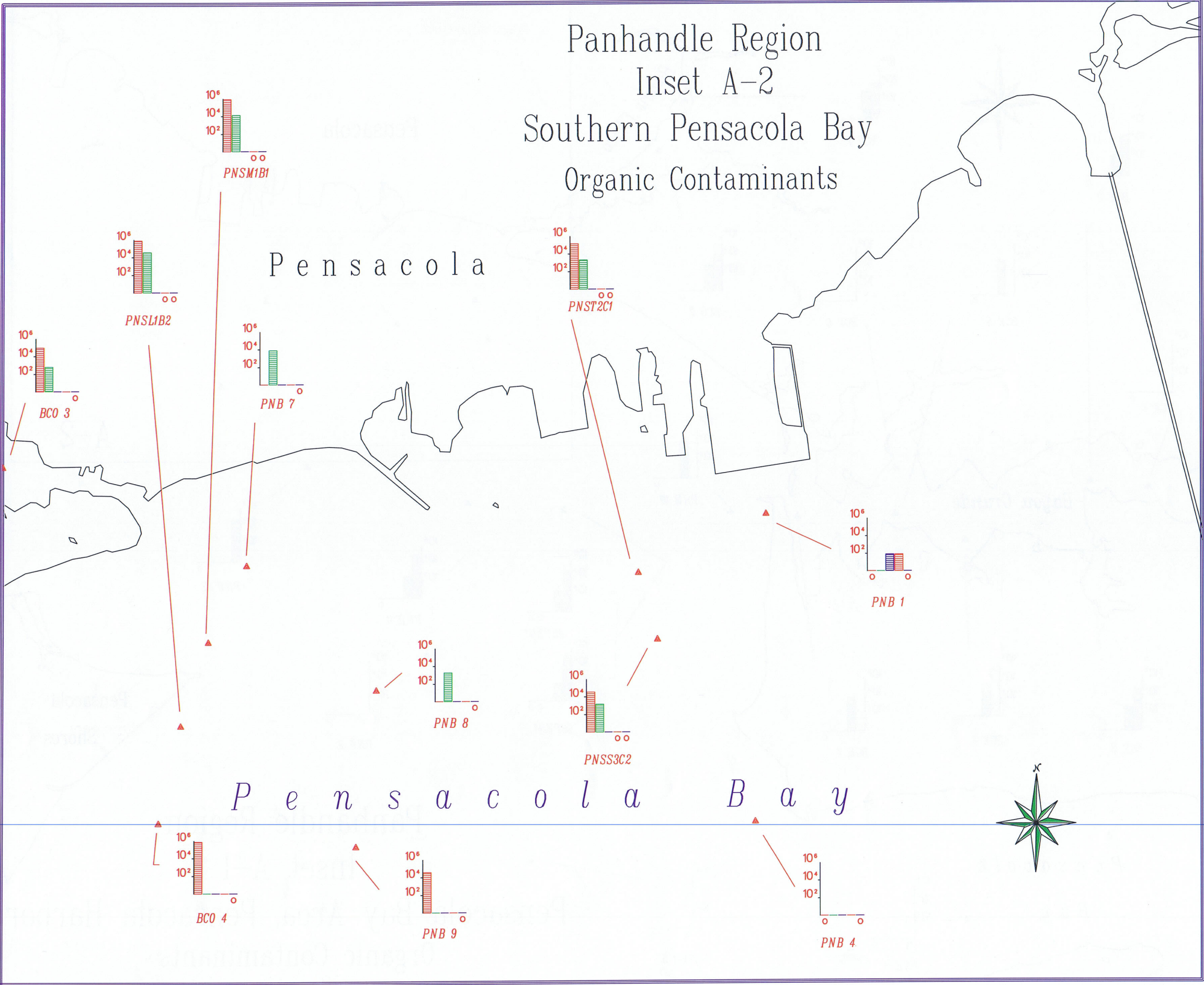


Map 65 - Panhandle Region Inset A -
Pensacola Bay and Perdido Bay

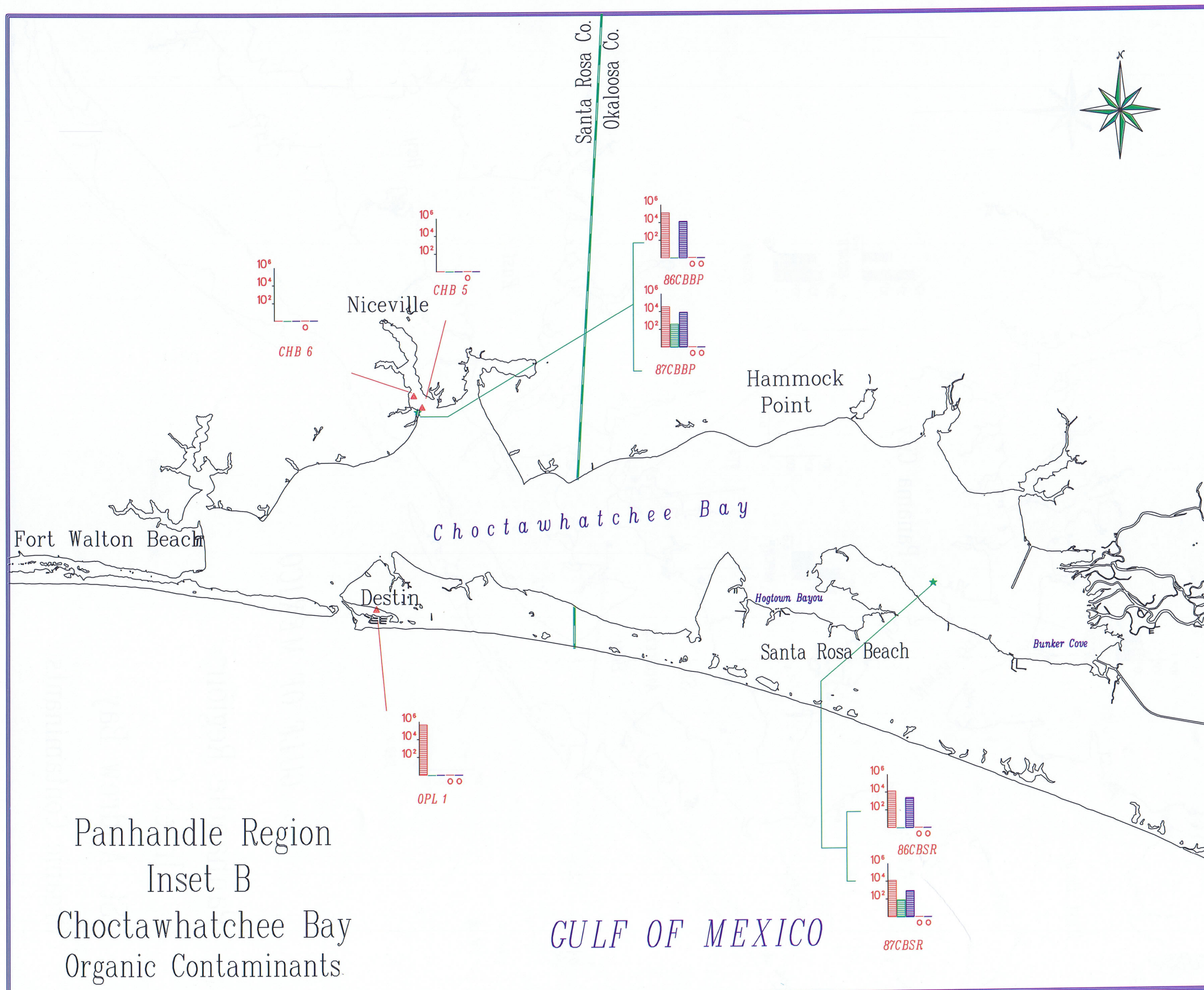


Map 66 - Panhandle Region Inset A-1 -
Pensacola Bay Area/Pensacola Harbor

Panhandle Region
Inset A-2
Southern Pensacola Bay
Organic Contaminants

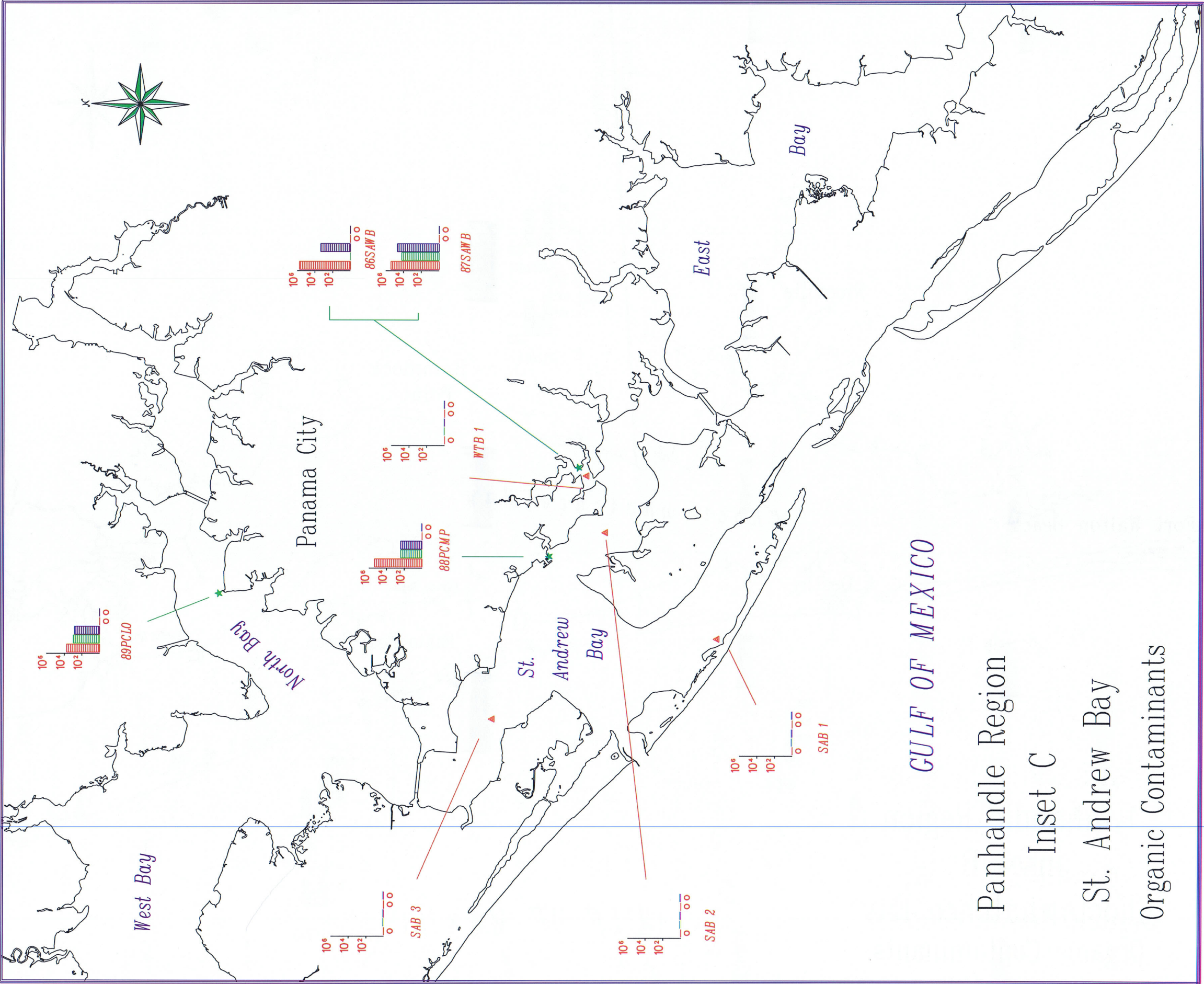


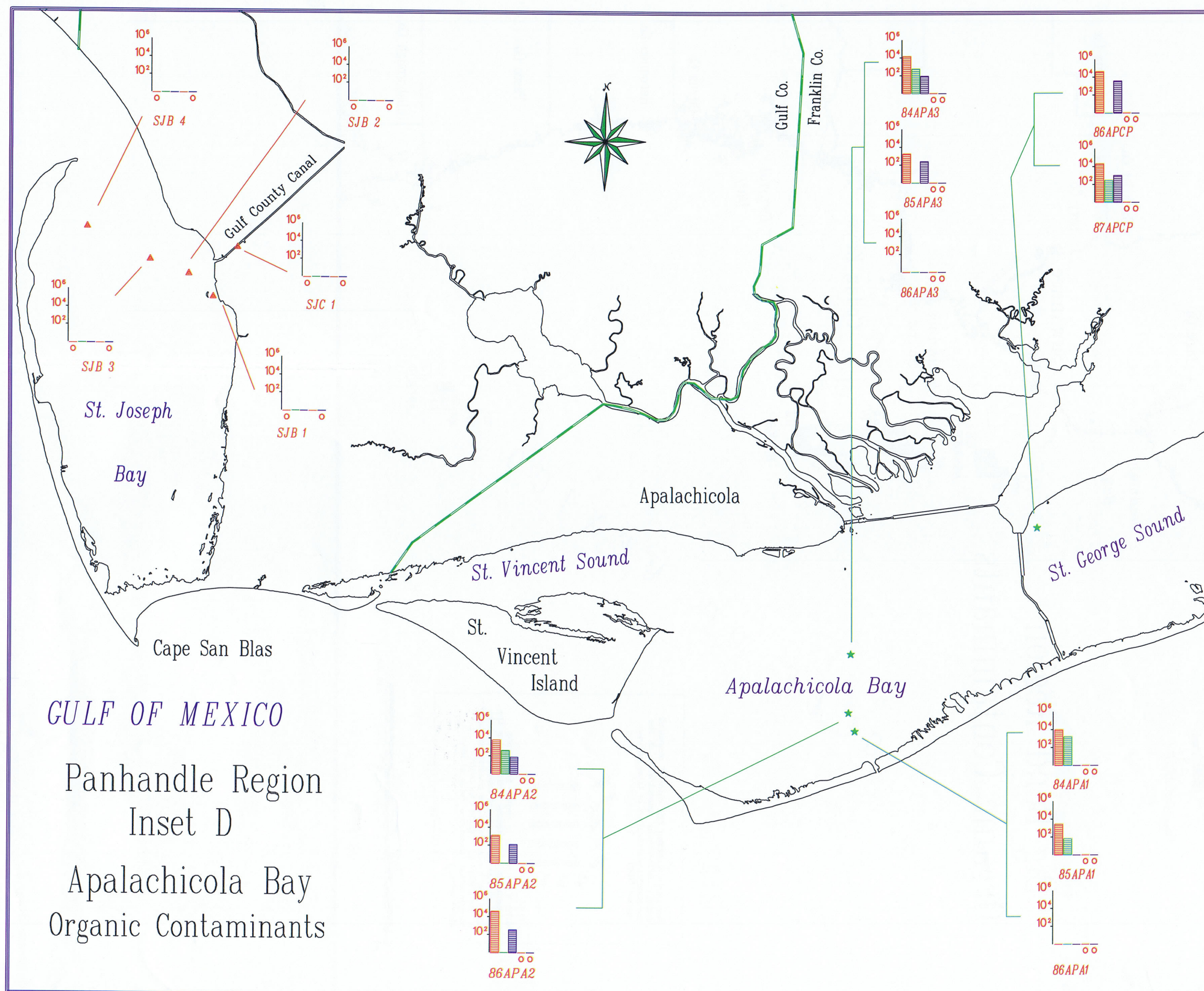
Map 67 - Panhandle Region Inset A-2 -
Southern Pensacola Bay



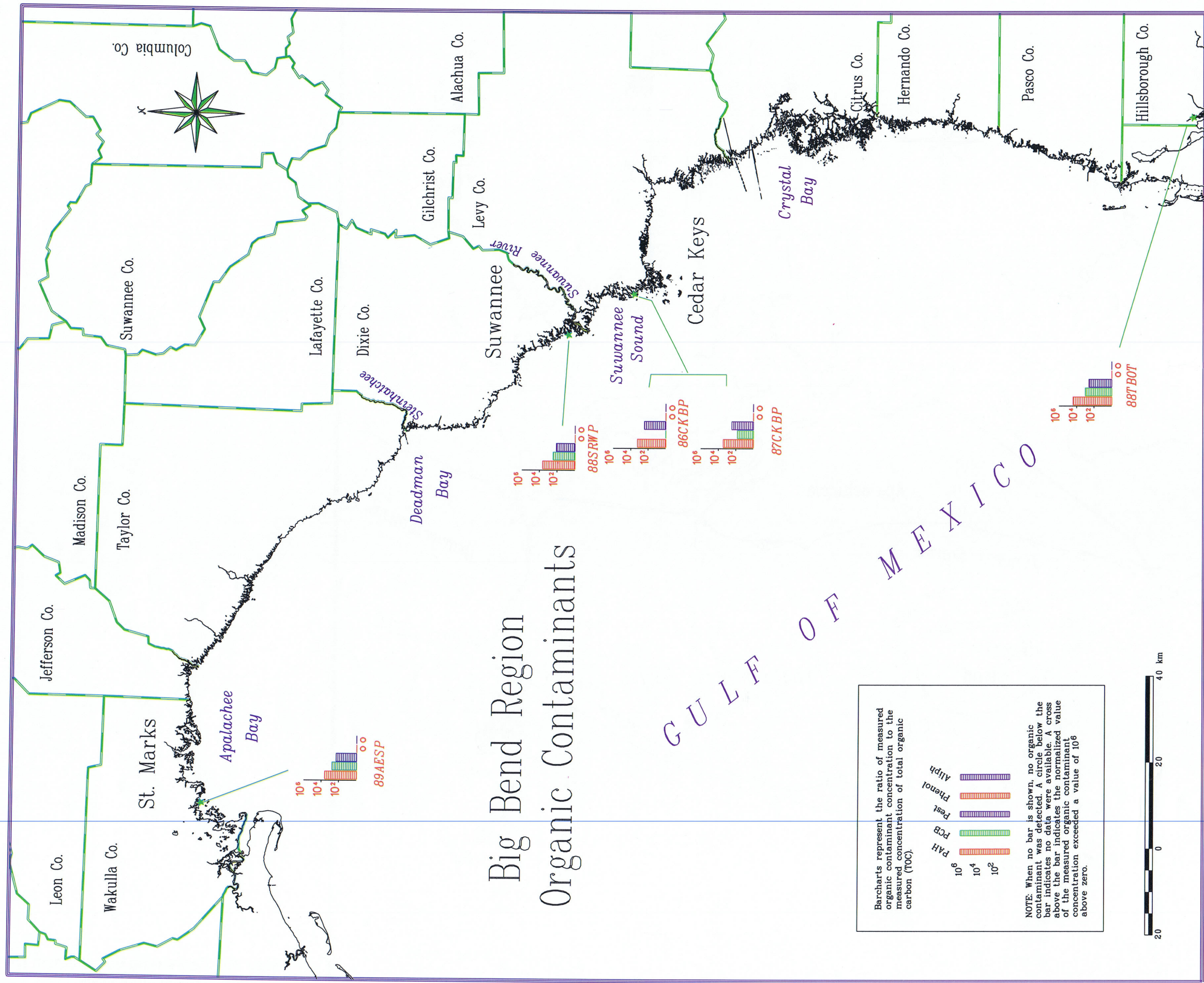
Map 68 - Panhandle Region Inset B -
Choctawhatchee Bay

Map 69 - Panhandle Region Inset C -
St. Andrew Bay

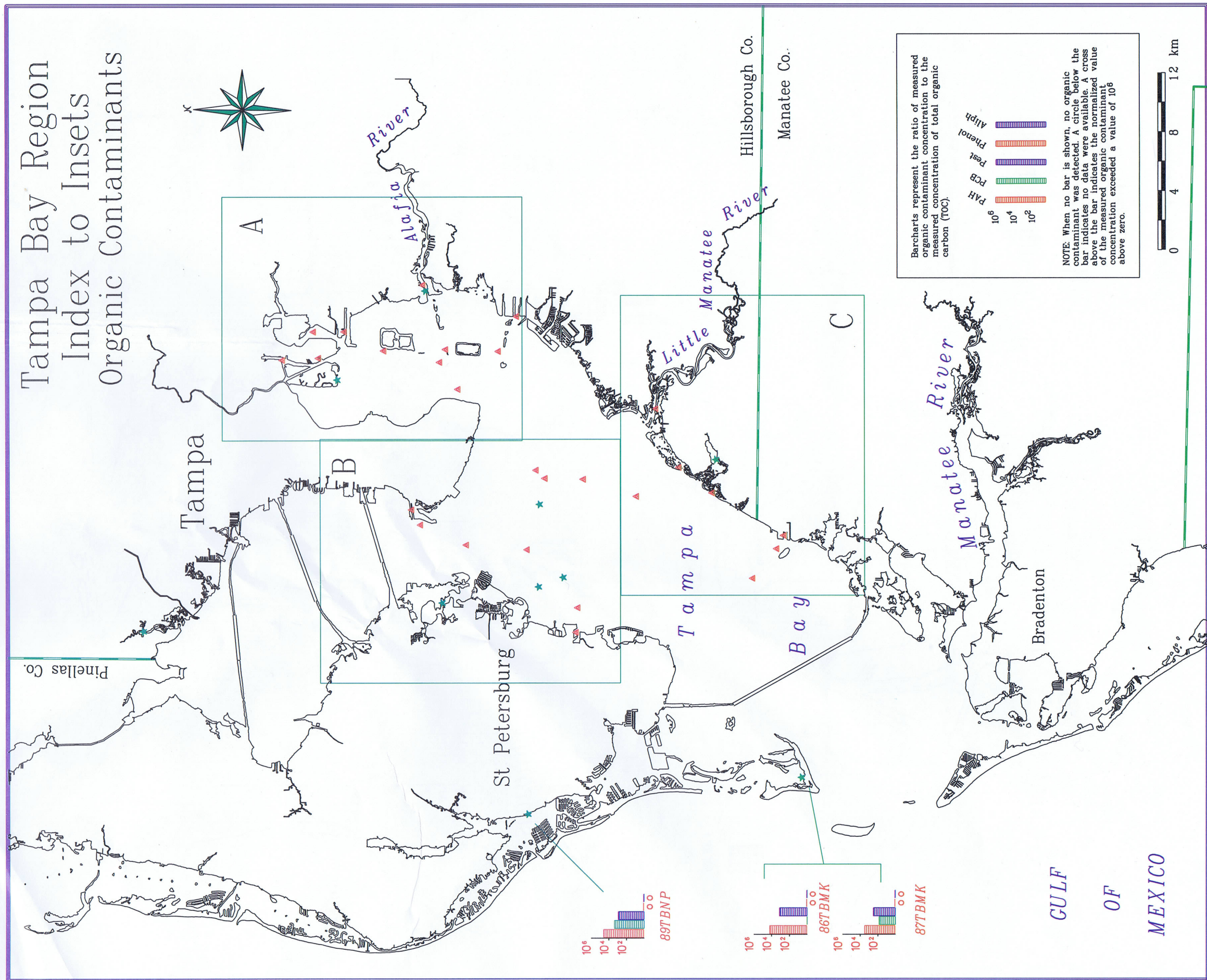




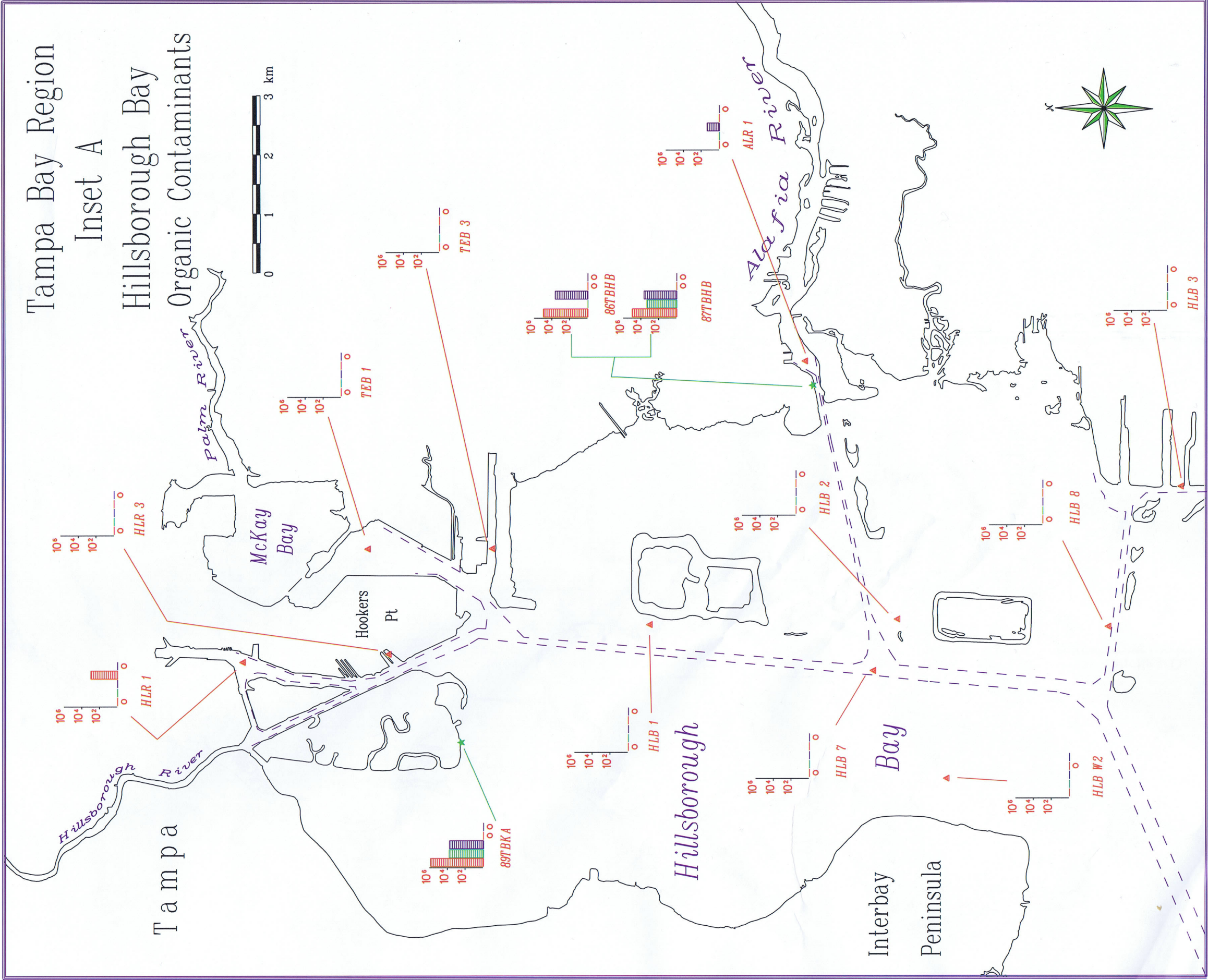
Map 70 - Panhandle Region Inset D -
Apalachicola Bay



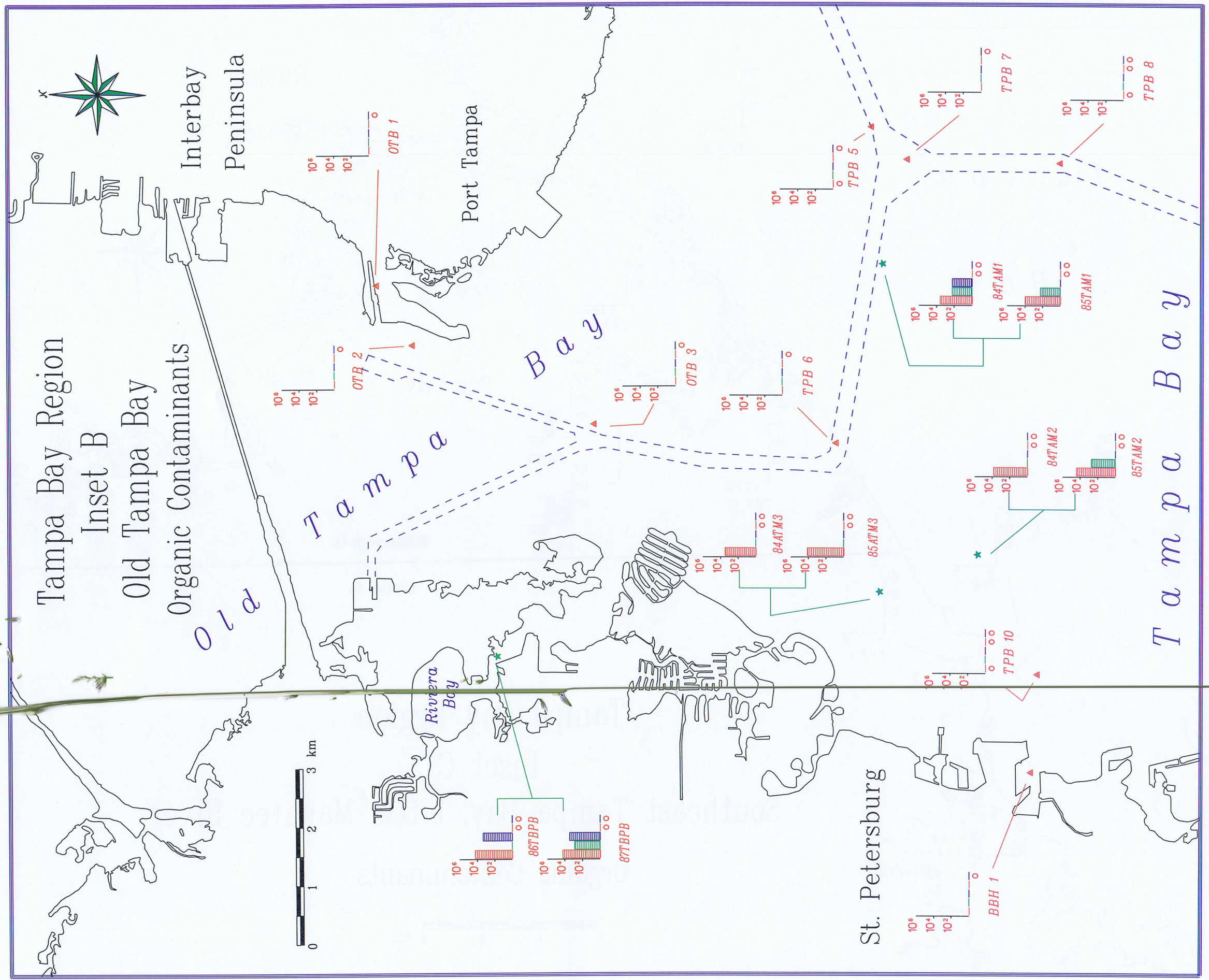
Tampa Bay Region Index to Insets Organic Contaminants



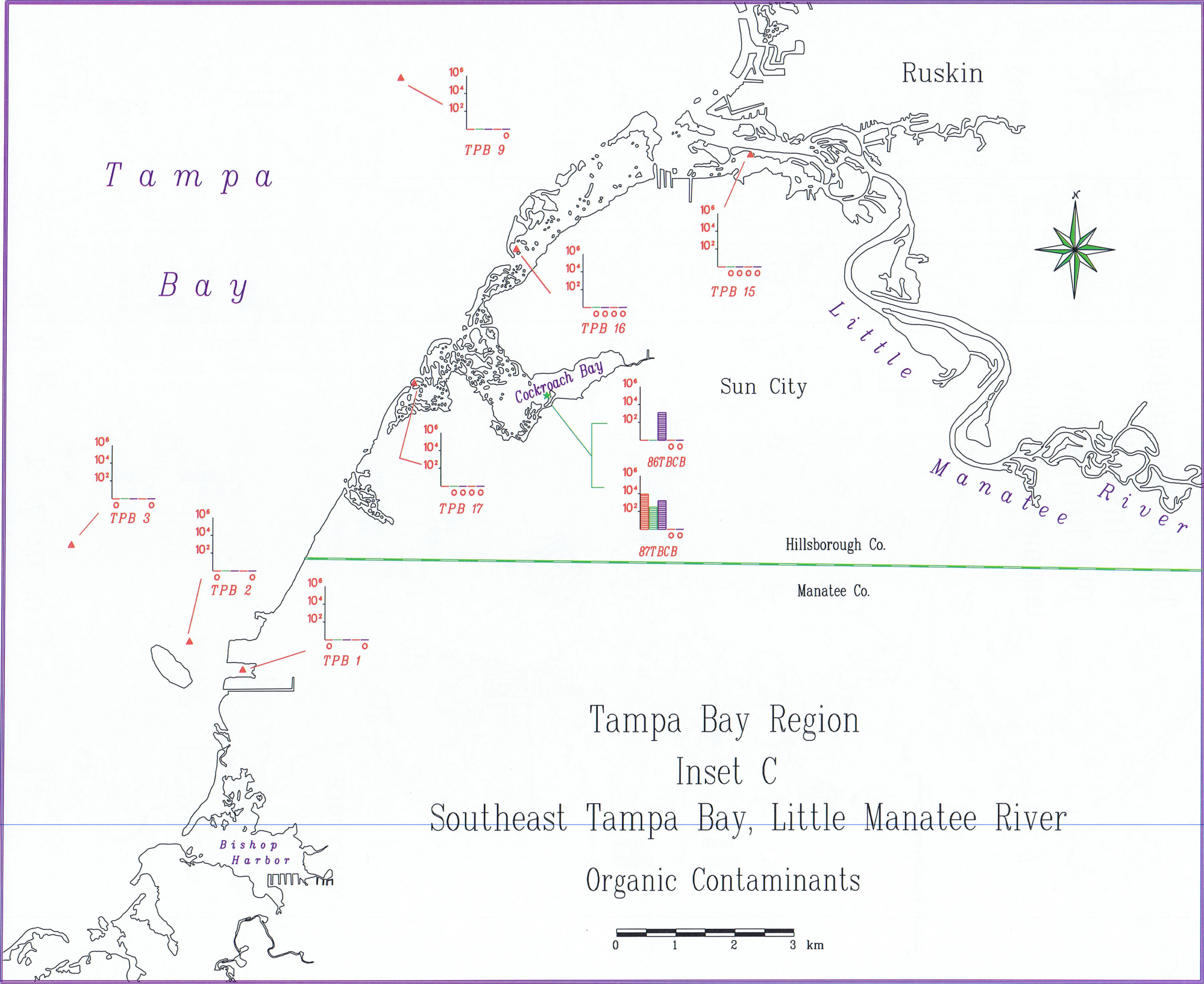
Map 72 - Tampa Bay Region Index to Insets



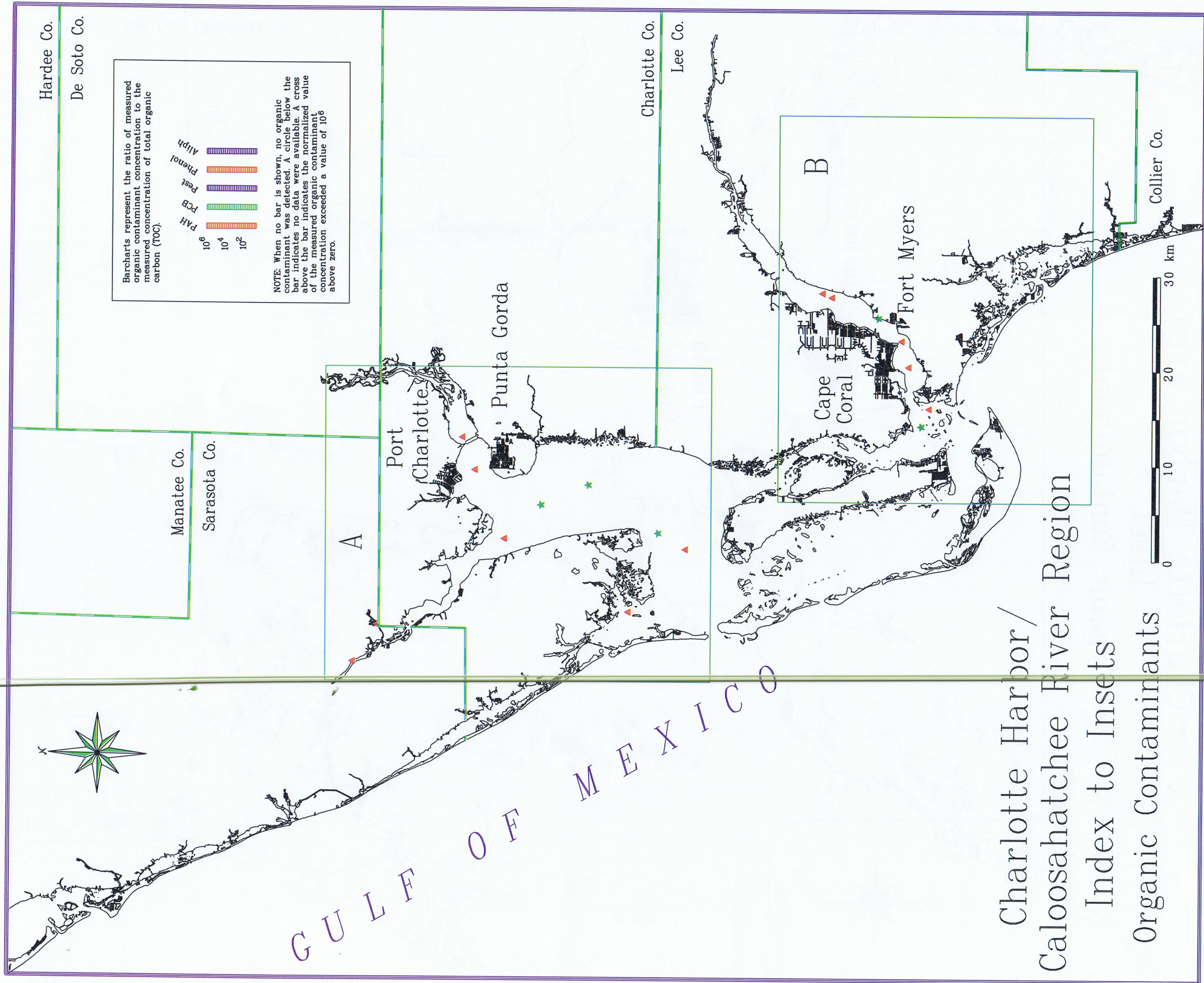
Map 73 - Tampa Bay Region Inset A - Hillsborough Bay



Map 74 - Tampa Bay Region Inset B - Old Tampa Bay

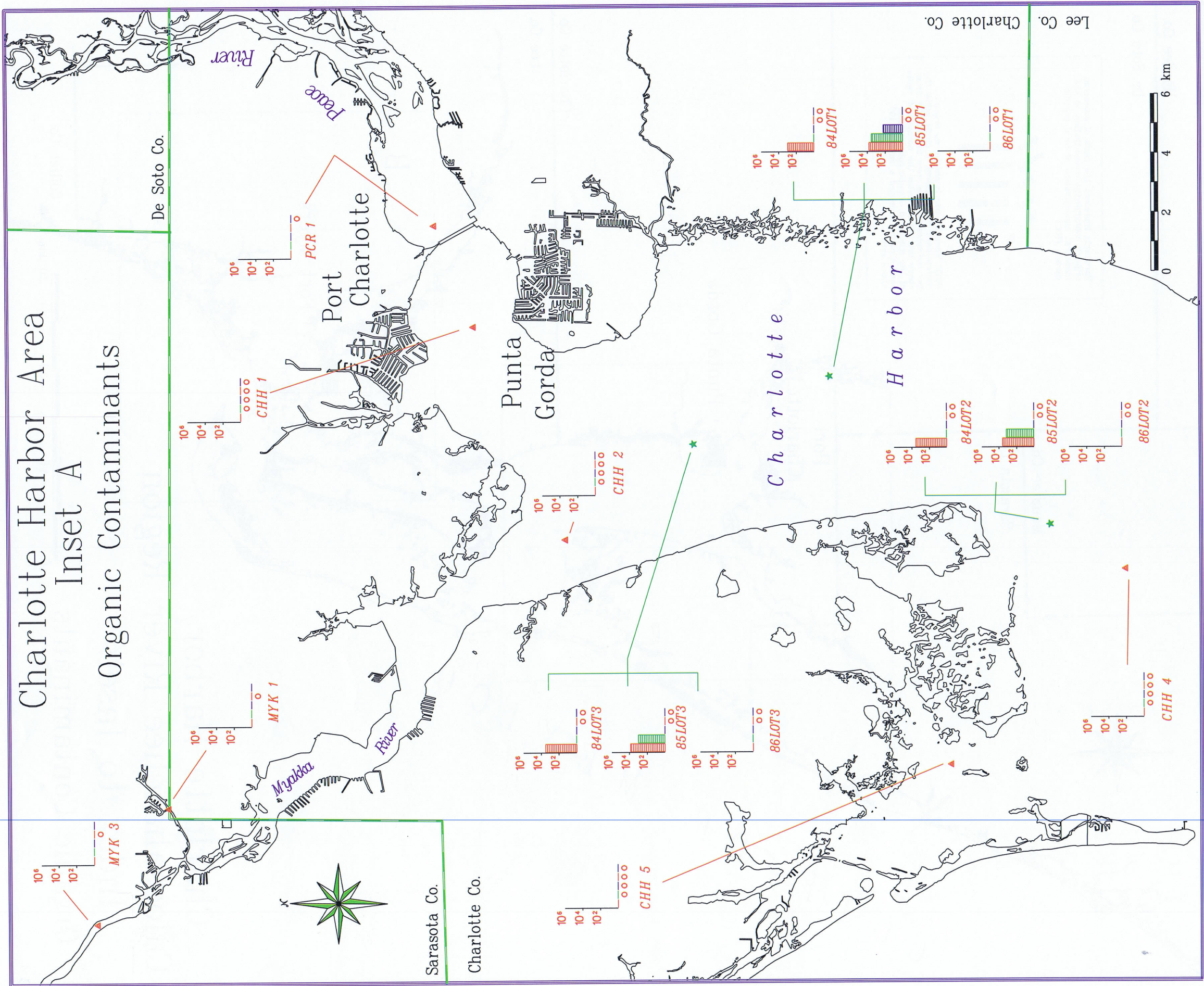


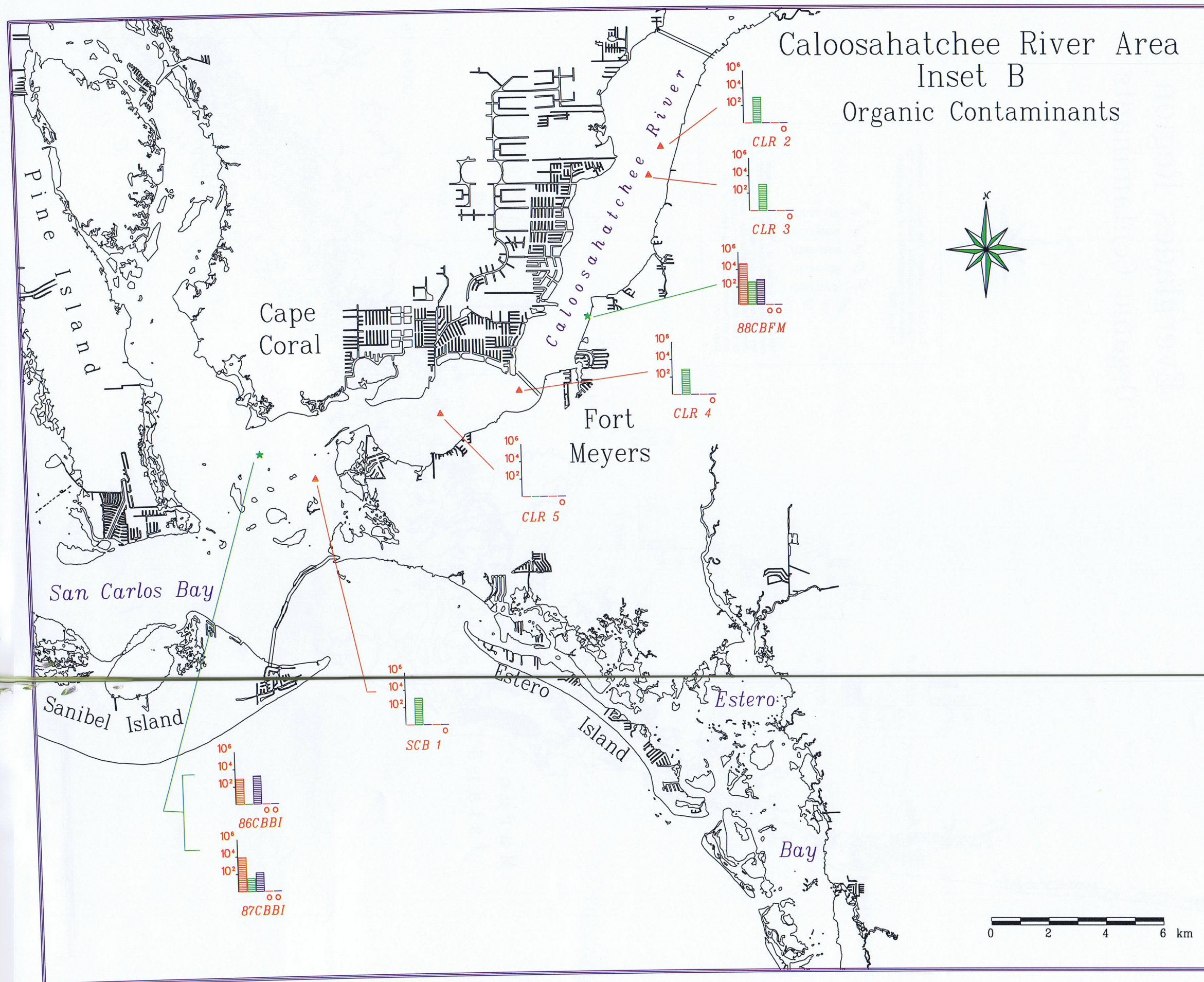
Map 75 - Tampa Bay Region Inset C - Southeast Tampa Bay/Little Manatee River



Map 76 - Charlotte Harbor and Caloosahatchee River Region Index to Insets

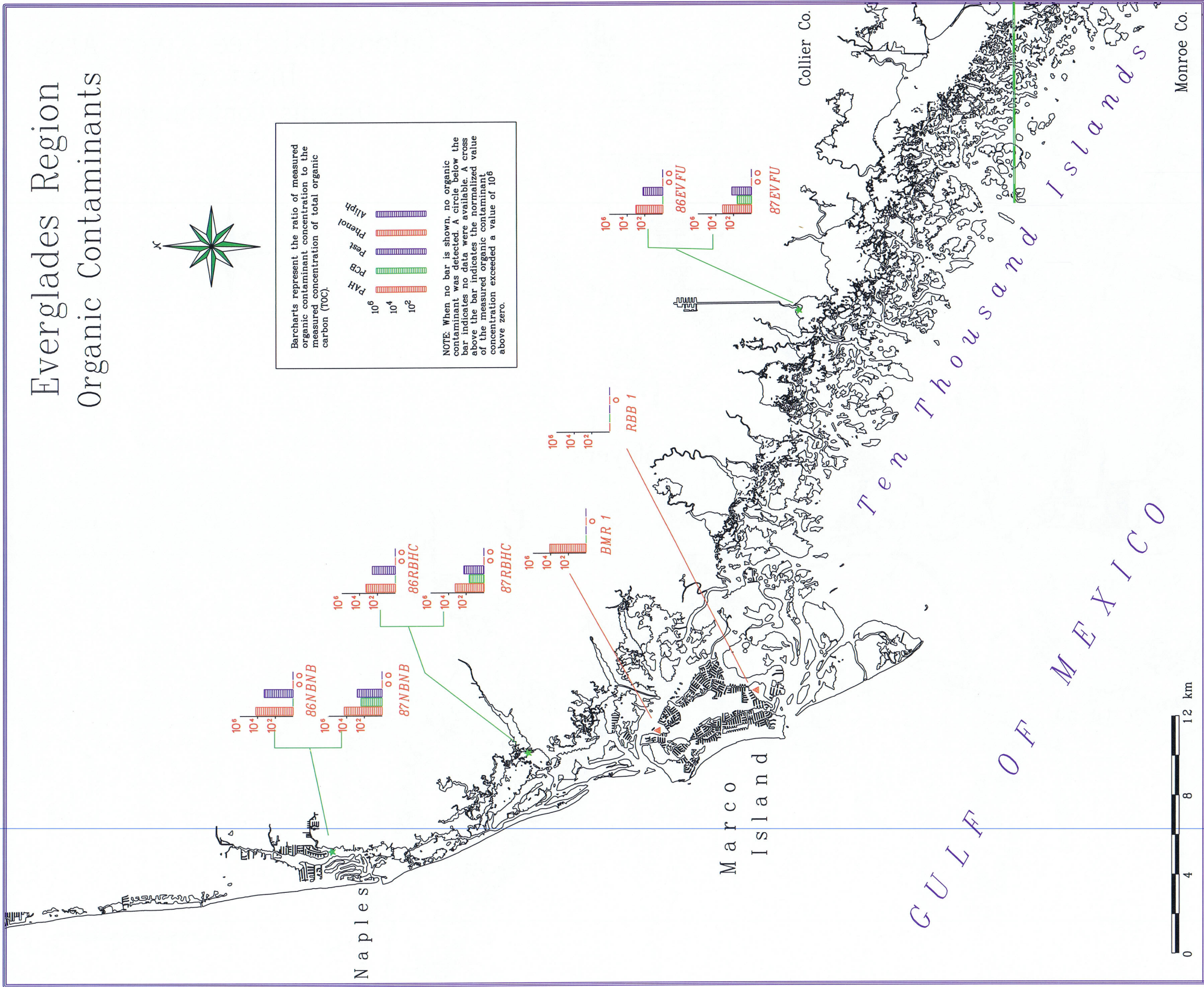
Map 77 - Charlotte Harbor Area Inset A



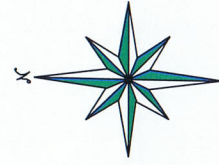


Map 78 - Caloosahatchee River Area Inset B

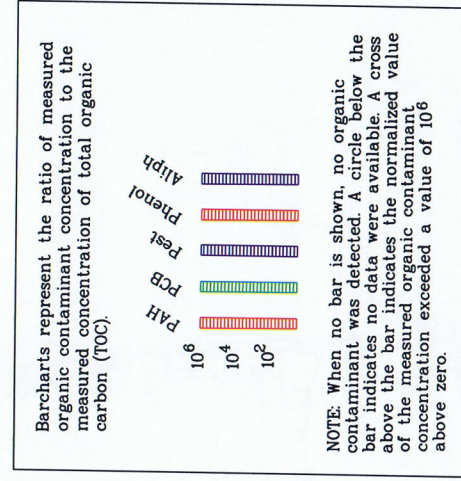
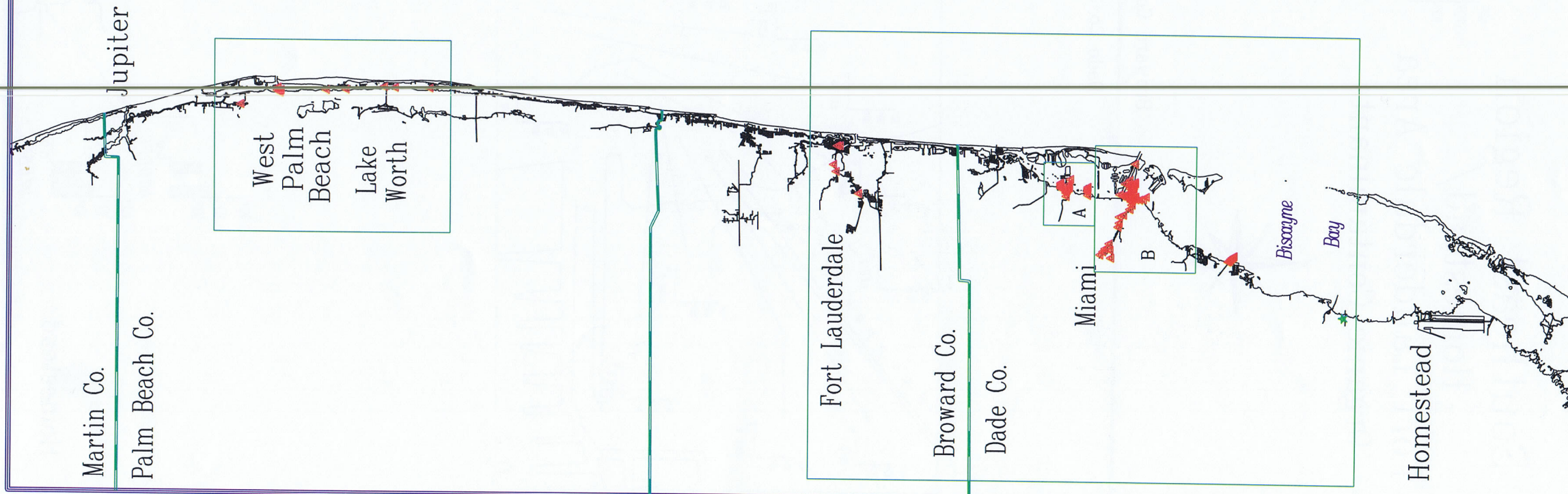
Map 79 - Everglades Region



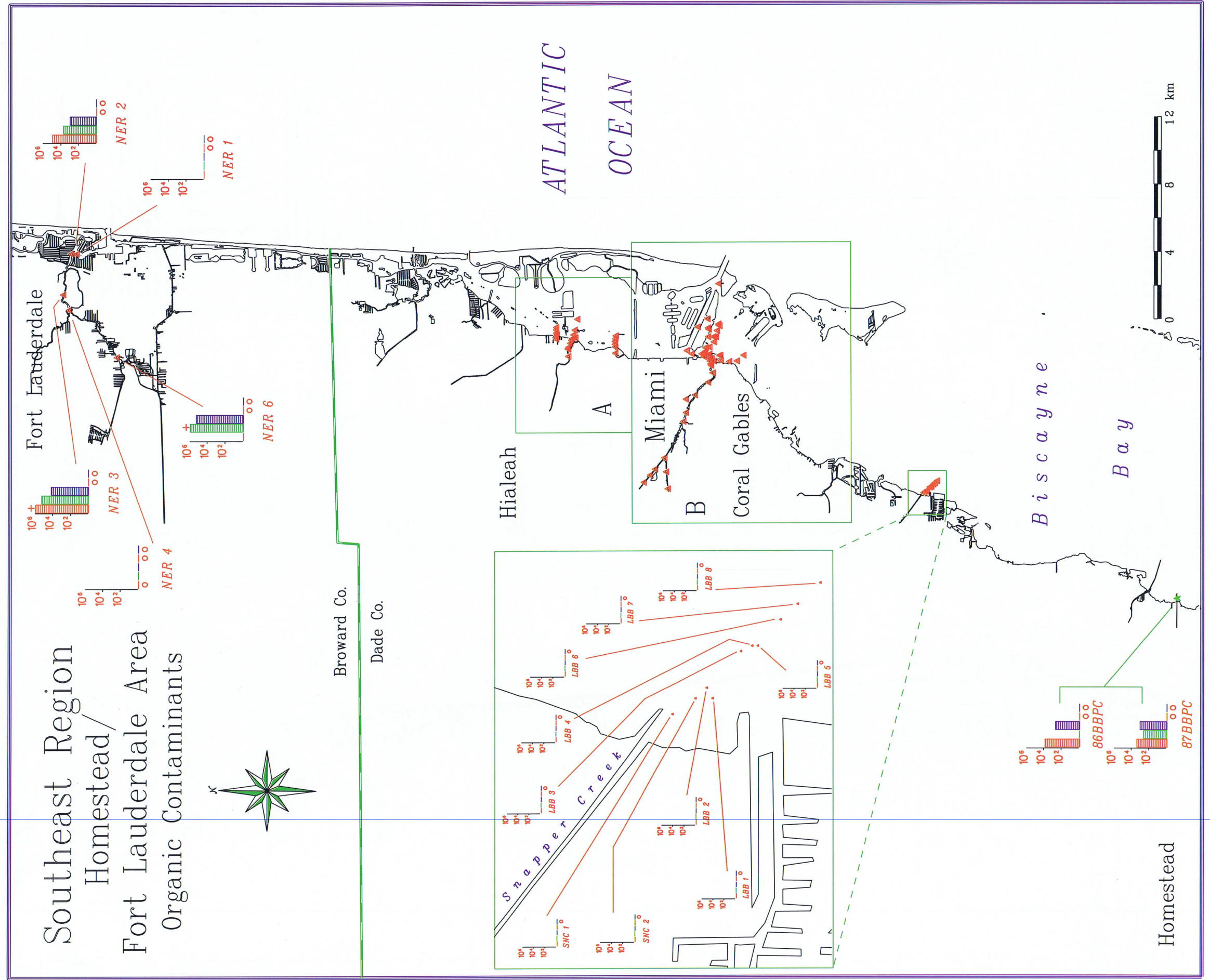
Southeast Region Index to Insets Organic Contaminants



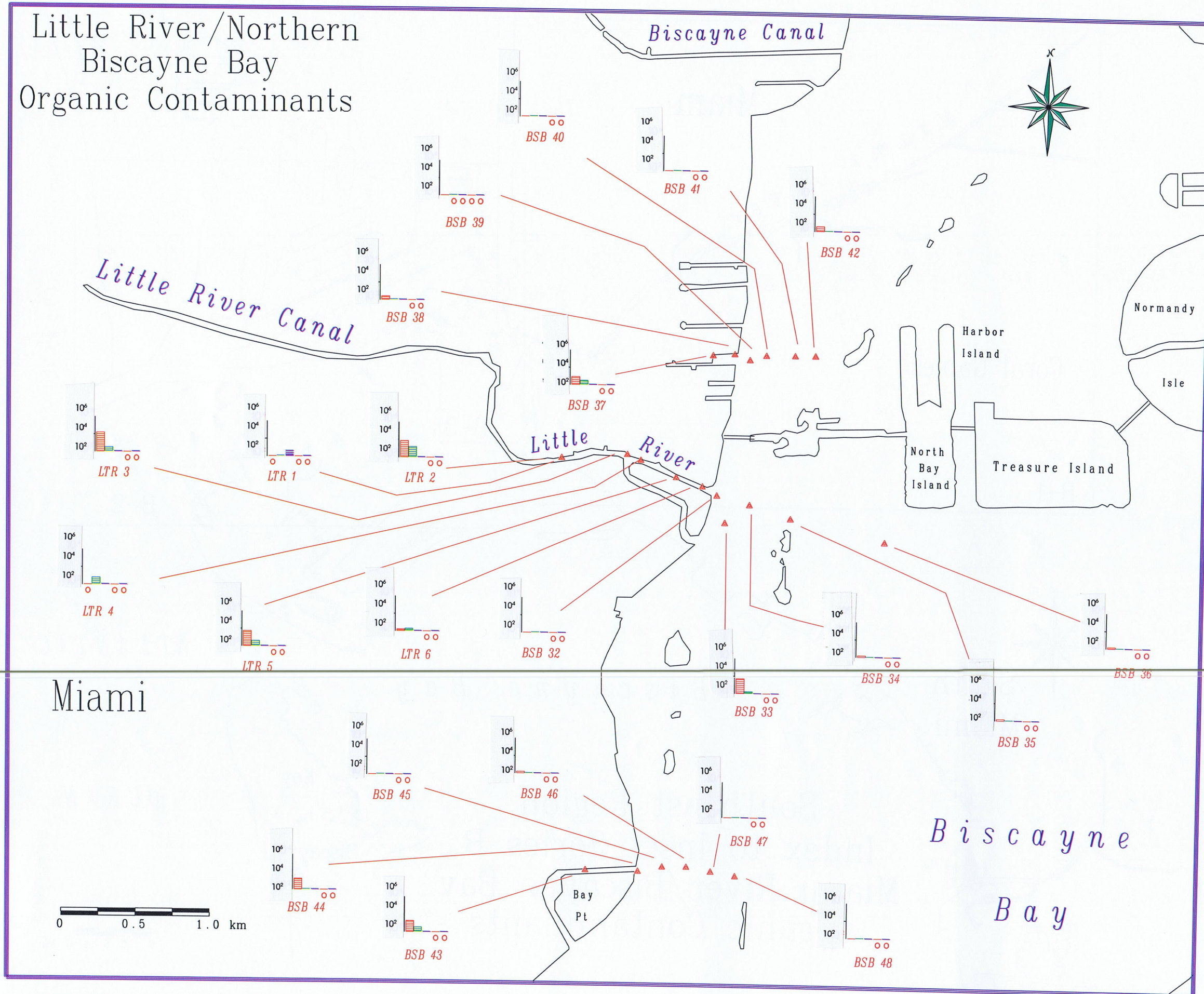
A T L A N T I C O C E A N



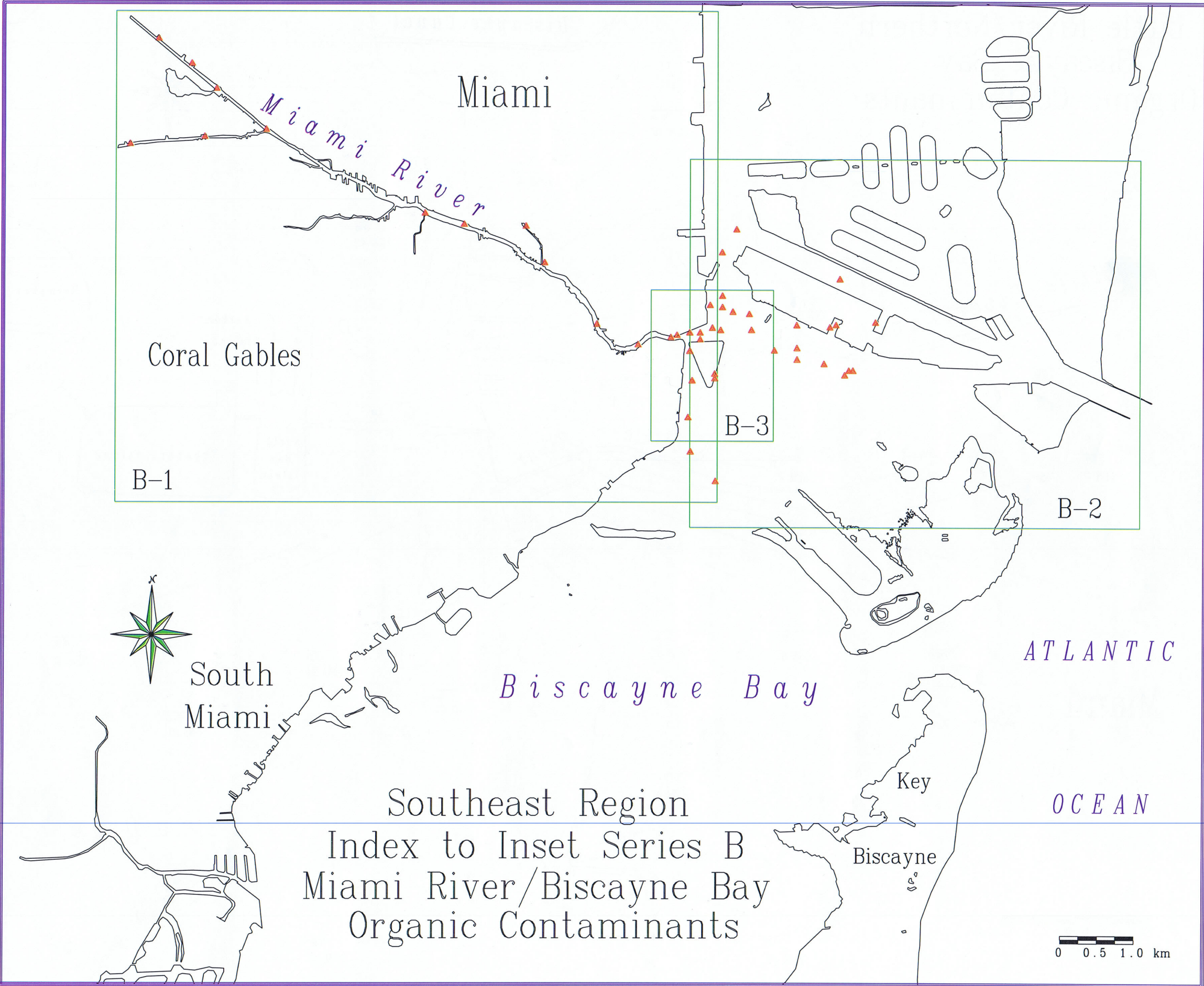
Map 80 - Southeast Region Index to Insets



Little River/Northern Biscayne Bay Organic Contaminants

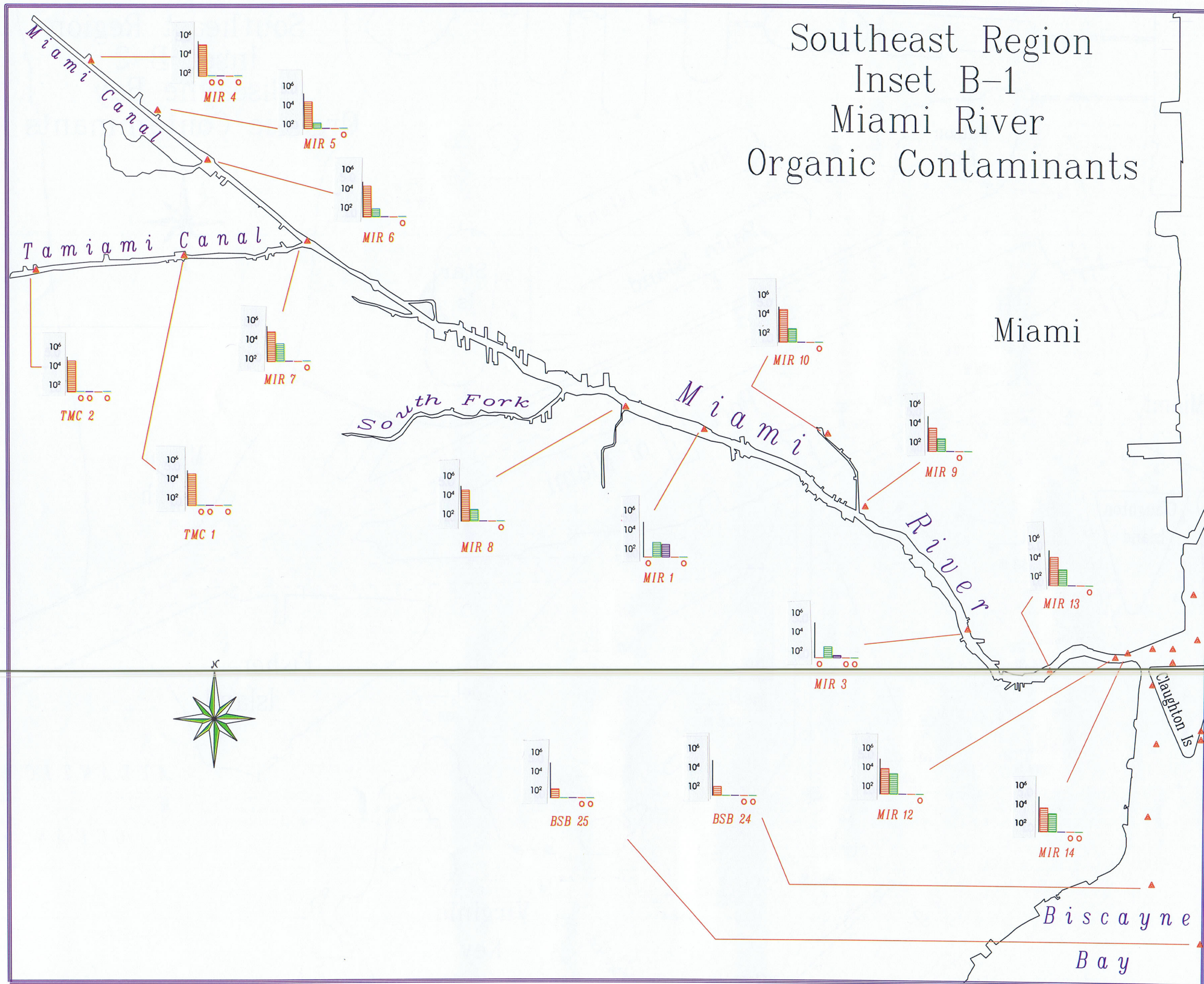


Map 82 - Southeast Region Inset A -
Northern Biscayne Bay

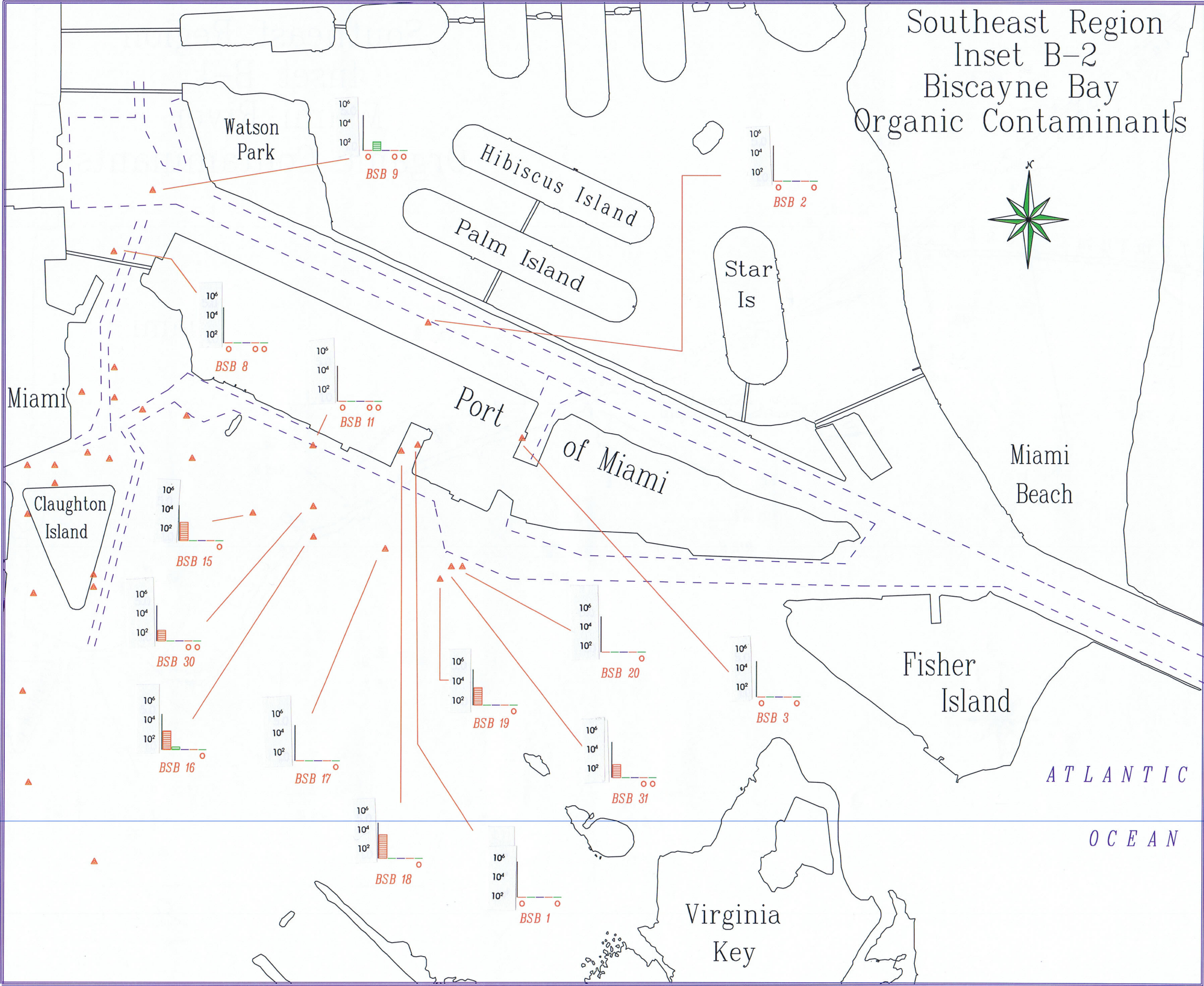


Map 83 - Southeast Region
Index to Inset Series B

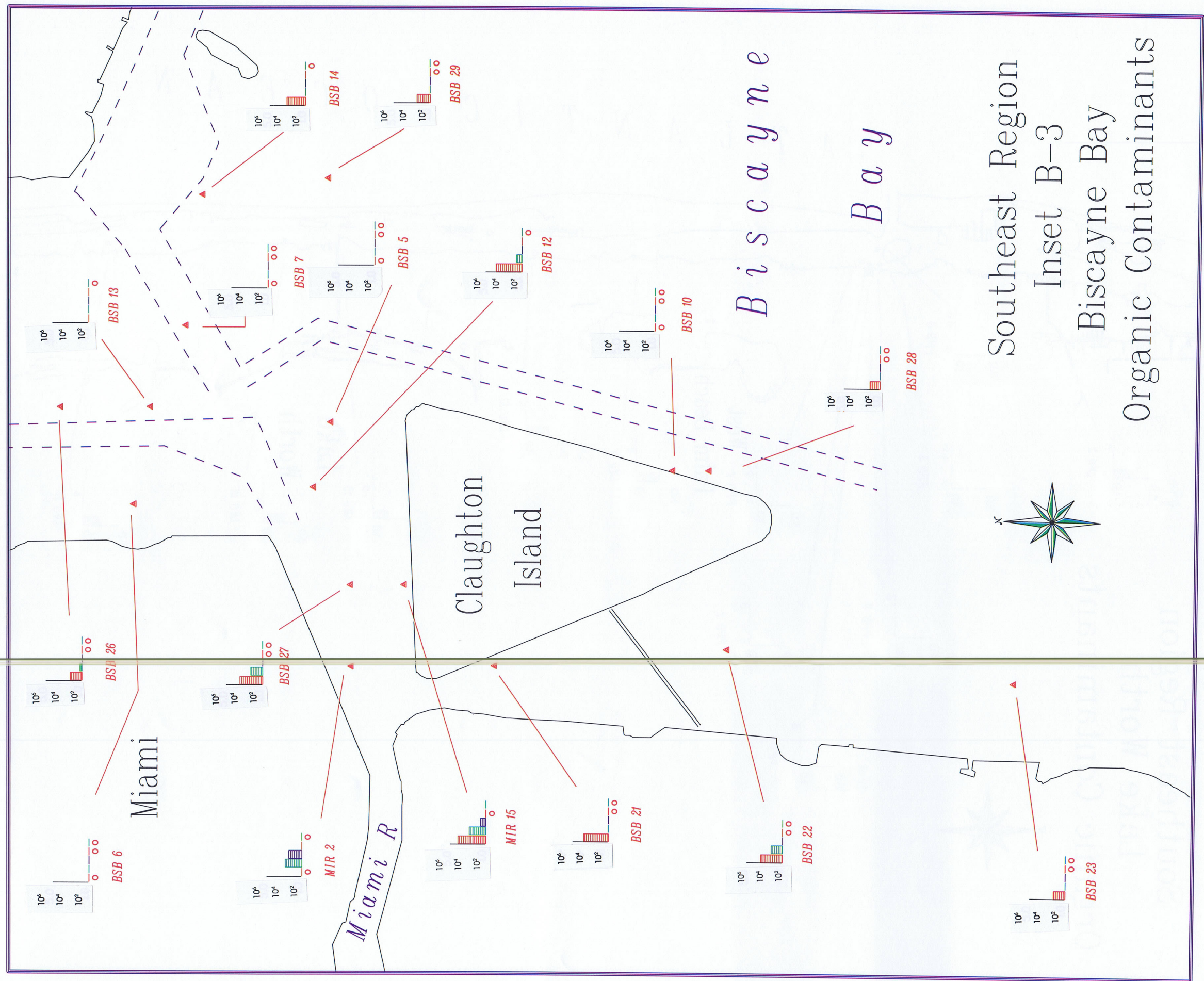
Southeast Region Inset B-1 Miami River Organic Contaminants



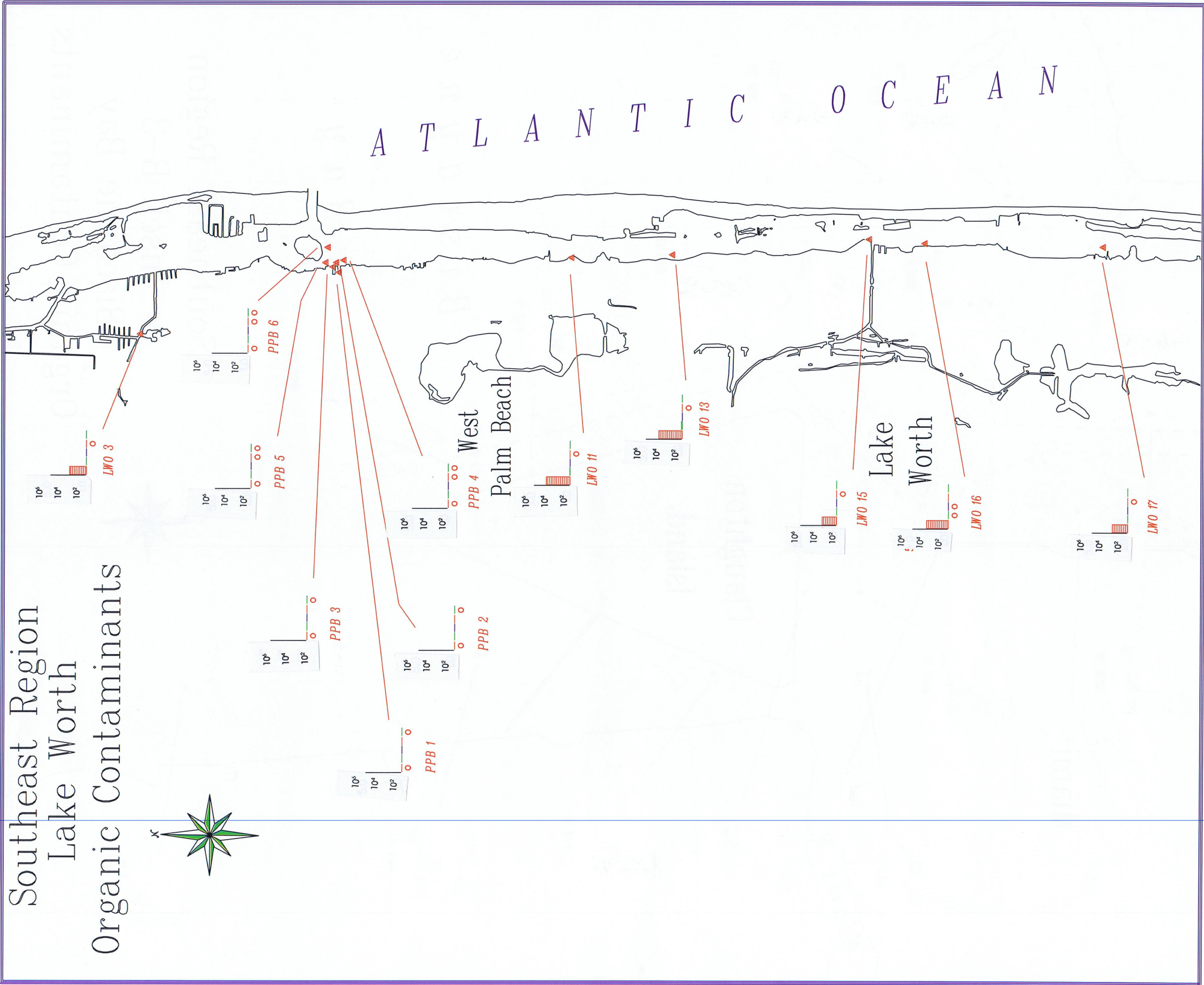
Map 84 - Southeast Region Inset B-1 -
Miami River



Map 85 - Southeast Region Inset B-2 -
Biscayne Bay

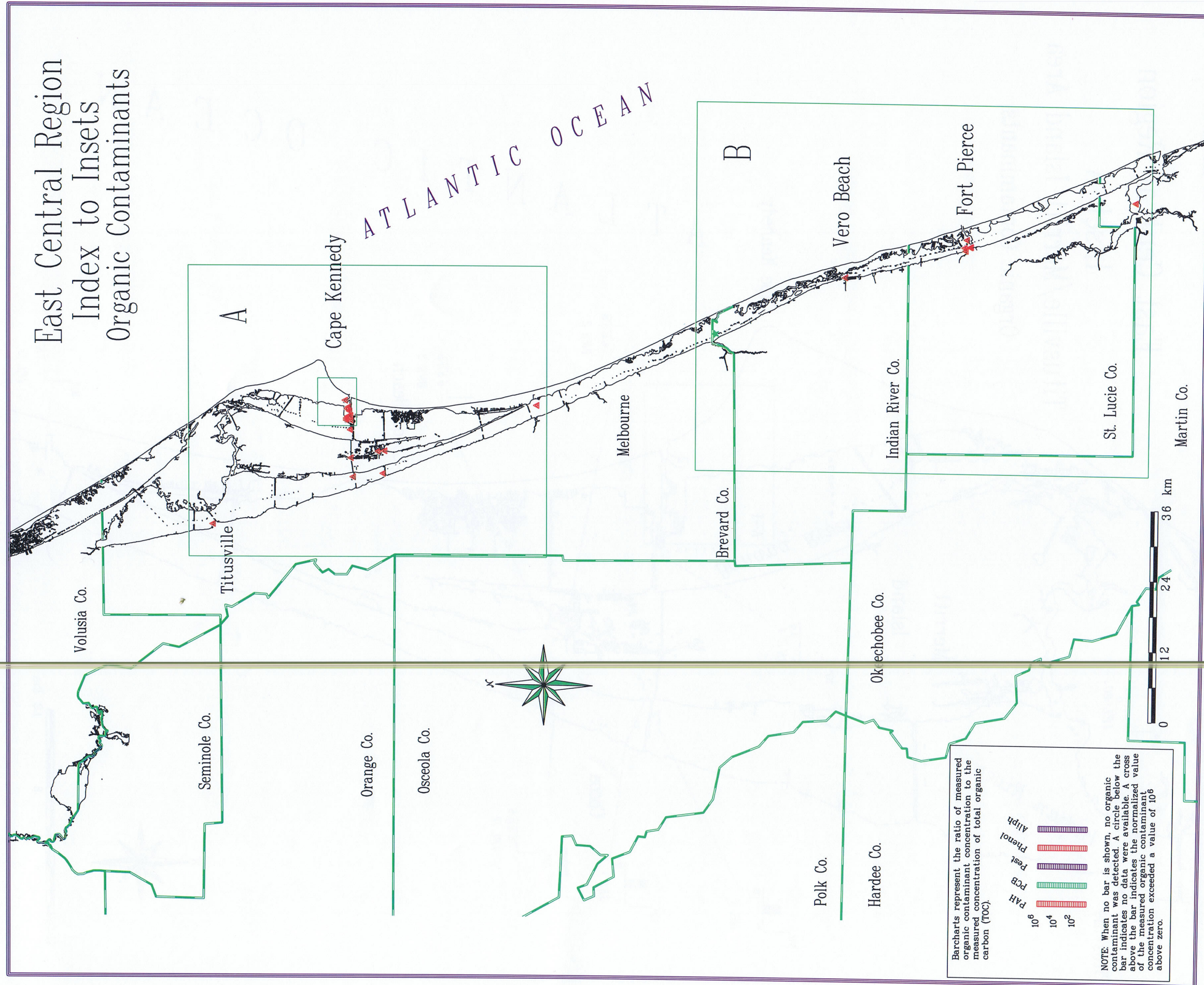


Map 86 - Southeast Region Inset B-3 - Biscayne Bay

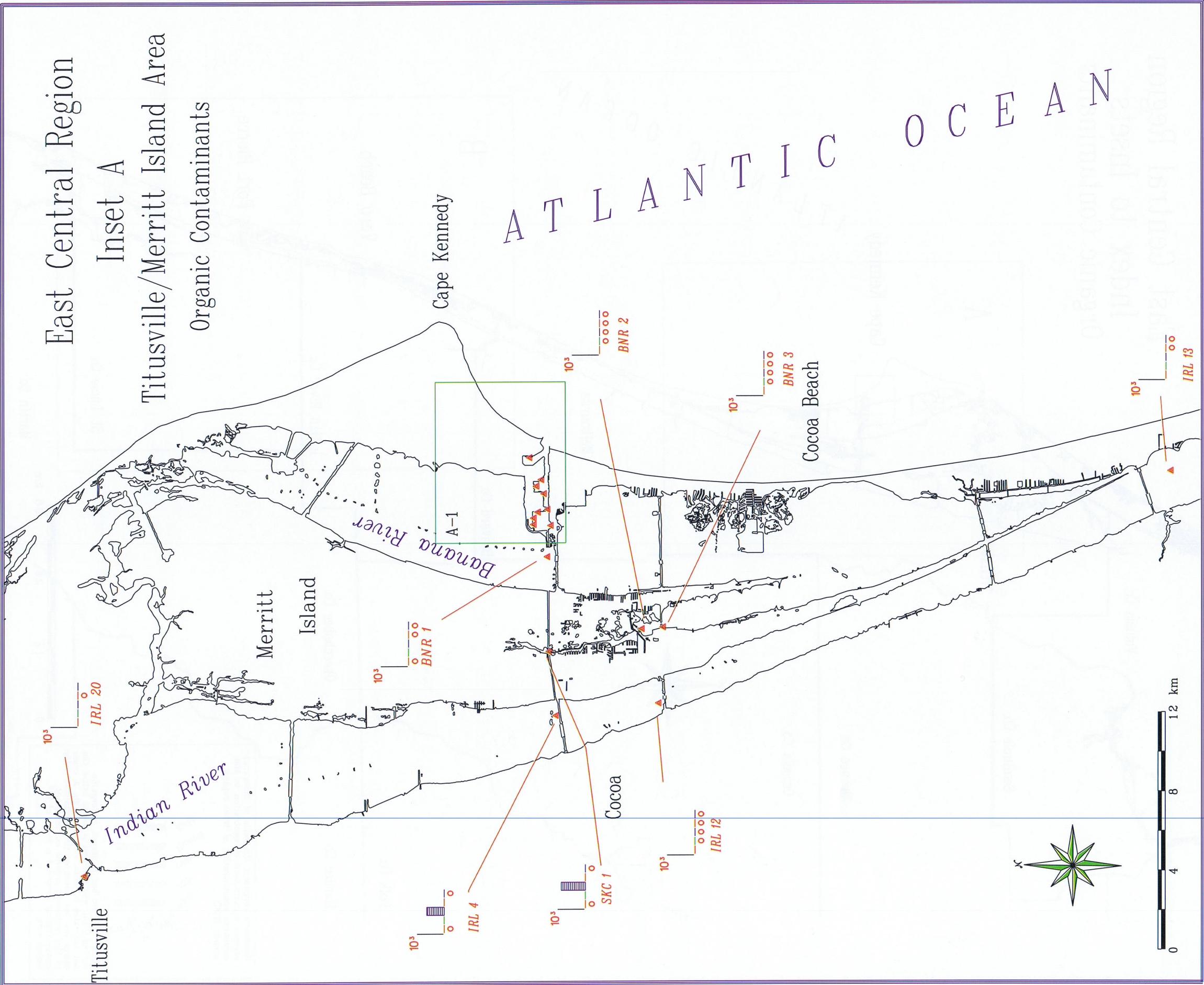


Map 87 - Southeast Region
Lake Worth Lagoon Area

East Central Region Index to Insets Organic Contaminants

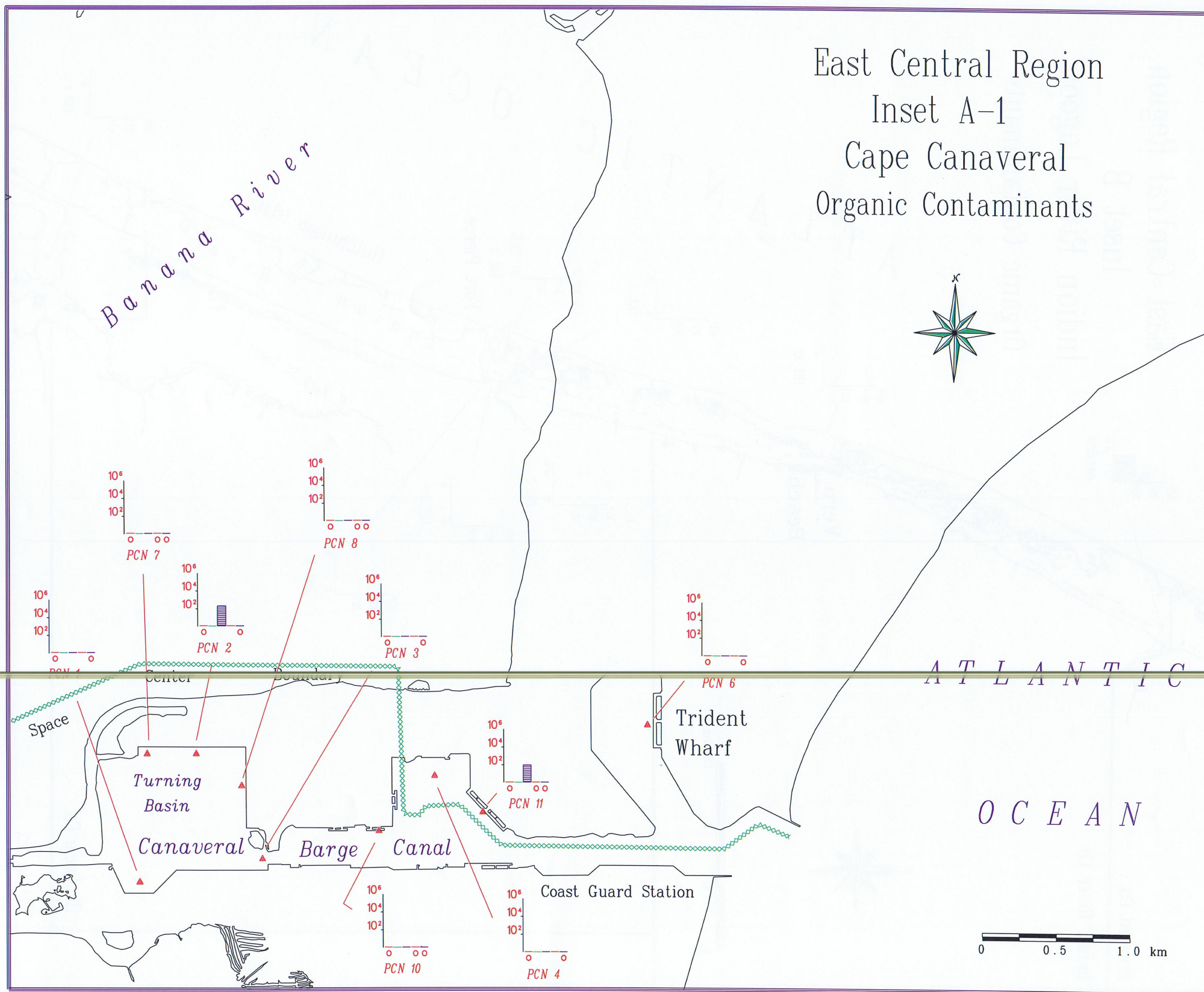


Map 88 - East Central Region Index to Insets

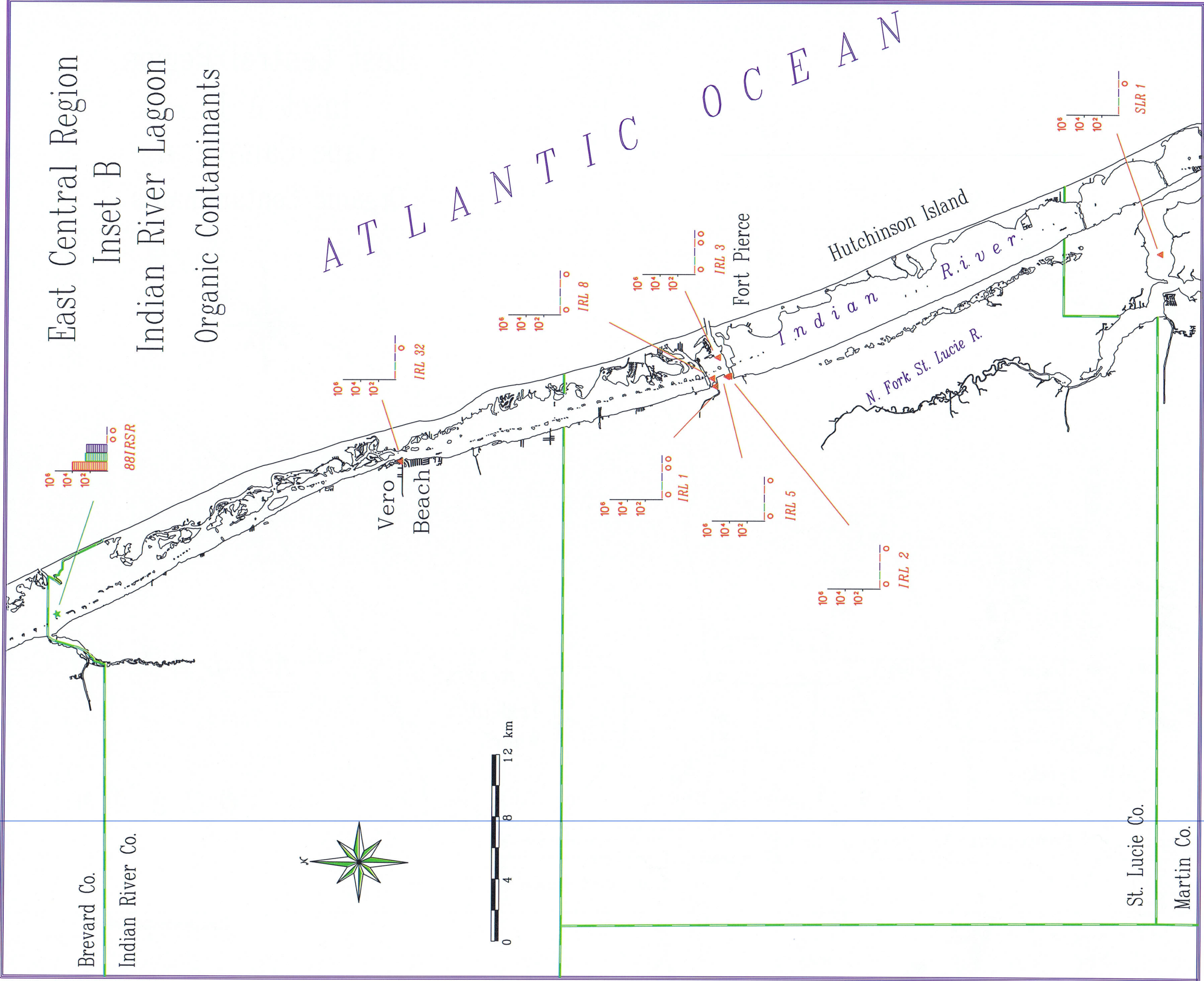


Map 89 - East Central Region Inset A -
Titusville/Merritt Island Area

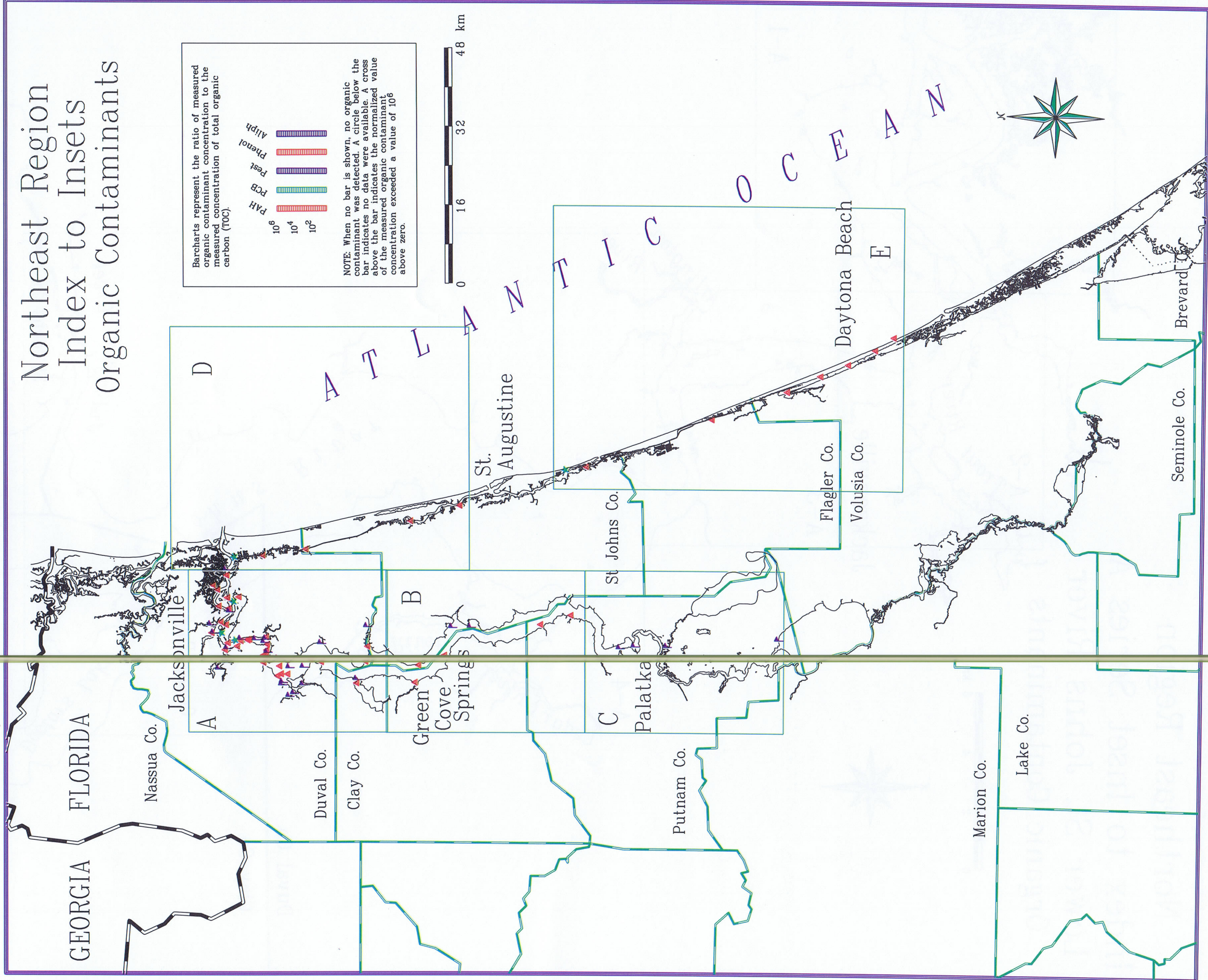
East Central Region
Inset A-1
Cape Canaveral
Organic Contaminants



Map 90 - East Central Region Inset A-1 -
Cape Canaveral

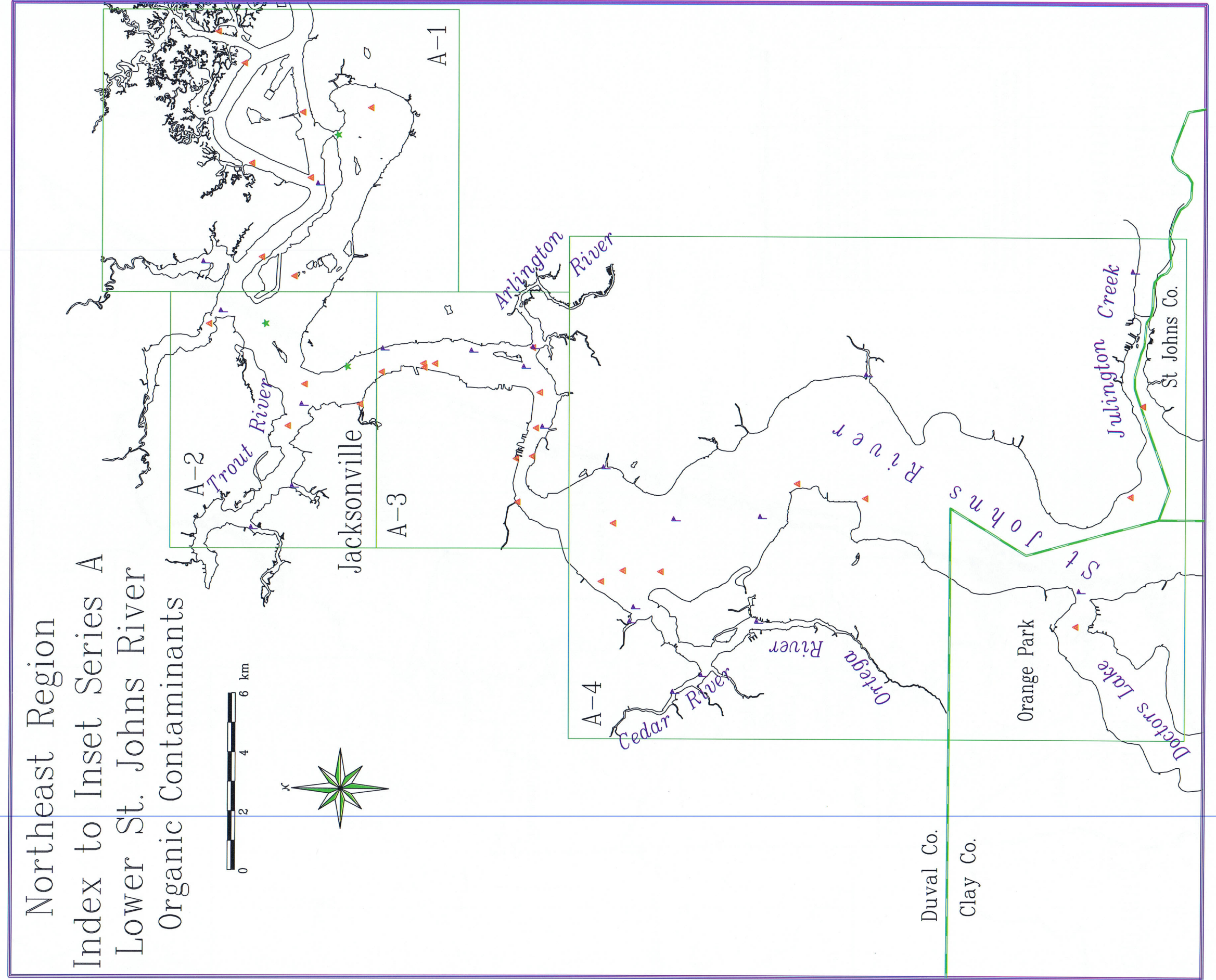


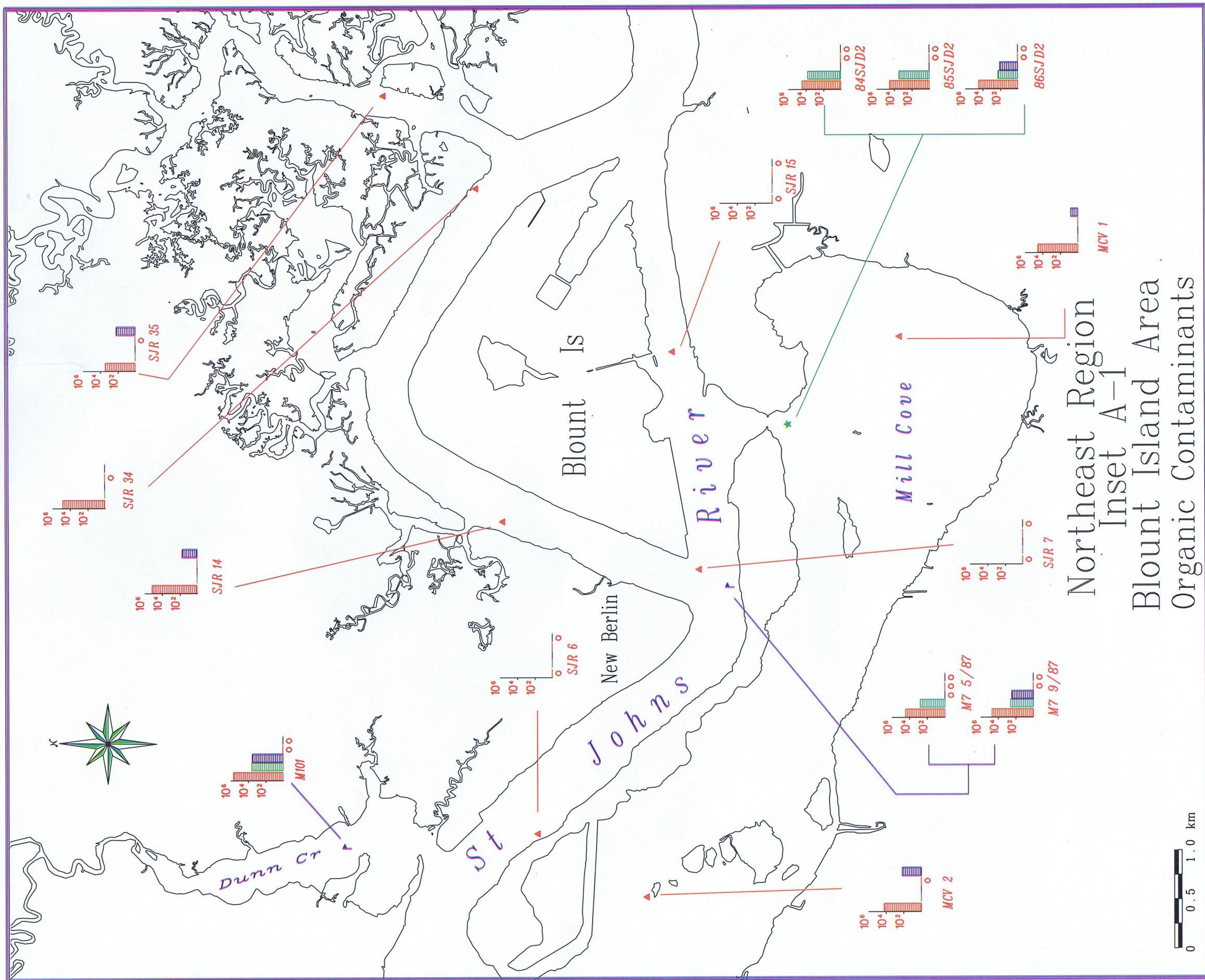
Map 91 - East Central Region Inset B -
Indian River Lagoon



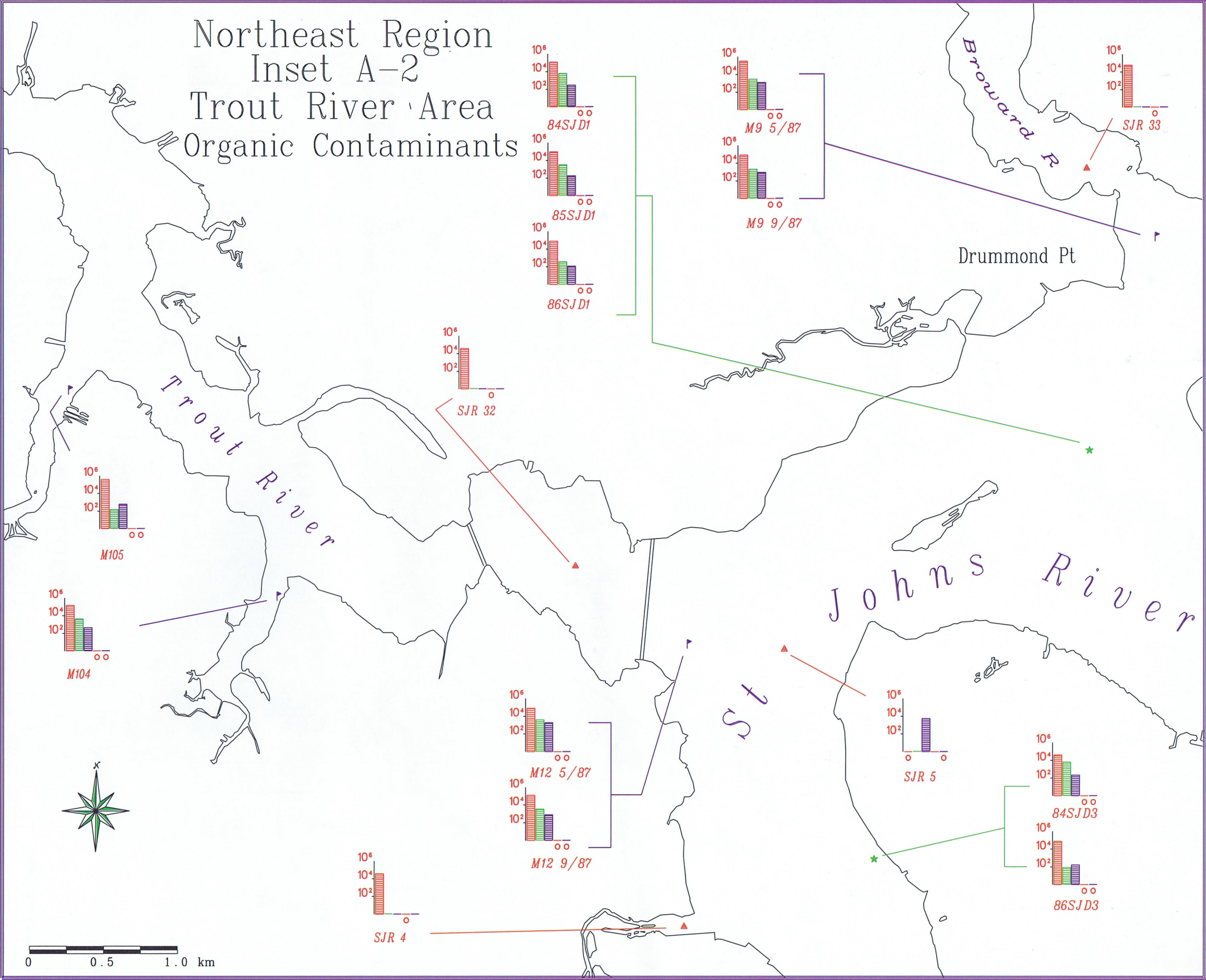
Map 92 - Northeast Region Index to Insets

Map 93 - Northeast Region Index to Inset
Series A - Lower St. Johns River





Map 94 - Northeast Region Inset A-1 - Blount Island Area

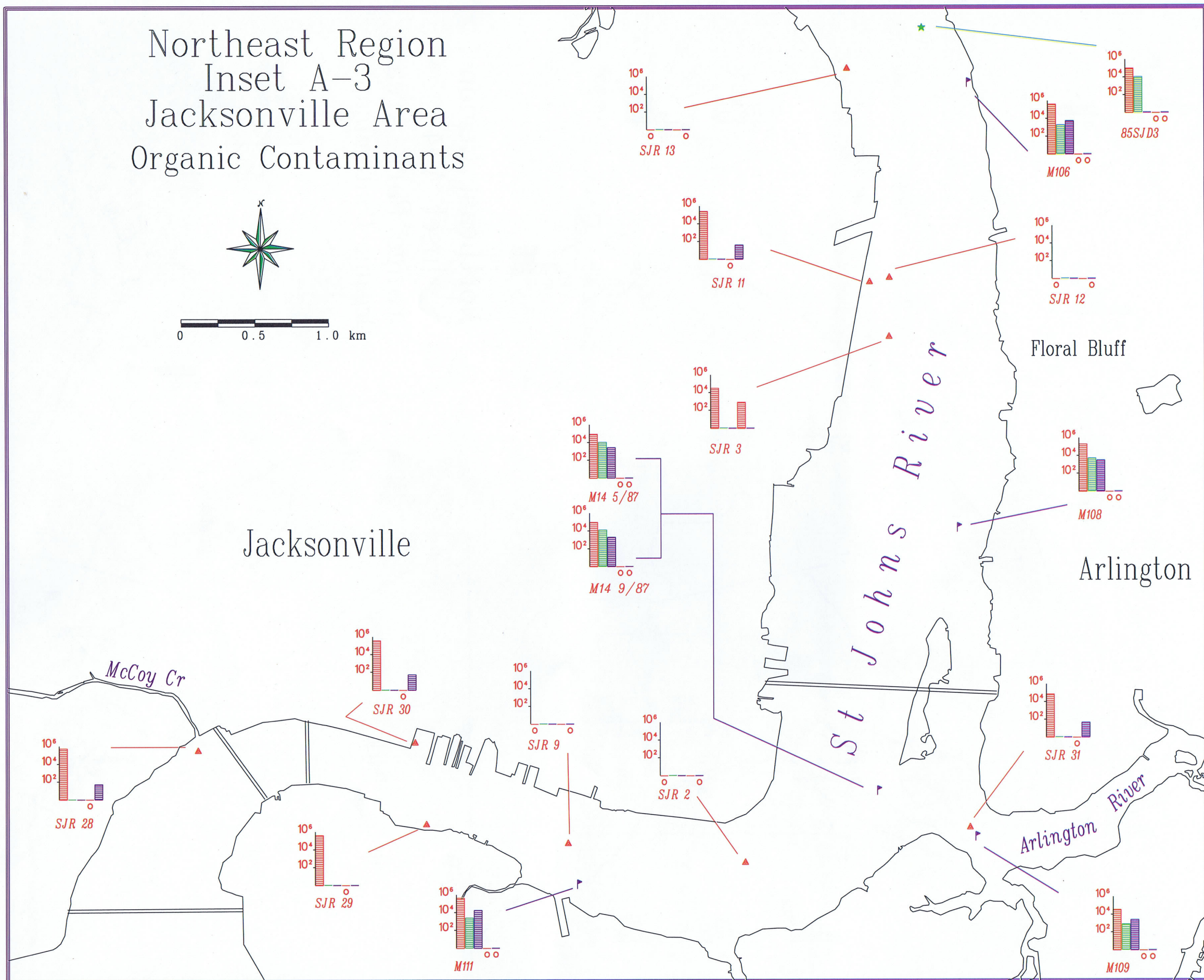


Map 95 - Northeast Region Inset A-2 -
Trout River Area

Northeast Region Inset A-3 Jacksonville Area Organic Contaminants

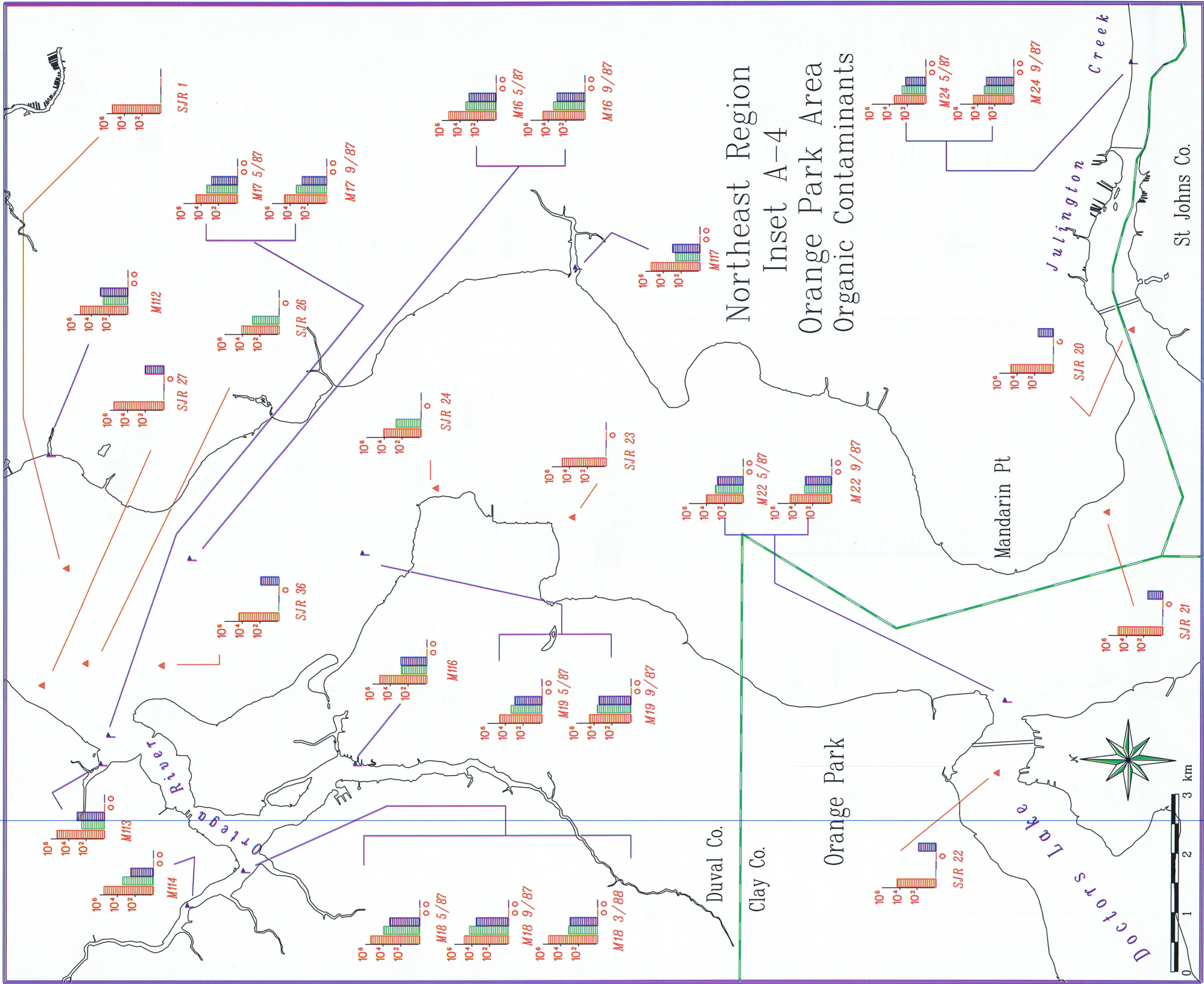


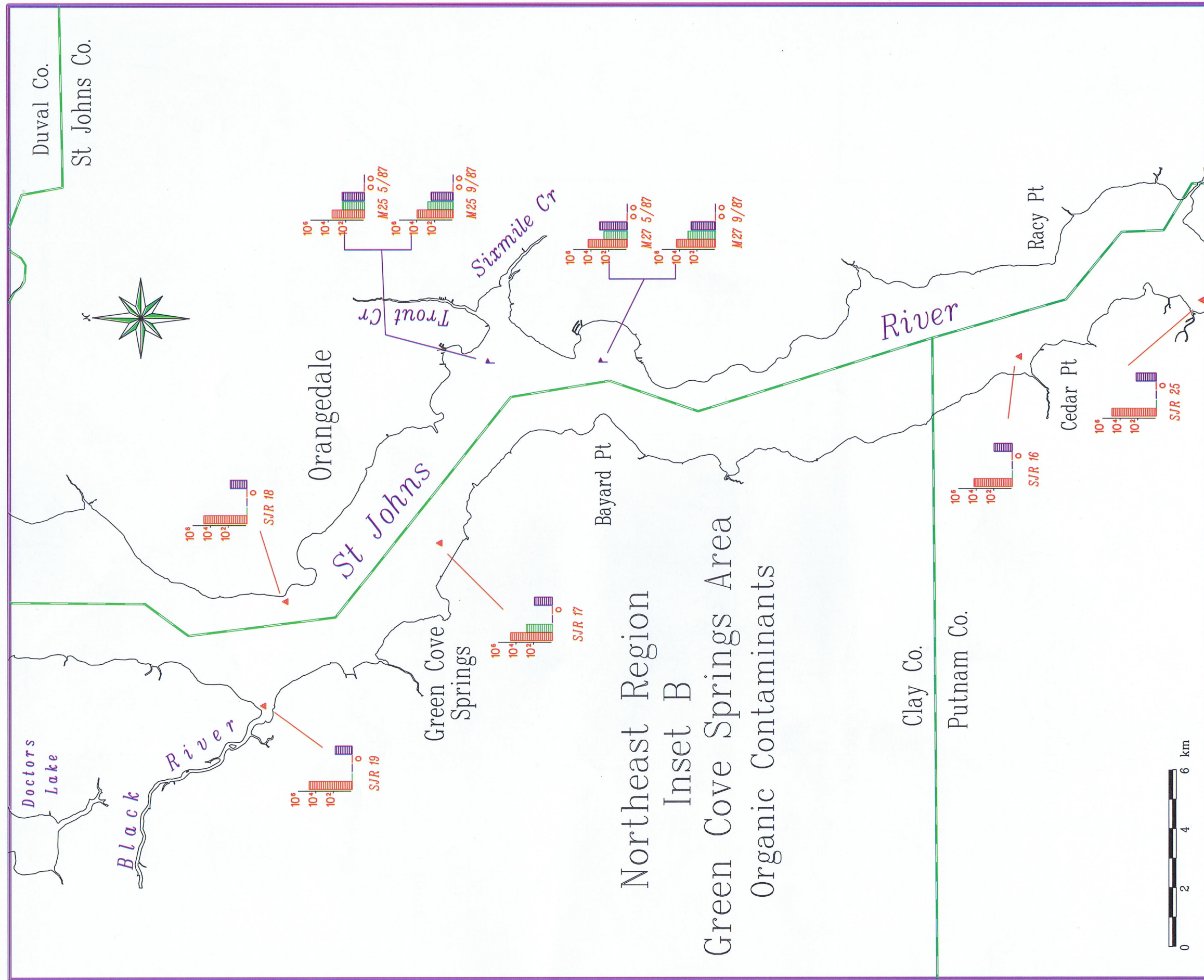
0 0.5 1.0 km



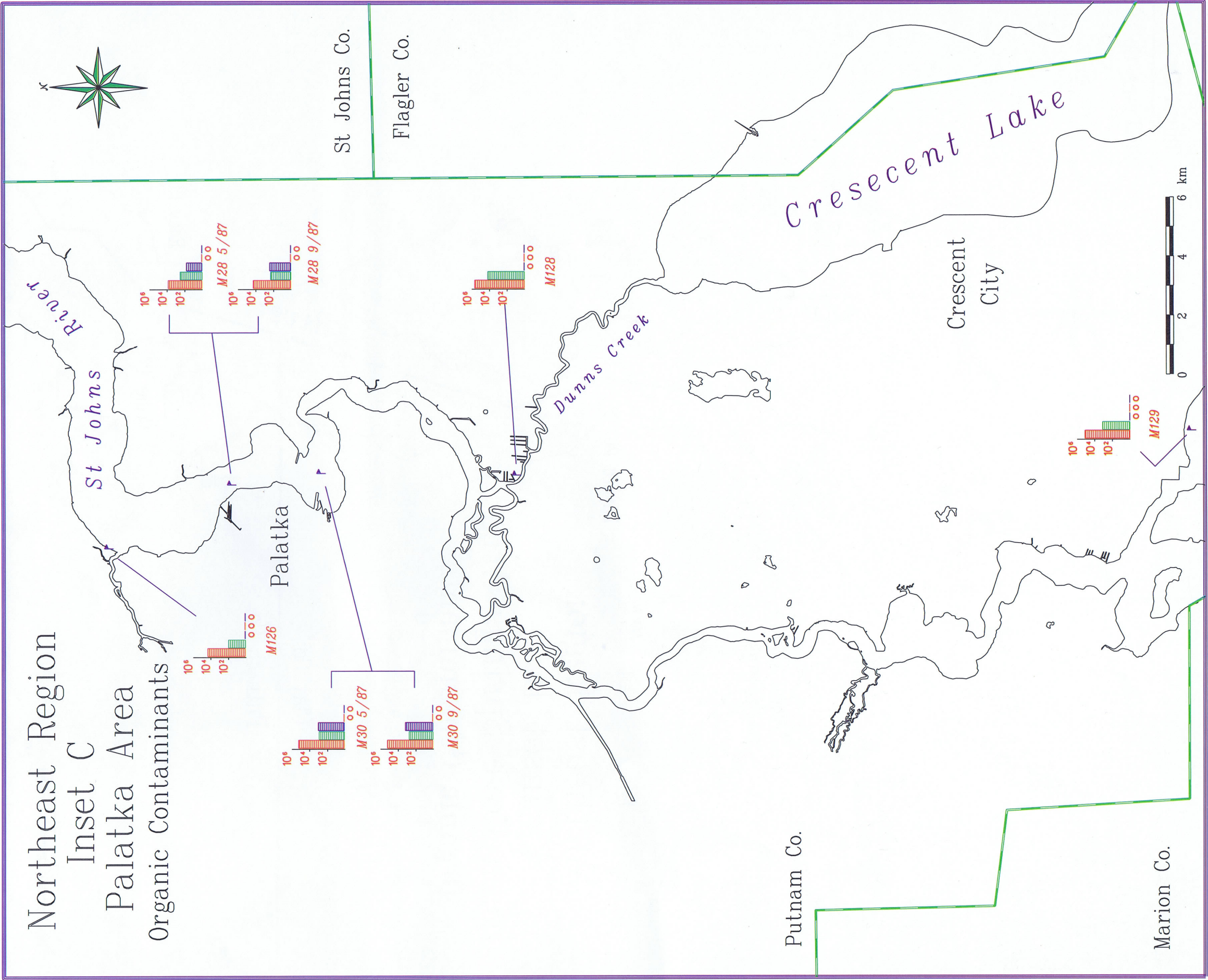
Map 96 - Northeast Region Inset A-3 -
Jacksonville Area

Map 97 - Northeast Region Inset A-4 - Orange Park Area

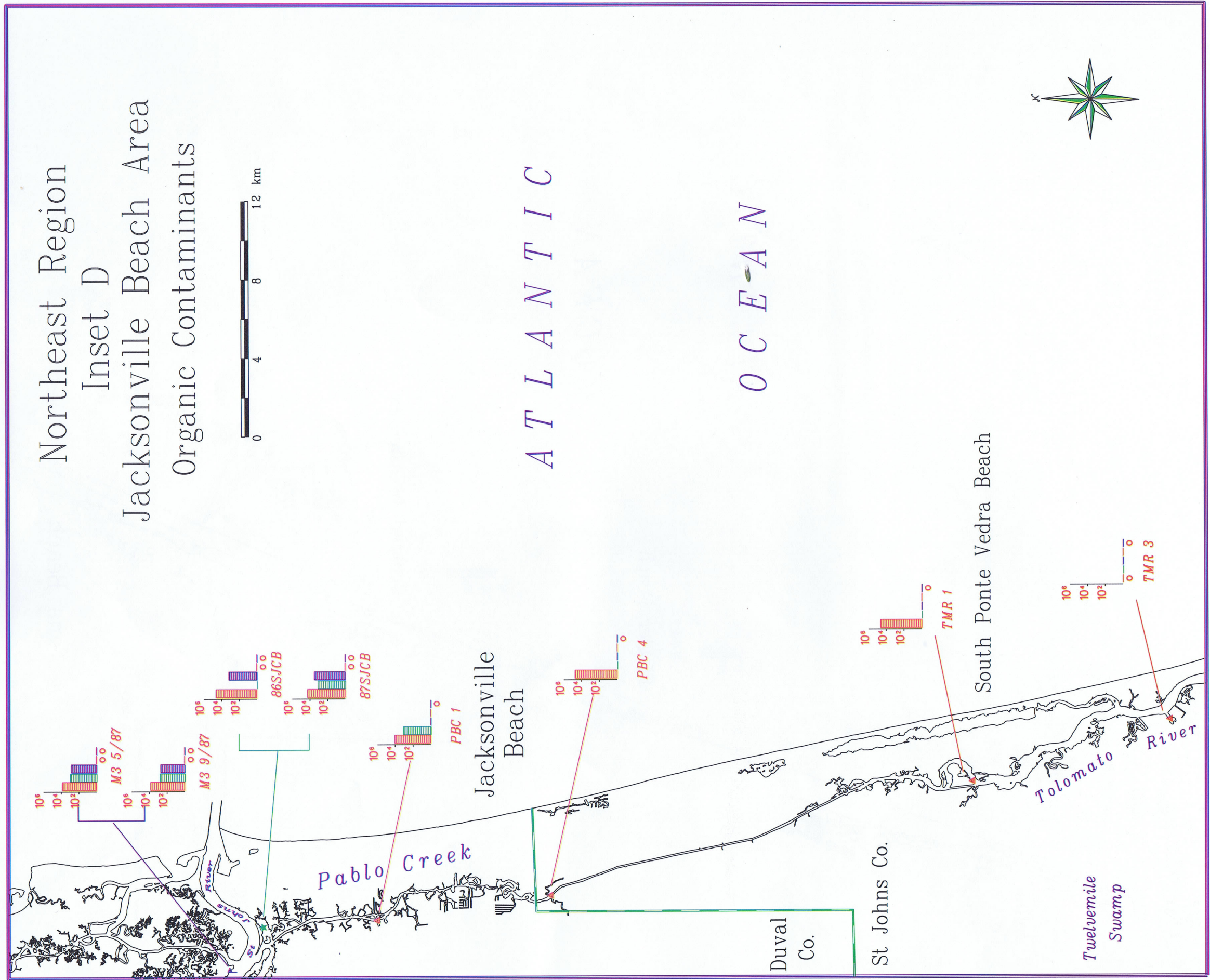




Map 98 - Northeast Region Inset B -
Green Cove Springs Area



Map 99 - Northeast Region Inset C - Palatka Area



Map 100 - Northeast Region Inset D -
Jacksonville Beach Area

Map 101 - Northeast Region Inset E -
Flagler Beach Area

