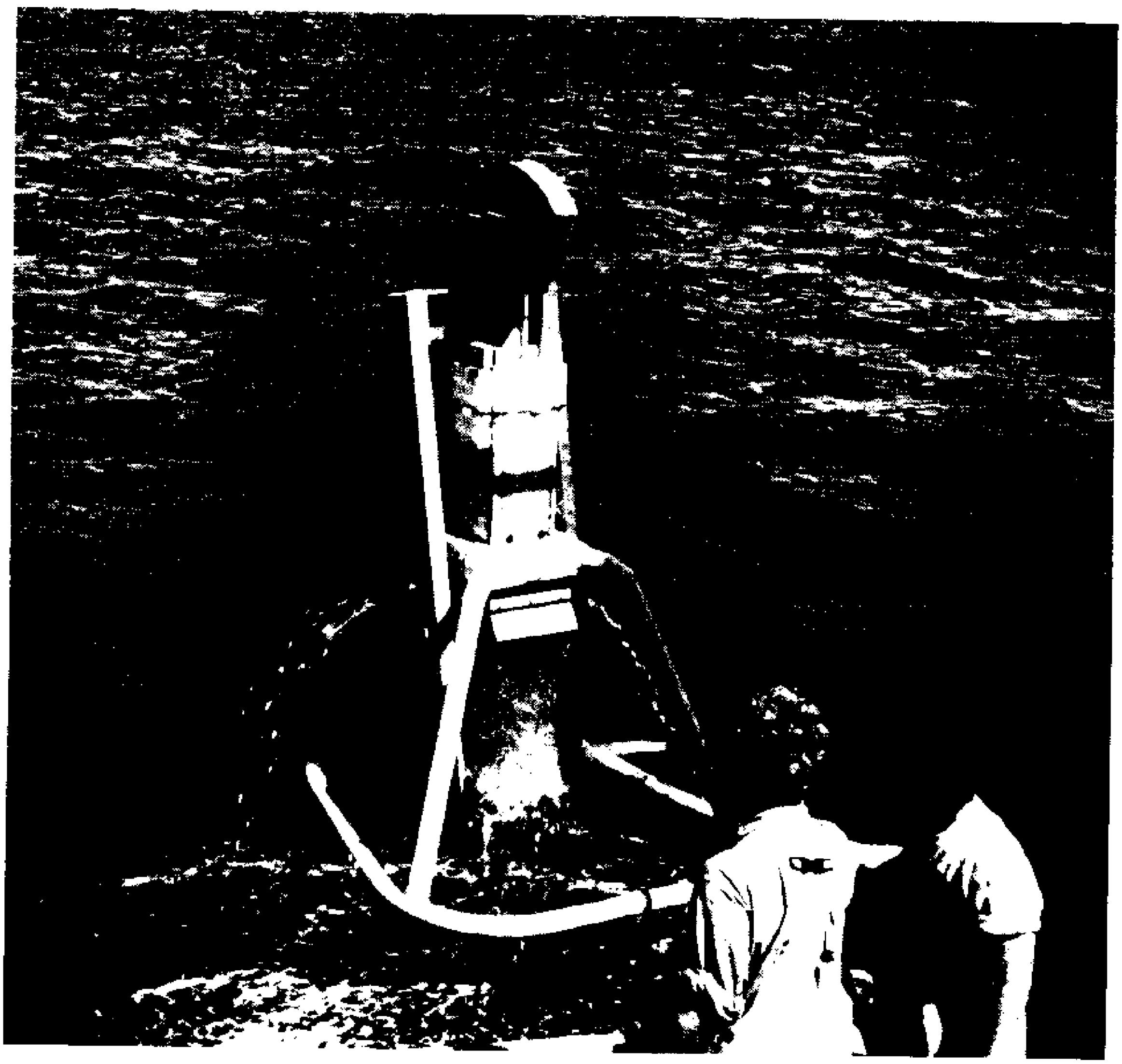
Marine Studies of San Ped... Bay, California

PART VII

SEDIMENT INVESTIGATIONS



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SEDIMENT COMPOSITIONS IN LOS ANGELES-LONG BEACH HARBORS AND SAN PEDRO BASIN

by

Kenneth Y. Chen and James C.S. Lu

Environmental Engineering Programs
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PART VII

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SEDIMENT COMPOSITIONS IN LOS ANGELES-LONG BEACH HARBORS AND SAN PEDRO BASIN

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ABSTRACT. Most surface sediments in the Los Angeles-Long Beach Harbors and nearby San Pedro Basin are grossly contaminated, with the exception of a few localities. Restricted dredging of polluted sediments from fractional areas of the harbor complex is probably beneficial to the ecosystem if the polluting substances can be properly disposed of. The Los Angeles County Sanitation District sewer outfall at White's Point is found to contribute substantial amounts of trace metals and chlorinated pesticides to the San Pedro Basin, while the harbor complex is found to be an important source of polychlorinated biphenyls into the San Pedro Basin. Interrelationships of pollution parameters are presented.

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Cover photograph by John Soule
Box corer operated from R/V Velero IV

I. INTRODUCTION

Compositions of the newly deposited fine-grained sediments in an aquatic system document the influence of man's activity in the recent past. The Los Angeles metropolitan area is among the most populous areas in the world; the influx of wastewater, industrial waste, surface runoff, aerial fallout, and many other minor sources continuously add to the chemical composition of nearshore sediments. In order to differentiate the natural background of these sediments from those of man-made pollution, a comprehensive baseline study is needed.

Sediments are known to contain the major fractions of contaminants and nutrients of aquatic environments. In general, sediments are regarded as the permanent sinks of pollutants and nutrients from the overlying waters; however, dynamic exchanges between sediment-water interfaces are known to occur constantly, especially when redox conditions are changed. In recent years, genuine concerns have arisen over the deposition of sediments in open water on a large scale due to the need for the maintenance and creation of navigable waterways. The uncertainty of the course of migration of chemical constituents between solid and solution phases, and the possible effects of the resedimentation of polluted sediment on the exposure level to benthic organisms at disposal sites have led to the postponement of many marine construction and dredging activities.

Since sediments may contain relatively high concentrations of biological toxicants or stimulants, the excavation and redeposition of large quantities of these substances might cause substantial changes to the biological communities--which can be harmful or beneficial. The removal of grossly contaminated organic-rich, sulfide-rich sediments can be beneficial to the organisms on one hand; however, unless such sediments are properly handled or treated, damage to the biological communities can result from: the depletion of oxygen which is generally associated with pulses of high oxygen demand; release of trace contaminants; and production of suspended fine sediment in the water column.

Concentrations of trace contaminants in seawater are normally very low (SCCWRP, 1973). This is because of the adsorption of trace metals on particulate matter and low solubility of trace organics such as chlorinated hydrocarbons in water phases as well as their strong propensity for attaching to the solid phase. Therefore, the history of water pollution can generally be found in the study of sediment concentrations --even though such analyses do not generally yield the potential of a sediment for pollution.

Due to the lack of information on the natural background levels of trace substances and the uncertainty on the pollutional status of dredged materials and their possible effects on water quality, many of the agencies regulating dredged material disposal have tended to take a very cautious approach in passing judgement on the impact of dredging activities and proposing mitigating procedures, with consequent confusion, delays, and seemingly unending appeal procedures.

This report deals with the distribution of contaminants and nutrients in sediments of the Los Angeles-Long Beach Harbors and the adjacent San Pedro Channel. Such a study is necessary to elucidate the history of different pollution parameters. This information is needed to assess the potential effect of the large scale deposition of sediment from the harbor area into adjacent open waters as a result of dredging operations. In addition, the importance of the harbor as well as the nearshore coastal water as the nursery for marine organisms emphasises the need for comprehensive baseline data from which to observe the changes as well as to predict the significance of future activities on the system.

II. SEDIMENT ANALYSIS VS. DREDGING CRITERIA

At present, much research is being conducted to study the effect of the disposal of dredged materials known to contain various levels of pollutants in sediment. However, up to the present, there is very little definitive information on the relationships of various types of sediments and their bioavailability upon disposal. In examining data on gross sediment concentrations, it should be fully recognized that such parameters may not bear direct or linear relation to biological potentials. Nevertheless, it can be said, in broad terms, that polluted sediments generally release higher concentrations of trace contaminants and nutrients than the natural sediment. The most significant ecological implication of the chemical compositions of sediments is probably reflected in the exposure level of benthic organisms after sediments are resettled.

For this reason, the early Environmental Protection Agency Criteria for Determining Acceptability of Dredged Spoil Disposal to the Nation's Waters (both fresh and marine) were entirely based on gross concentrations with the following numerical limitations:

Chemical Constituents	Conc. % (Dry wt. basis)
Volatile solids	6.0
Chemical oxygen demand	5.0
Total Kjeldahl nitrogen	0.1
Oil and grease	0.15
Mercury	0.0001
Lead	0.005
Zinc	0.005

TVS (%) dry = 1.32 + 0.98 (COD %)

Recent Federal regulations called for the establishment of a "Standard Elutriate Test," which would enable the differentiation of the fraction of a sediment without potential effect from the other fractions which may have potential effects (EPA, 1973). The requirements are as follows:

> Dredged material will be considered unpolluted if it produces a standard elutriate in which the concentration of no major constituent is more than 1.5 times the concentration of the same constituent in the water from the proposed disposal site used for the testing. The "standard elutriate" is the supernatant resulting from the vigorous 30-minute shaking of 1 part bottom sediment with 4 parts water from the proposed disposal site followed by 1 hour of letting the mixture settle and appropriate filtration or centrifugation.

Such a procedure in principle does indeed represent a significant improvement over the analysis of gross concentrations in sediments, because the elutriate analysis at least points to a short term water quality effect. However, such a procedure presents tremendous difficulties in practice. At present, the most serious problem in establishing such criteria is the extreme difficulty in evaluating the validity of data from seawater studies. The analysis of trace metals in seawater generally requires a highly sophisticated and elaborate laboratory setup with meticulous cleaning procedures. Even so, the variation of data from one laboratory to another is enormous (Patterson, 1974). To create a new test such as the "Standard Elutriate Test" without thoroughly testing it prior to adoption would certainly create serious problems for the enforcement of regulations. The cost of setting up equipment to perform a meaningful study is generally beyond the reach of most laboratories.

In addition, the Standard Elutriate Test as outlined in the EPA guidelines does not take into consideration the possible changes of environmental variables which may alter the availability of toxicants and nutrients for biota. Therefore, in the absence of a more comprehensive indicator or experimental procedure, the gross analysis of sediment concentration will serve a vital function in evaluating the pollution status of sediments as well as the possible pollution potential of disposing such sediments into another aquatic environment.

In any particular geographical area, the baseline concentrations of most substances are probably equivalent to those from primary and secondary weathered minerals. The substances of concern probably exist largely within the mineral crystalline lattice. On the other hand, some of the inputs from land sources are probably adsorbed to charged particles, organic surfaces, and hydrous oxides of iron and manganese, or exist in soluble form in interstitial water. It is felt that pollutants which are not an inherent part of the mineral structure can pose potential short and long term water quality effects under different environmental conditions.

III. SEDIMENT COMPOSITIONS AND THEIR RELATION TO THE POTENTIAL EFFECTS OF DREDGING ACTIVITIES

The dredging operations and disposition of the dredged sediments into the open ocean, bays, estuaries, and inland waters has generated considerable concern for possible degradation of the water quality, especially the migration of trace metals, chlorinated hydrocarbons (chlorinated pesticides and polychlorinated biphenyls), and nutrients. The expected environmental consequences range all the way from "a temporary increase in turbidity during construction"(Army Engineer District Studies, New York, Philadelphia, and Honolulu, 1971), to "polluted material placed in deep waters at a more rapid rate than would result from natural processes" (Army Engineer District Studies, Buffalo, NY, 1972), to "loss of existing natural environment and disruption or loss of marine life in the area" (Army Engineer District Studies, Rock Island, Illinois, and New York, 1971 and 1972). In a recent report of the Corps of Engineers (Boyd, et al., 1972), the environmental impact associated with dredging is classified into two categories: direct effects on biological communities and indirect effects on biological activities. The indirect effects include alteration of the sediment-water interface with subsequent release of biostimulatory or toxic chemicals, and the creation of turbidity clouds. The environmental impacts associated with open water disposal are categorized as short-term and long-term effects, the short-term effects including creation of turbidity, sediment buildup and oxygen depletion; and the long-term effects including the possible presence of biostimulants and toxins, and possible release mechanisms after deposition.

The effects of dredging on water quality in the Pacific Northwest have been studied by the Environmental Protection Agency (O'Neal and Sceva, 1971); dredging equipment, soil disposal practices, and sediment characteristics were considered. The U.S. Army Engineer District (Buffalo, NY, 1972) conducted a pilot sediment removal program during which valuable data were compiled concerning the effects of sediment removal on water quality and aquatic life--flora and fauna. Biggs (1968) studied the environmental effects of overboard spoil disposal in the Chesapeake Bay. His results showed that measurable quantities of suspended sediment extended as far as 4 km from the disposal site. The author concluded that the spoil on the bottom did not remain within the limits of the disposal area, and that dissolved nutrients contained within the spoil sediment pore-water were probably released to the environment. Cronin (1971) studied the gross physical and biological effects of dredging operations in the Upper Chesapeake Bay and found a substantial increase of total phosphate and nitrogen in water. Most other studies of dredging operations on water quality were directed at the turbidity and oxygen depletion (Serruya, 1968-69; Cairns, 1967). Windom (1972) conducted laboratory and field studies to determine the effects of disposing polluted and nonpolluted sediments on salt marshes and on water quality, and concluded that until a significant variety of dredging situations have been studied, no generalized conclusion can be drawn on the water quality effects.

In the study of open water disposal, the main factors involved are the nature of the trace substances and nutrients present in the sediment and the possibility of their release. The environmental conditions of the receiving water such as pH, oxygen concentration, ionic strength, and concentrations of organic substances may well be the deciding factors in the fate of trace contaminants and nutrients upon deposition. The most serious contaminants present in sediments are heavy metals and chlorinated pesticides; polychlorinated biphenyls (PCB's) are also of importance. The sorption phenomena and possible release of these substances through mechanisms such as dissolution, ion exchange, complex formation, and many other factors are not well defined at present.

Trace Metals in Sediments

Extensive analyses of sediments for metal content have been carried out (Shaheen and Chantarasorn, 1971; Hauser and Fauth, 1972; Gross, et al., 1971; Horowitz, 1970; Kalinenko and Nevesskii, 1971; Yu and Lubchenko, 1970; Council on Environmental Quality, 1971; Landstrom, et al., 1967.) Hauser and Fauth (1972) verified the presence of higher concentrations of barium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, silver, and zinc in sediment. Mercury has received particular attention due to its transformation to the highly toxic methylmercury by benthic organisms (Suggs, et al., 1972; Fagerstrom and Zernelov, 1971; Jensen and Zernelov, 1969; SCCWRP, 1971).

Quantitative data on thirty metallic elements present in marine and lacustrine sediments have been presented by Landstrom (1967). In Southern California, extensive analyses of trace metals around major sewer outfalls have been carried out (Galloway, 1972). According to Jones (1972), the sources for these elements are accessory mineral sites, lithic fragments, surface coatings on the grains, and clay minerals. Sea water may also leach metals from volcanic rocks and the metals are then sorbed by the sediment (Suggs, et al., 1972; Fagerstrom and Zernelov, 1971). Zinc and other metals are also accumulated by the bottom fauna (Duke, et al., 1969; Phelps, et al., 1969; Hannerz, 1968).

Pesticides in Sediments

A large number of sediment analyses have shown the presence of pesticides, with the organochloro and organophosphorus ones representing the two largest families (Lyons and Soman, 1972; Svante and Berggren, 1970; Newland, 1969; Meyers, et al., 1970; Greve and Verschuuren, 1971). Many authors believe that once the pesticides are adsorbed by sediment particles they are not released to the environment, so that the sediments, in effect, remove pesticides from natural waters. This has been shown for aldrin (Leshinowsky, et al., 1970), toxaphene (Veth and Lee, 1971), and DDT (Graetz, et al., 1970).

Undecomposed pesticides in sediments may still act as insecticides (Veth and Lee, 1971); the microbial degradation of organophosphorus insecticides, such as parathion (Graetz, et al., 1970), has been reported; microbial attack of gamma-BHC and hydroxyatrazine has also been observed (Chesters and Lee).

Rowe, Carter, and Mason (1970) observed that the adsorption of dieldrin and endrin by bottom sediments is pH sensitive; the adsorption of endrin was also salinity-dependent. According to Chesters and Lee, the governing factors in pesticide adsorption by sediments is the pesticide concentration and the organic matter content of the sediment.

PCB's in Sediments

Although the presence of polychlorinated biphenyls (PCB's) in sediments had already been observed in 1967 (Svante and Berggren, 1970), systematic studies have been carried out only recently. Papers presented at a 1972 A.C.S. Symposium on PCB's (Tasler and Munson; Berg, et al.; Yates, et al.; Flotard and Veith; Nimmo, et al.) reported on the ubiquitous occurrence and distribution of polychlorinated biphenyls in the aquatic environment. Scientists of the Water Resources Division of the U.S. Geological Survey (Yates, et al., 1972) found concentrations up to 3 mg/kg in bottom sediments. E.P.A. researchers (Nimmo, et al., 1972) monitored the extensive presence of a PCB, Arochlor 1254, in Florida coastal sediments; they found that a chronic exposure to sublethal concentrations of the material caused necrosis of hepatic cells in fish, shrimp, and oysters.

Organic Material in Sediments

The sources of organic matter in sediment usually originate from atmospheric and riverine introduction of pollutants, industrial and domestic wastes, agricultural and mining runoffs, accidental spillages, decompositional debris from marine organisms, especially those bioresistant, metabolic end-products from natural biota. Furthermore, there are numerous forms of intermediates derived from the interactions among various decomposed products resulting from living organisms. These terrestial stable organic molecules can be treated as products at different levels and stages in the geochemical diagenetic process of simple bioorganic molecules (Yen and Sprang, 1972).

On the average, the organic contents in marine sediments are only a minor part of the composition. The organic carbon contents range from 0.1 to 10% (Rashid, 1969). However, regardless of their quantities, the organic molecules may be the crucial factors in controlling the fate of trace contaminants in marine sediments.

Organic molecules in marine sediments possess reactive functional group sites. The inorganic cations such as heavy metals can be coordinated to these sites to form stable linkages, and in this manner the marine sediments can take up metals, thus functioning as a sink. The exchange capacity of sediments is partly dependent on the organic component of the sediment.

The metal complexes and chelates thus formed could further coordinate inorganic anions at the apexes. Inorganic anions such as sulfate, chloride, phosphate, etc., could easily be attached or detached under variable redox conditions. In this fashion the transport or the migration of nutrition-important anions such as phosphate is regulated by the sediments.

The inorganic components in sediments behave as chromatographic substances. Upon contact the organic molecules could be either adsorbed or fractionated, precipitated, and eluted. In this fashion simple organic and inorganic molecules from the coastal and estuary waters could be adsorbed and released. Heavy metals can also be liberated from sediment to ocean waters; accordingly, the marine sediment in this sense can be a source for heavy metals, although this would only occur under special conditions.

Organic substances in sediments may consist of amino acids, pesticides, carbohydrates, polysaccharides, lipids, browning reaction products, alkaloids, humic acids, hydrocarbons, pigments, bitumens, and kerogens. In addition to the naturally occurring molecules, synthetic pollutants such as PCB's and spilled oil are also present. Portions of the organic matter may be refractory products from biological degradation which are no longer biodegradable.

Association of Fine Particulates and Trace Pollutants

Trace contaminants, metals pesticides, and PCB's are associated with and concentrated in the colloidal particle size fraction of recently-formed sediment (Chen, 1974). In fresh water, storm water, or wastewater effluent, hydrolyzed trace metals and organic matter can be adsorbed onto colloidal particles such as metal oxides and hydroxides, microbial detritus, clays, and macro molecular protein, and in some instances react chemically with colloid surface groups.

Particulates from input sources can be divided into two groups: settleable and nonsettleable. Upon entering estuarine water, pollutants in the settleable particulates may remain in the solid form and reach the floor of an estuary or harbor through sedimentation. They may remain associated with detrital materials or redissolve. Nonsettleables are of the size of colloidal particles, which range roughly from 0.1 to 1.0 micrometers. A portion of nonsettleable colloids can be accumulated in the sediment of harbor waters through the combined physicochemical forces of coagulation and sedimentation.

Interactions of Chemical Constituents in Sediment

An understanding of the sorption and release mechanisms of trace substances can only be achieved by considering the sediment as a dynamic system where the composition and geochemistry of the bulk materials vary through:

(a) diffusion of ions within the sediment
(b) reactions occurring in the interstitial (pore) water
(c) humic binding forces
(d) organic/inorganic complexes
(e) nutrient mobilization
(f) reactions at the sediment-water interface
(g) mobility of cations from the sediment
(h) water-sediment exchange reactions

Many authors have studied the composition and geochemistry of sediments in toto. So, while Mun and coworkers(1967) studied the inorganic components of sediments, Puey (1967) gave a detailed description of the organic materials present. A present-day sediment consists of inorganic clays, silts, and sands, organic substances from the slow degradation of biological materials, and man-produced materials, either adsorbed from water or deposited directly and incorporated (Army Engineer District, New York, n.d.). Large bacterial populations are also present (Esernoglou and Anthony, 1971), together with a diversity of benthic organisms (Cairns and Dickson, 1971), which are affected by the presence of industrial or municipal wastes. Some organisms such as tubified worms are positively affected (Wagner,1968), while the effect on Foraminifera is negative (Schafer, 1968).

This diversity makes the chemistry of sediments very complex. Numerous chemical characterizations of bottom deposits have been presented in the literature (Holt, et al., 1970; Grissinger and McDowell, 1970). A sediment presents a vertical variation in composition related to the physical structure and the redox conditions which can be monitored by color difference (Sanger and Gorham, 1971), or by measuring the nature and amounts of the gases adsorbed and released (Bean, 1969; Pamatmat and Fenton, 1968).

As already mentioned above, the composition and chemistry of sediments are the products of a series of individual events which have received specific attention and can be considered separately as follows:

1. Diffusion of Ions within the Sediment

The diffusion of ions in unconsolidated sediments is influenced by several environmental variables, such as redox potential, chemical interactions, and physical structure. Ion diffusion coefficients in marine sediments have been determined using radioactive isotopes (Duursma and Bosch, 1970). The rates range from one-half to one-twentieth of those applying to diffusion of ions and molecules in free solution, and may be predicted from the porosity and the path tortuosity of host sediments (Manheim, 1970).

2. Interstitial (Pore) Water

The chemistry of pore waters and the relationships with the sediments retaining them has been studied by Sharma (1970) for glaciomarine sediments of Southeast Alaska. The author observed that the total ionic concentration is generally less in interstitial water than in overlying water, and intermixing is negligible. Other authors (Presley, et al., 1967; Bischoff and Lung, 1971) confirmed Sharma's conclusions but found that some ions, and especially manganese, were more concentrated in the pore water. Dobbins (1970) further observed that cationic concentrations in interstitial water decreased with depth in estuarine sediments.

3. Humic Binding

The interaction of metallic ions with humic acid yields complexes comparable to the ones formed by EDTA (Koshi, et al., 1969). Iron, copper, zinc, and lead complexes have been identified (Sieburth, 1971), and the exchange capacity of the humic fraction has been found of the order of 2.5 meq/g (Rashid, 1969).

4. Organic/Inorganic Complexes and Nutrient Mobilization

The subject of nutrient (P,N) mobilization from sediments is of great interest because of its relation to eutrophication. Notwithstanding the numerous studies carried out, no agreement on the role of sediments has been reached. The function of sediment as a reservoir of nutrients for the overlying water has been affirmed by McKee and coworkers (1970); other researchers, on the other hand, have considered sediment only as a sink with respect to phosphorus (Holt, 1969; Kinimel and Ling, 1970; Shapiro, 1970; Committee on Nutrients in Water, 1970). The mechanism of phosphorus retention by sediments has also not been cleared; some authors believe that organisms (McKee, et al., 1970), or at least organic/inorganic complexes (Schindler, et al., 1971), are the primary concentrators; others have postulated a gel complex of hydrated iron oxide (Shukla, et al., 1971).

5. Reactions at the Sediment-Water Interface

The sediment-water interface is the site of oxidation-reduction reactions between dissolved oxygen and sediment components. Schindler and Honick (1971) monitored the redox potential at a sediment-water interface over a six-month period. Bouldin (1968) derived equations describing the diffusion of oxygen across the interface under steady and non-steady state conditions.

6. Mobility of Cations from the Sediment (Water-Sediment Exchange Reactions)

The mobility of cations, and especially of heavy metals, from sediments has a direct bearing on the environmental impact of dredge spoil disposal. The release of toxic elements by displaced sediments would make them hazardous to marine life (or human life, through the food chain) if disposed of in deep waters, and would pollute ground waters over a prolonged period of time if disposed of on land sites in contact with aquifers.

Lee (1970) assessed the possible factors involved in the exchange of elements and compounds between waters and sediments in a critical study. The exchange reactions were described as occurring under physical (hydrodynamic) control, chemical control, or biological control. The chemical aspect was also considered in detail by Carroll (1959).

Metals migrate within a sediment to oxidized or reduced zones according to the mobility and solubility of the respective ions. Thus Bonatti and coworkers (1971) found that Mn, Ni, Co, and La were concentrated in the upper oxidized zone (Eh + 100 mV) of a hemipelagic sediment, while Cr, V, and U concentrated in the lower reduced zone (Ed - 400 mV). Laboratory studies have shown that Cu, Fe, Mn, and Zn were released by sediment under anaerobic conditions, but not under aerobic ones (Chen and Yen, 1972). These results confirmed the finding by Mortimer (1971) that Fe and Mn may be released by sediment only when the oxygen concentration at the sediment-water interface falls below 1 or 2 mg/l.

The exchange of elements between sediments and water may be studied using radioactive tracers (Duke, et al., 1968; Kudo and Gloyna, 1971). Except for mercury, which may be released from sediments via biological transformation into methyl mercury (Fagerstrom and Zernelov, 1971; Jensen and Zernelov, 1969), the only elements found to exhibit a significant migration from sediments into overlying waters were Ca (Sharma, 1970; Presley, et al., 1967; Bischoff and Lung, 1971; Dobbins, 1970) and Mg (Monais, 1970), the latter in lesser degree; Lobchenko and Kaplin (1968) determined an exchange rate of Ca^{2+} by Cu^{2+} or Zn^{2+} of 1 - 1.7 meq/g.

The most extensive reviews of sediment chemistry in relation to their pollution potential have been those of Keeley and Engler (1974) and Lee and Plumb (1974). However, both reports conclude that no definitive predictor relationships of sediment chemistry and pollution capabilities under different environmental conditions are possible at present. Extensive research carried out by the Army Corps of Engineers Waterways Experiment Station and its contractors on dredged materials research may soon be able to provide some definitive answers on the relationships of sediment chemistry and potential impacts of dredging activities.

IV. METHODOLOGY FOR SEDIMENT ANALYSIS

Analysis of sediment is substantially different from that of water and sewage. The U.S. Environmental Protection Agency has published a manual for the analysis of freshwater sediments (December, 1969); however, no publication can be found for the complete chemical analysis of marine sediments. The following section is a summary of experimental procedures which have been modified after "Standard Methods" (1971) and the EPA manual on freshwater sediment, adopted for the analysis of marine sediments.

A. Moisture Content

Place a known weight of sediment in an aluminum foil dish in an oven at 105°C for 24 hours or longer, until constant weight is obtained. The moisture content is expressed as:

$$\% \text{ moisture content} = \frac{\text{wet wt.} - \text{dried wt.}}{\text{wet weight}} \times 100$$

B. Volatile Solids Content

Dry a known weight of sample in a crucible in an oven at 103°C for one hour and weight it. Then ignite the dried sample in a muffle furnace at 550°C for 15 minutes and weigh again.

$$\text{mg/kg volatile solids} = \frac{\text{dry wt.} - \text{residue}}{\text{dry weight}} \times 10^6$$

C. Oil and Grease Content

Extract a known weight of sediment with petroleum ether. Separate the mixture and transfer the extract to a flask of known weight. The extract is then evaporated on an oil bath at 70°C until constant weight is obtained.

$$\text{mg/kg oil and grease} = \frac{\text{g residue}}{\text{g dried weight}} \times 10^6$$

D. Immediate Oxygen Demand

Measure 2 - 3 g sample in a 300 ml DO bottle and fill up with distilled water. Add 2 ml manganese sulfate solution followed by 2 ml alkali-iodide-azide reagent well below the surface of the liquid and stopper it. After 15 minutes, add 2.0 ml conc. H_2SO_4 and immediately titrate with 0.0375 N sodium thiosulfate solution to a pale straw color. Use starch as indicator. Prepare a blank and treat it the same way.

$$\text{mg/kg IOD} = \frac{(a-b) \times 0.0375 \times 8000}{\text{g dried weight}}$$

a: ml sodium thiosulfate solution used for sample
b: ml sodium thiosulfate solution used for blank

E. Chemical Oxygen Demand

Weigh approximately one gram of sediment in a round-bottom flask; add 50 ml distilled water, 1 g of $HgSO_4$, 25 ml 0.250 N potassium dichromate solution, and 75 ml conc. H_2SO_4. Reflux the mixture for 2 hours, cool and dilute to about 350 ml. Titrate the excess dichromate with ferrous ammonium sulfate, using ferrion as indicator. Reflux in the same manner with blank consisting of 50 ml distilled water and reagents.

$$\text{mg/kg COD} = \frac{(a - b)\, c \times 8000}{\text{g dried wt.}}$$

a: ml ferrous ammonium sulfate solution used for sample
b: ml ferrous ammonium sulfate solution used for blank
c: normality of ferrous ammonium sulfate solution

F. Nitrogen

Weigh about 1.5 g sample in a Kjeldahl flask. Add 180 ml distilled water and 15 ml phosphoric buffer solution. Distill into a flask containing 30 ml boric acid until 120 ml is collected. Titrate the solution with 0.02 N H_2SO_4 to determine the ammonia nitrogen content. Add 30 ml digestion reagent to the remaining portion and heat under a hood for about 30 minutes. Cool and dilute to 180 ml. Neutralize with sodium hydroxide-sodium thiosulfate reagent. Distill and collect 120 ml distillate into a flask containing 30 ml boric acid. Titrate with

0.02 N H_2SO_4 to determine the organic nitrogen content. Carry a blank determination on distilled water and reagents.

$$mg/kg\ N = \frac{(a - b)\ c \times 14{,}000}{g\ dried\ wt.}$$

a: ml H_2SO_4 solution used for sample
b: ml H_2SO_4 solution used for blank
c: normality of H_2SO_4 solution

G. Total Phosphorus

1. Digestion

Place about 1 g of well-mixed sample into a Teflon beaker. Treat it with 4 - 5 drops of HF, 5 ml HNO_3, and 3 ml $HClO_4$ solution. Digest the mixture on a hot plate until solution is almost dry. Cool and add 20 ml of distilled water, then centrifuge the digested sample. Collect the supernatant in a 250 ml Teflon beaker. Adjust pH to 0.2 - 0.3 with 6 N HNO_3 and pass through a cation exchange resin, such as ANGC-243 (manufactured by IONAC Chem. Co.). Collect the eluate in a beaker, adjusting the flow rate to no greater than 5 ml per minute. After passing the liquid through the column three times, the solution is then neutralized with 6 N NaOH and 6 N HNO_3 to pH 7. Dilute the solution to exactly 200 ml. Regenerate the ion exchange resin with 1:1 HCl and wash with distilled water.

2. Determination

Pipet 50 ml of digested sample. Add 2.0 ml molybdate acid solution and mix by swirling. Add 2.0 ml sulfonic acid solution and mix again. After exactly five minutes, measure the absorbance vs. the blank at a wave length of 690 nm. Prepare a calibration curve by using a suitable volume of standard phosphate solution.

H. Sulfide (Total)

A titrimetric method is used for sulfide determination. A 1-liter reaction flask and two 250 ml absorption flasks are necessary. The procedure is:

1. Measure 5 ml zinc acetate and 95 ml distilled water into each of the two absorption flasks. Connect the reaction flask and two absorption flasks in a series and purge the system with N_2 gas for at least 2 minutes. Transfer about 5 g of sediment into the reaction flask and add 500 ml distilled water with complete mixing.

2. Acidify the sample with 10 ml conc. H_2SO_4 and replace the prepared 2-hole stopper tightly. Pass N_2 through the sample for one hour.

3. Add 10 ml of iodine solution and 2.5 ml conc. HCl to each of the absorption flasks; stopper, and shake to mix thoroughly.

4. Transfer contents of both flasks to a 500 ml flask and back-titrate with 0.025 N sodium thiosulfate titrant, using starch solution as indicator. Run a blank using the same reagents.

$$\text{mg/kg S} = \frac{(\text{ml iodine} - \text{ml } Na_2S_2O_3) \times 400}{\text{g dry weight}}$$

I. Total Organic Carbon

Weigh about 5 grams of sediment sample in a 150 ml beaker. Adjust pH below 2 by adding 1:1 HCl; then bubble N_2 through the sample for 10 minutes. Dry the sample in the beaker for 24 hours in the temperature range of 70^0 to 100^0C. Weigh a portion of 0.5 - 1 g of dry sample into a special TOC crucible. Determine TOC content using LECO TC-12 Automatic Carbon Determinator.

J. Metal Analysis

1. Sample preparation

a. Digestion (except Hg and As):

Weigh about 1 g of sediment into a platinum crucible. Add 5 ml HF and 30 ml of 1:1 HNO_3. Cover with aluminum foil and digest on a sand bath until the remaining residue is about 3 ml. Add 20 ml of conc. HNO_3 and continue the digestion until the solution becomes clear. Cool; filter, and dilute to 100 ml.

b. Digestion for mercury:

Weigh about 5 g of well-mixed sample into an Erlenmeyer flask. Treat it with 20 ml conc. HNO_3 and 15 ml 2% $KMnO_4$. Seal the flask and heat it in a constant-temperature water bath at 70^0C for 12 hours. Allow the flask to cool and then centrifuge the digested sample. Collect the supernatant in a 100 ml volummetric flask and add 1:1 solution to the mark.

c. Digestion for arsenic:

Weigh an appropriate amount of well-mixed wet sample (from 0.5 - 5.0 g of sediment) into a 250 ml round-bottom digestion flask with two necks, and add 40 ml of conc. nitric acid, 5 ml of conc. sulfuric acid, plus small glass beads as boiling stones. The flask is heated on an electric heating mantle at a temperature of about $100^{\circ}C$ under a fume hood. Digest it in this reflex system overnight, until the solution is clear, or stop the condenser cooling water and increase the flask heat to fume off all the nitric acid--until strong fumes of sulfuric acid are evolved. After cooling under the hood, use distilled water to wash the sample into an Erlenmeyer flask having a 24/40 ground joint flask. The final volume of washed sample must be about 35 ml. Acidify the sample with 5 ml conc. HCl; add successively, with thorough mixing after each addition, 2 ml 15% KI solution and 8 drops, 0.4 of 20% $SnCl_2$ reagent. Allow 15 minutes for reduction of arsenic to the trivalent state, then follow the standard SDDC method for the generation of arsine.

2. Analytical Methods

Basically three different methods were used for this study according to the suitability of the method for different metal analyses.

1. Atomic absorption method for the analysis of Cd, Cr, Cu, Fe, Pb, Mn, Ni, and Zn.

2. Flameless Atomic Absorption method for Hg analysis.

3. Silver Diethyl-dithiocarbamate method for As analysis.

K. Chlorinated Pesticides and Polychlorinated Biphenyls (PCB's) (Official Method of Analysis of the Association of Analytical Chemists, 1970; Reynolds, 1969; Goerlitz and Law, 1971; Richard and Kirk-Othmer, 1964; Armur and Burke, 1970; Snyder and Reinert, 1971)

The overall method includes sample extraction, cleanup, partitioning concentration, injection to the gas chromatographic columns, identification and calculation of chlorinated pesticides and PCB's peaks from the gas chromatograms.

Reagents:

1. Nanograde Hexane
2. Nanograde Ethyl Ether
3. Pesticide Quality Petroleum Ether

4. Pesticide Quality Acetonitrile
5. Florisil 60--100 mesh stored at 130^{o}C
6. Hg--Analytical Reagent Grade
7. Anhydrous Sodium Sulfate Granular (Baker)
8. Celite
9. KOH--Analytical Reagent Grade
10. Ethanol

Procedure:

1. Determine moisture content of sediment on separate sample.

2. Weigh 15.0 g sediment as received.

3. Extract 1 hour with 300 ml of a 3:1 mixture of trile: water using a reciprocating shaker. Include sample water in ratio.

4. Filter through Whatman #4 using 9 cm Buchner funnel filter, adding 5 g Celite as filter aid.

5. Rinse the sample with 20 ml acetonitrile and filter it as in step 4.

6. Transfer the filtrate to 1000 ml separatory funnel containing the following: 50 ml petroleum ether and 10 ml NaCl saturated solution.

7. Shake the mixture for one minute, then add 200 ml water and shake again for 30 seconds. Collect the aqueous phase in a second separatory funnel and the solvent phase in a 250 ml Erlenmeyer flask. Repeat extraction of the aqueous phase using 50 ml petroleum ether.

8. Discard the aqueous phase and combine the petroleum ether extracts into K.D. evaporator and evaporate on steam bath to cs. 7 ml.

9. Prepare a 400 x 20 mm column with 15 g acitvated florisil (60/100 mesh) topped with 15 g anhydrous sodium sulfate. Wash with 70 ml petroleum ether. When petroleum ether wash sinks through the top surface of sodium sulfate, add the extract and immediately begin eluting with 175 ml 100% petroleum ether. Change receiver, discarding initial wash.

10. Add 100 ml 6% ethyl ether in petroleum ether when previous elution fluid just touches the top surface of anhydrous Na_2SO_4 surface; change receivers.

11. Add 150 ml 15% ethyl ether; petroleum ether (15 + 85) when elution fluid sinks and collect in a third receiver.

12. Evaporate each eluate to 10 ml in K.D. evaporator.

13. The eluates are run separately on a gas chromatograph equipped with a Ni^{63} electron capture detector. The columns were 6 feet long and ¼ inch I.D. packed with 5% DC-200; 7.5% QF-1 and 1.5% OV-17; 1.95 QF-1. All columns were preconditioned at 250°C with flow of N_2 gas in a few mls/minutes for 36 hours.

PCB's and most DDE are recovered in 0% ethyl ether fraction. Most organochlorine compounds are recovered in 6% fraction. Endrin and Dieldrin are recovered in 15% ethyl ether and petroleum ether fraction. If sulfur is found to be present in large amounts and interfering with determinations of other components, the extract is treated with mercury to form mercury sulfide for sulfur removal.

In the determination of PCB's and DDE, if some extra unknown interfering peaks are observed in 0% ethyl ether, petroleum ether function, the 0% extract is further treated with Dehydrohalogenation reagent. Chemical conversion and breakdown of some of the interference to their corresponding low boiling points takes place while PCB's remain unchanged. DDE is also unaffected.

V. SEDIMENT DISTRIBUTION OF POLLUTIONAL PARAMETERS IN SAN PEDRO BASIN AND LOS ANGELES-LONG BEACH HARBORS

The sediment compositions of Southern California coastal waters have been previously reported (SCCWRP, 1973; Galloway, 1972; Bruland, 1974). Studies by Galloway (1972) show that most trace elements, with the exception of iron, manganese, and cobalt, occur in substantially higher concentrations in the proximity of sewer outfalls, even though the accumulation in the sediments is estimated to be around 10 to 15% of the total input (Hendricks and Young, 1974). Bruland (1974) studied the anthropogenic fluxes of Pb, Cr, Cd, Zn, Cu, Ag, V, and Mo into the sediments of the San Pedro, Santa Monica, and Santa Barbara Basins and found significant contributions from aerial fallout, storm and river runoff, and sewage input. Also, quantitative data on the sources of input, and models of pollutant transport have been more extensively studied than most other coastal waters adjacent to population centers. However, little information is available on the sediment compositions of harbor waters and their relationship to the pollution of adjacent ocean waters.

Baseline sediment compositions on the Los Angeles Harbor and the San Pedro Basin were studied for three purposes: (1) to evaluate the natural background sediment composition of the San Pedro Basin; (2) to assess the potential enrichment factors if the dredged sediment is redeposited in San Pedro Channel (long a dump site for industrial wastes); and (3) to identify the major sources of pollutant inputs into the channel and their mode of transport.

In this study, three types of core samples were used. Box cores were used for obtaining samples in San Pedro Basin. Grab samplers were used in most surface samples for Los Angeles Harbor, and drilling rigs were used to obtain deep sediments up to 40 feet in depth in the proposed Liquefied Natural Gas (LNG) route.

Each sample was analyzed for roughly 35 parameters. It is fully realized that not all of these parameters have significance in determining pollution potentials of sediments. This is especially true for some of the conventional parameters used in water and wastewater characterizations.

San Pedro Basin

A total of 24 box cores were collected in San Pedro Basin between Los Angeles-Long Beach Harbor and Santa Catalina Island. In addition, five box cores were collected beyond Catalina Island. Each core sample was subdivided into several sections, depending on the length of the core. In general, samples were subsectioned according to the length: 0 - 2", 3 - 6", 7 - 12", and 1 to 2 feet. Box cores were collected from the Velero IV by the personnel of the Harbor Environmental Projects of the Allan Hancock Foundation at USC under the leadership of Dr. Dorothy Soule and Mr. Mikihiko Oguri.

From the data presented in Figures 1 to 9, a list of approximate natural background levels of trace metals in San Pedro Basin can be established. These are shown in Table I.

It should be realized that most sediments of San Pedro Basin are substantially higher than the values presented in the table. In addition, the so-called natural background levels are not uniform throughout the area. It simply represents the lowest concentration that can be found. Another estimate may be adduced from the natural rock and soil compositions in the drainage areas producing the surface runoff to the basins. In Figures 3 and 8, the concentrations of chromium and nickel in the stations beyond Catalina Island are found to be substantially higher than most of the other sediments studied. The geological formations or other problems involved in the sampling process rather than pollution probably account for these abnormally high concentrations in such areas.

In Figures 10 to 17, we have tried to construct some concentration contours of trace metals based on the data obtained. In constructing such isoconcentration lines, both concentrations from sediment analysis and water depth are considered. It should be fully realized that no rigorous mathematical model was employed. The intuition and personal judgement of the authors, using the data available, was the main method used. Therefore, no absolute accuracy is implied in these concentration contours.

In Figures 18 to 25, the general characteristics of the sediments are presented. All the sediments analyzed fall into the category of stable decomposed organics as classified by Ballinger and McKee (1971). Immediate oxygen demand is generally low in comparison with more active decomposing sediment and Kjeldahl nitrogen is almost equivalent to organic nitrogen in each case. This indicates that most of the nitrogen in these sediments is tied up with refractory organics with little possibility of further decomposition.

The distribution patterns of chlorinated hydrocarbons such as chlorinated pesticides and polychlorinated biphenyls are significantly different from those of trace metals. Since chlorinated hydrocarbons are not the natural constituents of sediment, their appearance indicates the influence of man's activities. The distribution of total DDT as shown in Figure 31 indicates the predominant influence of the sewer outfall; however, the input from the Los Angeles-Long Beach Harbors cannot be ruled out. The distribution of PCB's and Dieldrin shows that the contribution from White's Point sewer outfall may be small in comparison with those from the harbor complexes. This is not out of the ordinary, since the harbor complex is the receptacle of many industrial wastewaters.

TABLE I

NATURAL BACKGROUND LEVELS OF TRACE METALS IN SAN PEDRO CHANNEL

Element	Natural Background Level (mg/kg)
As	1 - 1.5
Cd	1 - 1.5
Cr	20 - 30
Cu	5 - 10
Fe	12,000 - 15,000
Pb	20 - 25
Hg	0.025 - 0.050
Ni	15 - 20
Zn	30 - 35

Los Angeles-Long Beach Harbors

More than forty sampling stations inside the harbor complex were selected. Figures 37 and 38 show the locations of these sampling points. Grab samples were collected from the Golden West by the personnel of the Harbor Environmental Projects of the Allan Hancock Foundation. The results of the sediment analysis are shown in Tables 2 to 4. In many cases, stations were sampled more than once to observe the effects of bottom scouring, circulation, and sediment transport during the elapsed period. Even though replicate analyses have shown narrow ranges of analytical results, substantial differences in chemical compositions were shown for the sediments collected about one month apart. The slight variations in the locations of the sampling points may account for the major part of the difference, due to the non-homogeneity of the surface sediments.

Sediment samples from sampling stations shown in Figure 38 were obtained quite close to the bank instead of the midchannel. The relative intensity of contamination of the surface sediments in the harbor complex is shown in Figure 39. The pollution status of harbor sediments is divided into a relative scale of 10, with 1 the most contaminated and 10 the least polluted. The average chemical compositions are shown in Table 5. The ranking was based mainly on the content of total organic carbon and a few toxic metals such as mercury, zinc, and cadmium. The reason for using total organic carbon as a major parameter in determining the pollutional status is the linear relationship of total organic carbon to other pollutional parameters. Even though the harbor sediments in general contain less TOC than the surface sediments of San Pedro Basin, the harbor sediments generally contain substantially higher values of immediate oxygen demand. The other noticeable difference is the PCB content. While the San Pedro Basin contains relatively low concentrations of PCB 1254 and 1260, and no 1242, the harbor surface sediments contain high concentrations of all PCB's.

Proposed Route for the Transport of LNG in Los Angeles Harbor

Sediment samples from the proposed LNG route were collected by Dames and Moore, environmental consultants, using drilling rigs. Each core was subsectioned at the interval of 3 feet and homogenized prior to analysis. The positions of corings are shown in Figure 38. Particle size distributions are listed in Table 6. Each core was divided into many sections, each at 3 to 5 feet, depending on the property of the sediment. The surface sediment of each core, i.e. the first column of each core shown in Table 6, was analyzed for physical and chemical characteristics which are tabulated from Tables 7 to 9. Most of the analytical results from these sediments cannot be compared with those of grab samples, because grab samples collect the top few inches of sediment while the samples from piston cores have been homogenized from the top 3 feet. Since the surface sediments are the most contaminated, the homogenized samples are in effect diluted many times by the subsurface sediments which are less contaminated. Therefore, these data are not used in zoning the pollution status of the harbor complex.

The profiles of pollutants in the surface sediments are shown in Figures 40 to 42. It is obvious that the concentrations of pollutants decrease rapidly from Station I, which is close to the Terminal Island Sewage Treatment Plant, and increase again toward the breakwater region. Around the sewer outfall, most of the sediments are close to silty clay, and around the breakwater area, mostly sandy silt. The middle portion contains mostly silty sand. The particle size distribution may partially account for the levels of pollutants in the sediment.

Sediment Characteristics

No effort has been made to locate the specific associations of pollutants in the sediments; however, many interesting interrelationships of pollutional parameters can be found from the results of chemical analysis. This is especially true for the linear relationship exhibited by trace metals and total organic carbon, total volatile solids, or sulfide and trace metals. Trace organics such as chlorinated pesticides and polychlorinated biphenyls show little relationship to other parameters even though sediment transport and the fates of particulates seem to be the predominant factors affecting the distribution of pollutants. No effort was made to determine the grain size distribution of sediments in the San Pedro Basin and surface sediments of the harbor complex.

From the depth variations of most parameters, it seems relatively safe to conclude that input from man's activities has apparently altered the sediment characteristics--even in the deep ocean, though such types of influence are generally deemed to be minimal.

The concentration of trace metals in the channel transects are closely related to other pollutional parameters such as COD, TOC, TVS, and sulfide. The most interesting part is the linear relationship of metal concentration vs. water depth. Such a relationship implies the transport of fine grain sediment from land sources into the deep channel. Since the background levels around the harbor entrance are similar to those of natural sediment, it is reasonable to assume that a combination of "slumping" and slow settling of solids from the L.A. County sewer outfall, as well as adsorption by organic matters and clay particles of pollutants out of solution, is a major source of pollutant transport in the San Pedro Channel. While the total organic carbon (TOC) of the Los Angeles-Long Beach Harbor sediment is generally below 2%, the TOC in the San Pedro Channel generally ranges from 2 to 4 %, both on a dry weight basis. Analysis of organic components of the surface sediments of the harbor complex and San Pedro Basin indicates that the ocean sediments contain more stable organic components such as humic substances, whereas harbor sediment contains a higher fraction of fulvic acids.

Since most pollutants entering the sediment are associated with particulates in one way or another, their position in the sediment can probably be classified into several functional groups: sorbed on the surface or particulate matter; bound in fulvic and humic materials; precipitated as metal sulfide; attached to an oxide coating; sorbed on the exchange sites of clay minerals; or incorporated in the detrital organic or mineral phase. The major fraction within the crystalline lattice of mineral or natural sediment will probably not be released upon disposal. Changes in redox, pH, or composition of solution media probably bring about changes in the availability of trace substances. However, no definitive information can be found.

VI. SUMMARY AND CONCLUSIONS

With the exception of very few localities, most surface sediments in the Los Angeles-Long Beach Harbors and San Pedro Basin are grossly contaminated. The fate of these substances in the sediments and their long-term effects are not well understood at present. The question of whether sediments act as sink or as a source of pollutants may depend greatly on the changes of environmental variables. There are very few remedies available to undo the pollution of the past, as the selective removal of pollutants from sediments is almost impossible. Therefore, emphasis should be placed on prevention of these types of irreversible processes of pollution.

The sediments of San Pedro Basin are almost as polluted as those of the Los Angeles-Long Beach Harbors. In addition to the practice of ocean dumping of industrial wastes within the study area, the sewage discharge from White's Point may account for a substantial amount of pollutants. The past practice of designing sewer outfalls for the diffusion, dilution, and dispersion of sewage might work well for dissolved substances; however, such a practice may not be very effective for the problems associated with particulates. The sediment transport processes may concentrate pollutants in the deep channel and may reverse the planned function of ocean outfall to disperse the pollutants. The ecological consequences of accumulating contaminants in the deep basin cannot be properly evaluated at present, because little information is available on the effects of these pollutants on the biota in the ocean bottom.

Data from this study show that the Los Angeles County Sanitation District sewer outfall at White's Point has been the major source of trace metals and chlorinated pesticides such as DDT, while the harbor complex contributes more of the polychlorinated biphenyls.

In many parts of the Los Angeles Harbor, which is relatively contaminated in comparison with the neighboring harbor, the most effective way (and perhaps the only way) of removing pollutants from the ecological system seems to be the excavation of sediments with proper disposal or productive usage of dredged materials after treatment. Ocean disposal of these sediments will probably add to the heavy accumulation of pollutants on the ocean bottom. Ocean disposal should be allowed if evidence shows that such disposal practice causes no harmful ecological impact.

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FIGURE 1

Distribution of Arsenic in the Sediments of San Pedro Channel (mg/kg dry weight)

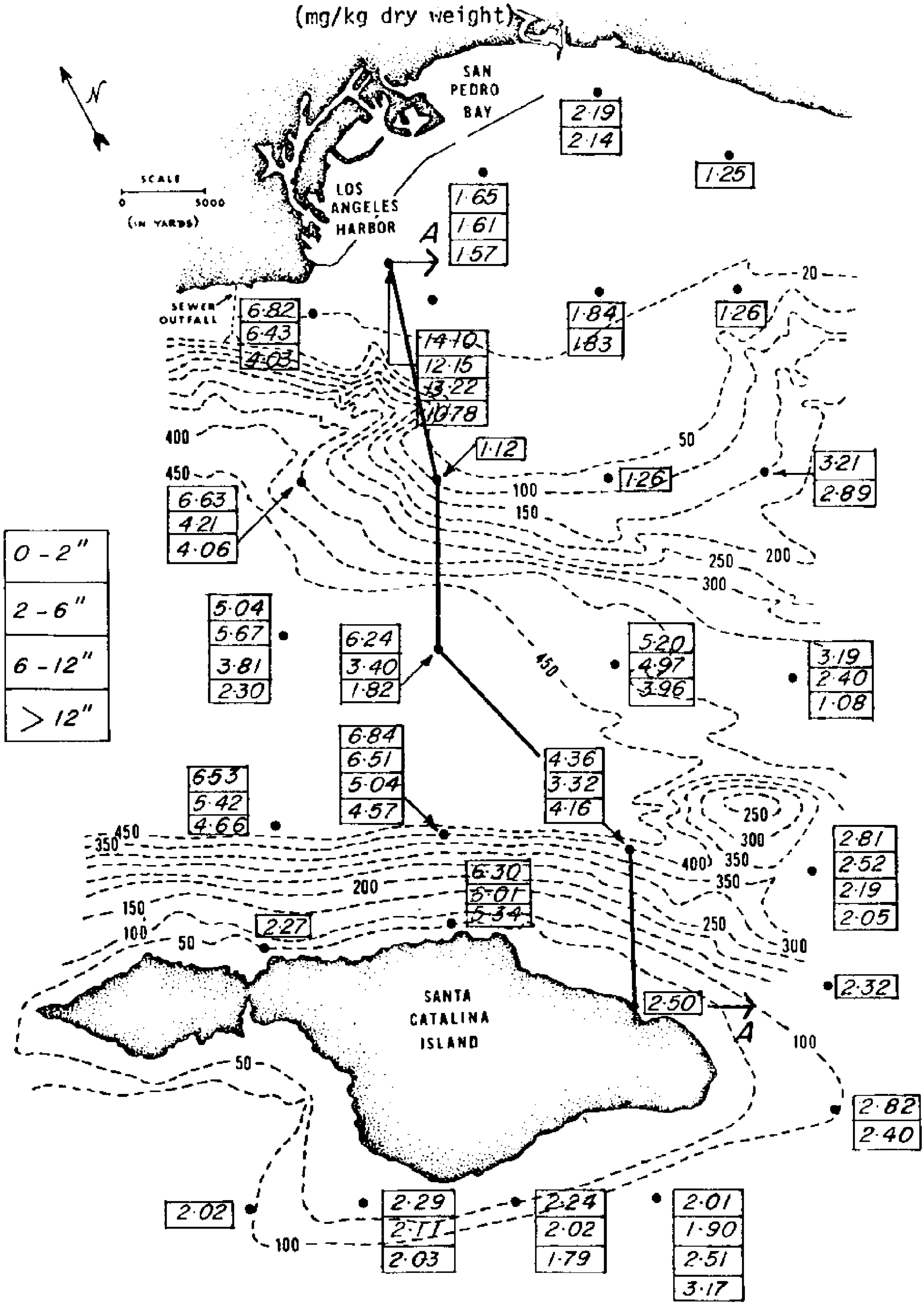


FIGURE 2

Distribution of Cadmium in the Sediments of San Pedro Channel (mg/kg dry weight)

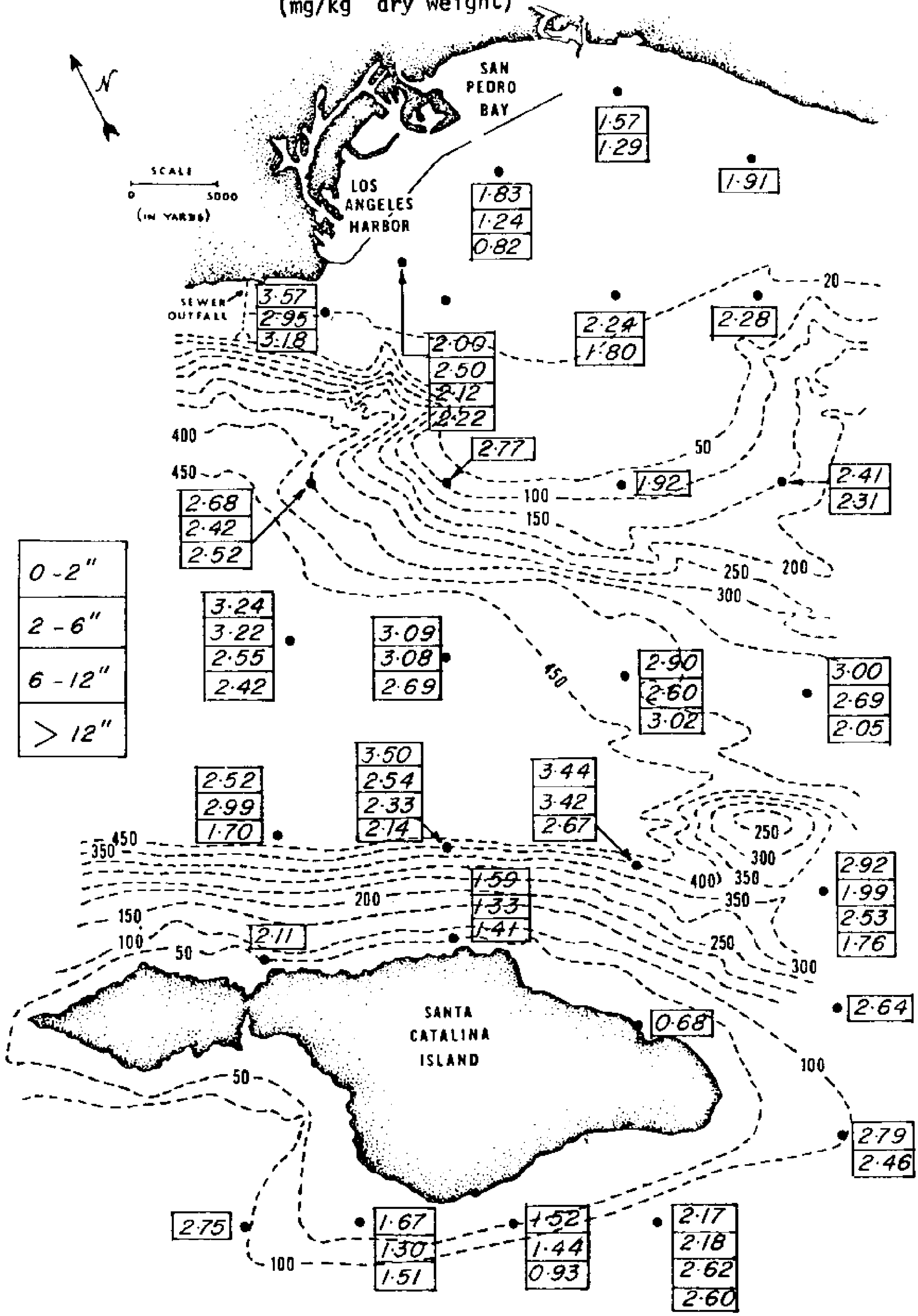


FIGURE 3

Distribution of Chromium in the Sediments of San Pedro Channel

(mg/kg dry weight)

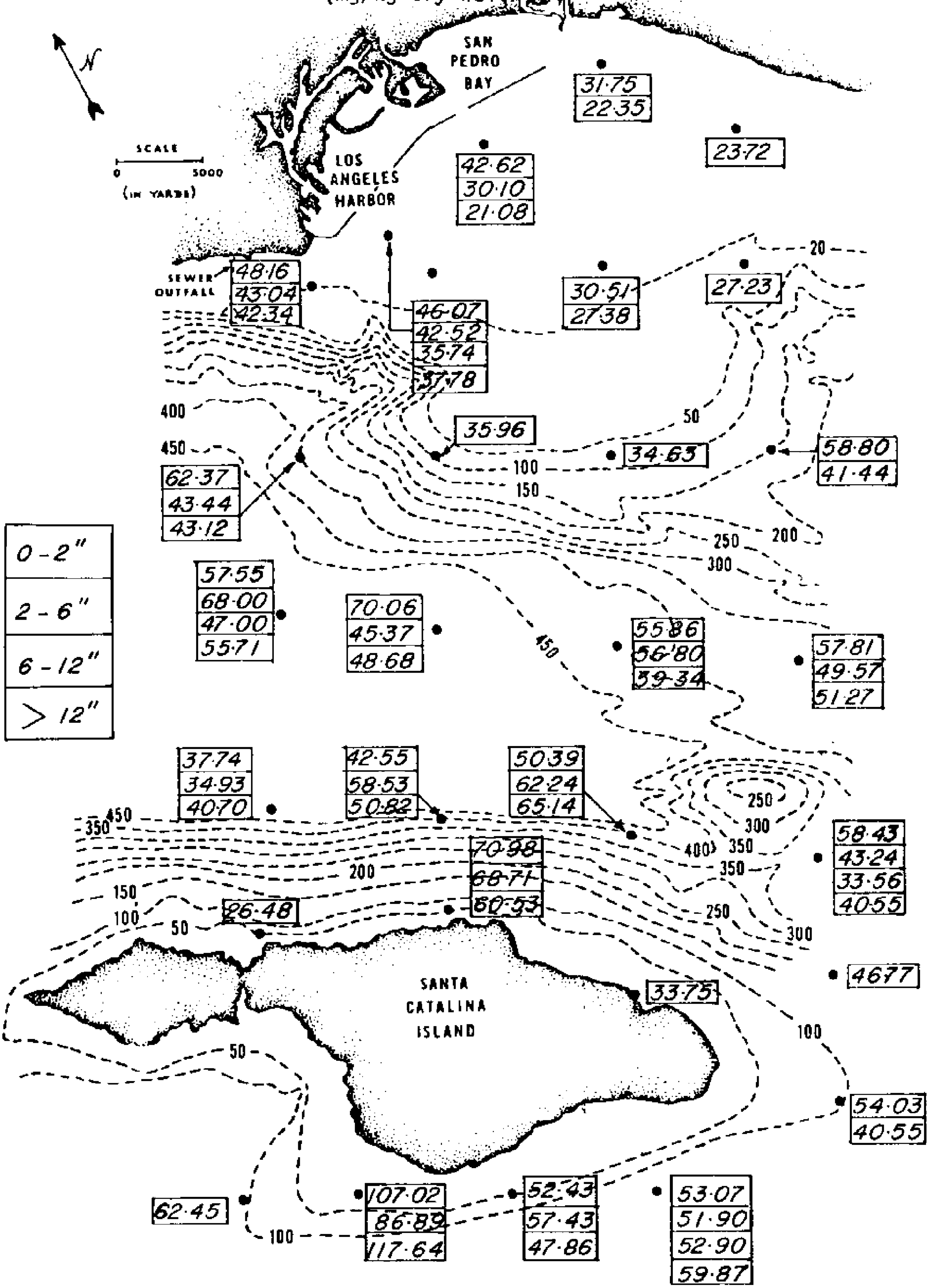


FIGURE 4

Distribution of Copper in the Sediments of San Pedro Channel

(mg/kg dry weight)

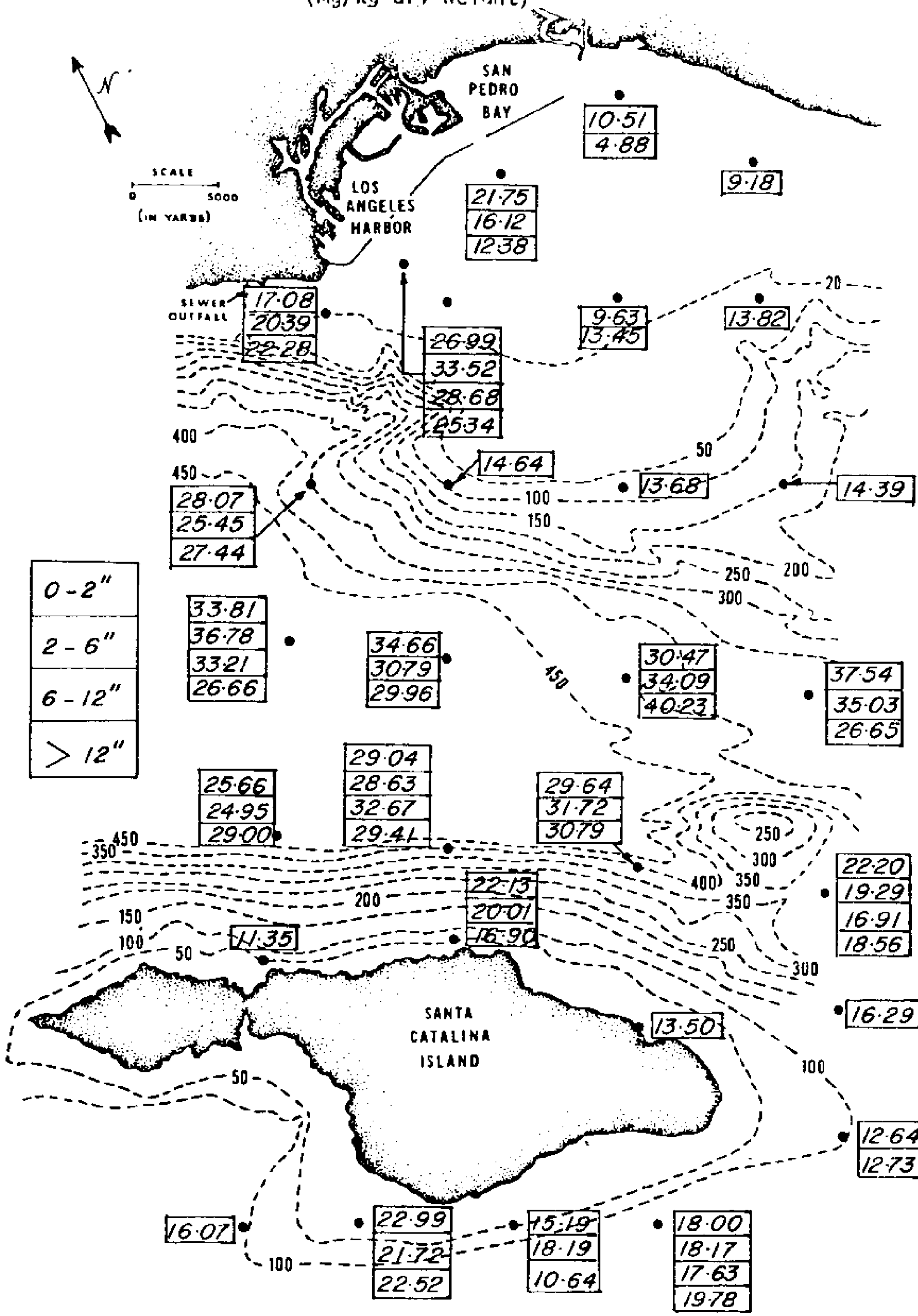


FIGURE 5

Distribution of Iron in the Sediments of San Pedro Channel

(mg/kg dry weight)

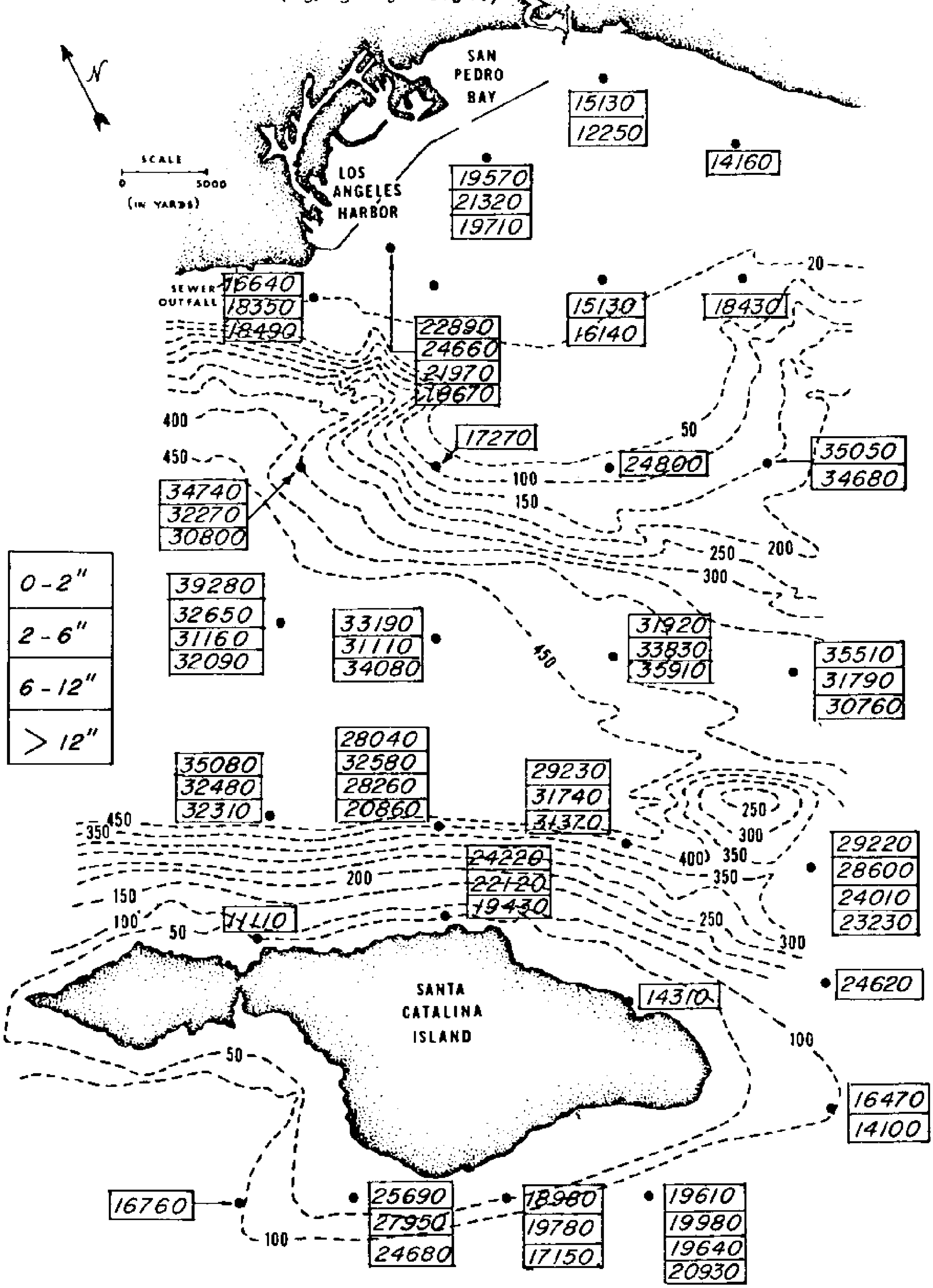


FIGURE 6

Distribution of Lead in the Sediments of San Pedro Channel

(mg/kg dry weight)

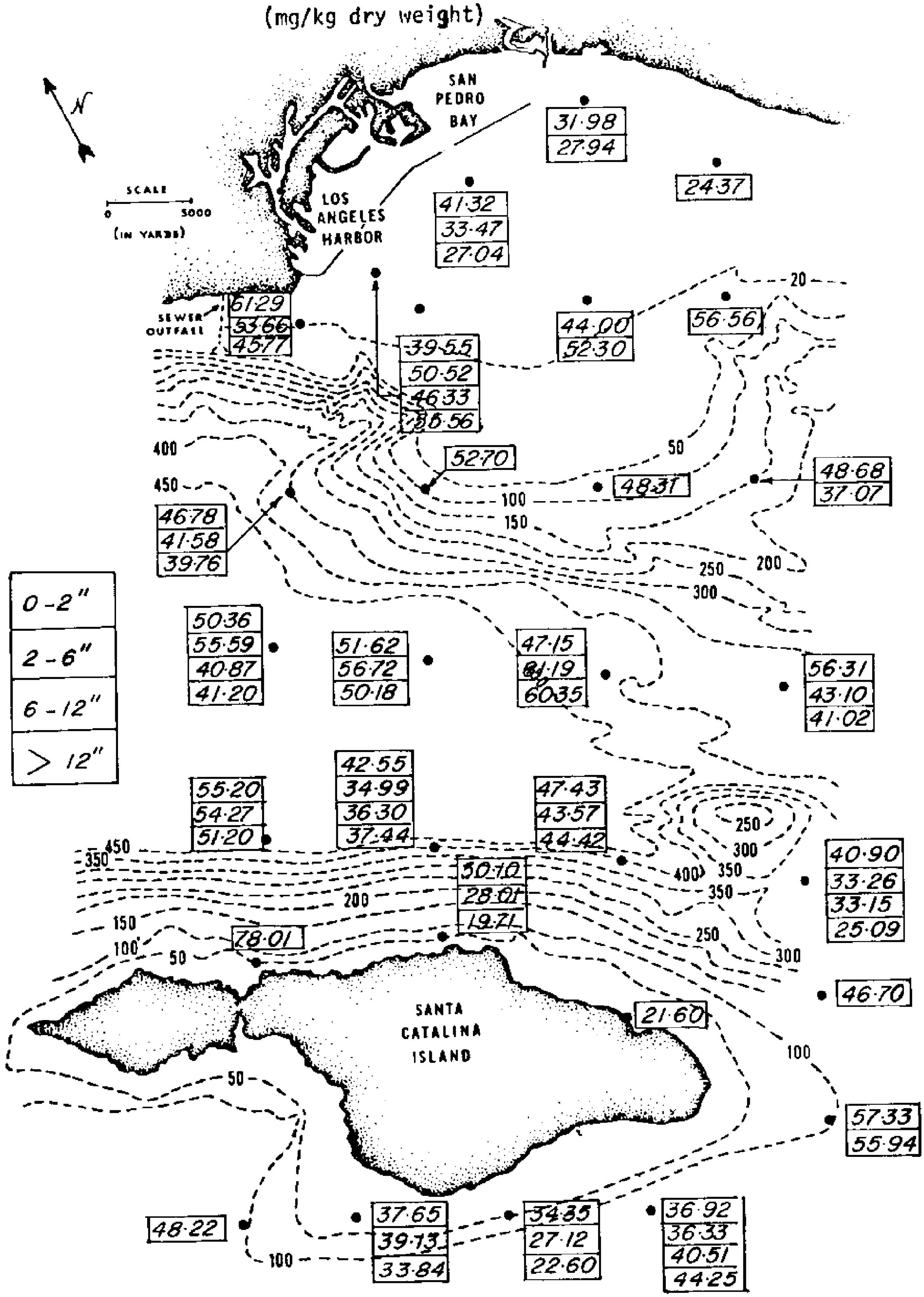


FIGURE 7

Distribution of Mercury in the Sediments of San Pedro Channel

(mg/kg dry weight)

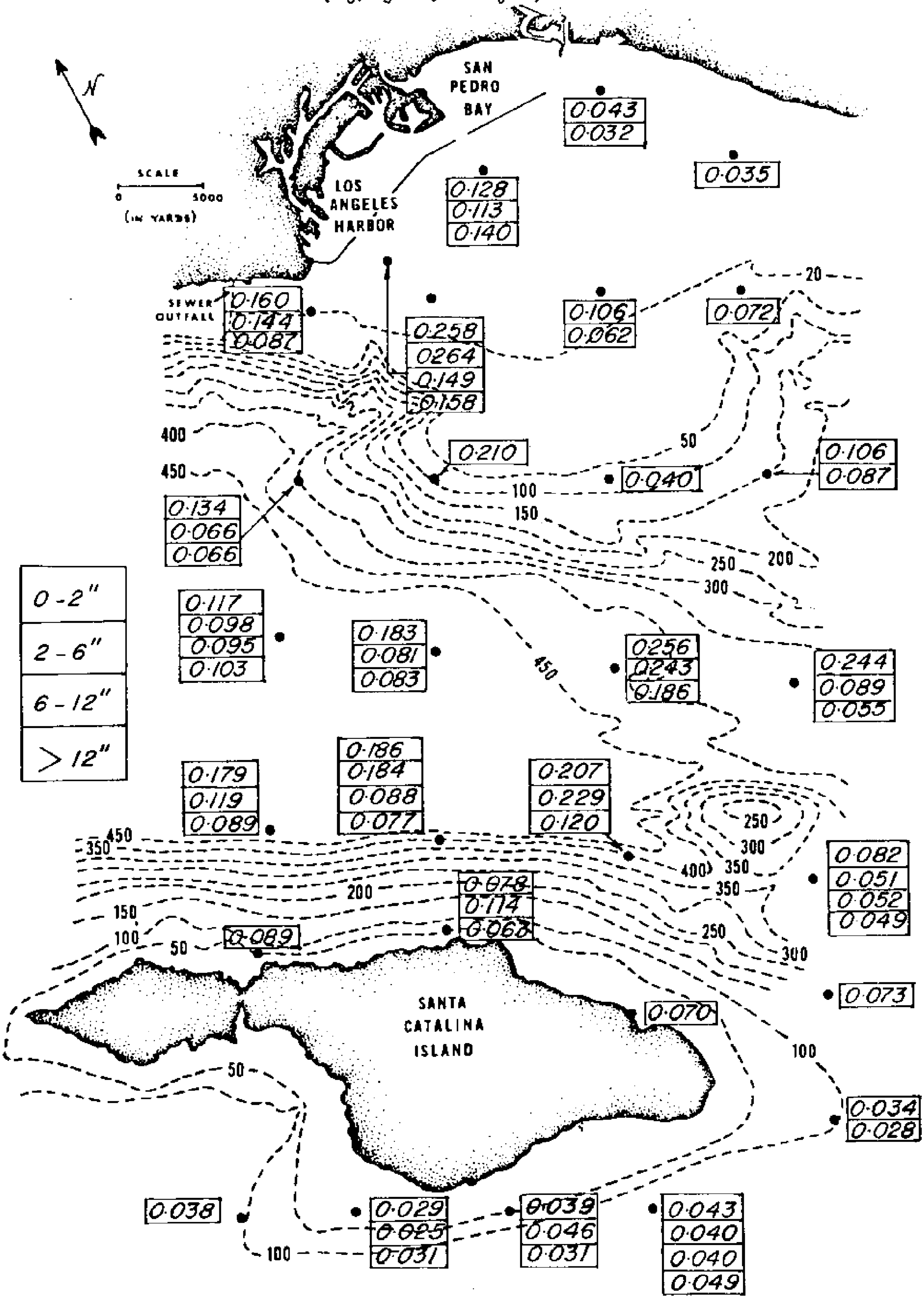


FIGURE 8

Distribution of Nickel in the Sediments of San Pedro Channel (mg/kg dry weight)

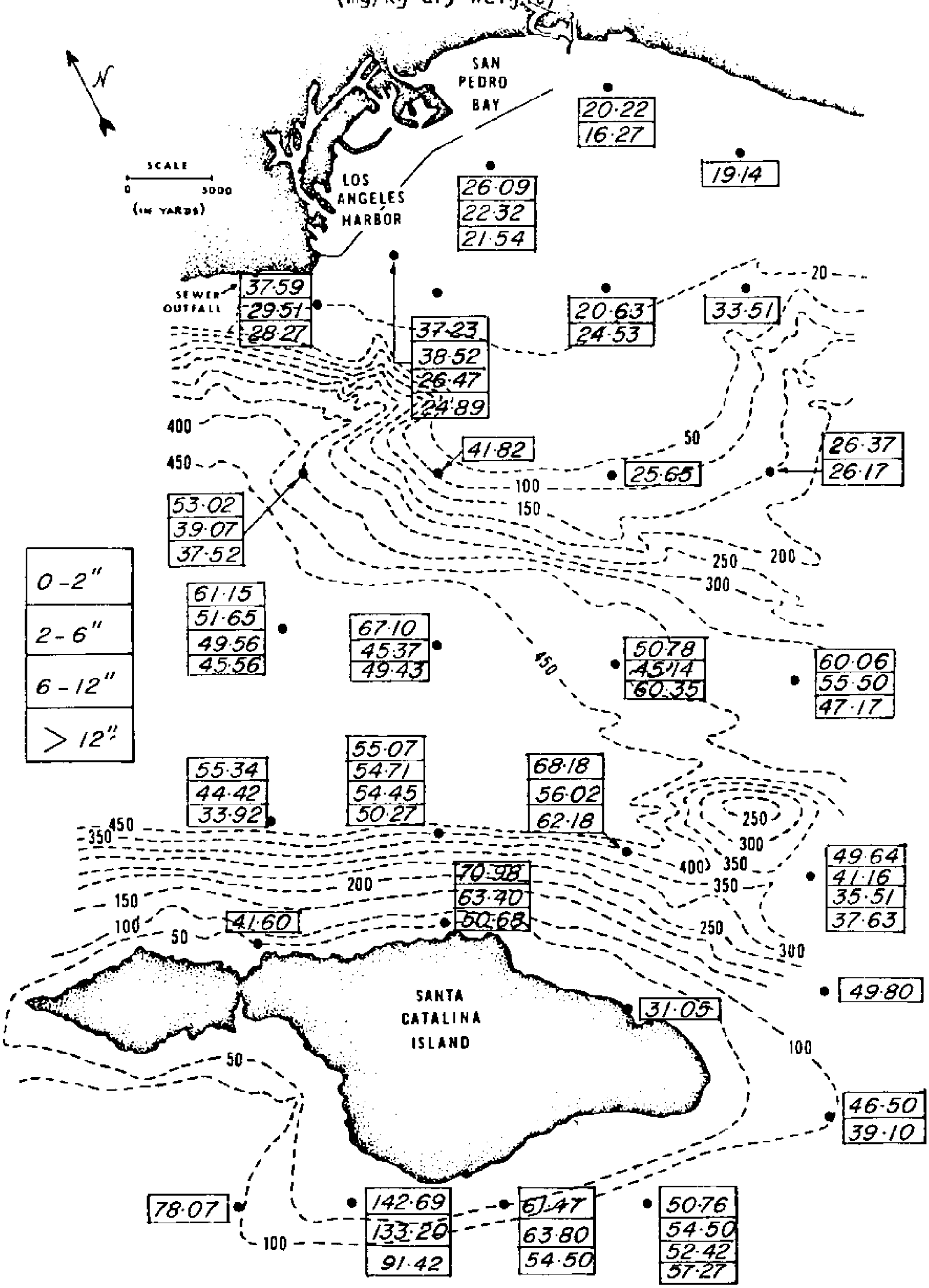


FIGURE 9

Distribution of Zinc in the Sediments of San Pedro Channel

(mg/kg dry weight)

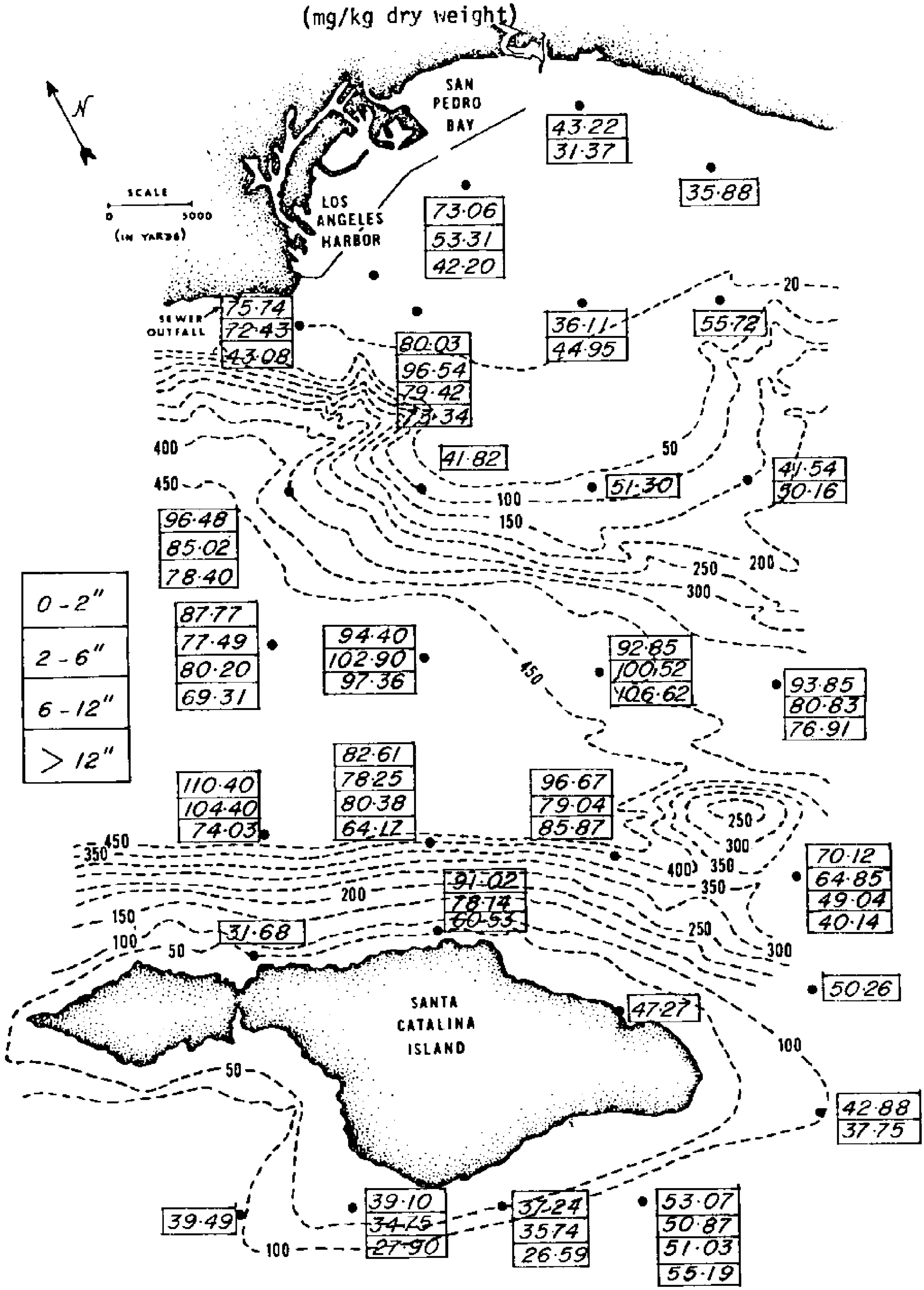
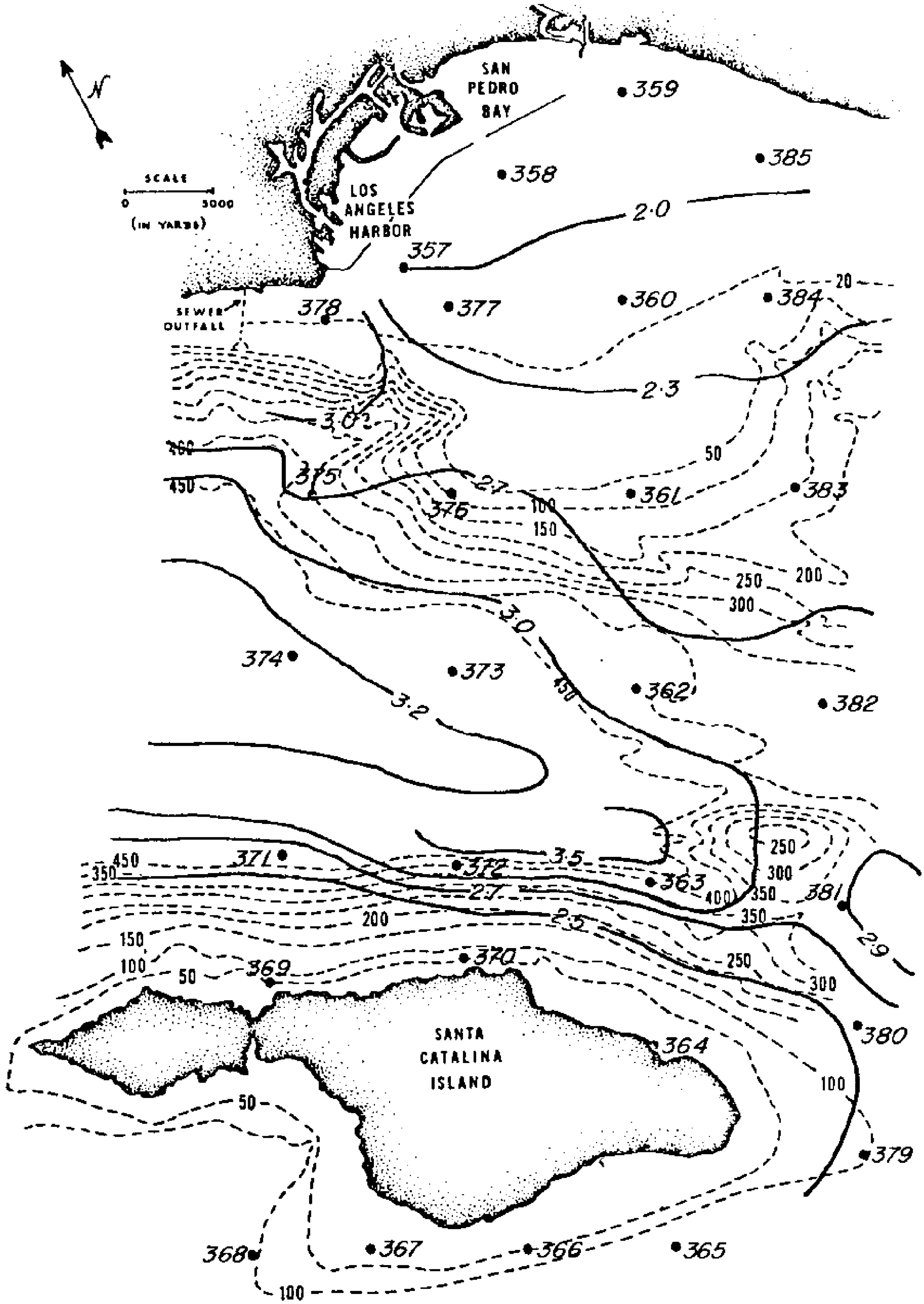


FIGURE 10

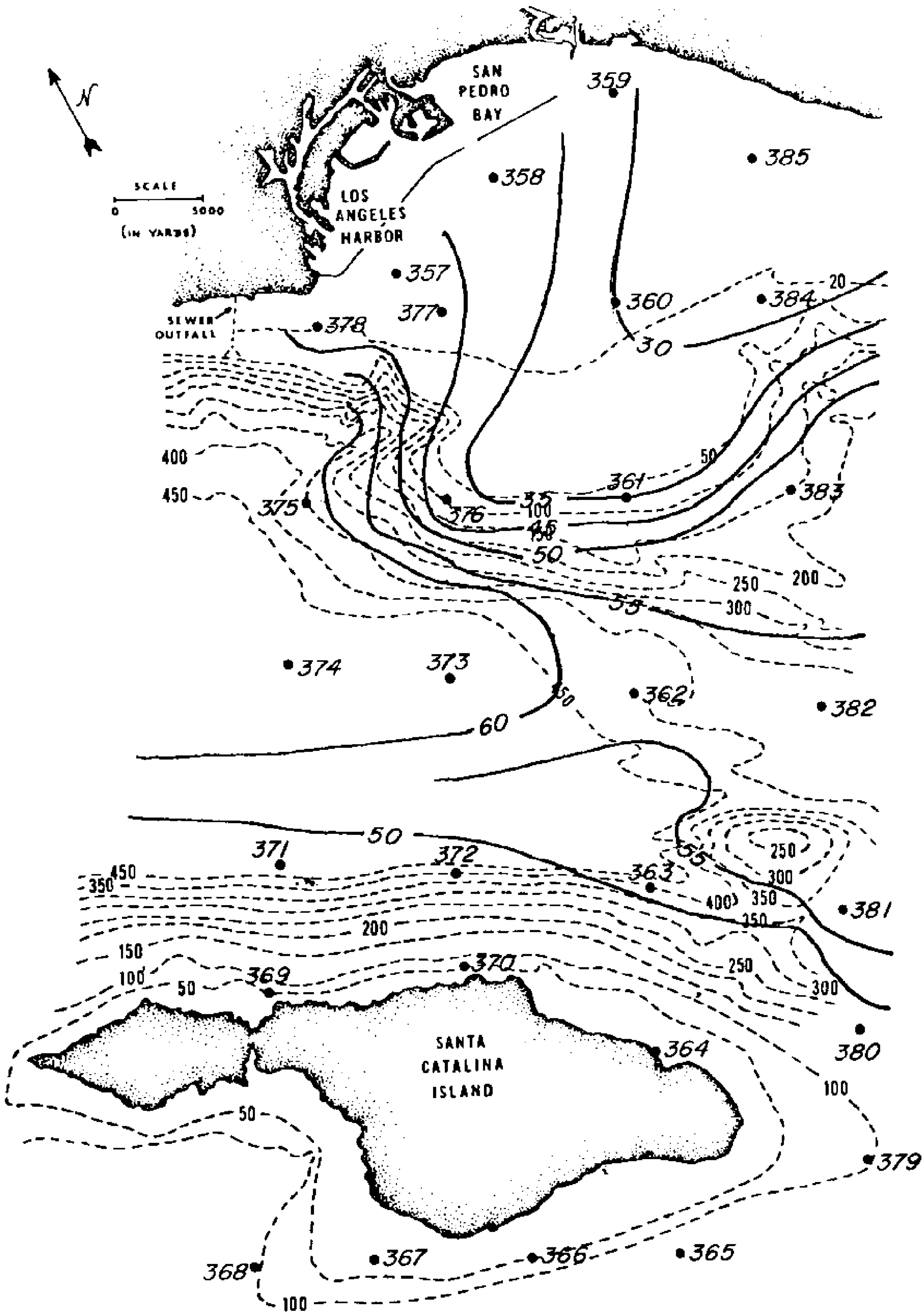
Cd (ppm) Isoconcentration Lines



Solid lines: Concentration
Broken lines: Contour

FIGURE 11

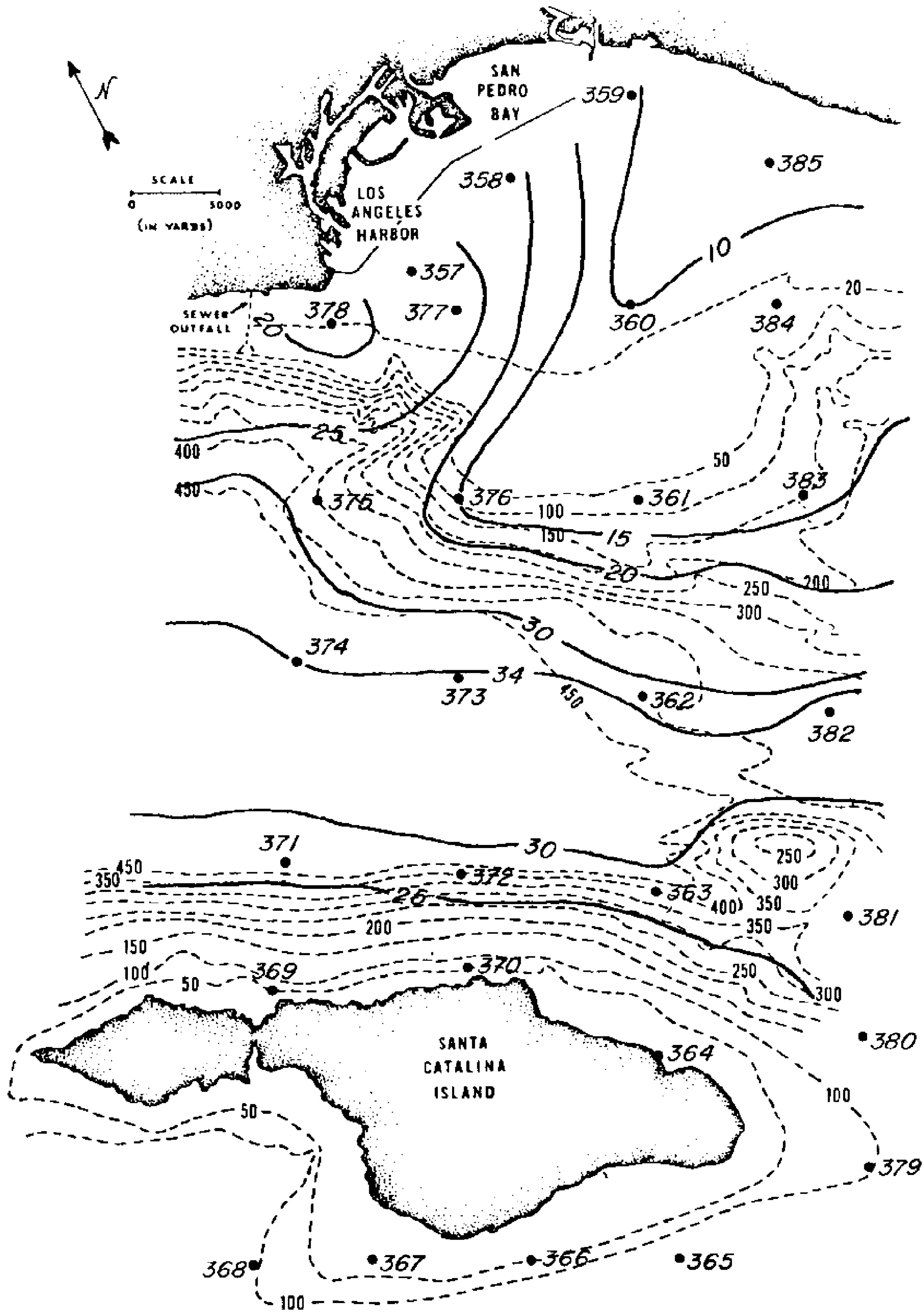
Cr (ppm) Isoconcentration Lines



Solid lines: Concentration
Broken lines: Contour

FIGURE 12

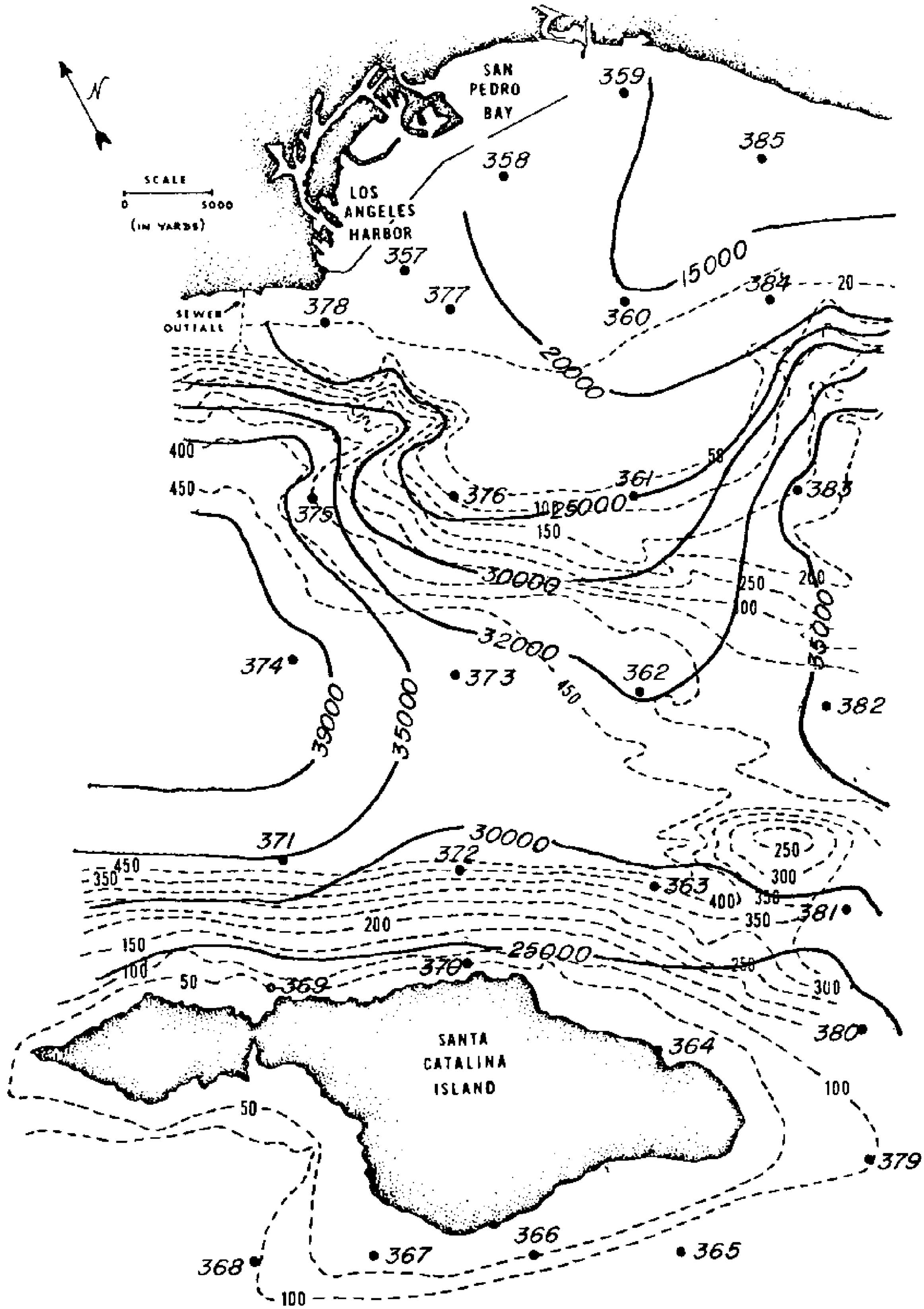
Cu (ppm) Isoconcentration Lines



Solid lines: Concentration
Broken lines: Contour

FIGURE 13

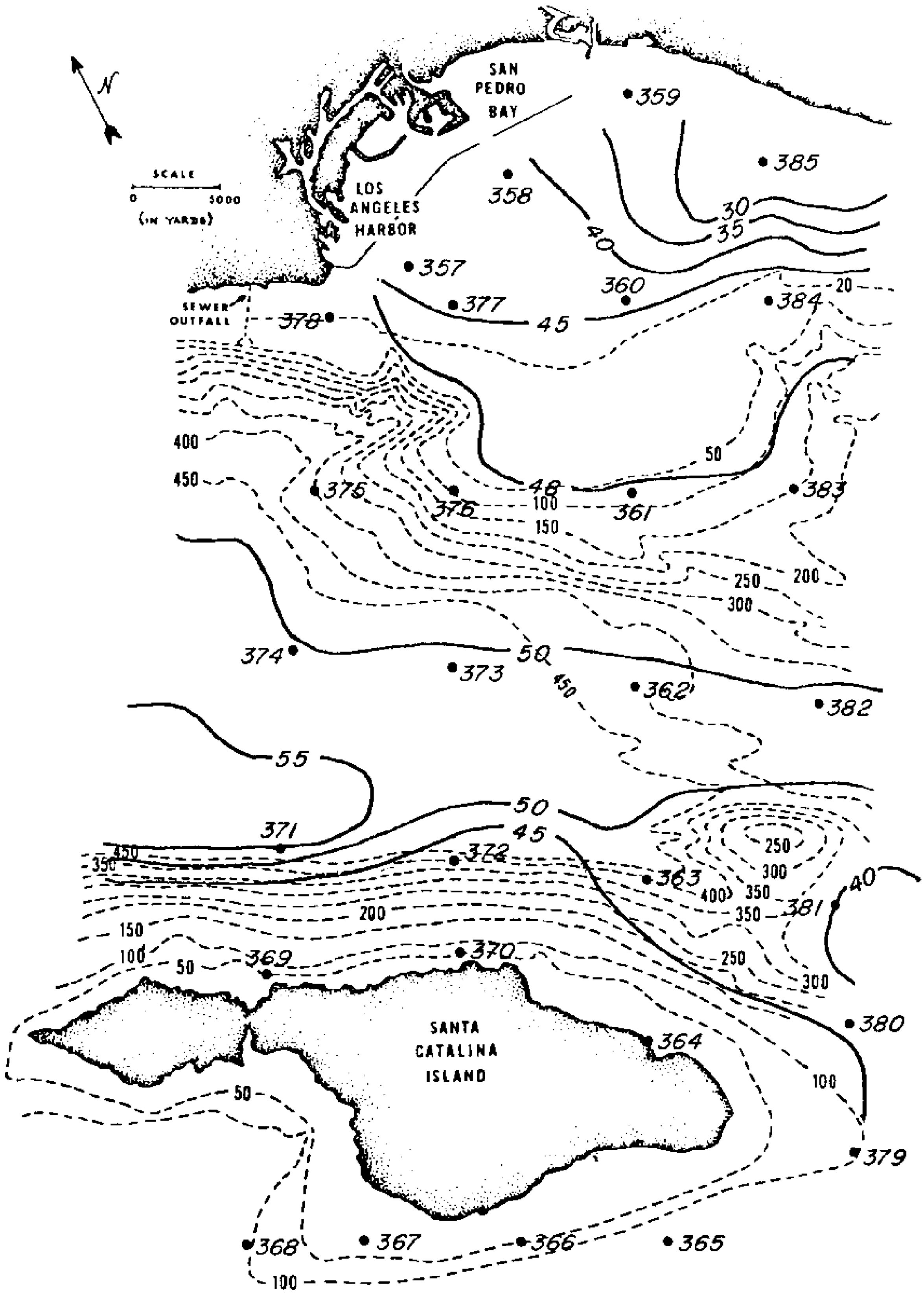
Fe (ppm) Isoconcentration Lines



Solid lines: Concentration
Broken lines: Contour

FIGURE 14

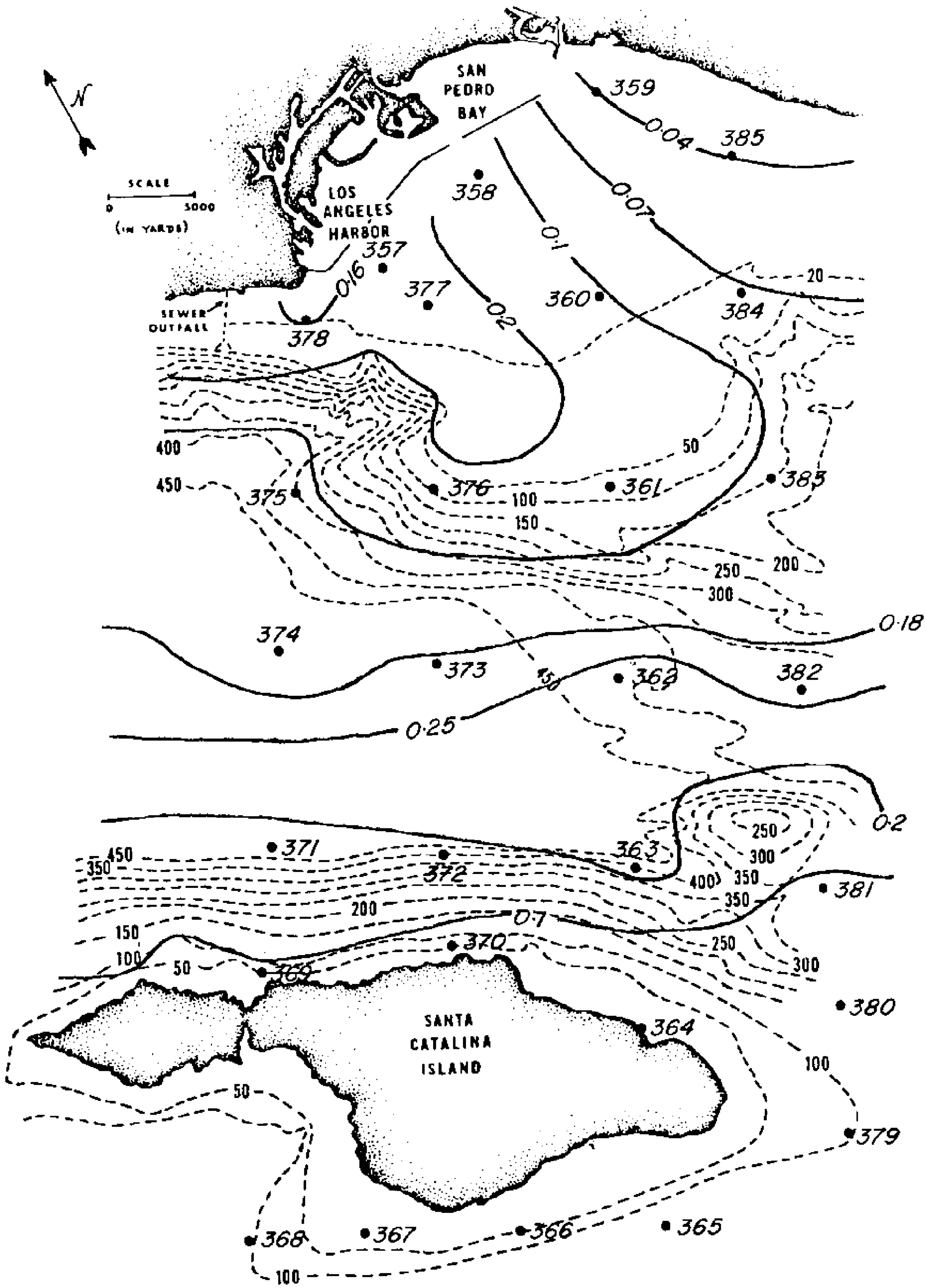
Pb (ppm) Isoconcentration Lines



Solid lines: Concentration
Broken lines: Contour

FIGURE 15

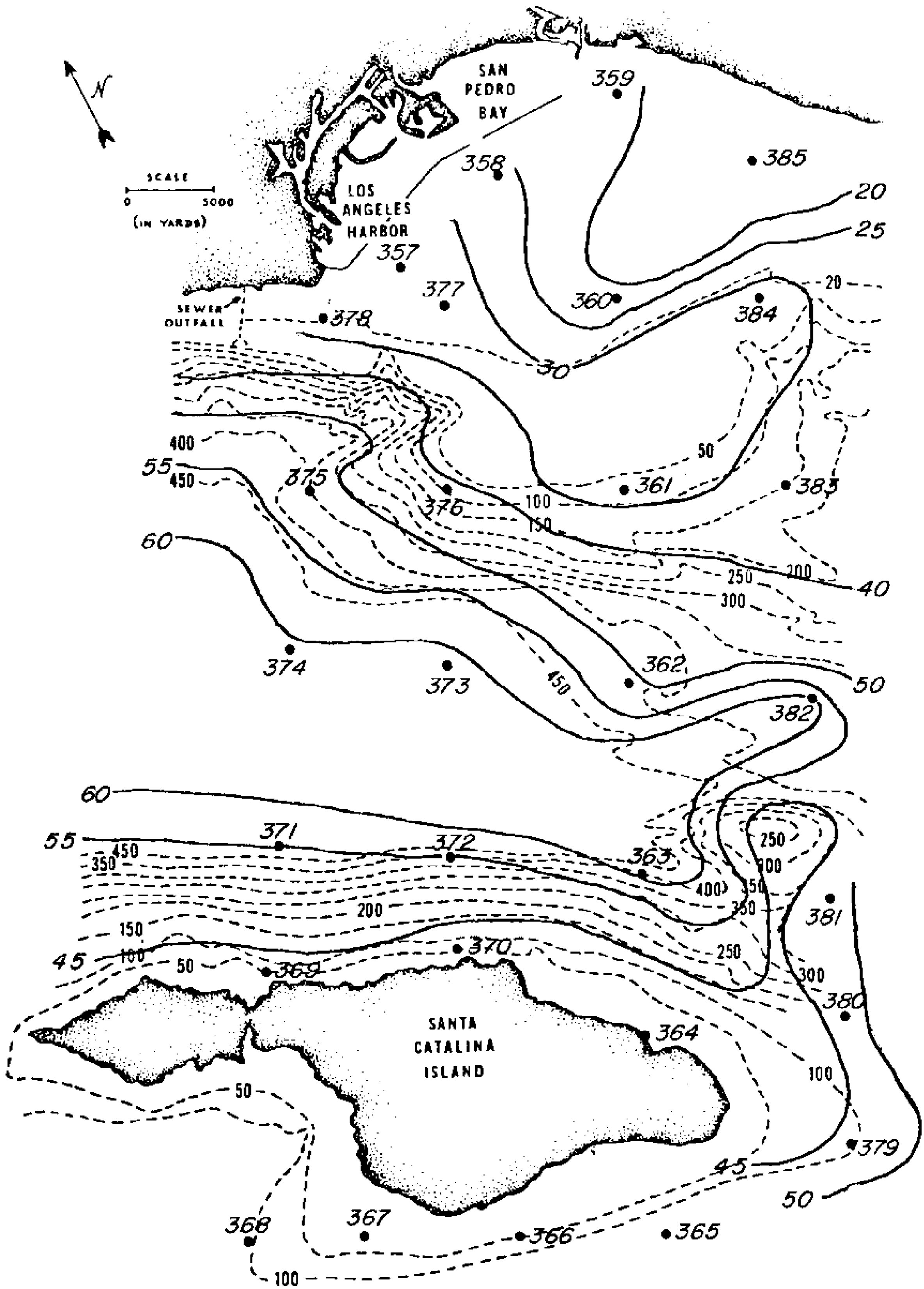
Hg (ppm) Isoconcentration Lines



Solid lines: Concentration
Broken lines: Contour

FIGURE 16

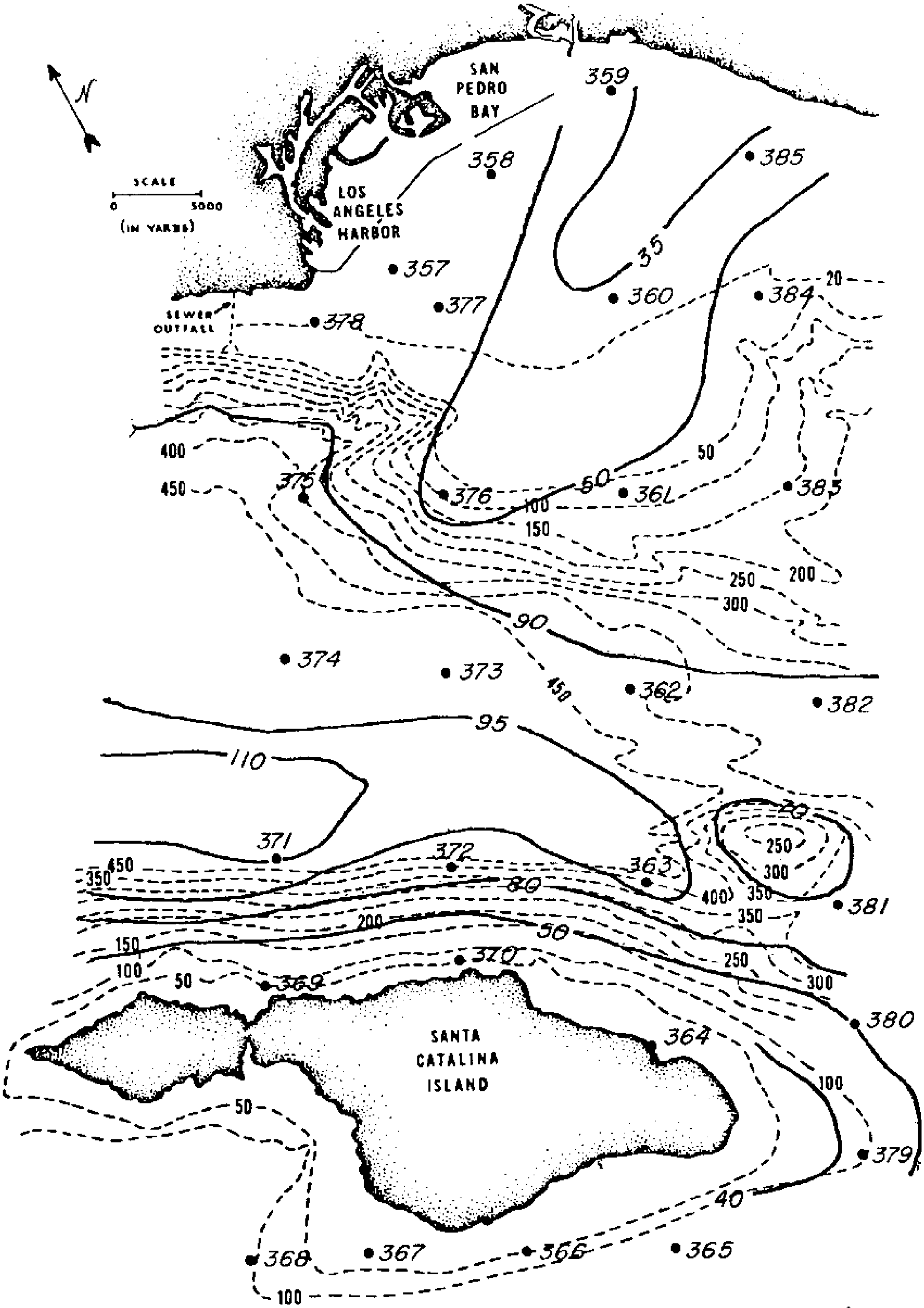
Ni (ppm) Isoconcentration Lines



Solid lines: Concentration
Broken lines: Contour

FIGURE 17

Zn (ppm) Isoconcentration Lines



Solid lines: Concentration
Broken lines: Contour

FIGURE 18

Chemical Oxygen Demand in the Sediment of San Pedro Channel ($x10^4$ ppm)

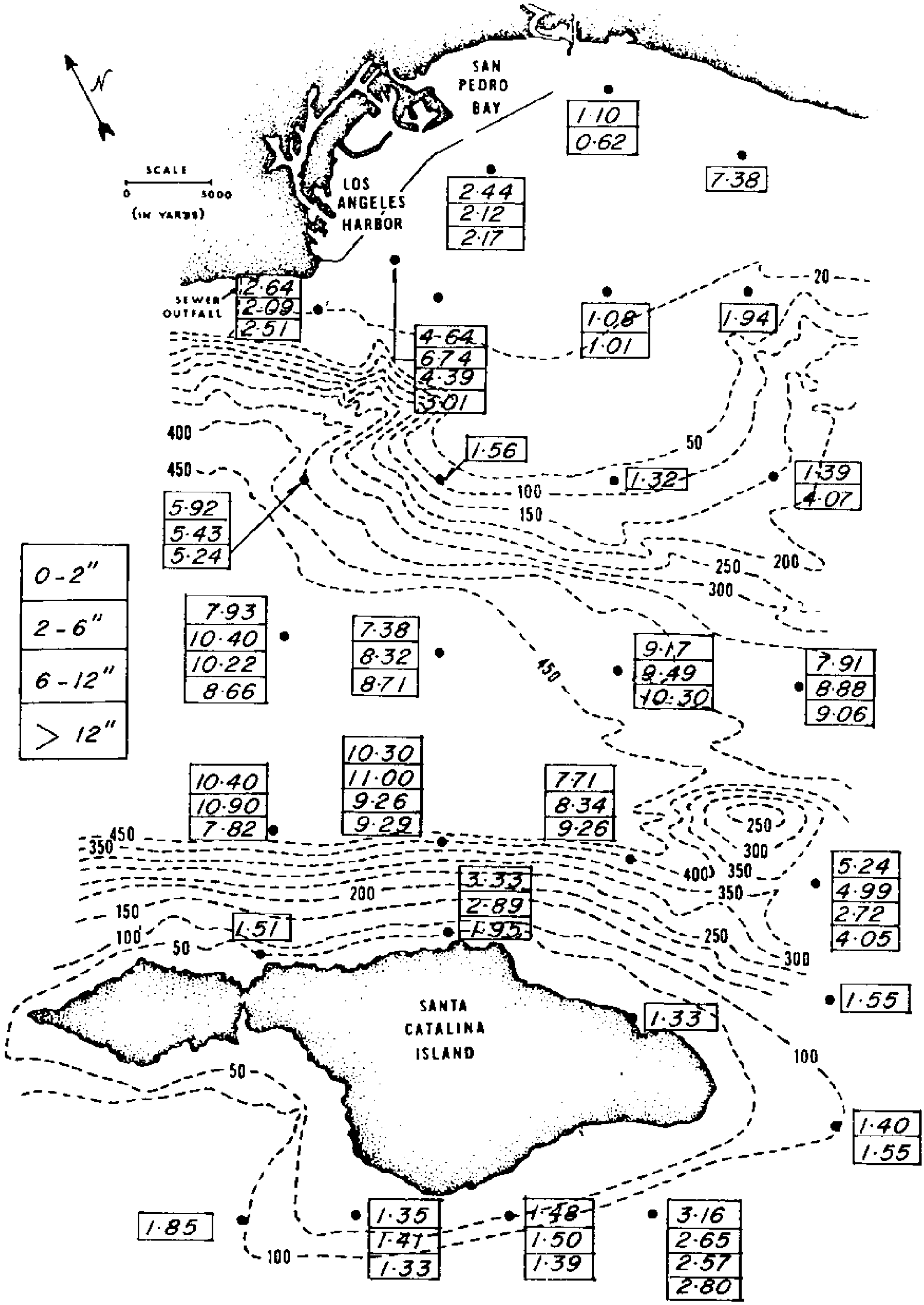


FIGURE 19

Immediate Oxygen Demand in the Sediment
of San Pedro Channel
(ppm)

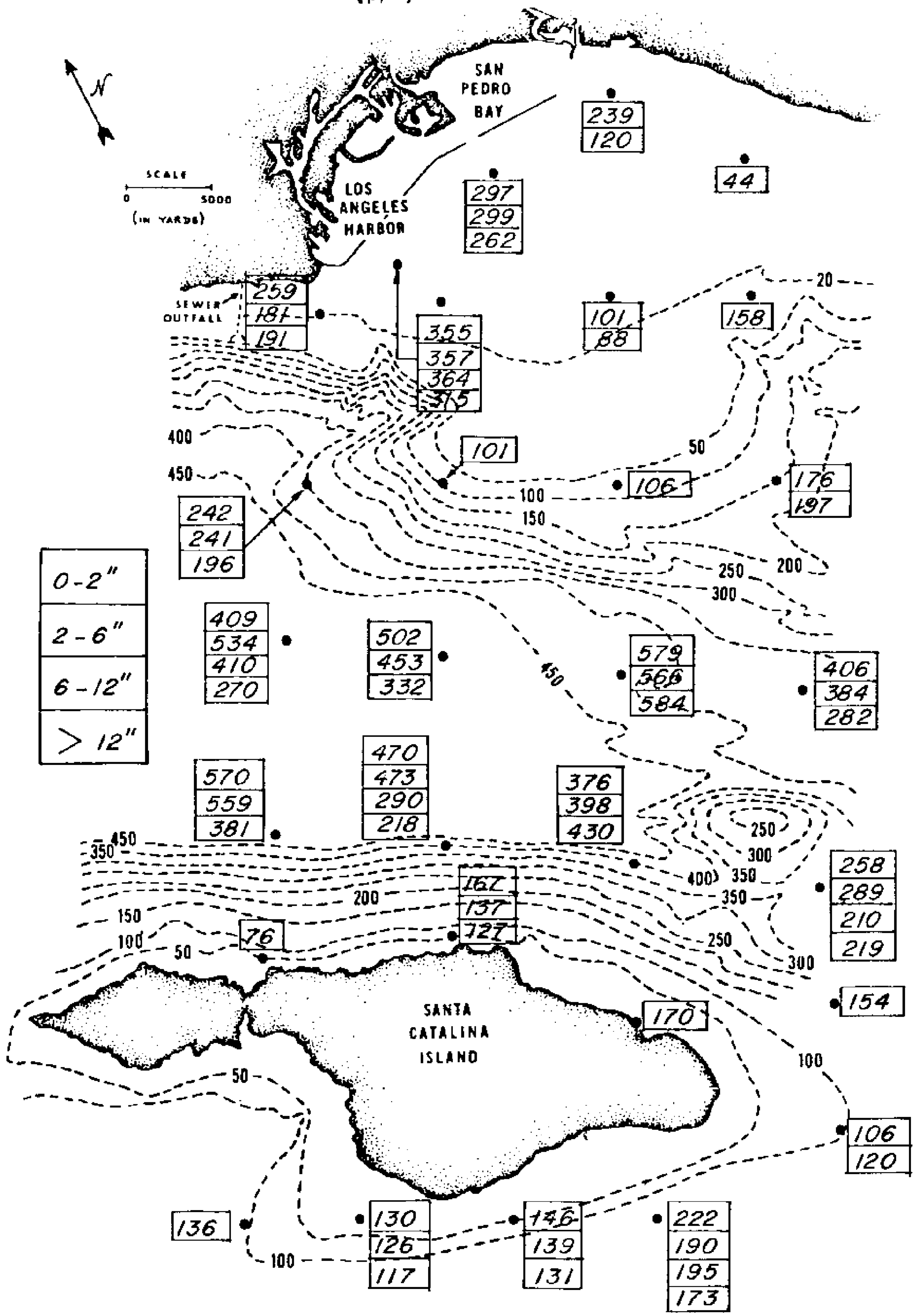


FIGURE 20

Kjeldahl Nitrogen (ppm) in the Sediment of San Pedro Channel

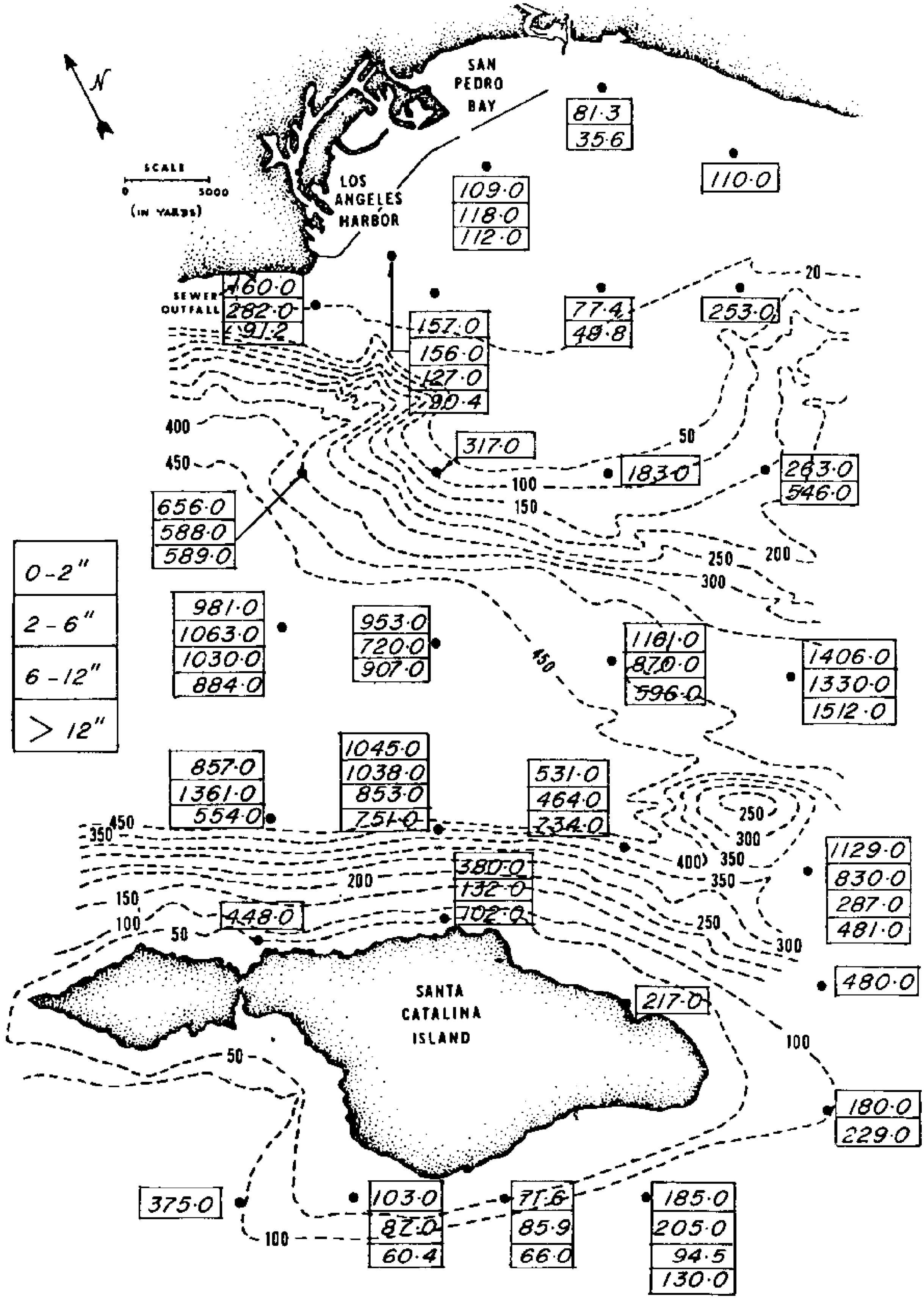


FIGURE 21

Organic Nitrogen (ppm) in the Sediment of San Pedro Channel

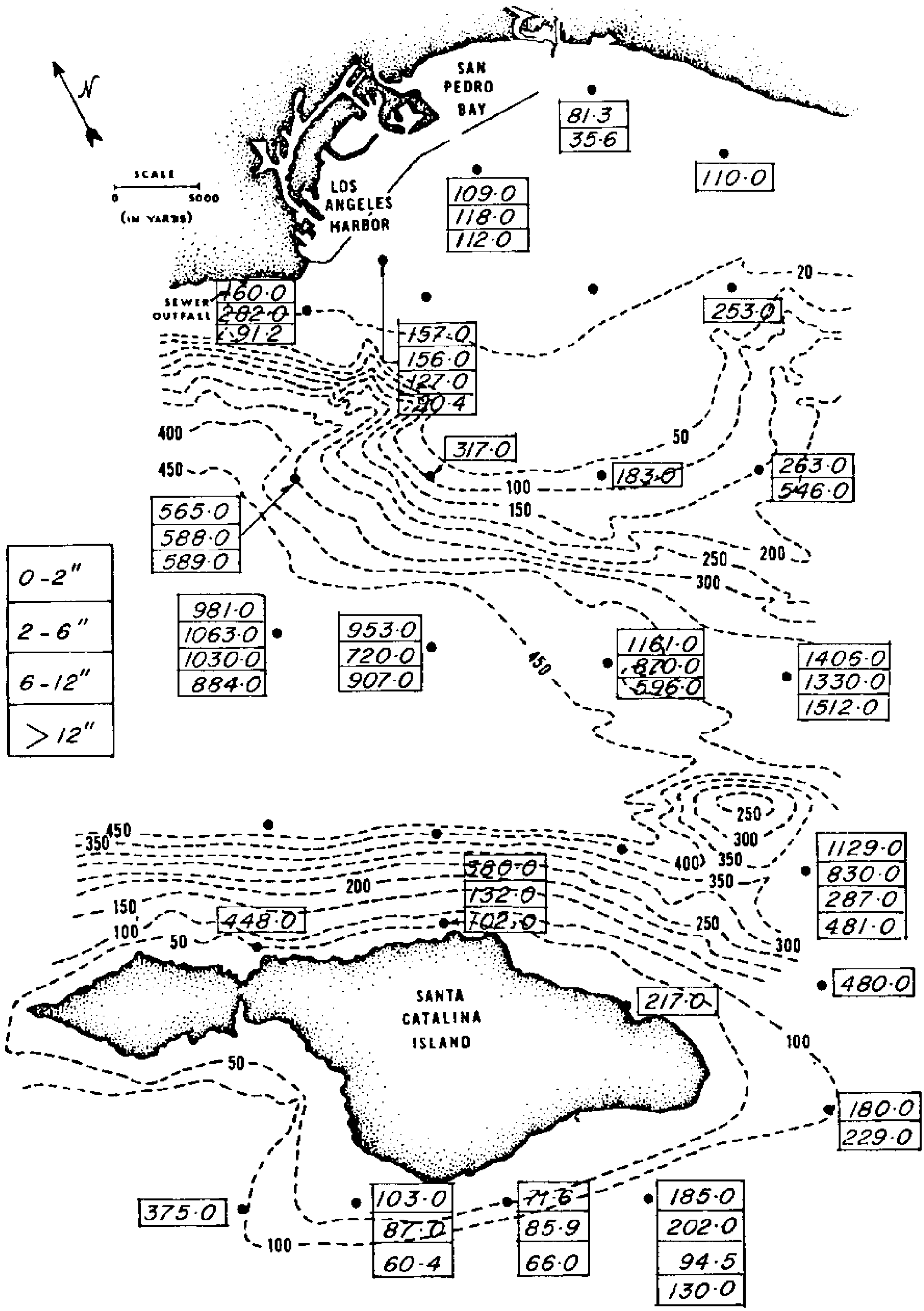


FIGURE 22

Oil and Grease in the Sediment
of San Pedro Channel (ppm)

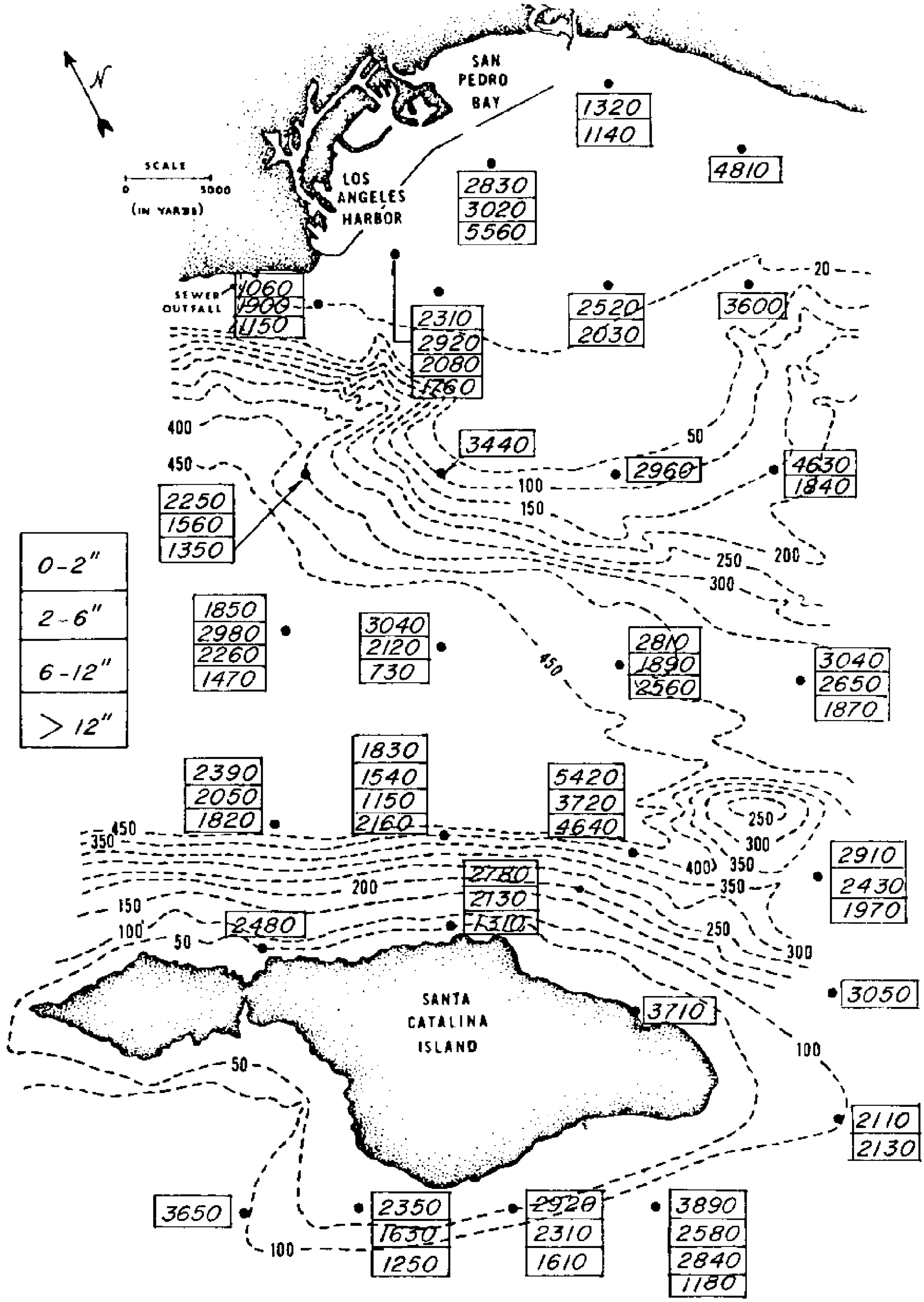


FIGURE 23

Total Phosphorus in the Sediment
of San Pedro Channel
(ppm)

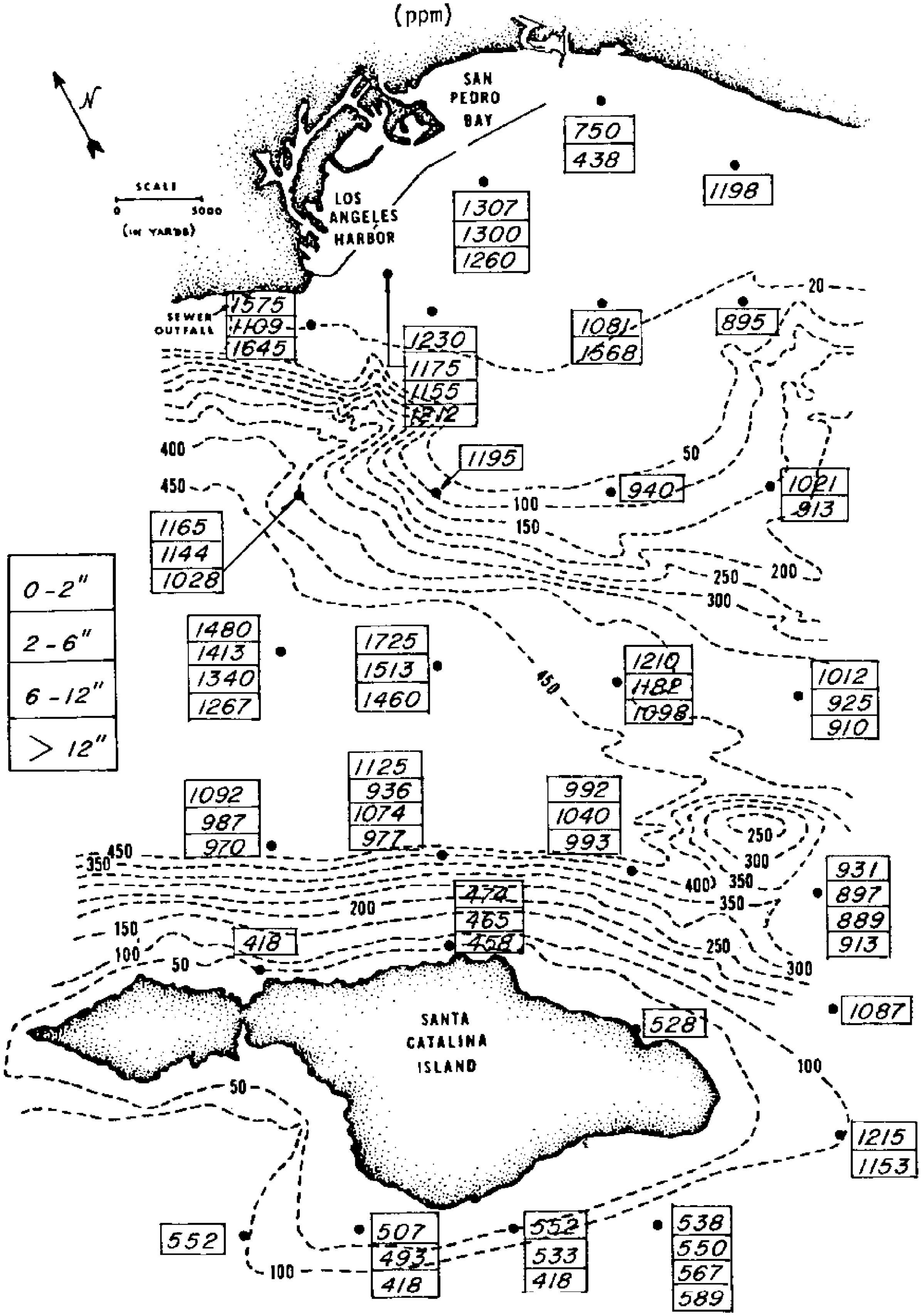


FIGURE 24

Total Organic Carbon in the Sediment of San Pedro Channel (%)

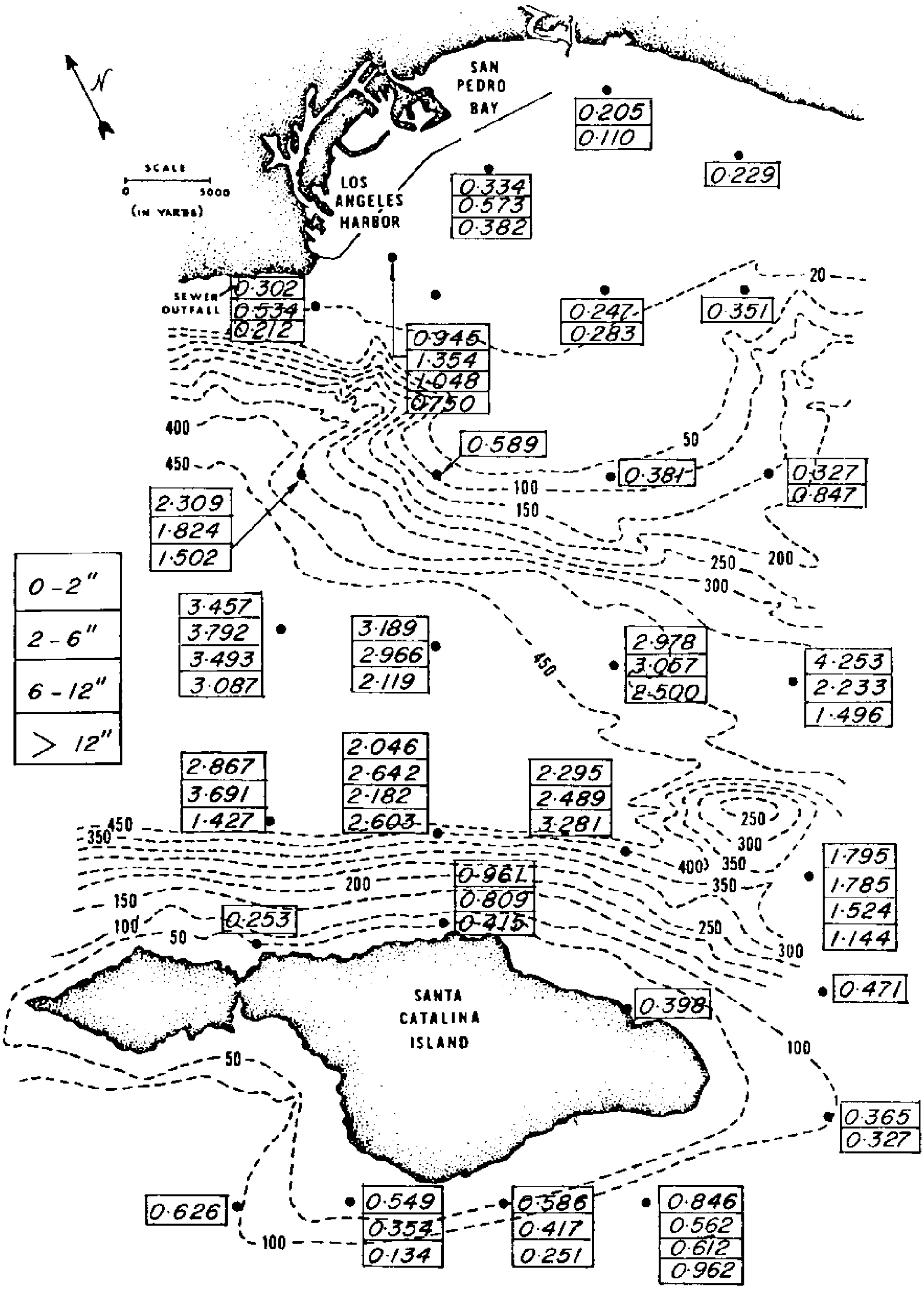


FIGURE 25

Total Volatile Substances in the Sediment of San Pedro Channel (%)

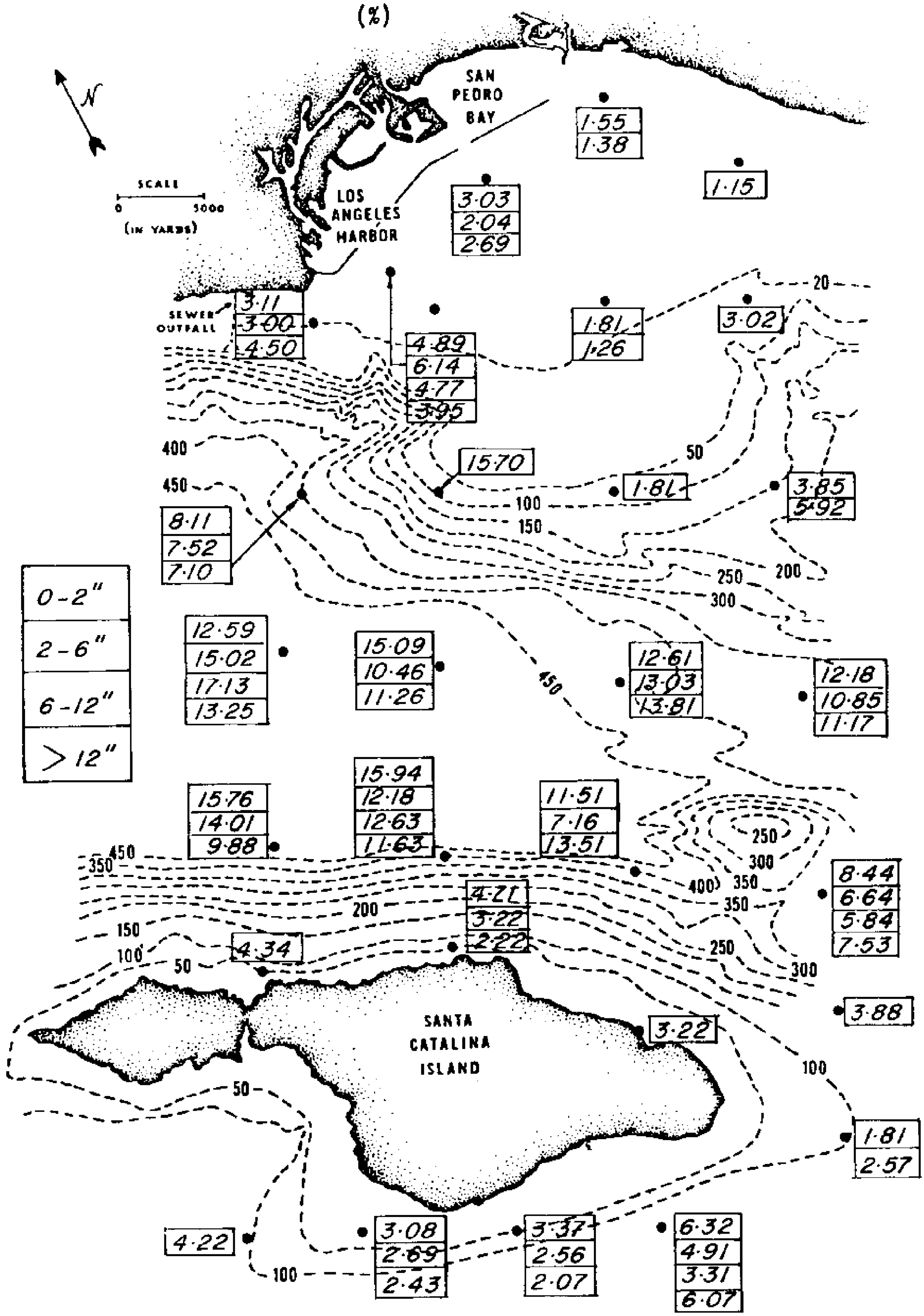


FIGURE 26

DDD (ppm) in the

Sediment of San Pedro Channel

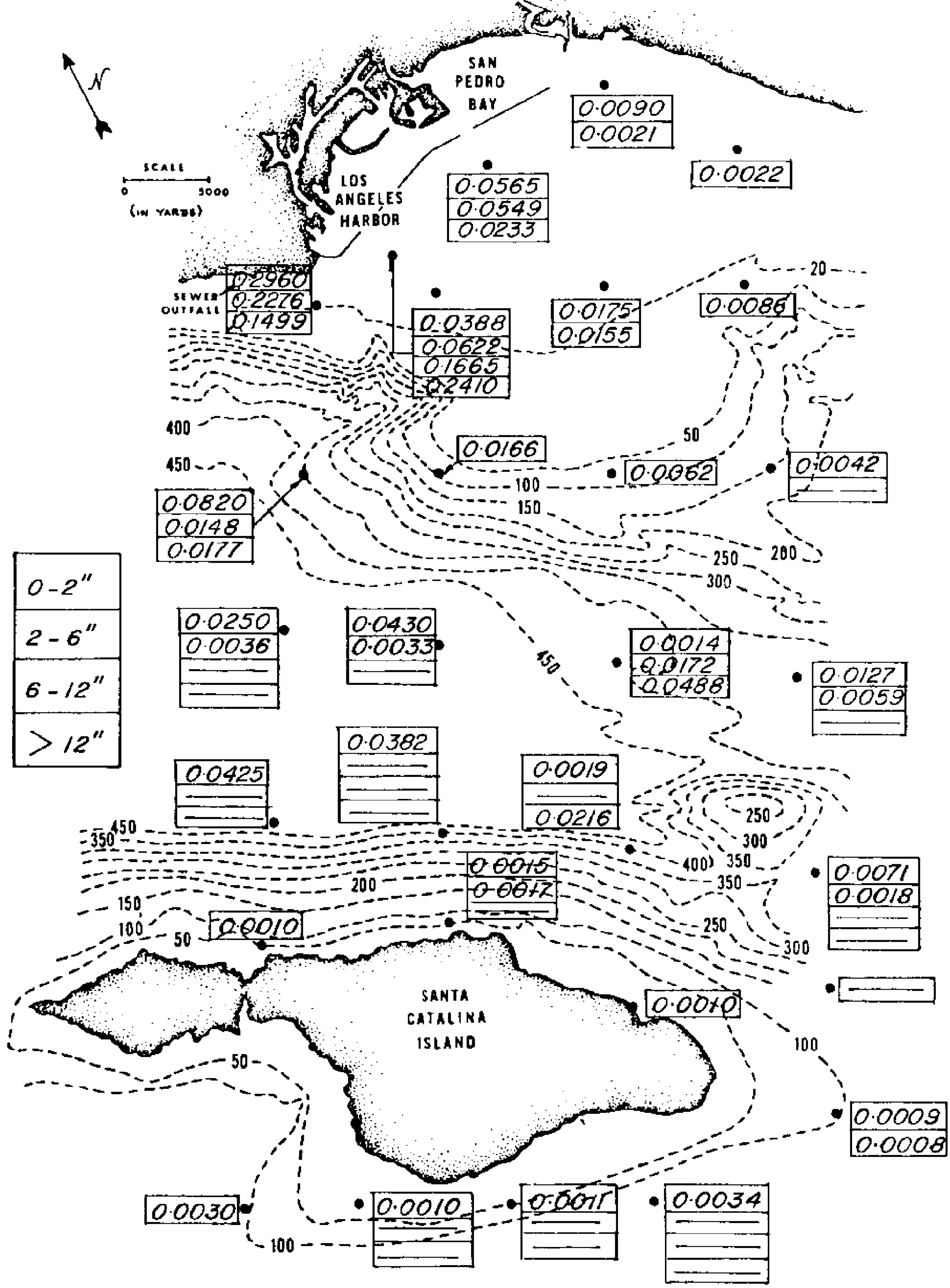


FIGURE 27

o,p'DDT (ppm) in the
Sediment of San Pedro Channel

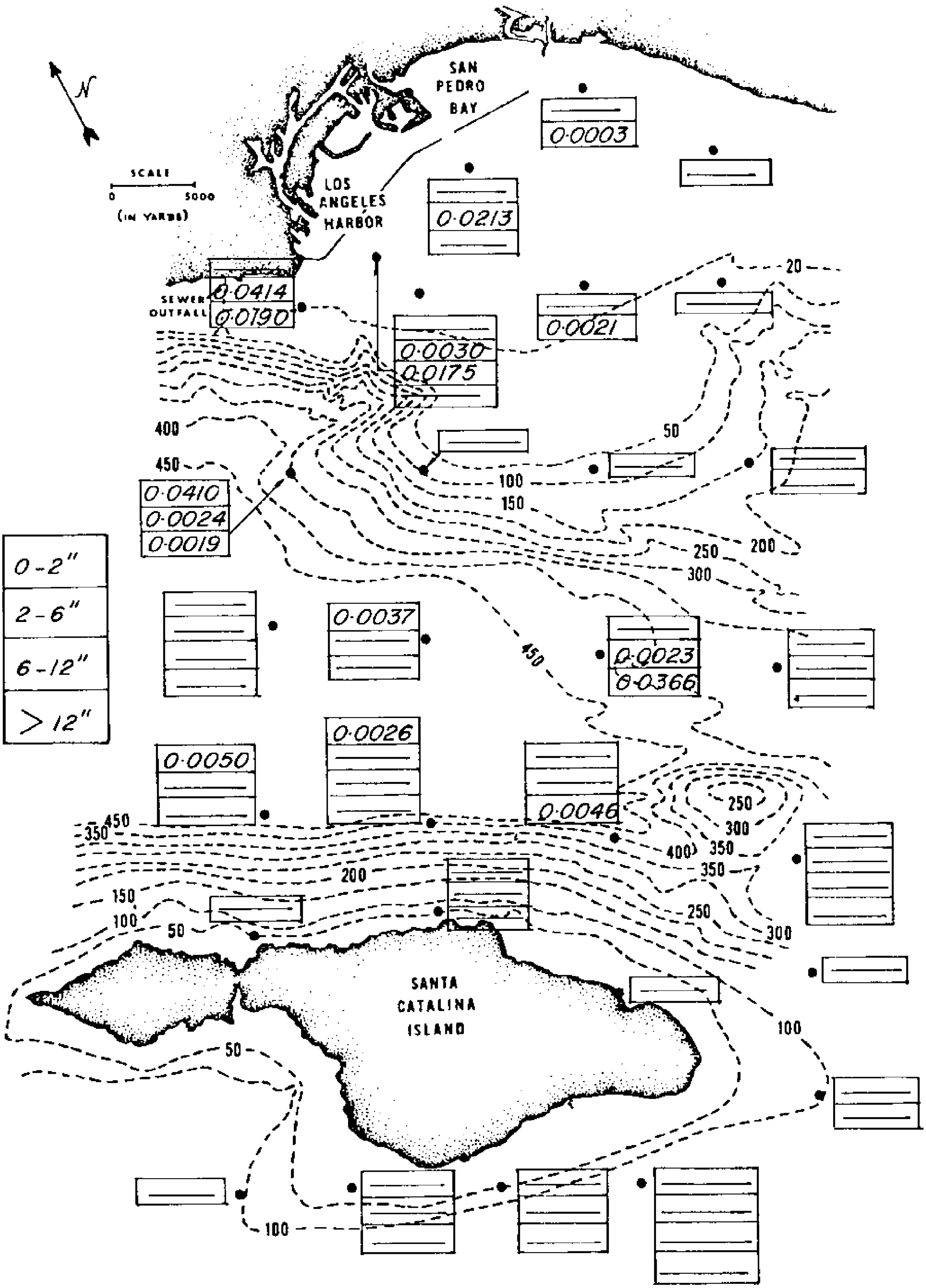


FIGURE 28

p,p'DDT (ppm) in the
Sediment of San Pedro Channel

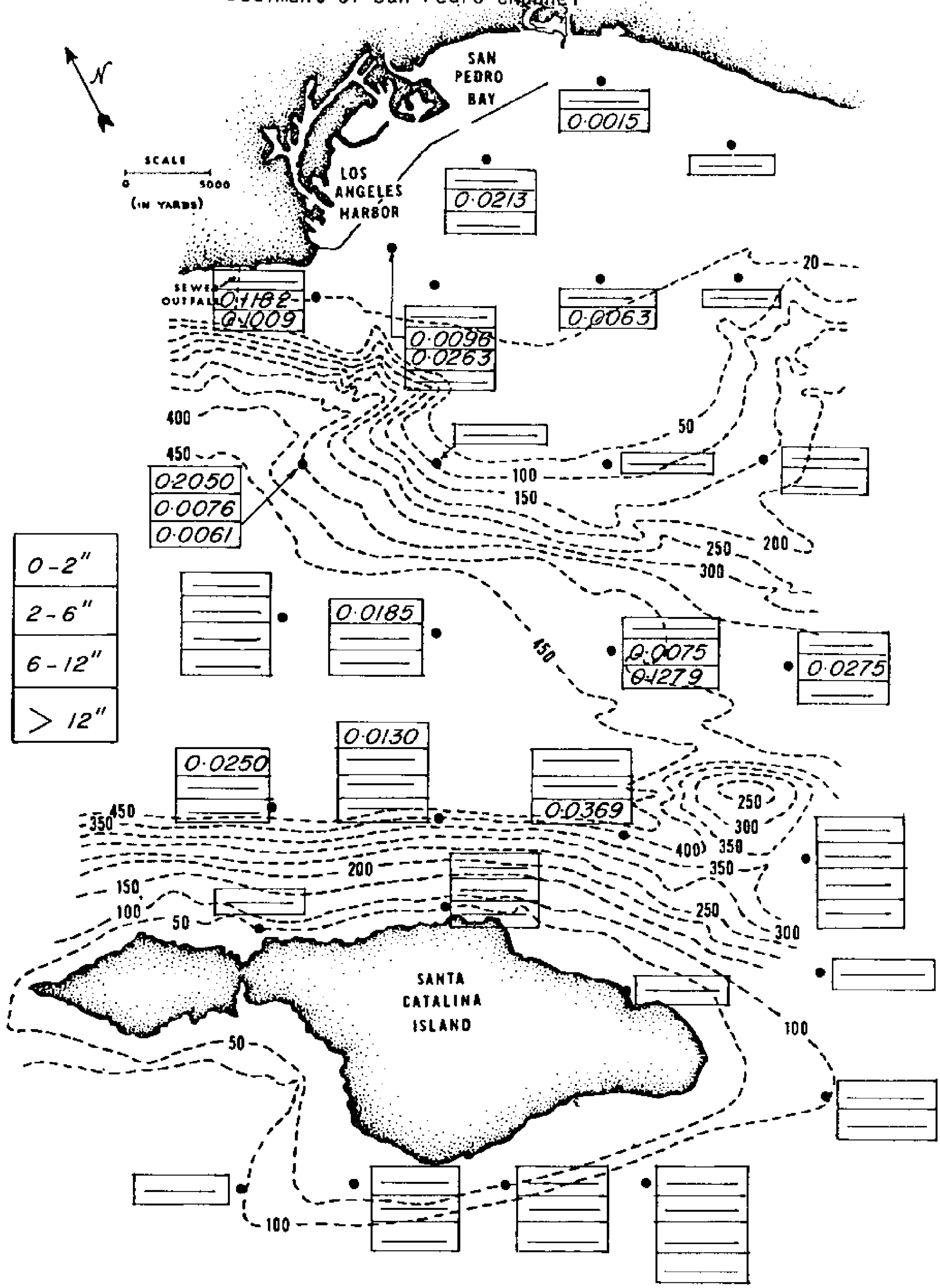


FIGURE 29

o,p'DDE (ppm) in the
Sediment of San Pedro Channel

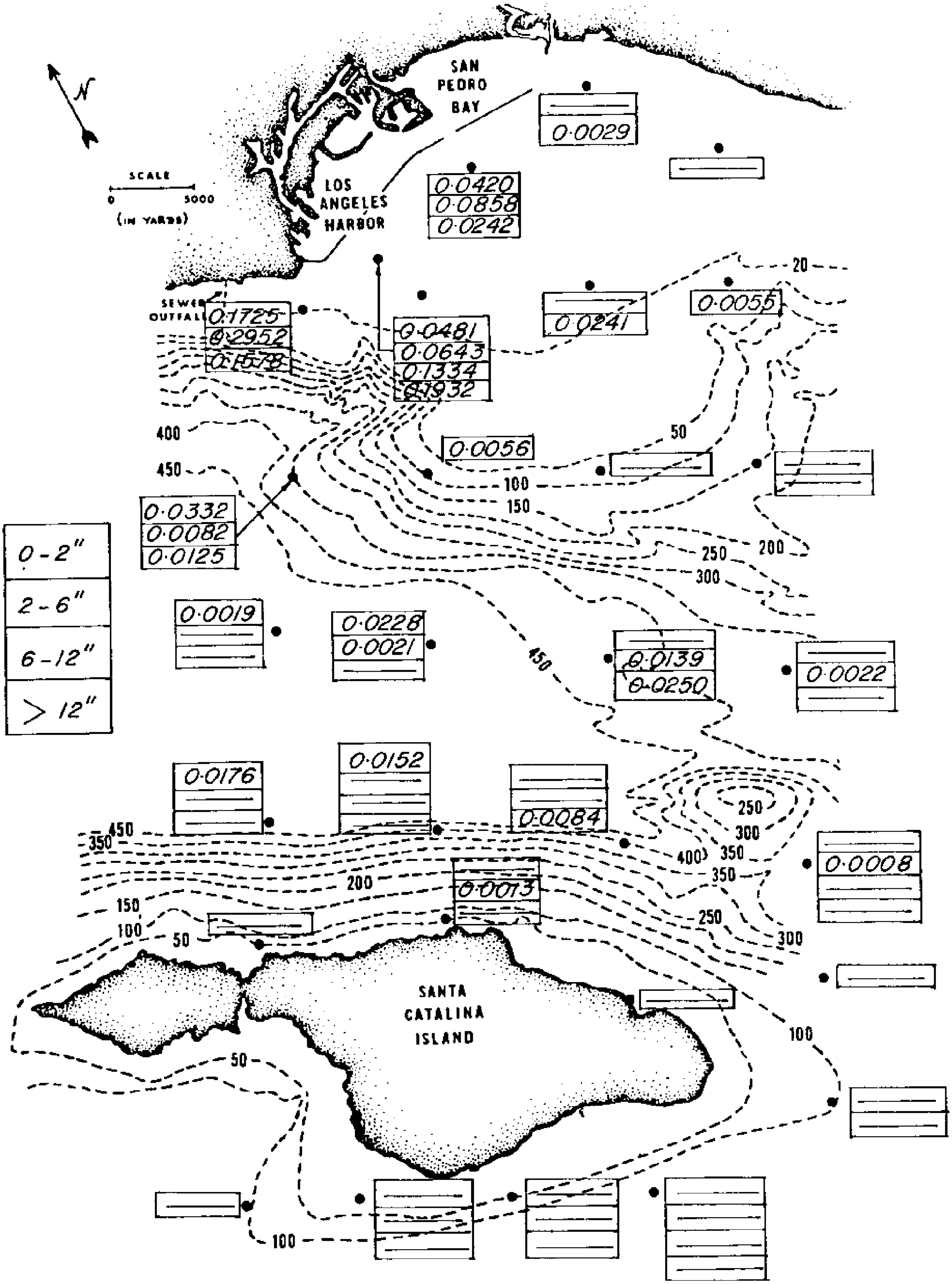


FIGURE 30

p,p'DDE (ppm) in the
Sediment of San Pedro Channel

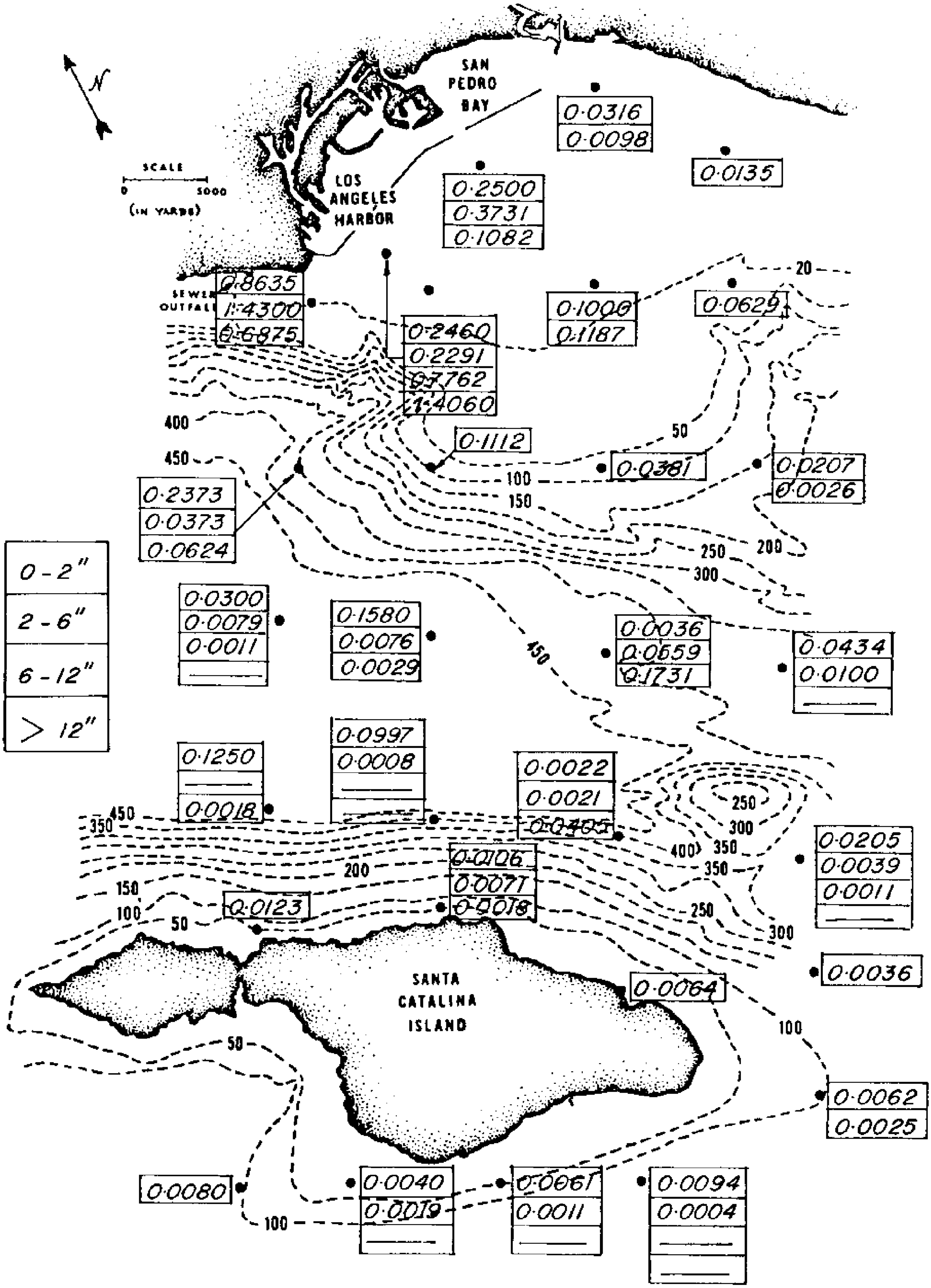


FIGURE 31

Total DDT (ppm) in the Sediment of San Pedro Channel

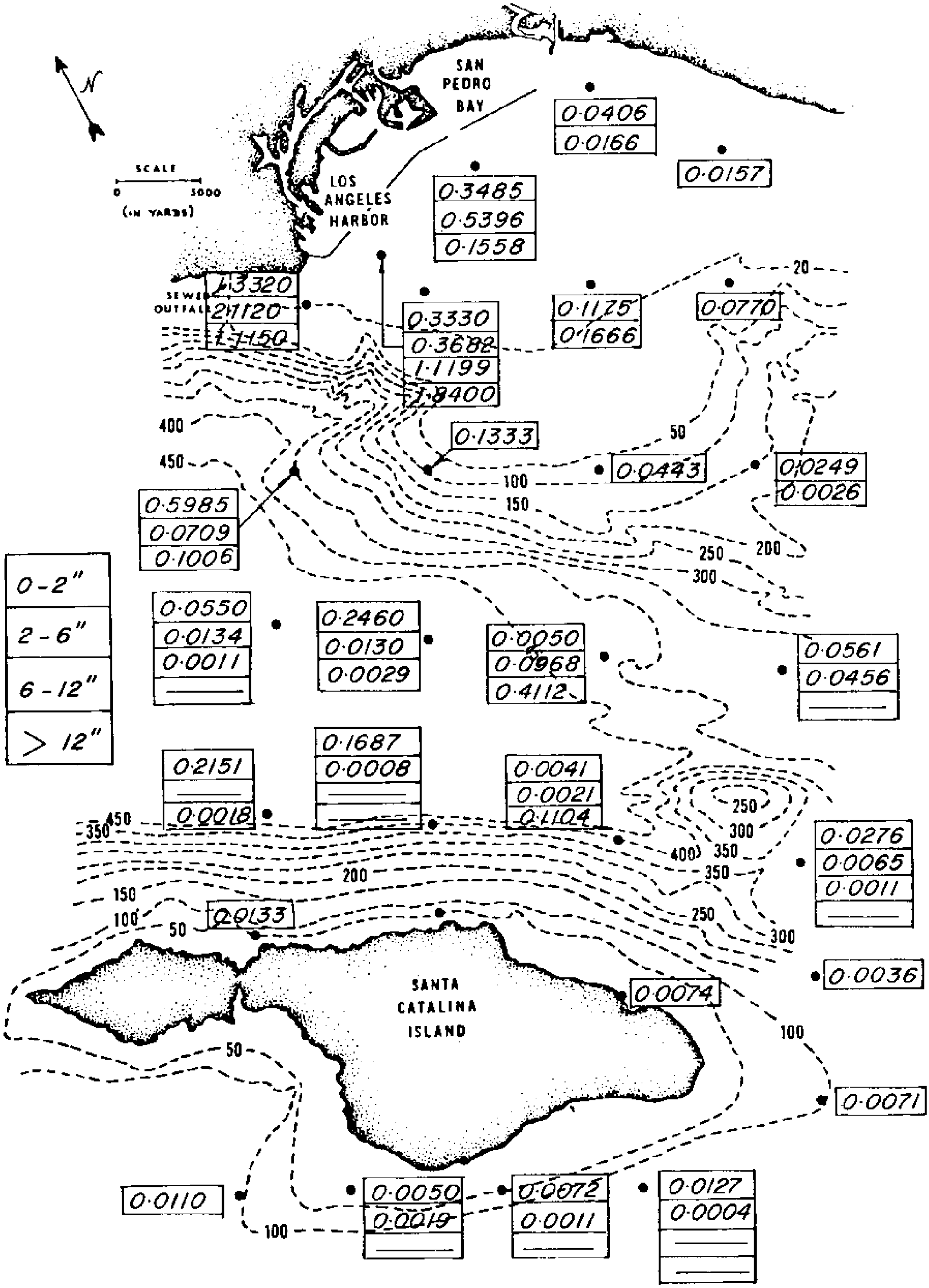


FIGURE 32

PCB 1254 (ppm) in the
Sediment of San Pedro Channel

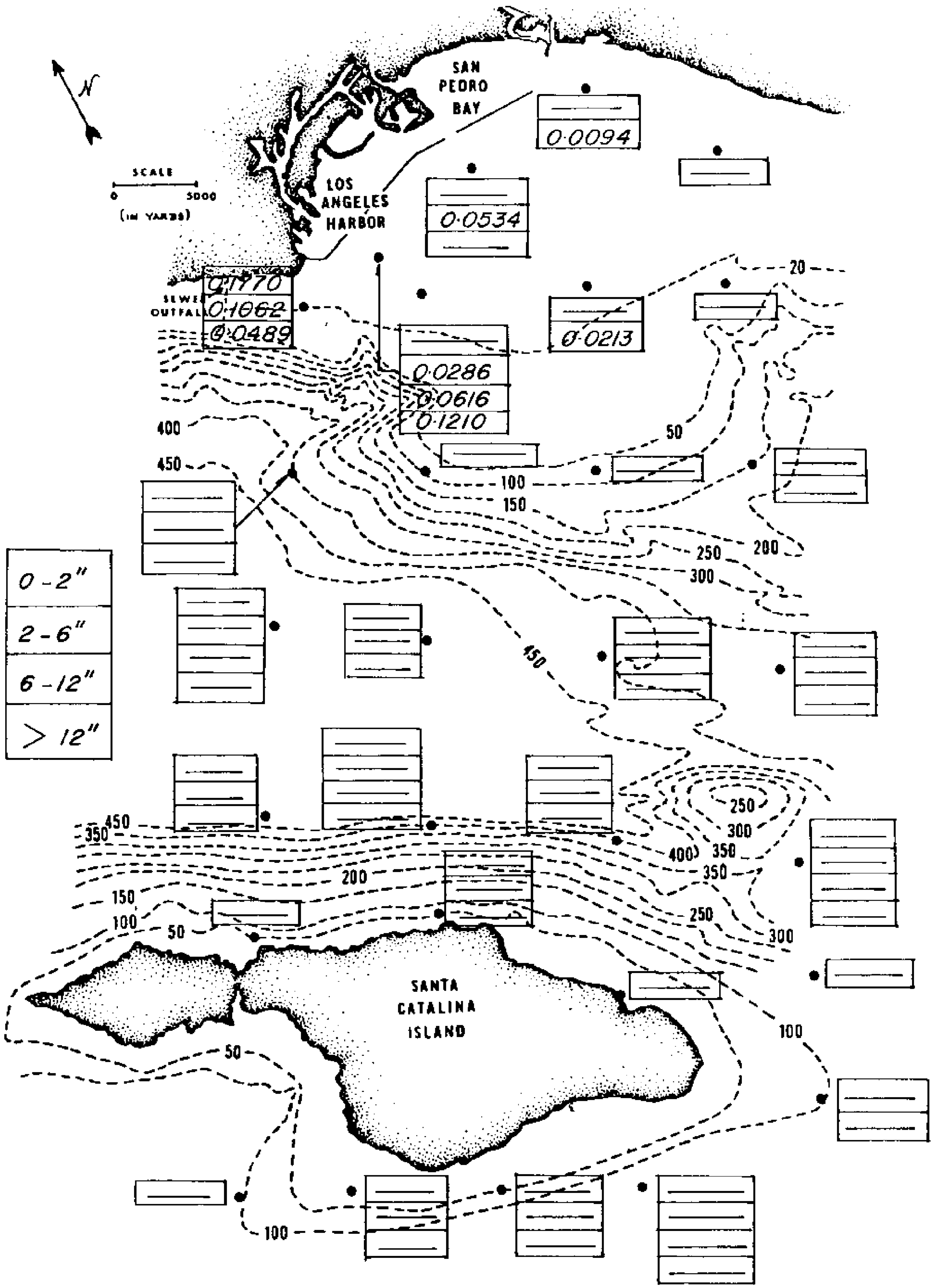


FIGURE 33

PCB 1260 (ppm) in the Sediment of San Pedro Channel

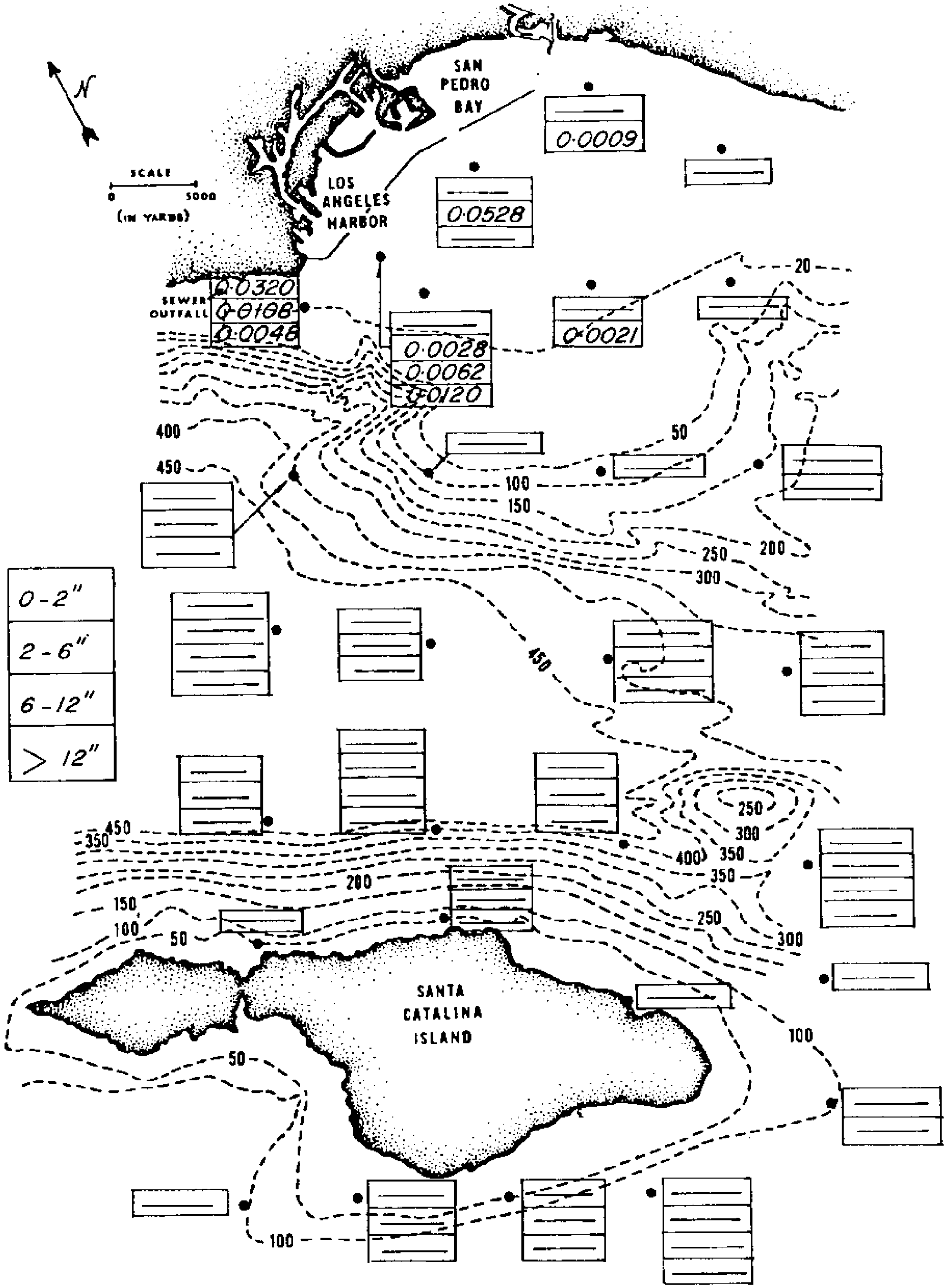
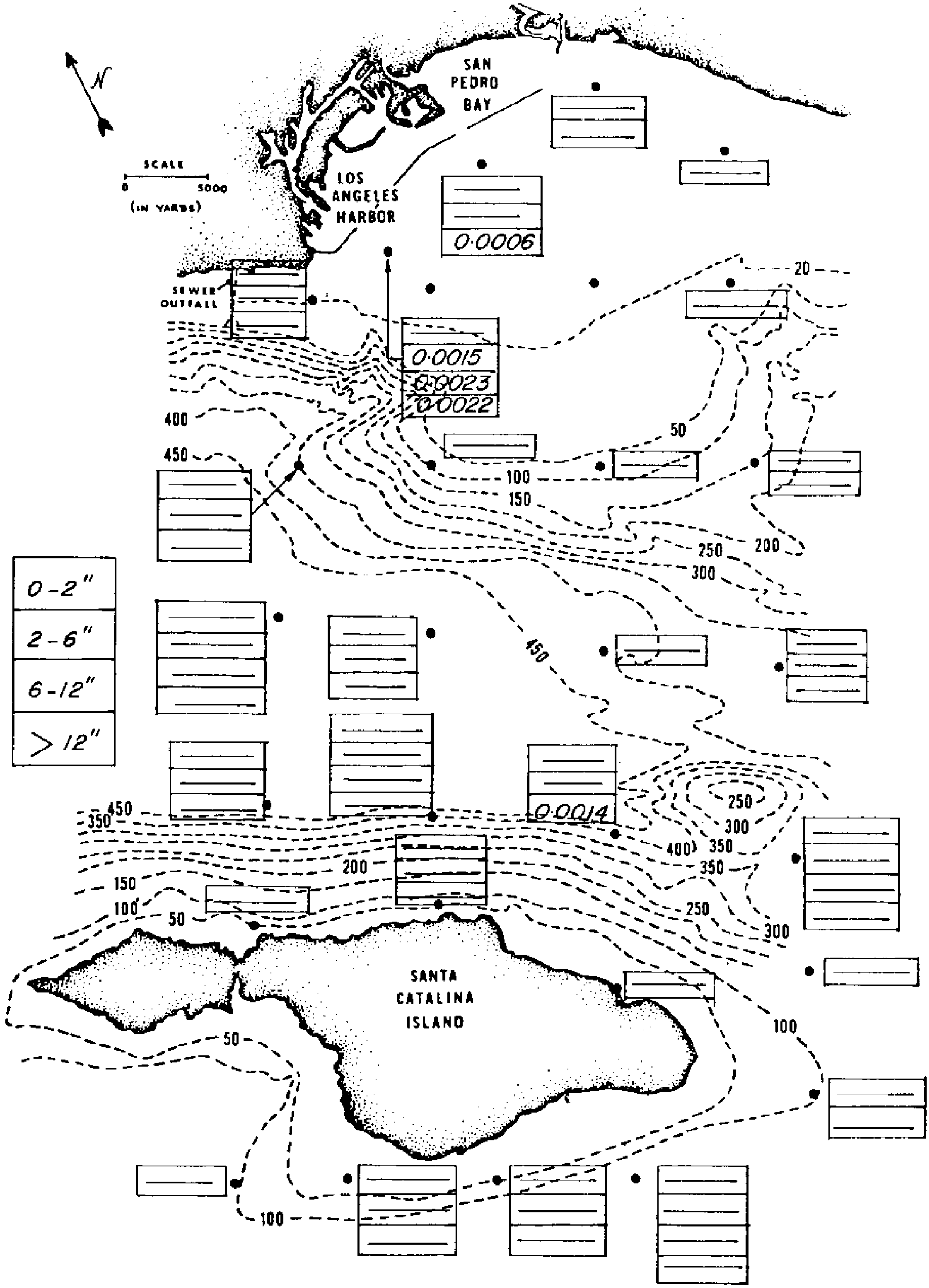


FIGURE 34

Dieldrin (ppm) in the
Sediment of San Pedro Channel



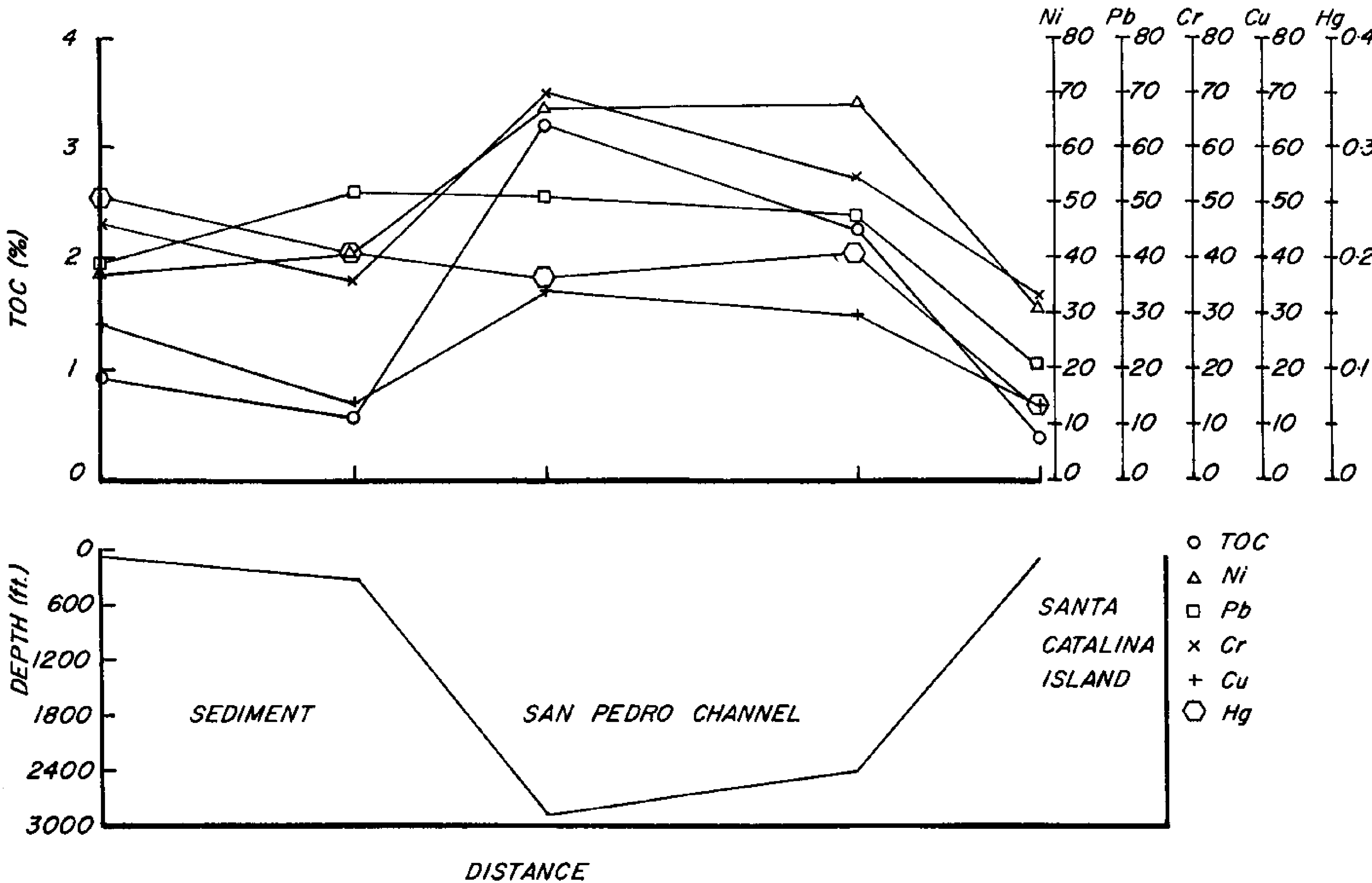


FIGURE 35

Profiles of Contaminants in San Pedro Basin (Section A-A of Figure 1)

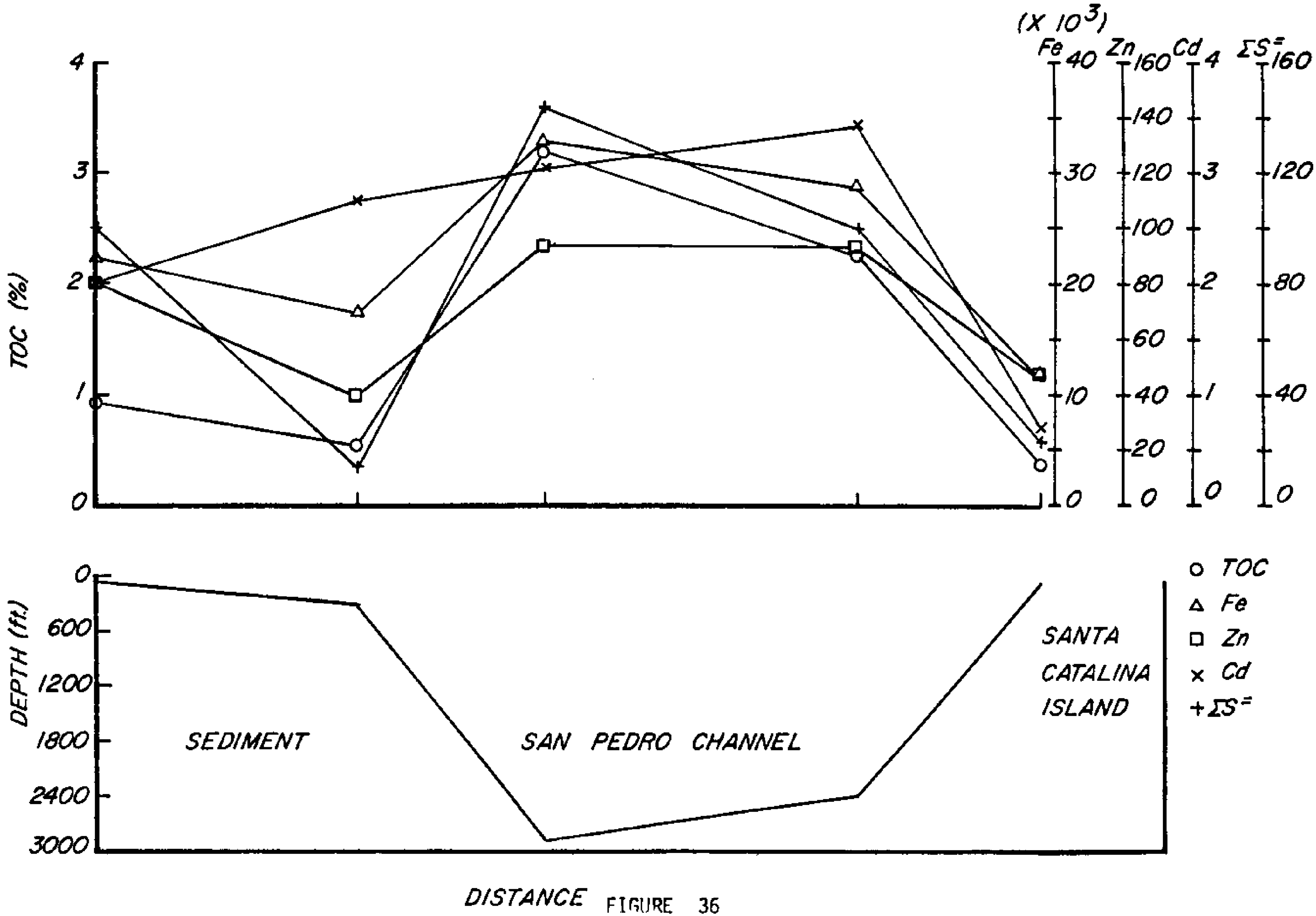


FIGURE 36

Profiles of Contaminants in San Pedro Basin (Section A-A of Figure 1)

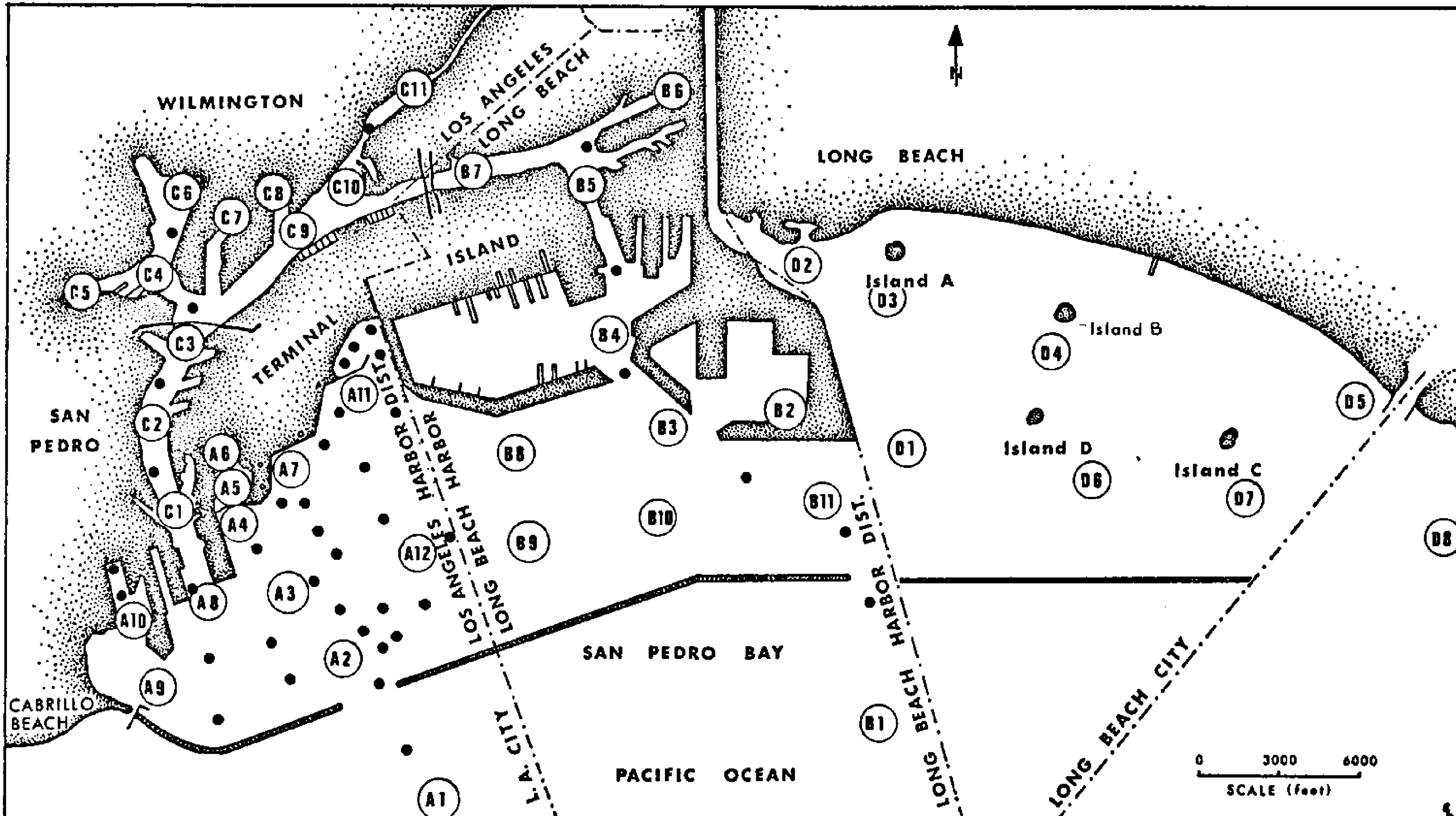


FIGURE 37

Stations for Surface Sediment Samples in Los Angeles-Long Beach Harbor

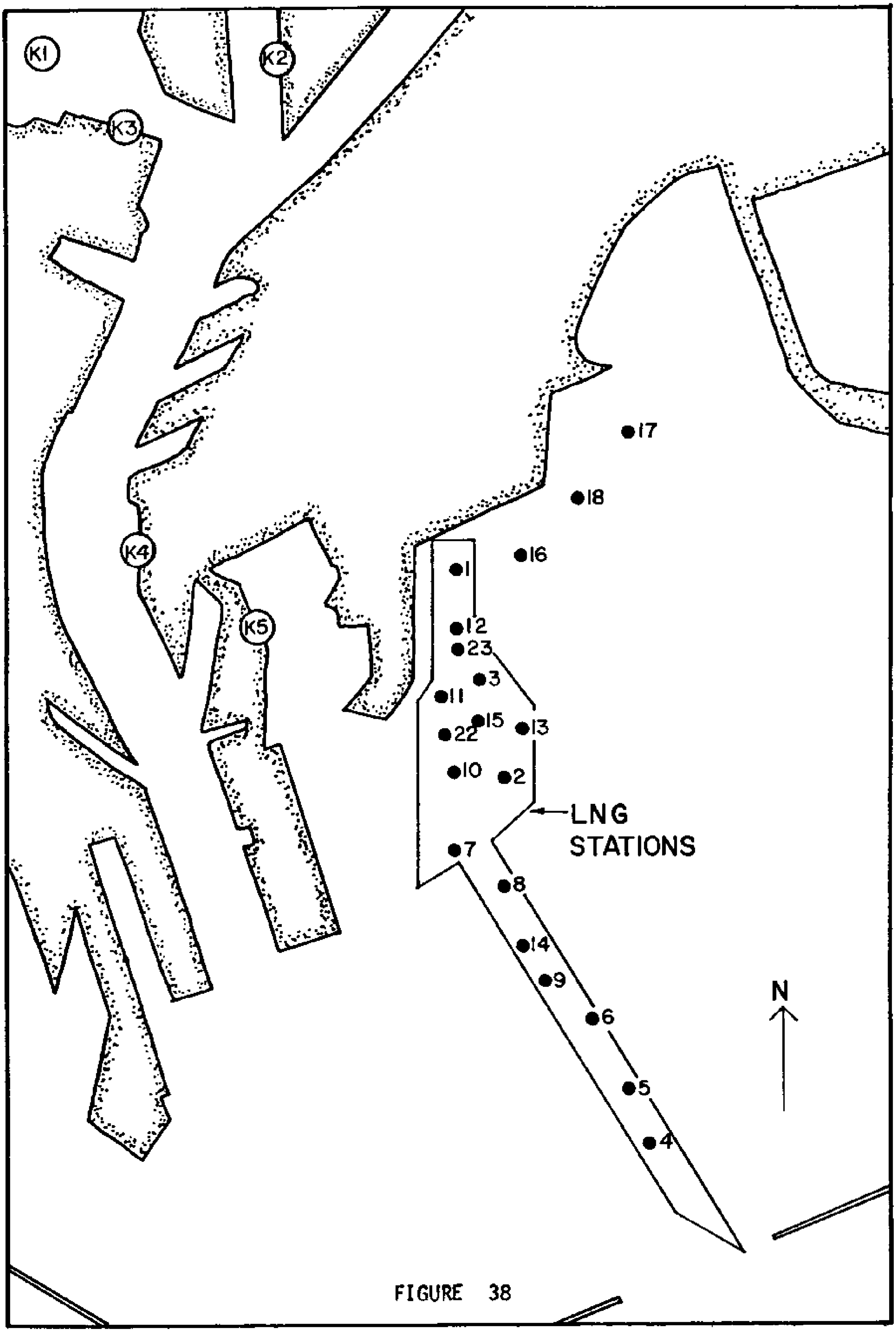


FIGURE 38

Sampling Stations for the Proposed LNG Route and Dominguez Channel

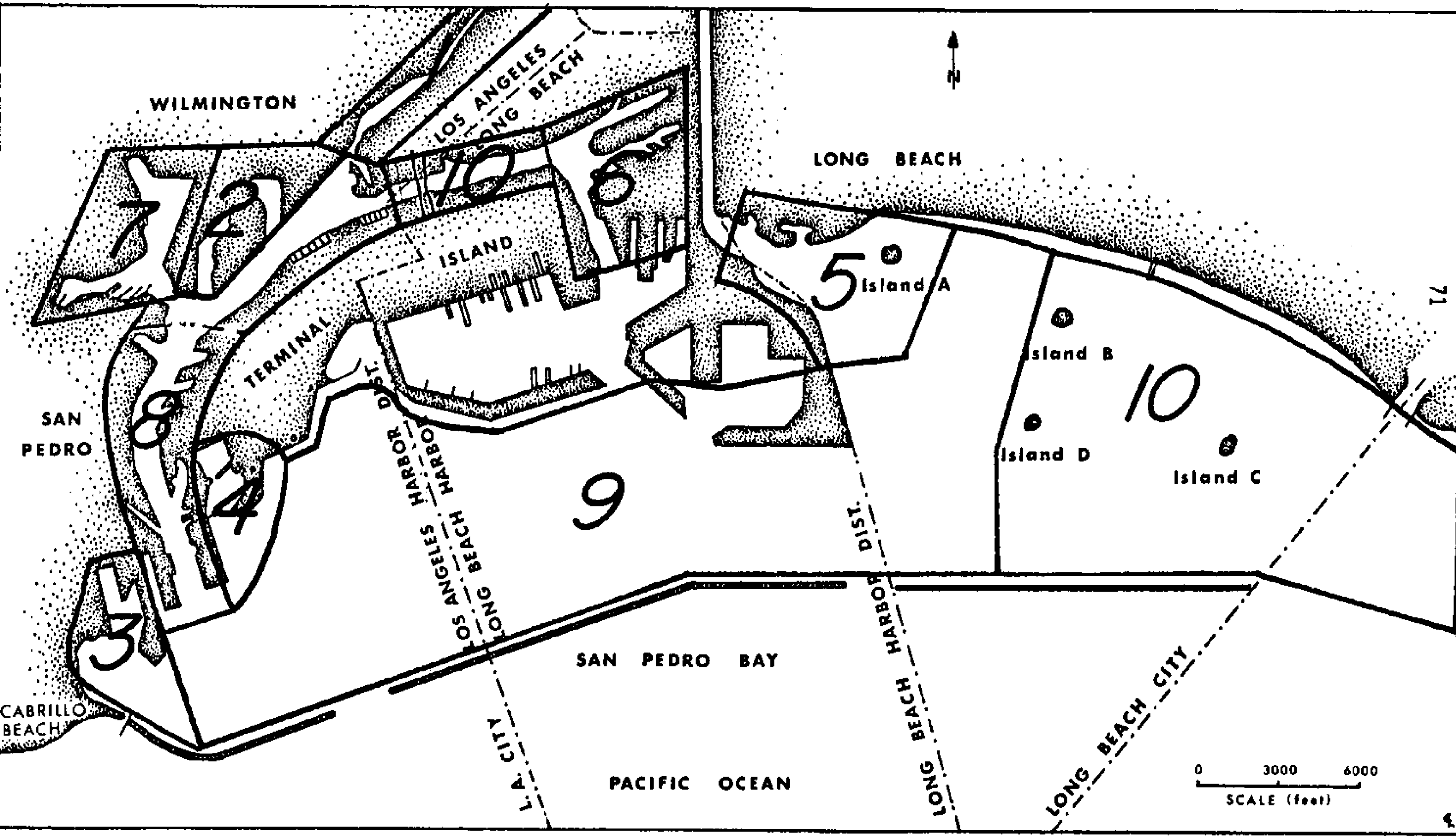


FIGURE 39: Relative Intensity of Contamination in the Surface Sediments of L.A.-L.B. Harbors (i.e., lowest number = most polluted)

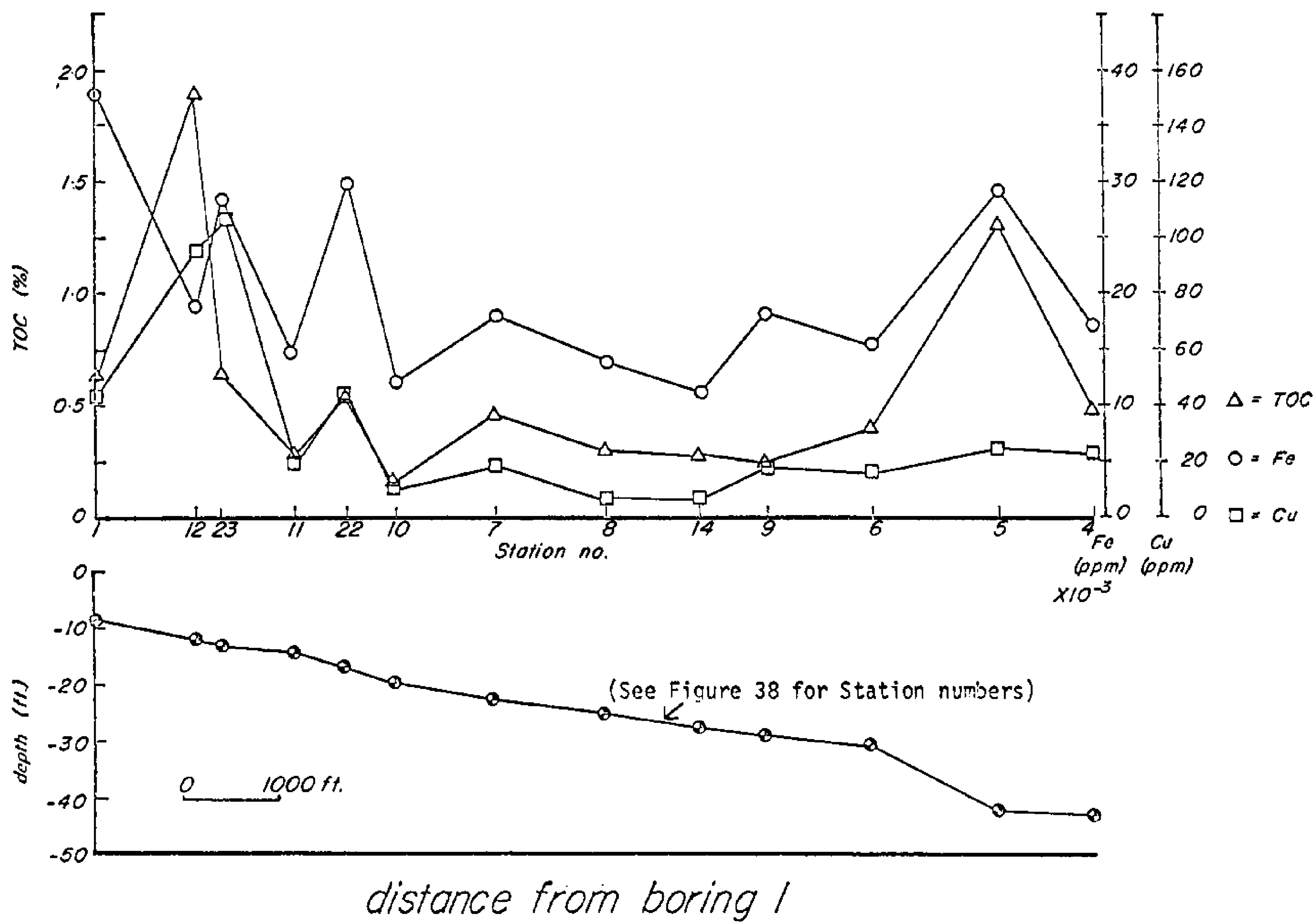


FIGURE 40

Profiles of Pollutants in the Surface Sediments of the Proposed LNG Route

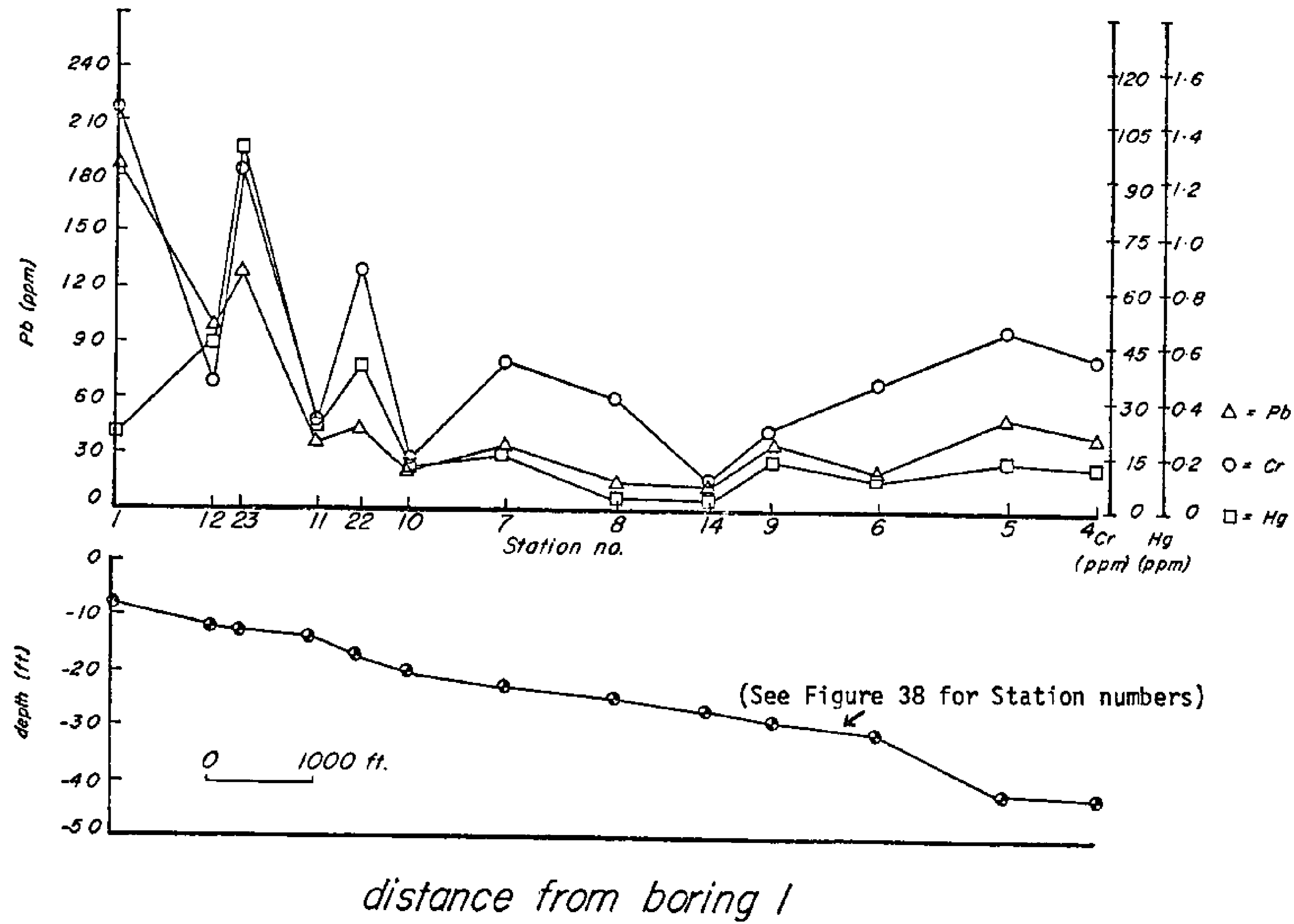


FIGURE 41

Profiles of Pollutants in the Surface Sediments of the Proposed LNG Route

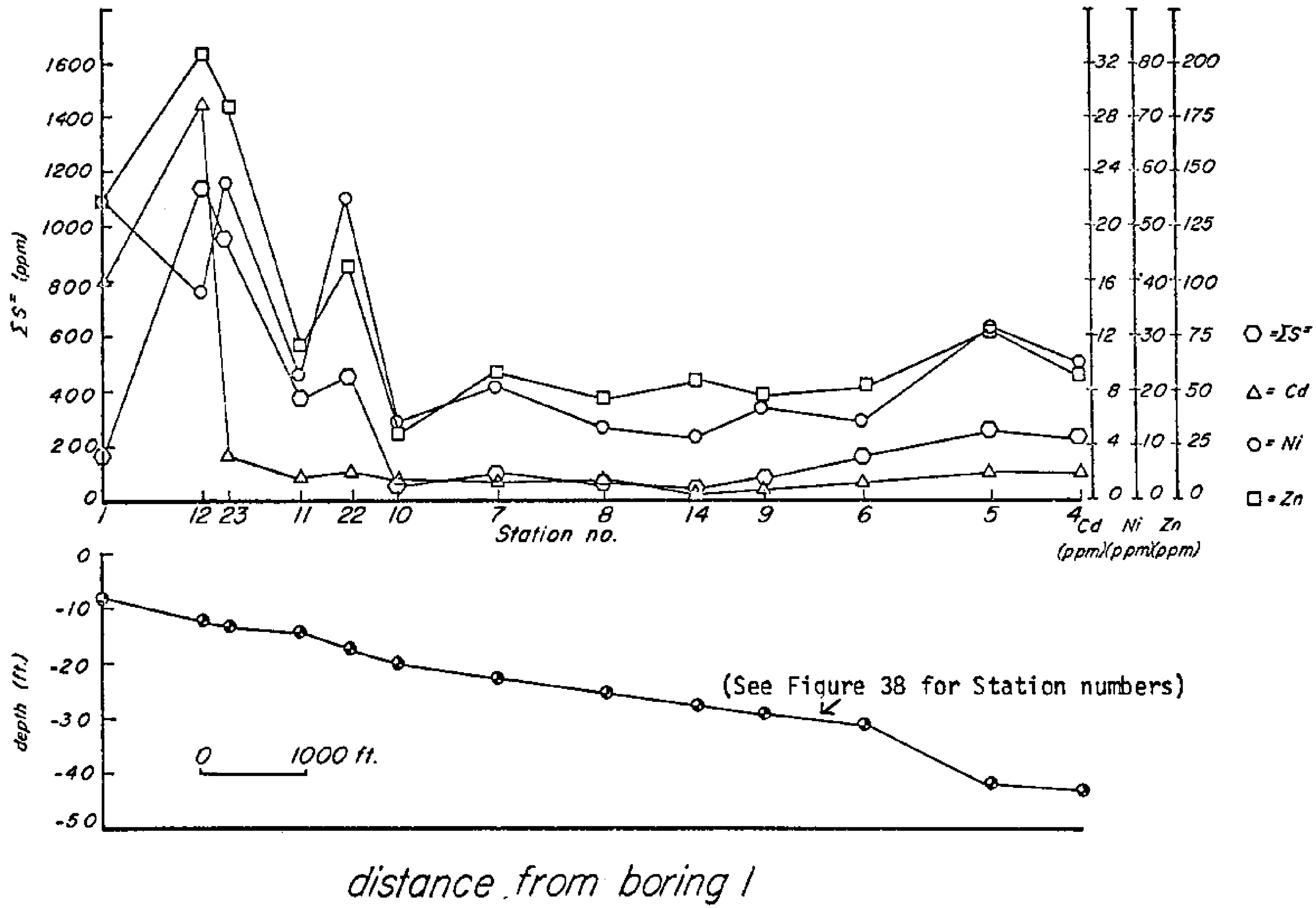


FIGURE 42

Profiles of Pollutants in the Surface Sediments of the Proposed LNG Route

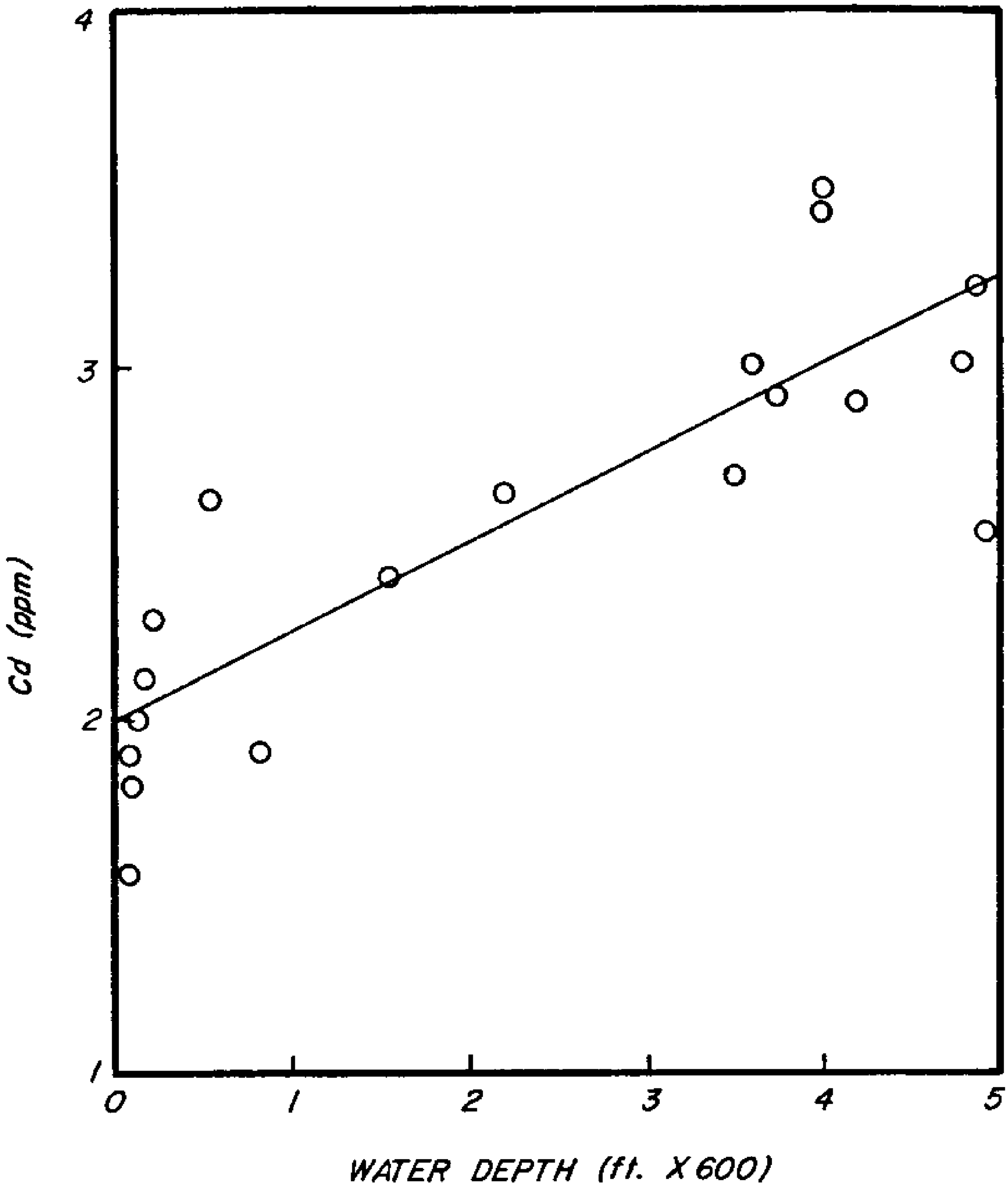


FIGURE 43

Cadmium Concentration vs. Water Depth
in San Pedro Basin

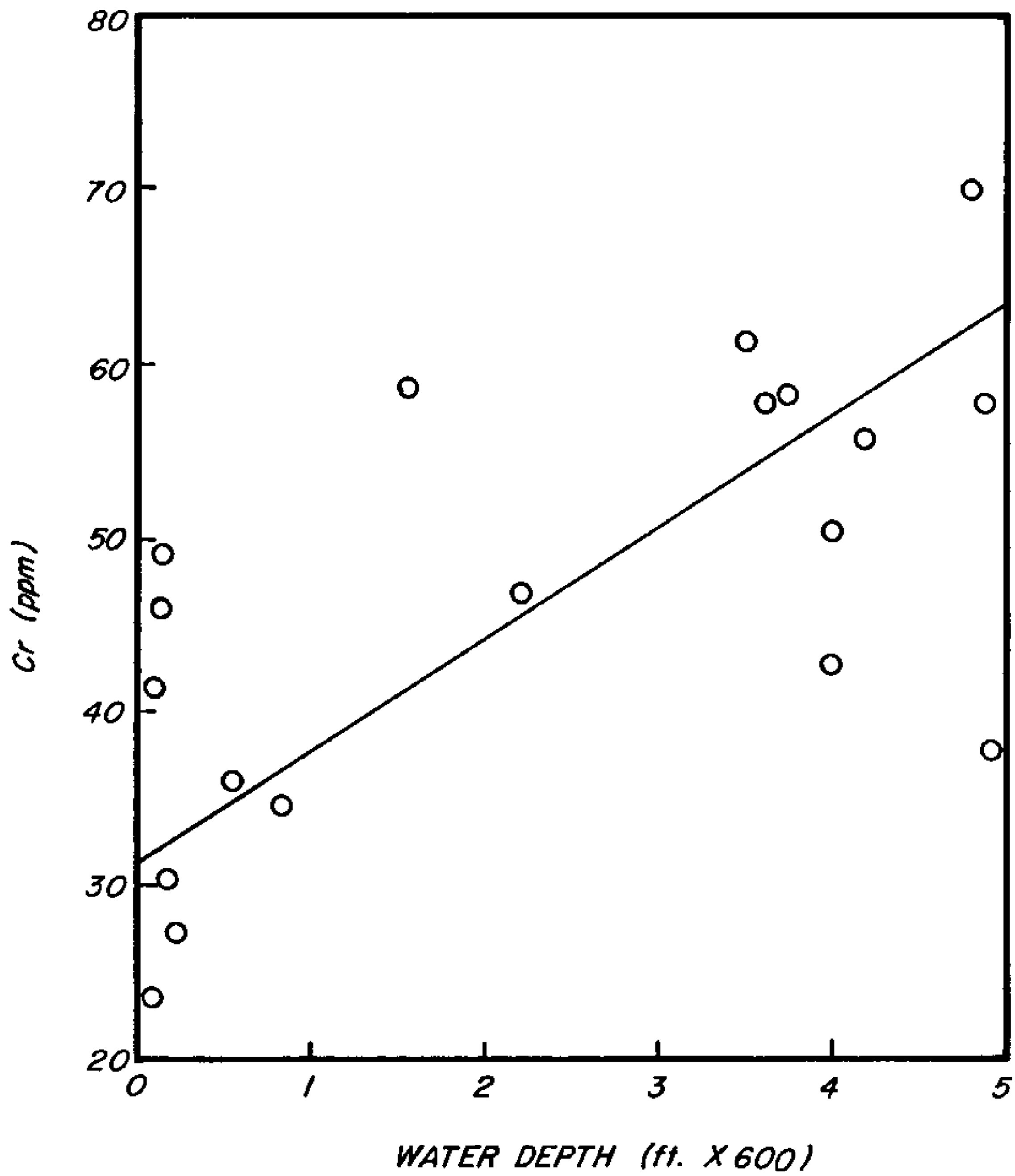


FIGURE 44

Chromium Concentration vs. Water Depth
in San Pedro Basin

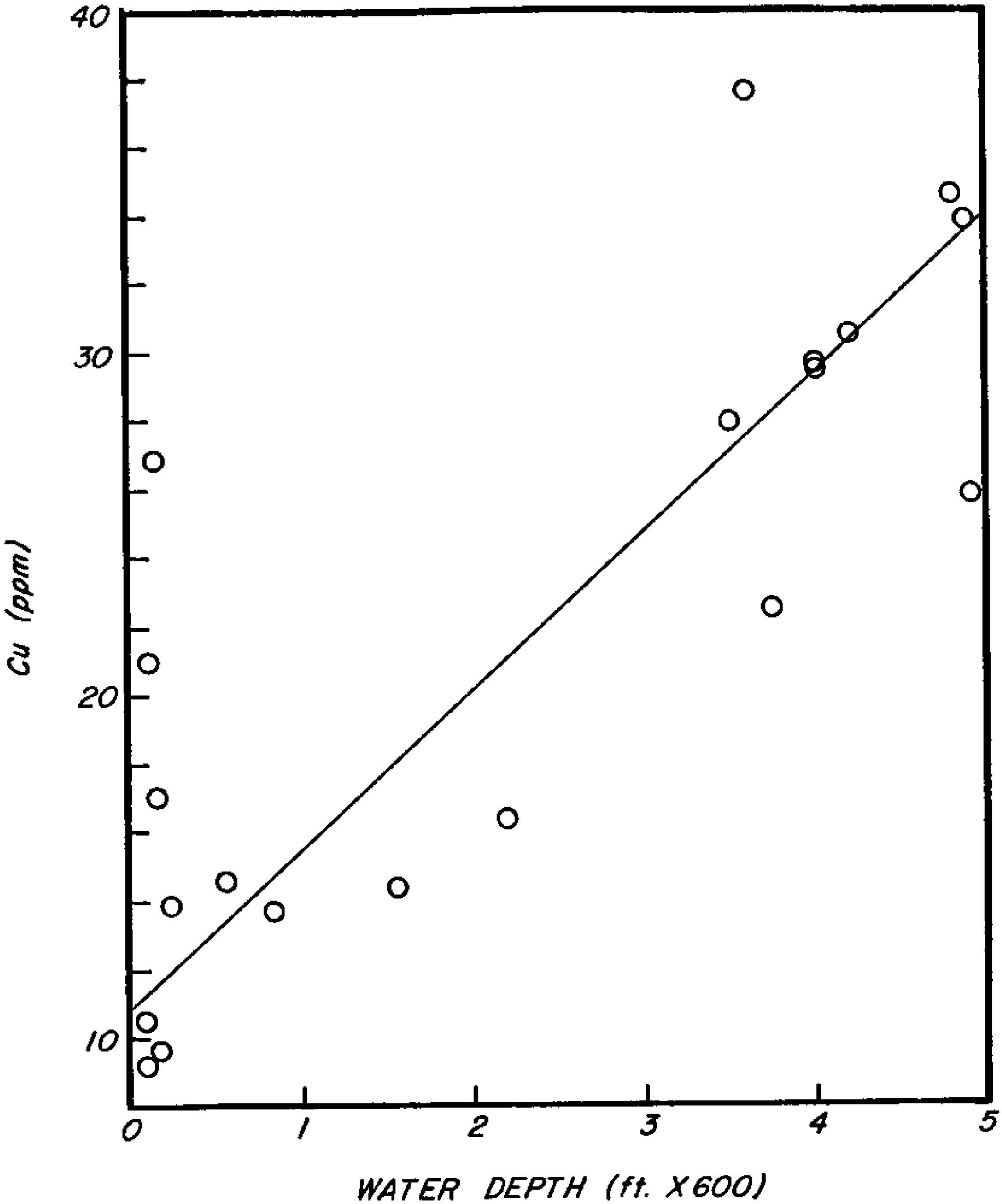


FIGURE 45

Copper Concentration vs. Water Depth in San Pedro Basin

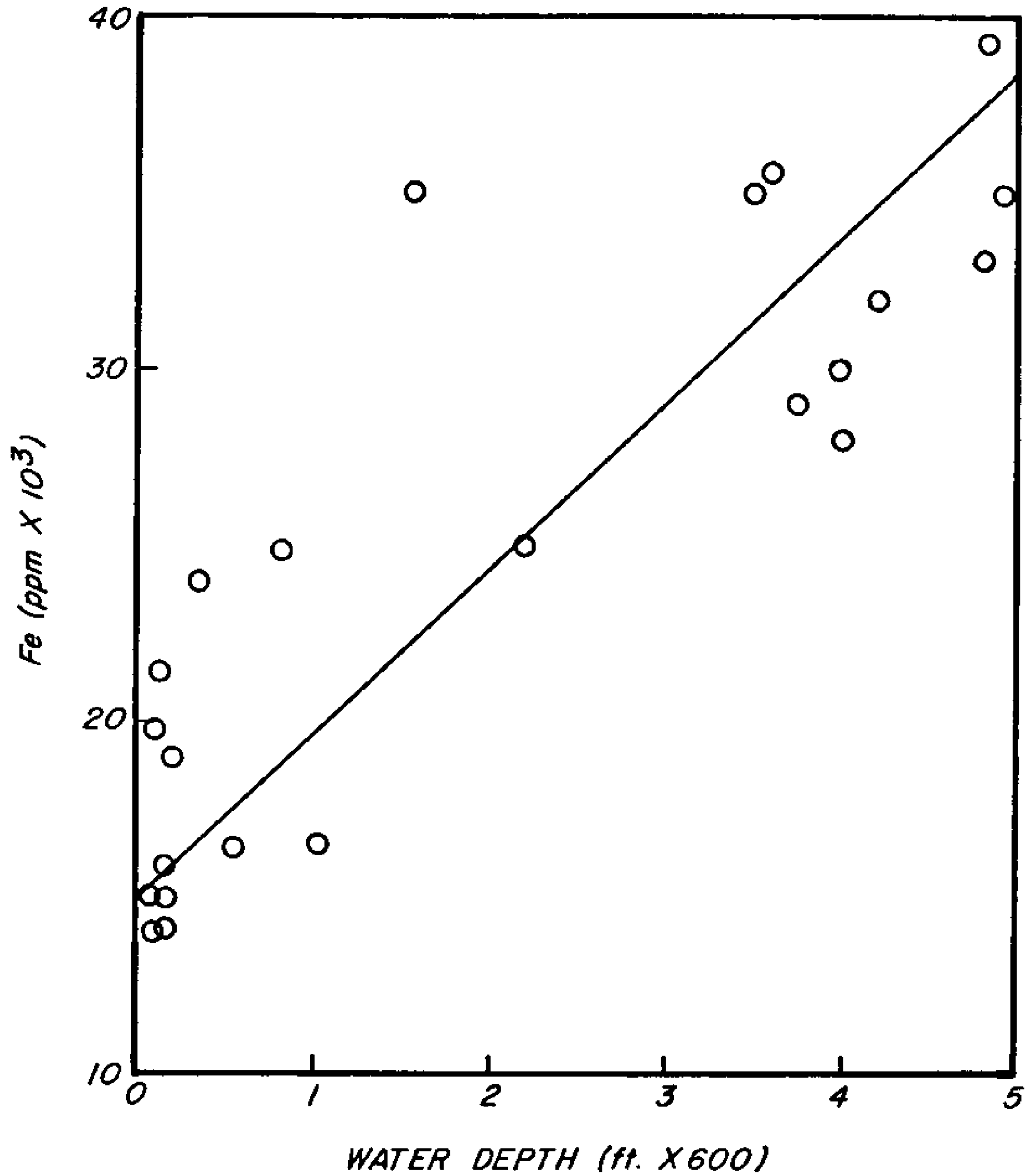


FIGURE 46

Iron Concentration vs. Water Depth in San Pedro Basin

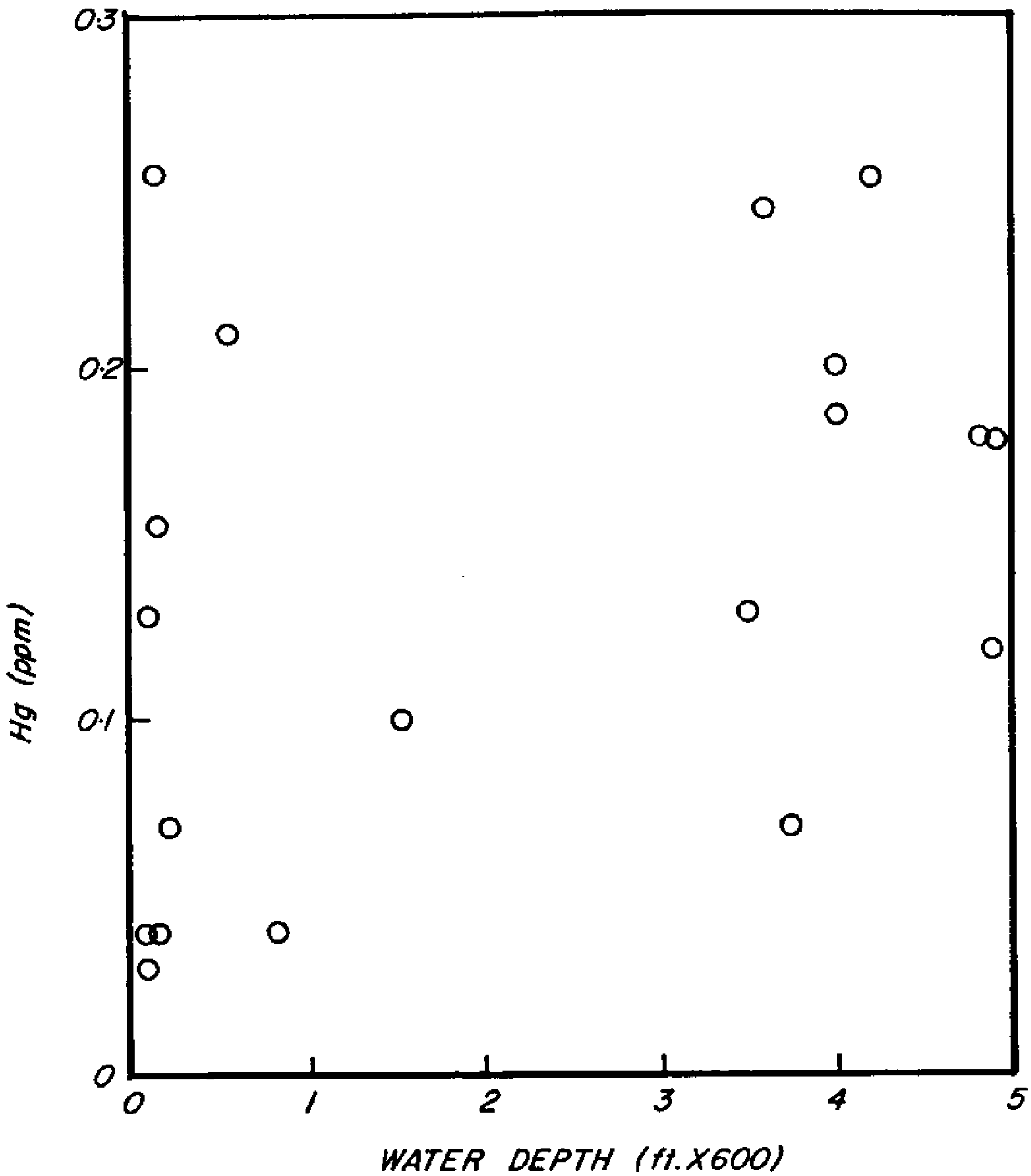


FIGURE 47

Mercury Concentration vs. Water Depth
in San Pedro Basin

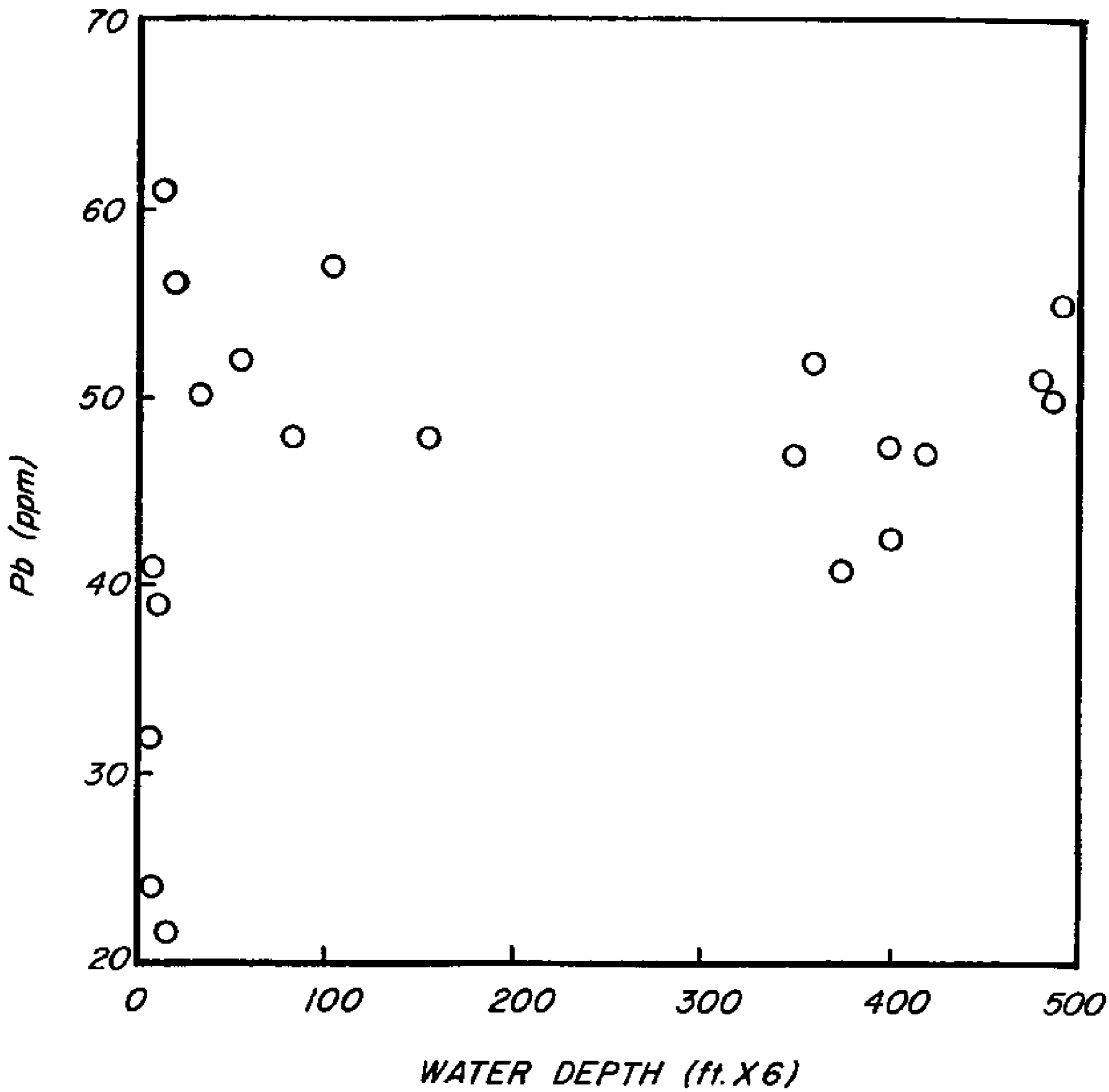


FIGURE 48

Lead Concentration vs. Water Depth in San Pedro Basin

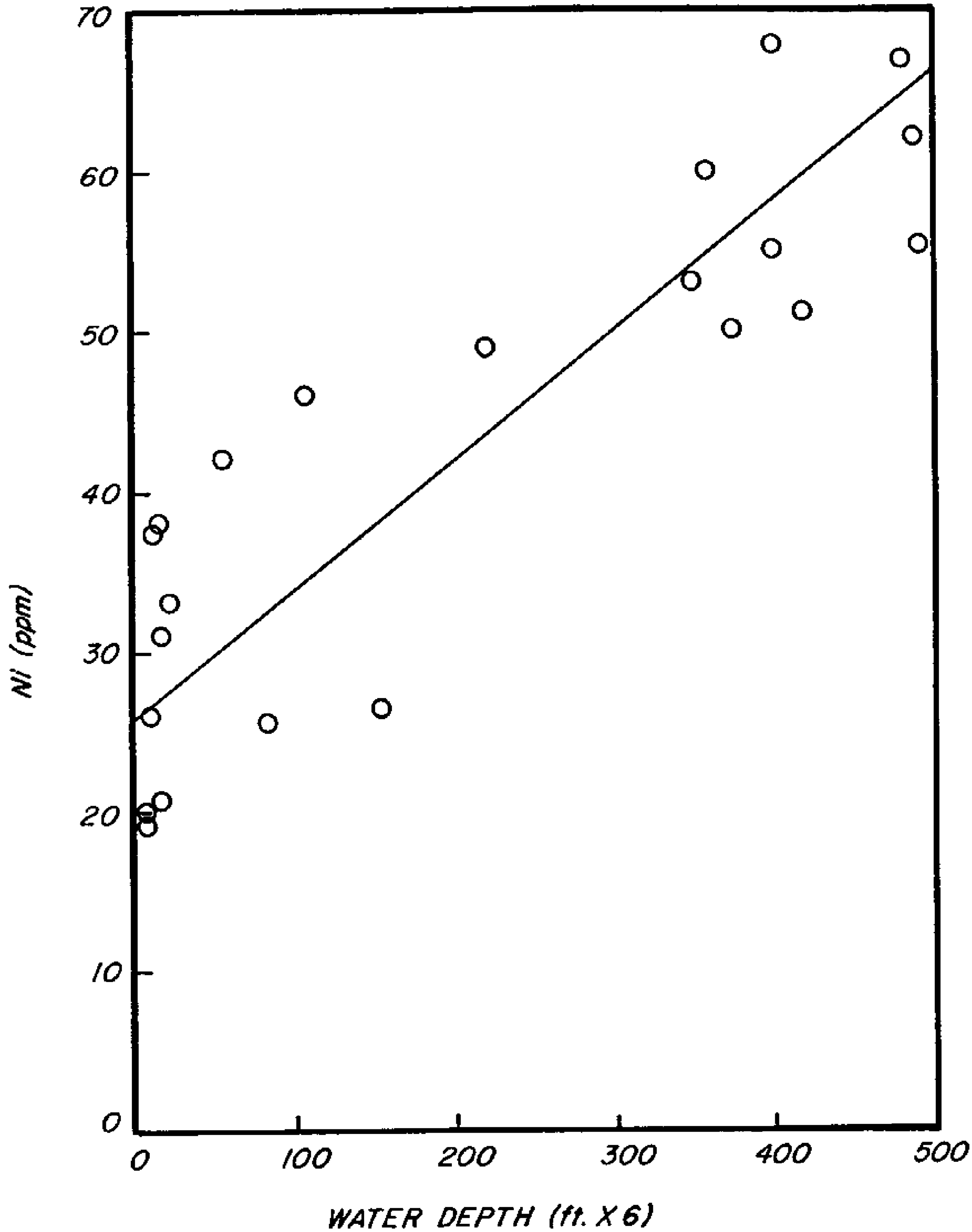


FIGURE 49

Nickel Concentration vs. Water Depth in San Pedro Basin

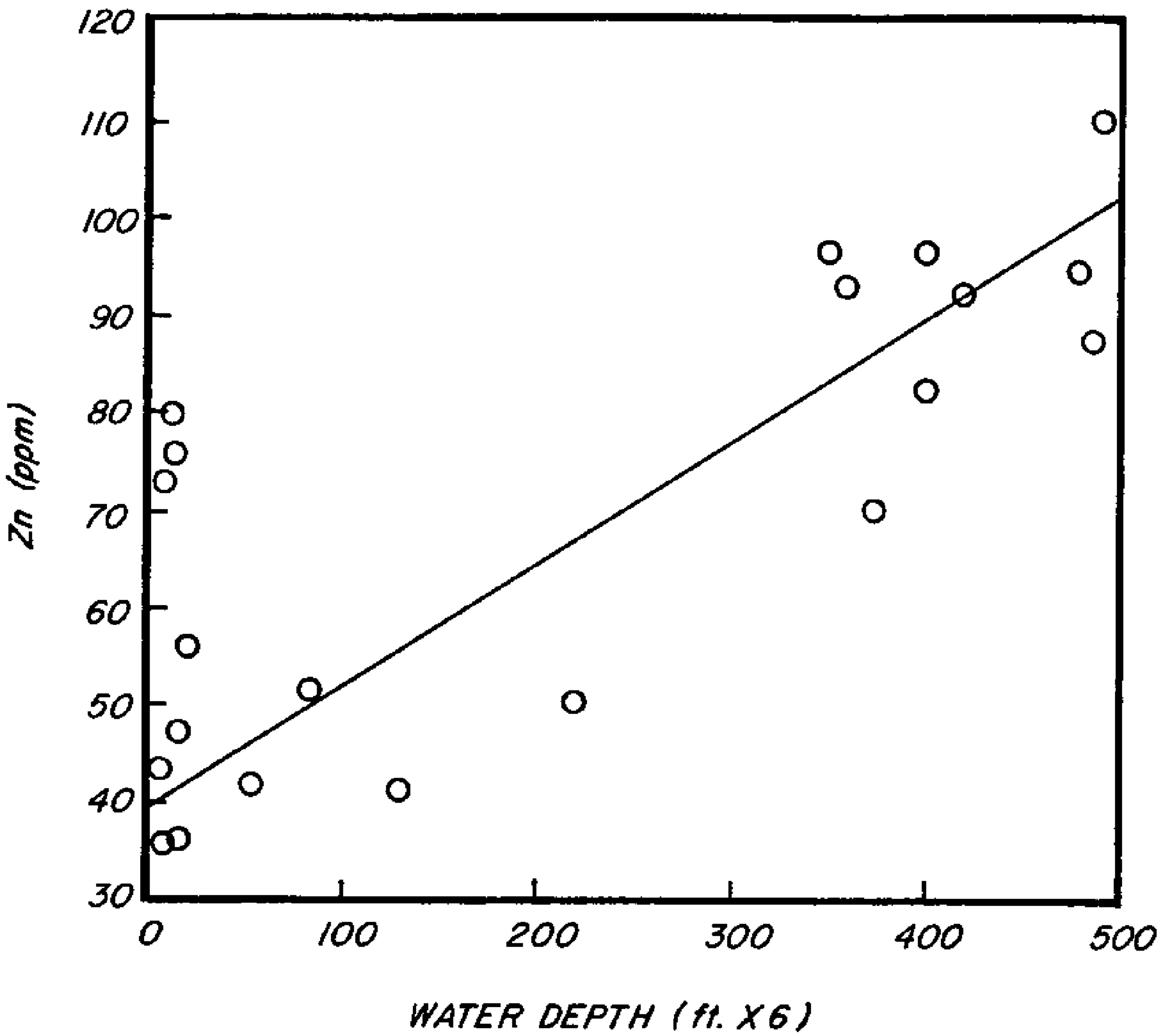


FIGURE 50

Zinc Concentration vs. Water
Depth in San Pedro Basin

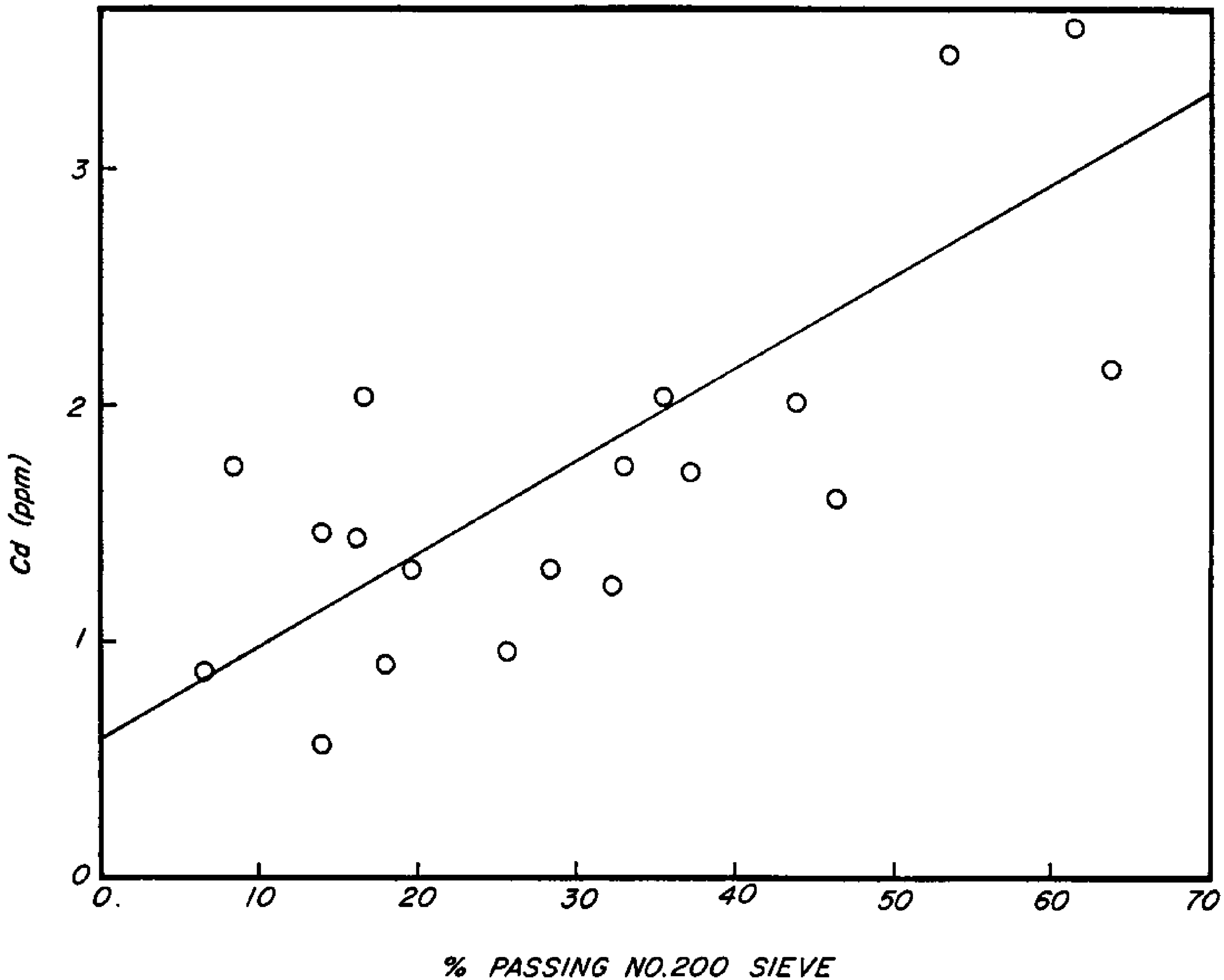


FIGURE 51

Cadmium Concentration vs. Percent of Surface Sediments Passing Sieve #200 in L.A. Harbor

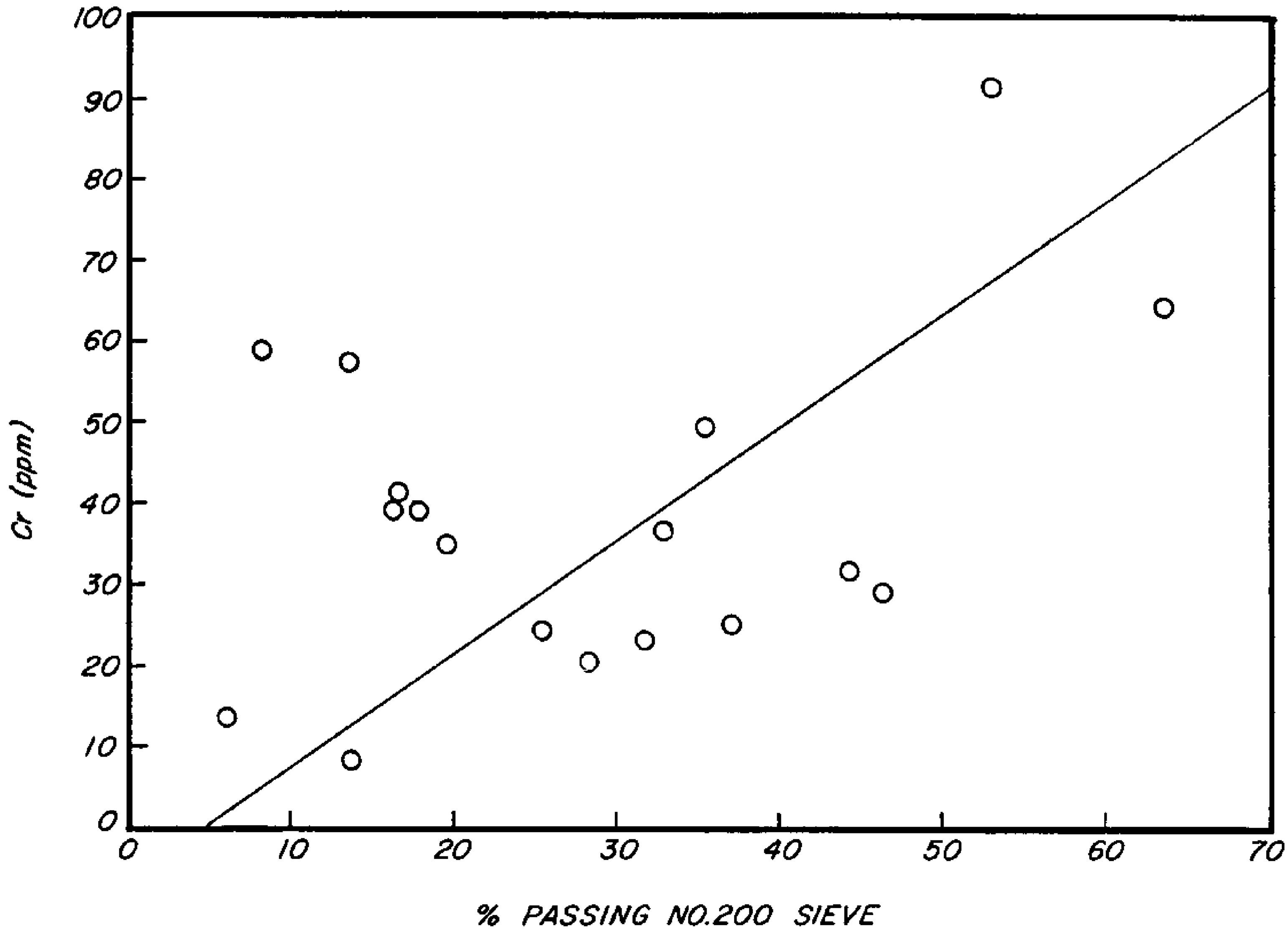


FIGURE 52
Chromium Concentration vs. Percent of Surface Sediments Passing Sieve #200 in L.A. Harbor

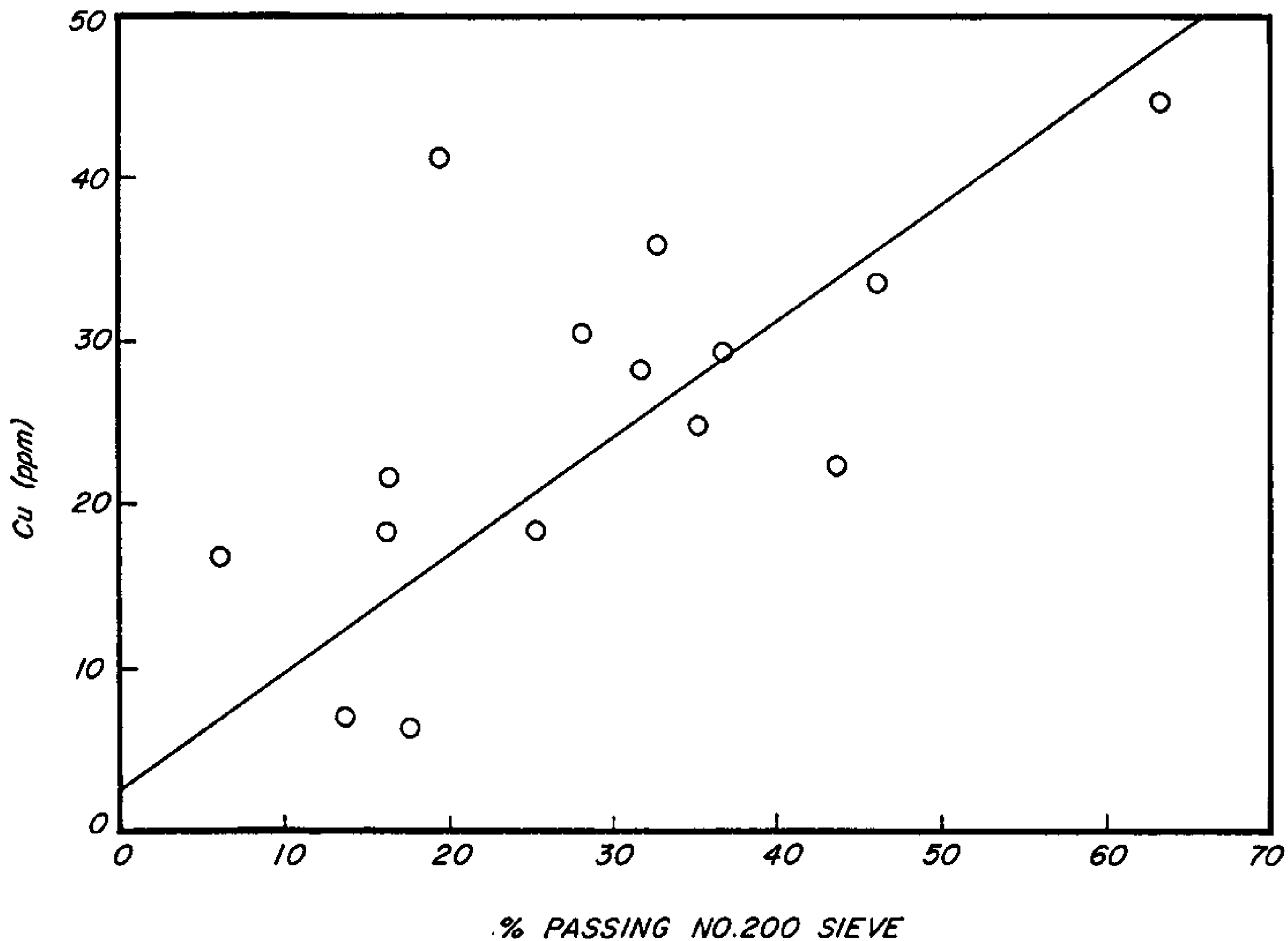


FIGURE 53

Copper Concentration vs. Percent of Surface Sediments Passing Sieve #200 in L.A. Harbor

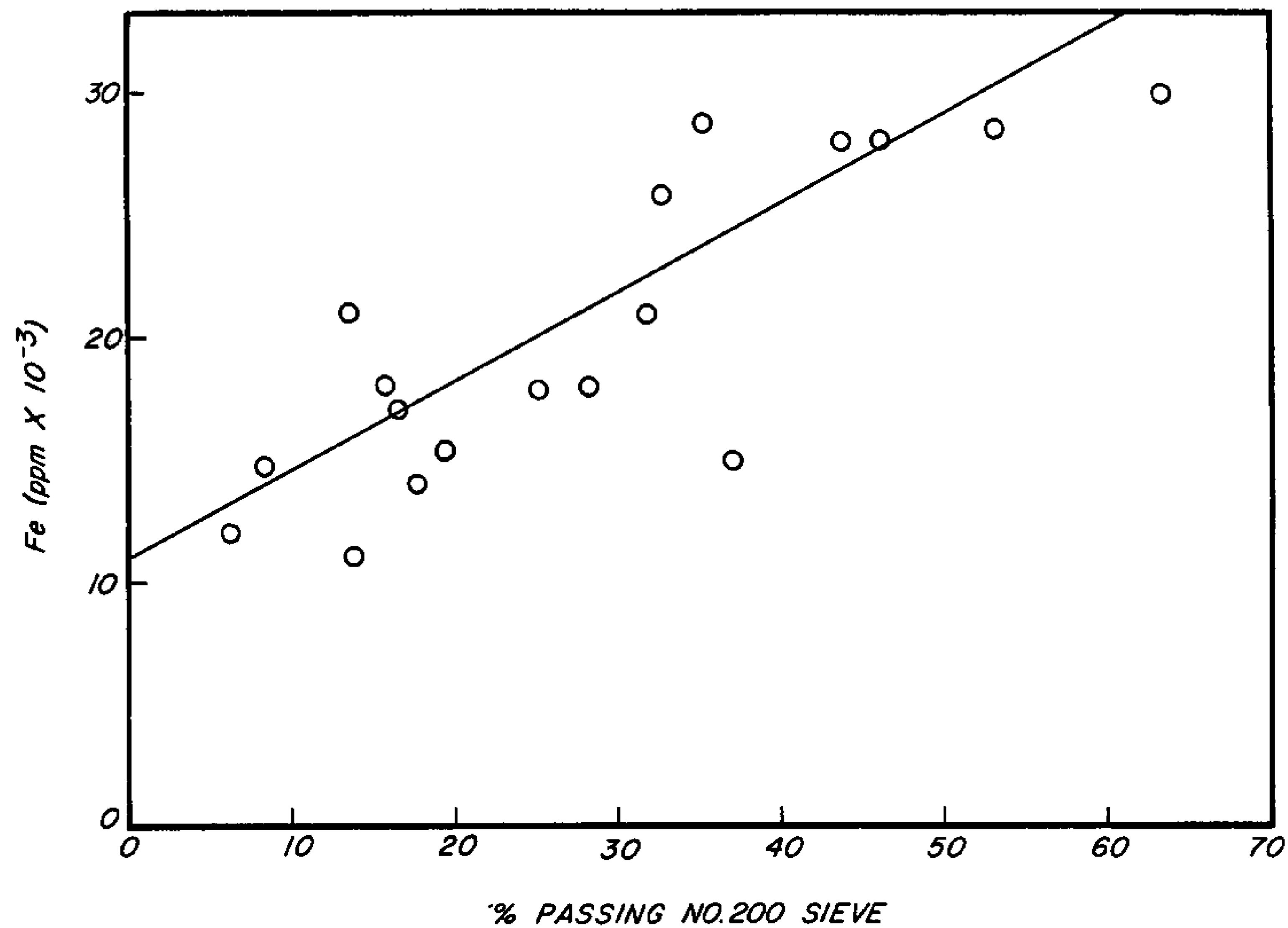


FIGURE 54

Iron Concentration vs. Percent of Surface Sediments Passing Sieve #200 in L.A. Harbor

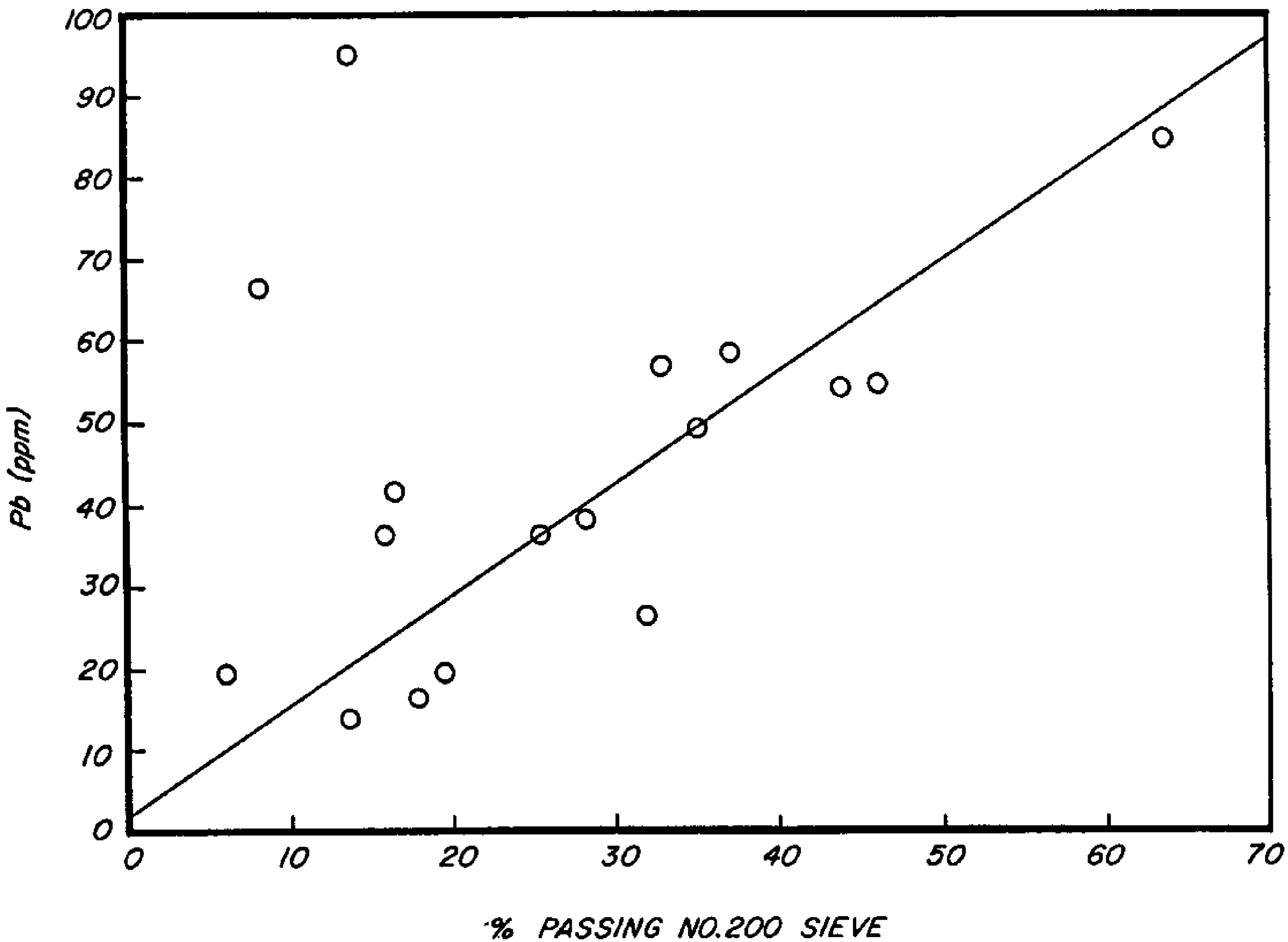


FIGURE 55

Lead Concentration vs. Percent of Surface Sediments Passing Sieve#200 in L.A. Harbor

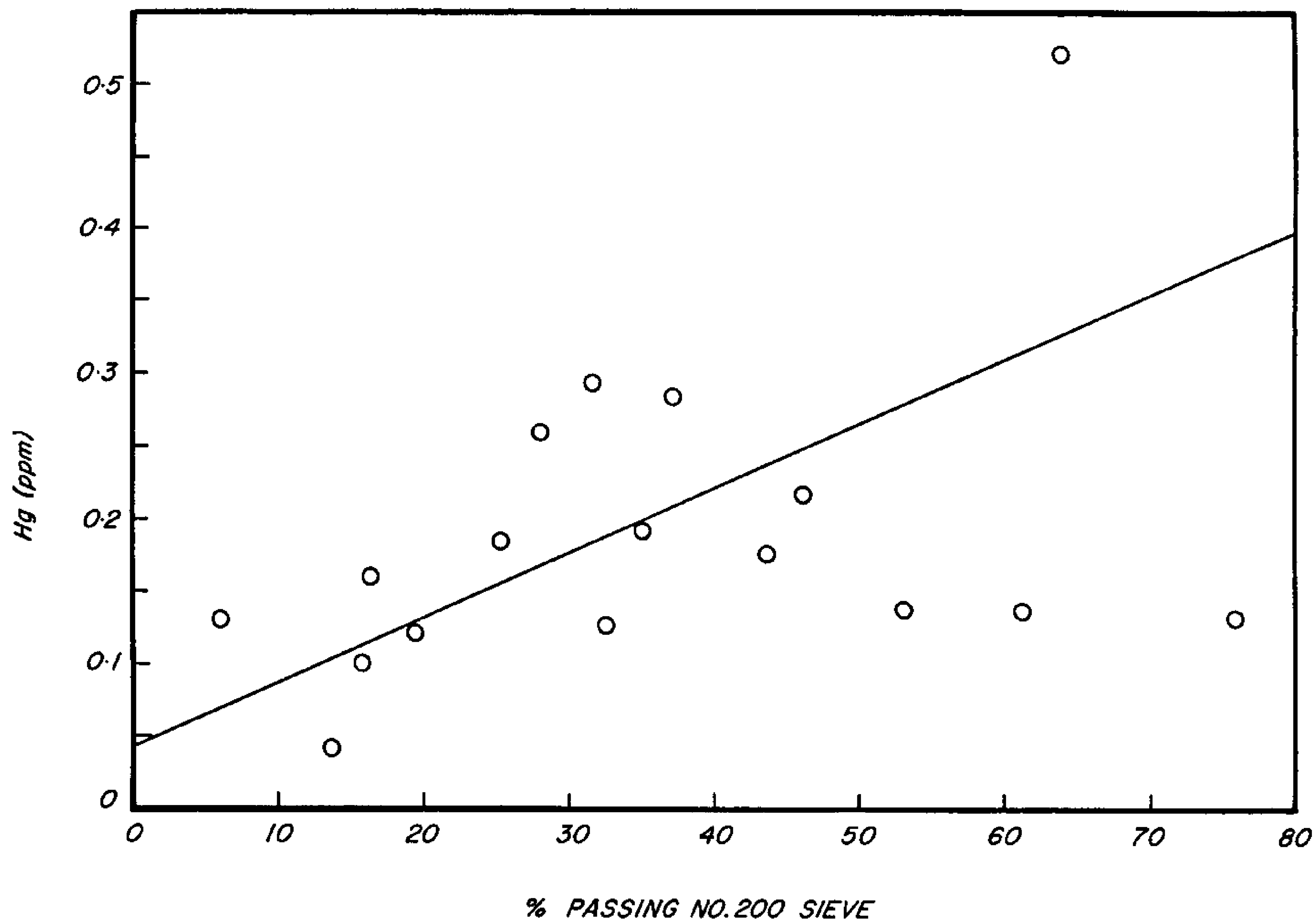


FIGURE 56

Mercury Concentration vs. Percent of Surface Sediments Passing Sieve #200 in L.A. Harbor

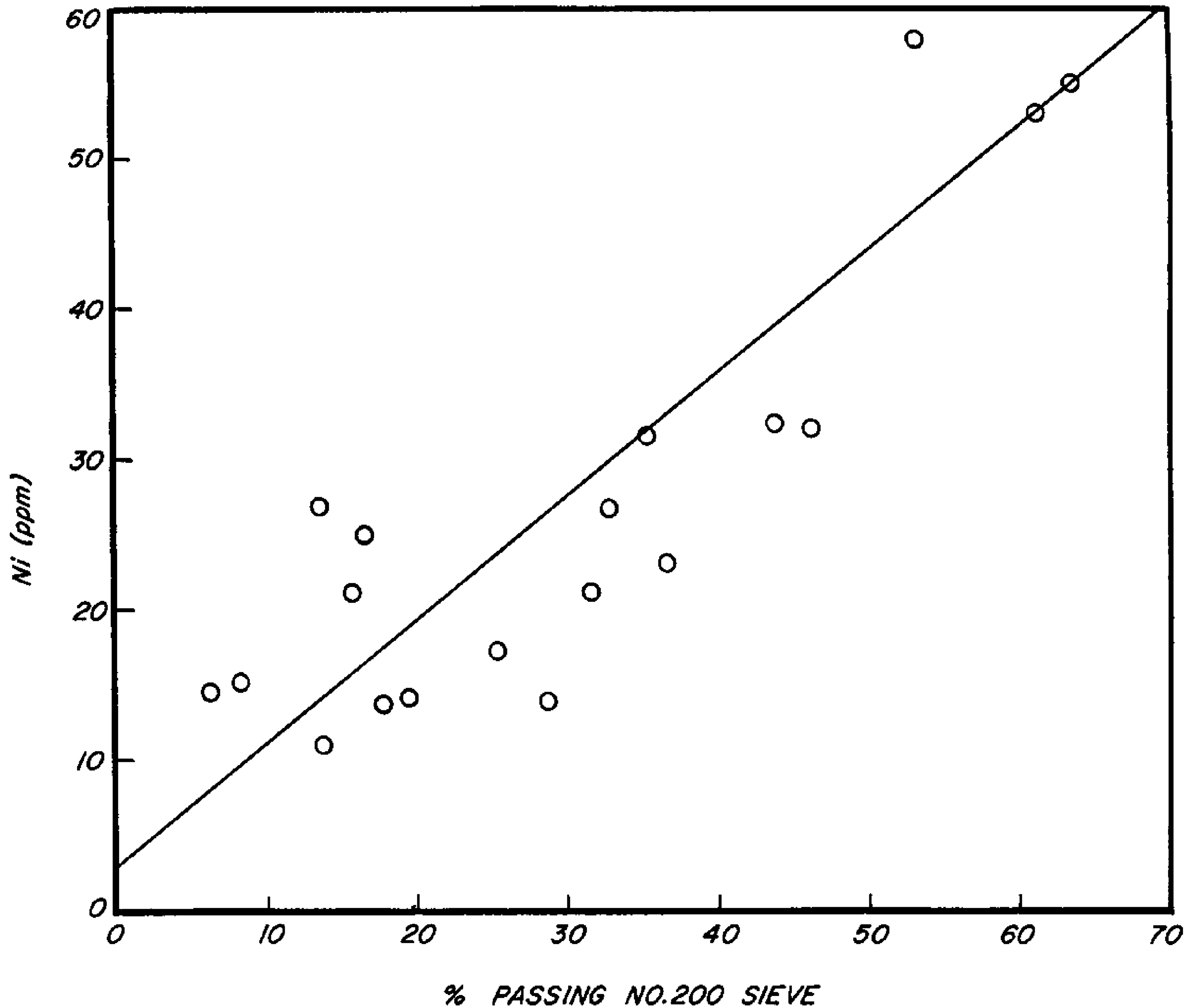


FIGURE 57
Nickel Concentration vs. Percent of Surface Sediments Passing Sieve #200 in L.A. Harbor

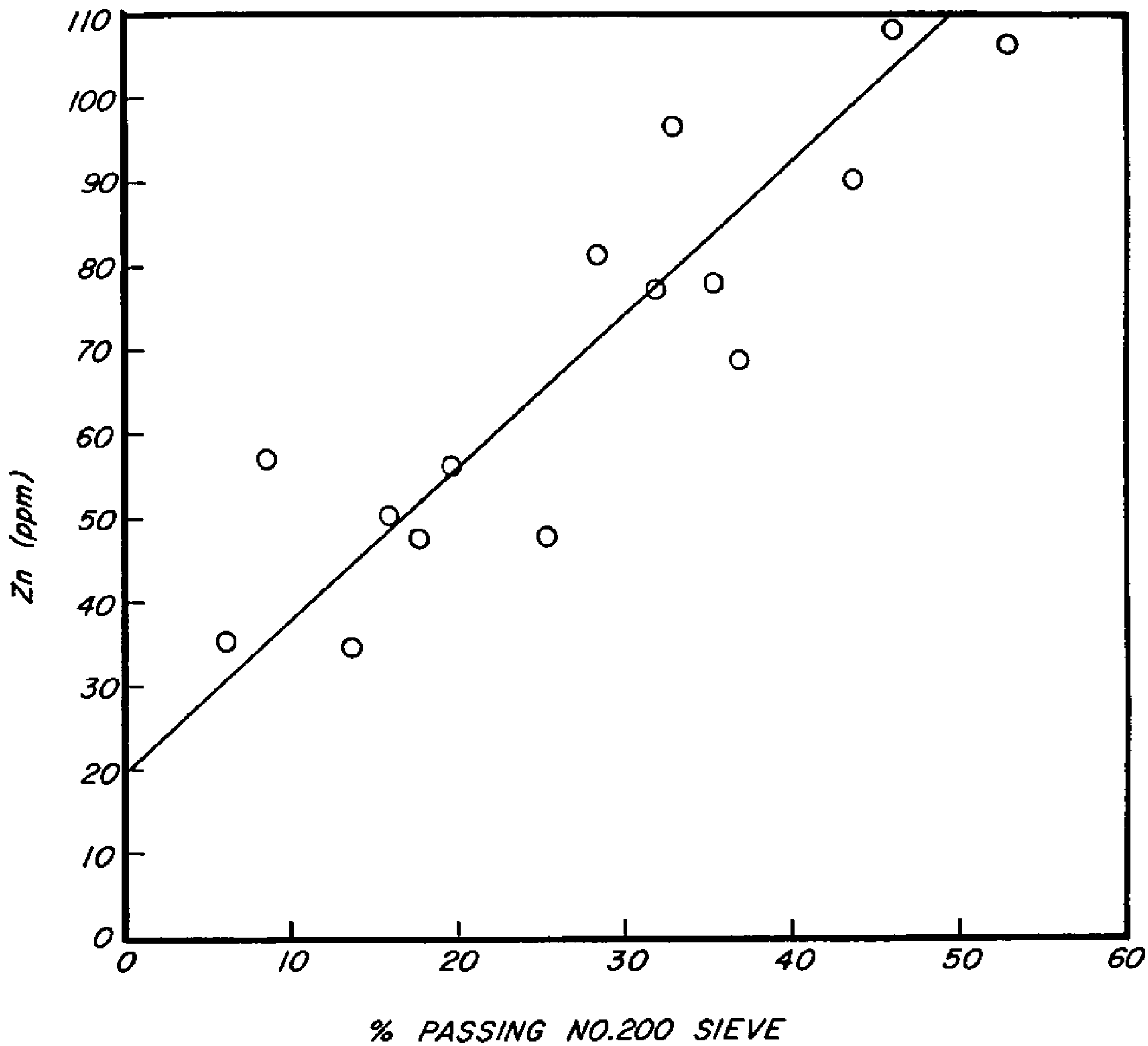


FIGURE 58

Zinc Concentration vs. Percent
of Surface Sediments Passing
Sieve #200 in L.A. Harbor

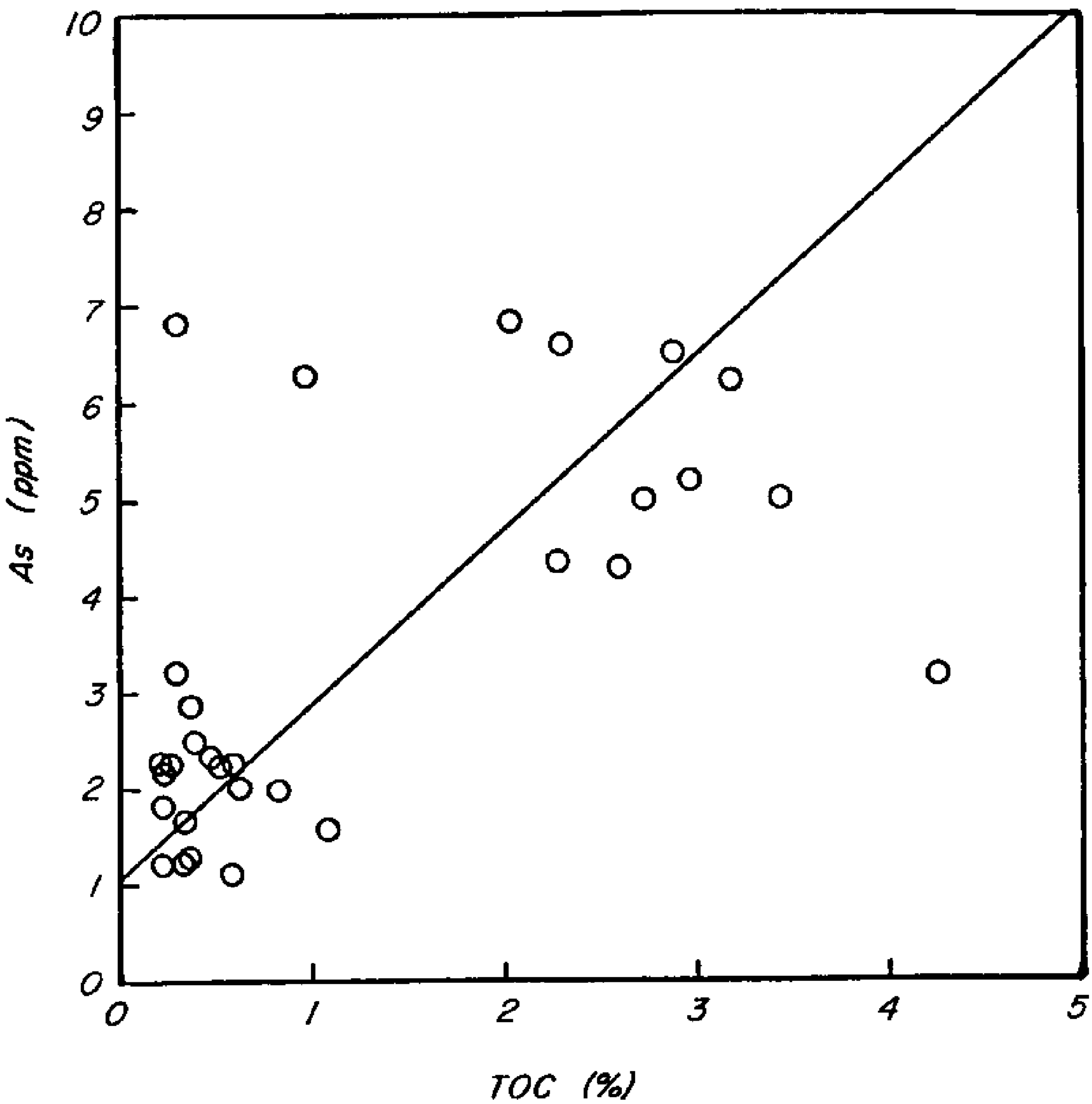


FIGURE 59

Concentration of Arsenic vs. Total Organic Carbon
in the Surface Sediments of San Pedro Basin

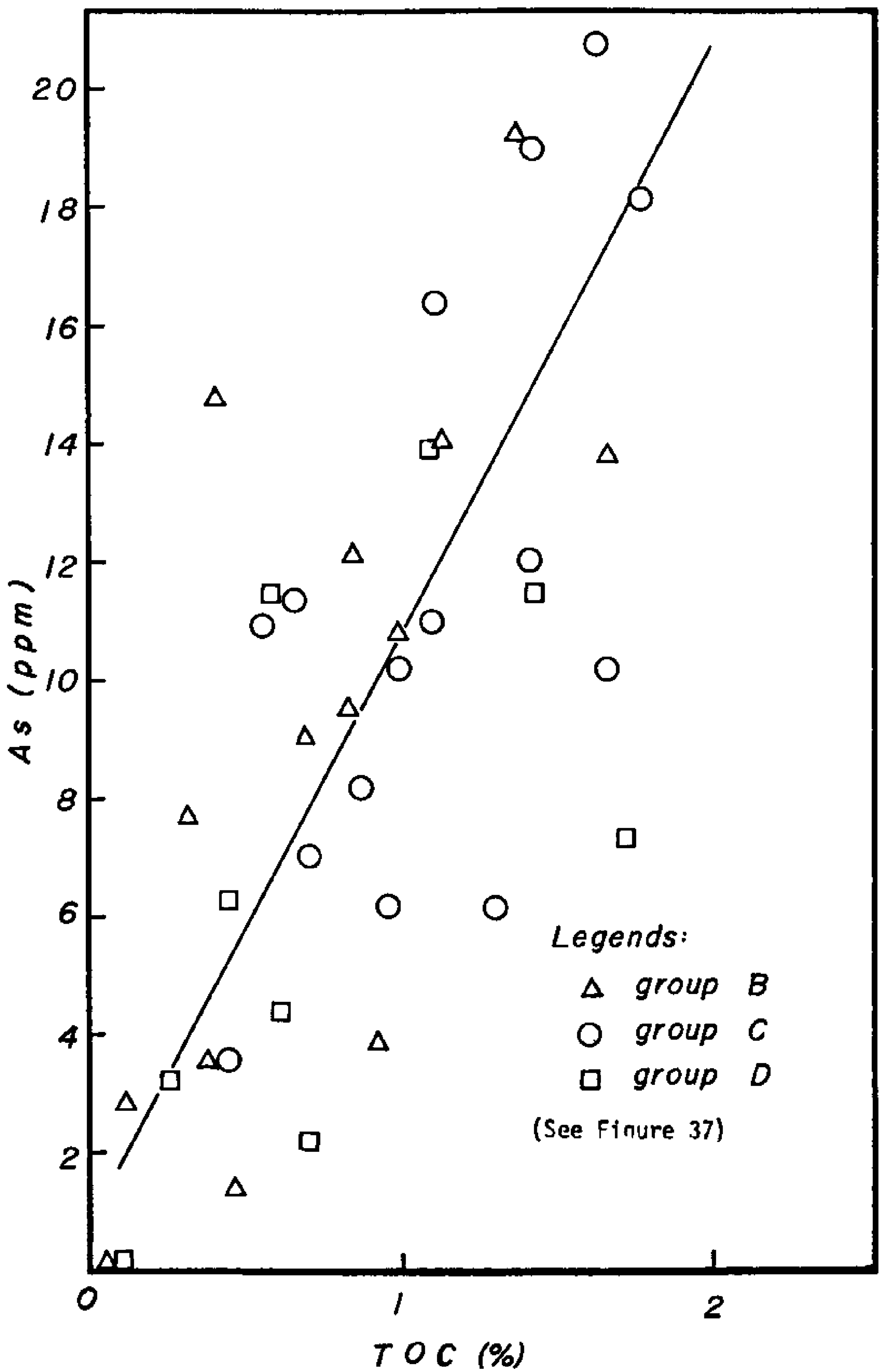


FIGURE 60

Concentration of Arsenic vs. Total Organic Carbon in the Surface Sediments of L.A. - L.B. Harbors

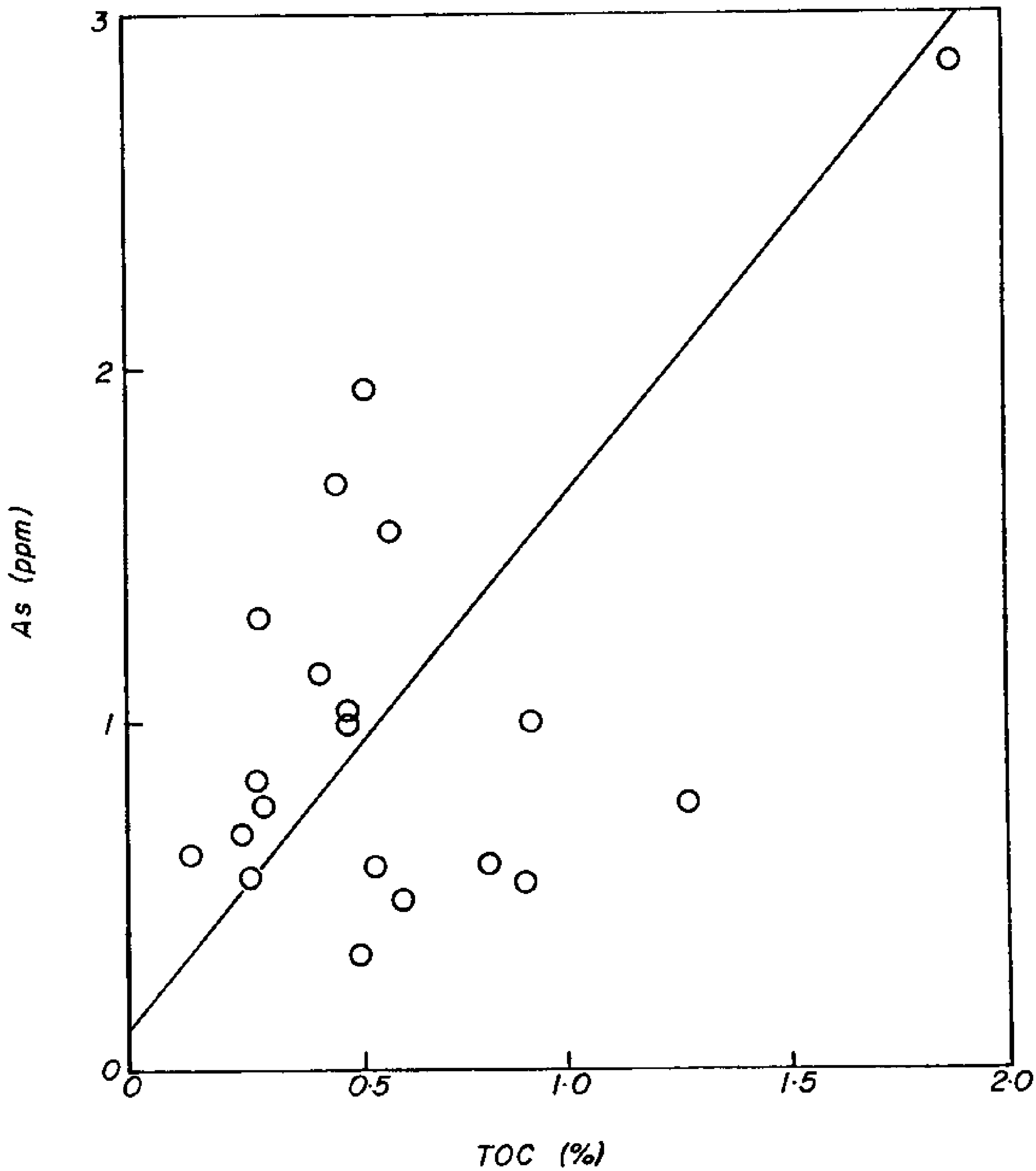


FIGURE 61

Concentration of Arsenic vs. Total Organic Carbon in the Sediments of the Proposed LNG Route

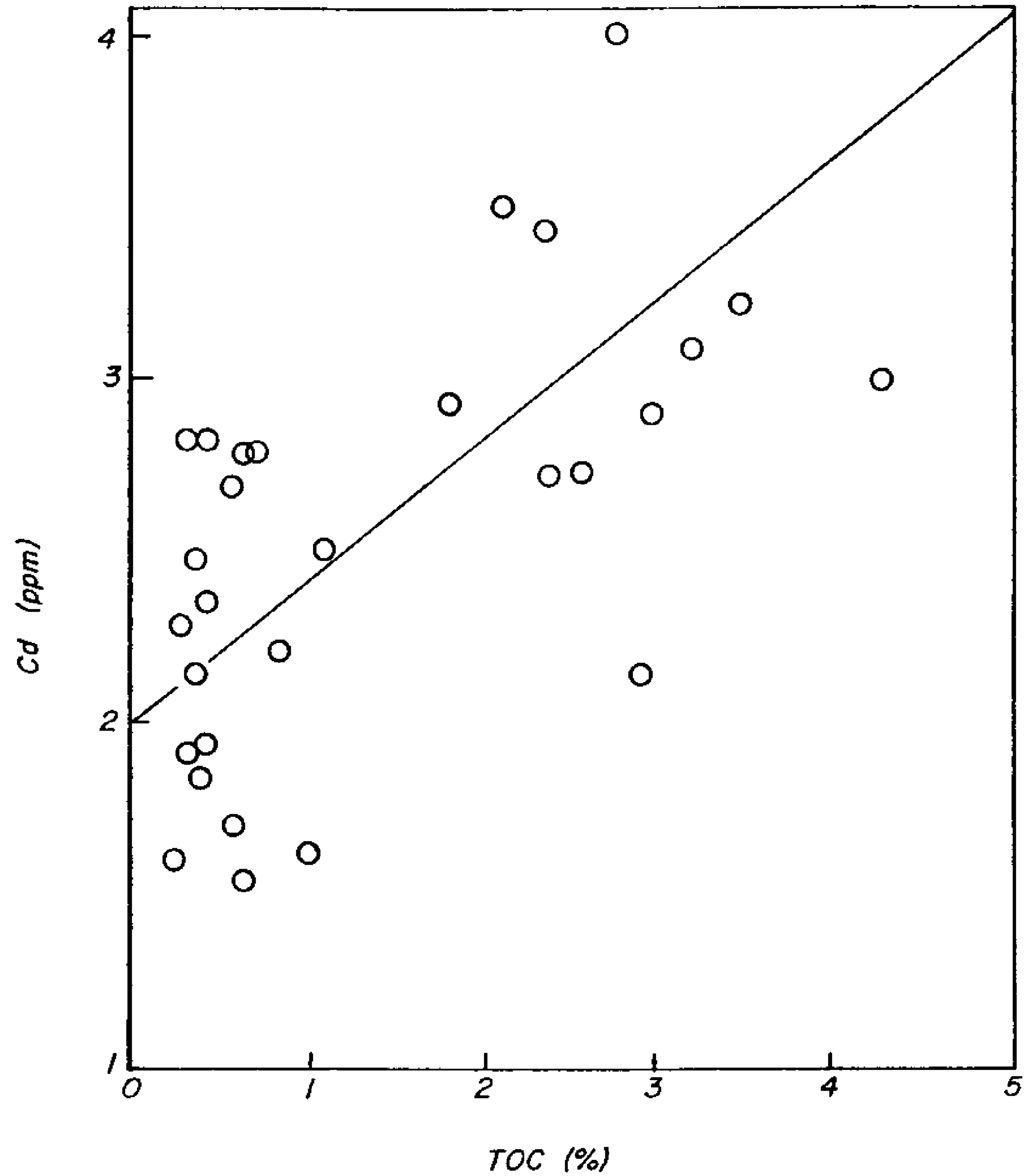


FIGURE 62

Concentration of Cadmium vs. Total Organic Carbon in the Surface Sediments of San Pedro Basin

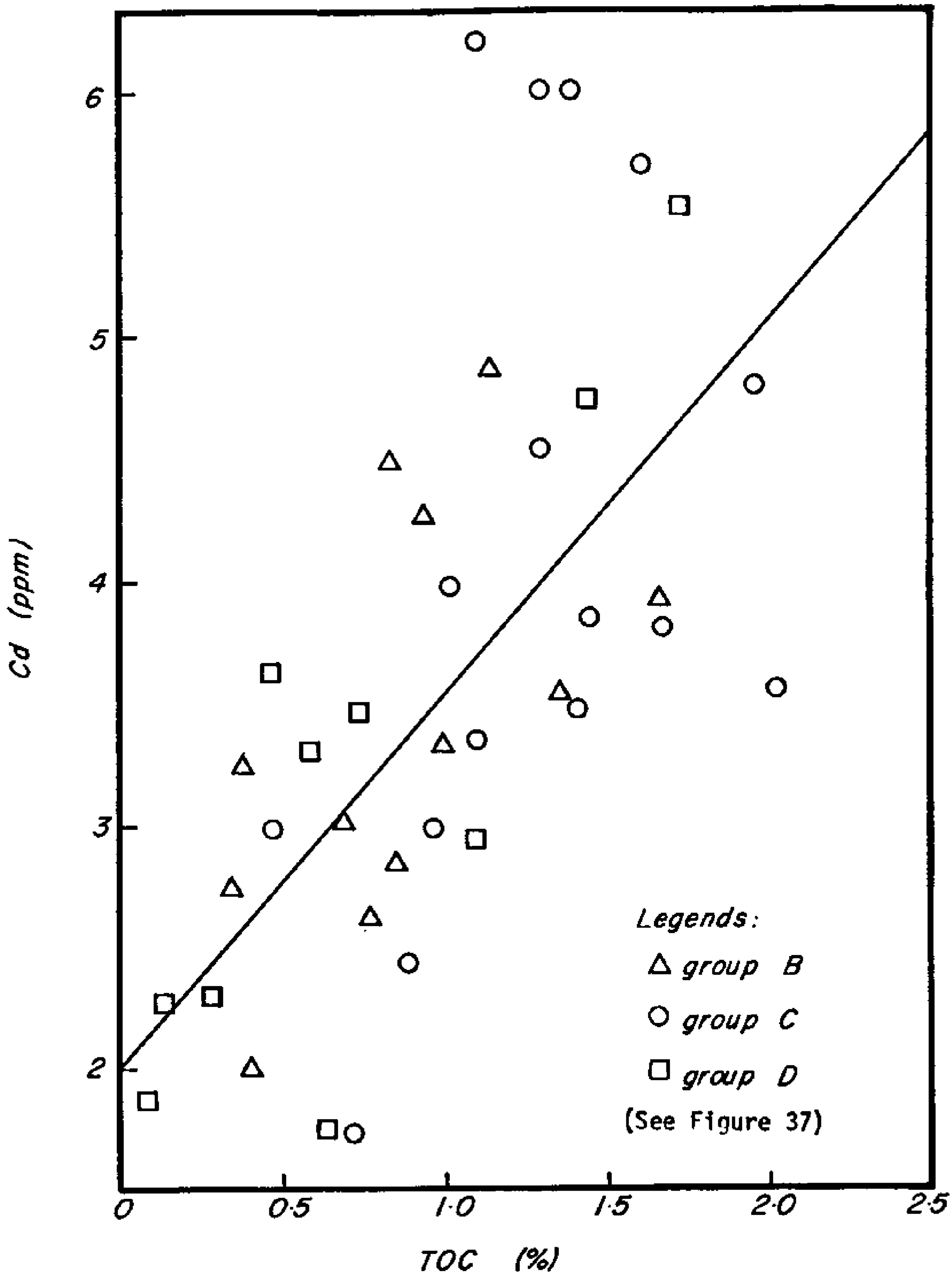


FIGURE 63

Concentration of Cadmium vs. Total Organic Carbon in the Surface Sediments of L.A. - L.B. Harbors

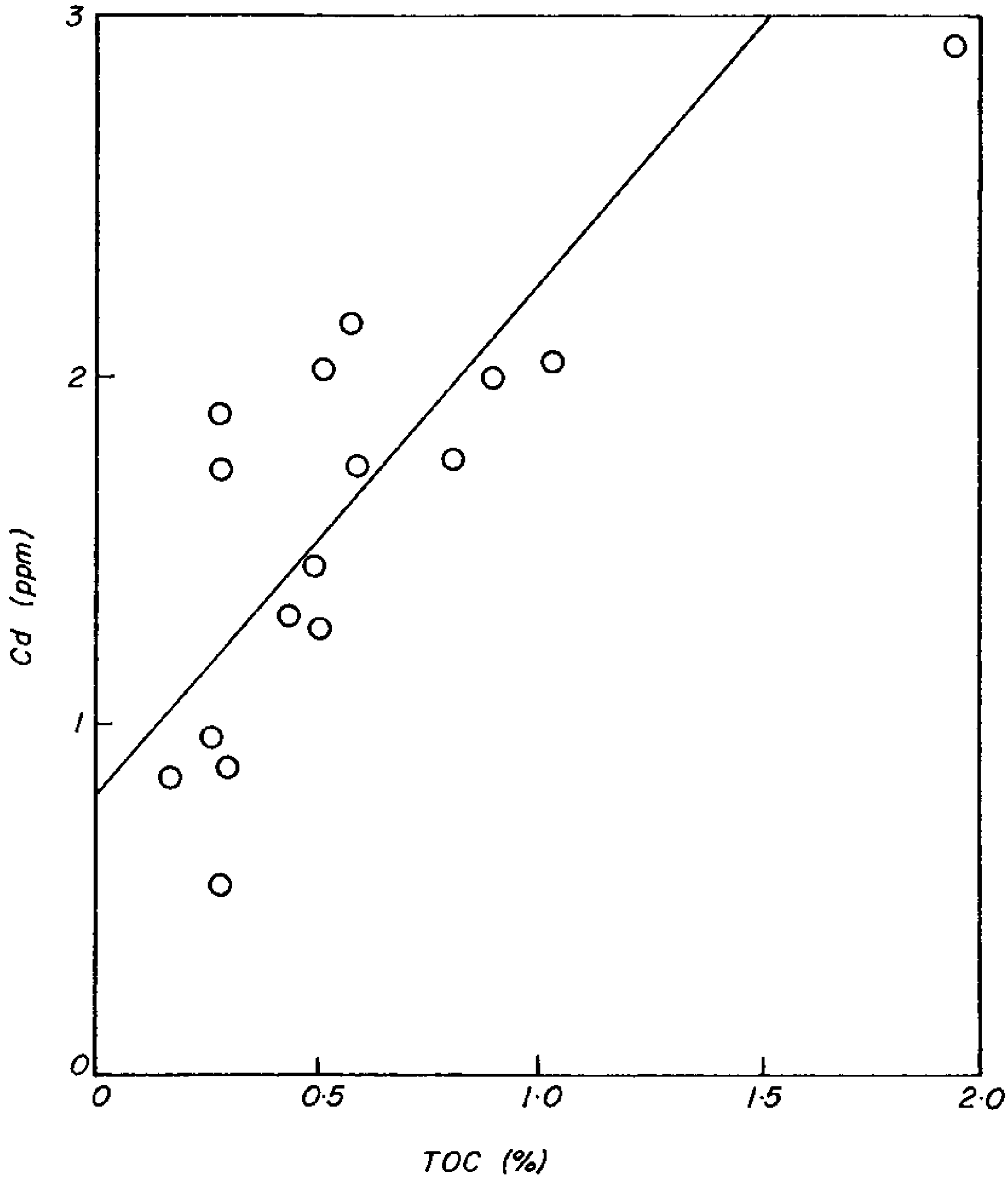


FIGURE 64

Concentration of Cadmium vs. Total Organic Carbon in the Sediments of the Proposed LNG Route

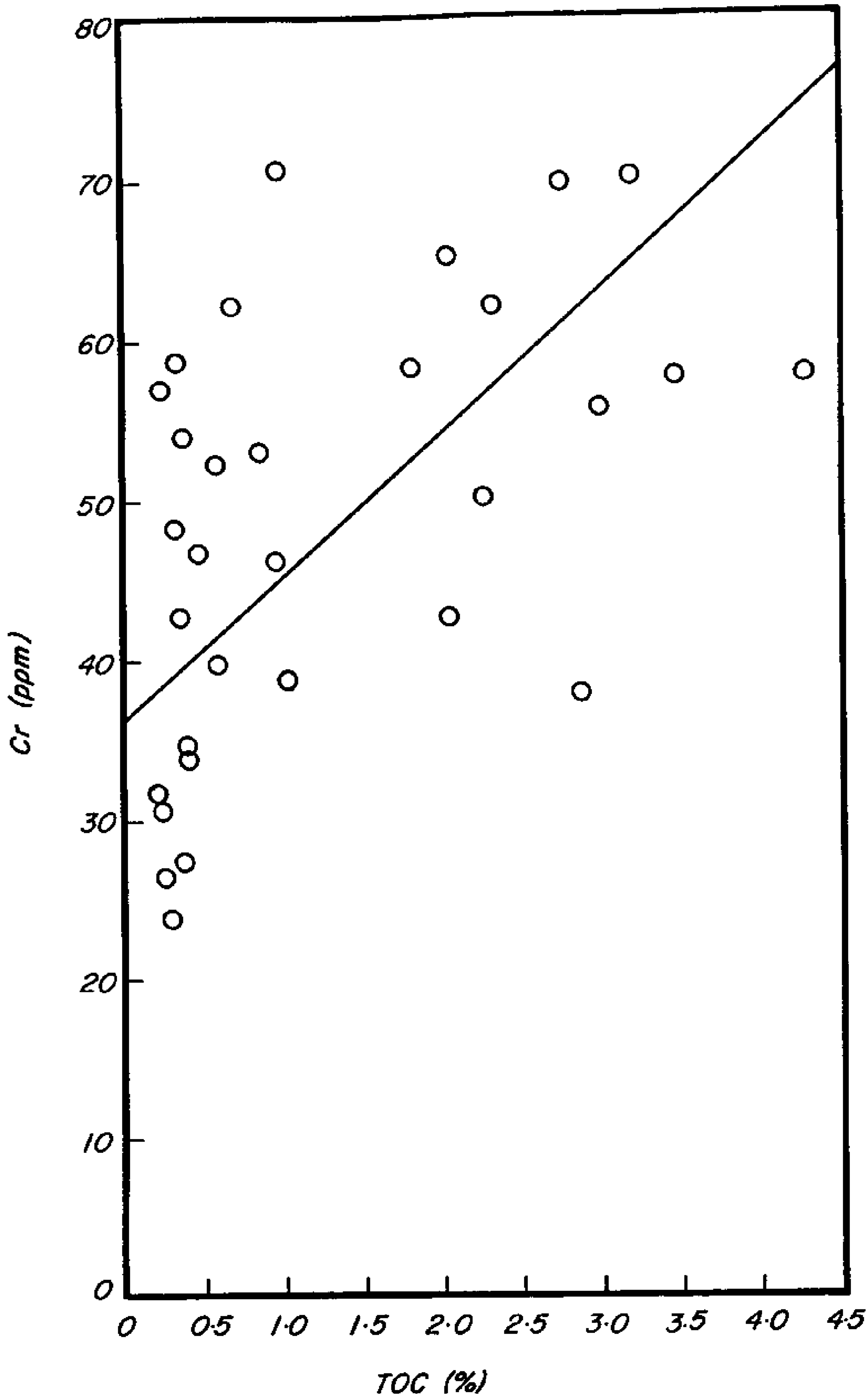


FIGURE 65

Concentration of Chromium vs. Total Organic Carbon in the Surface Sediments of San Pedro Basin

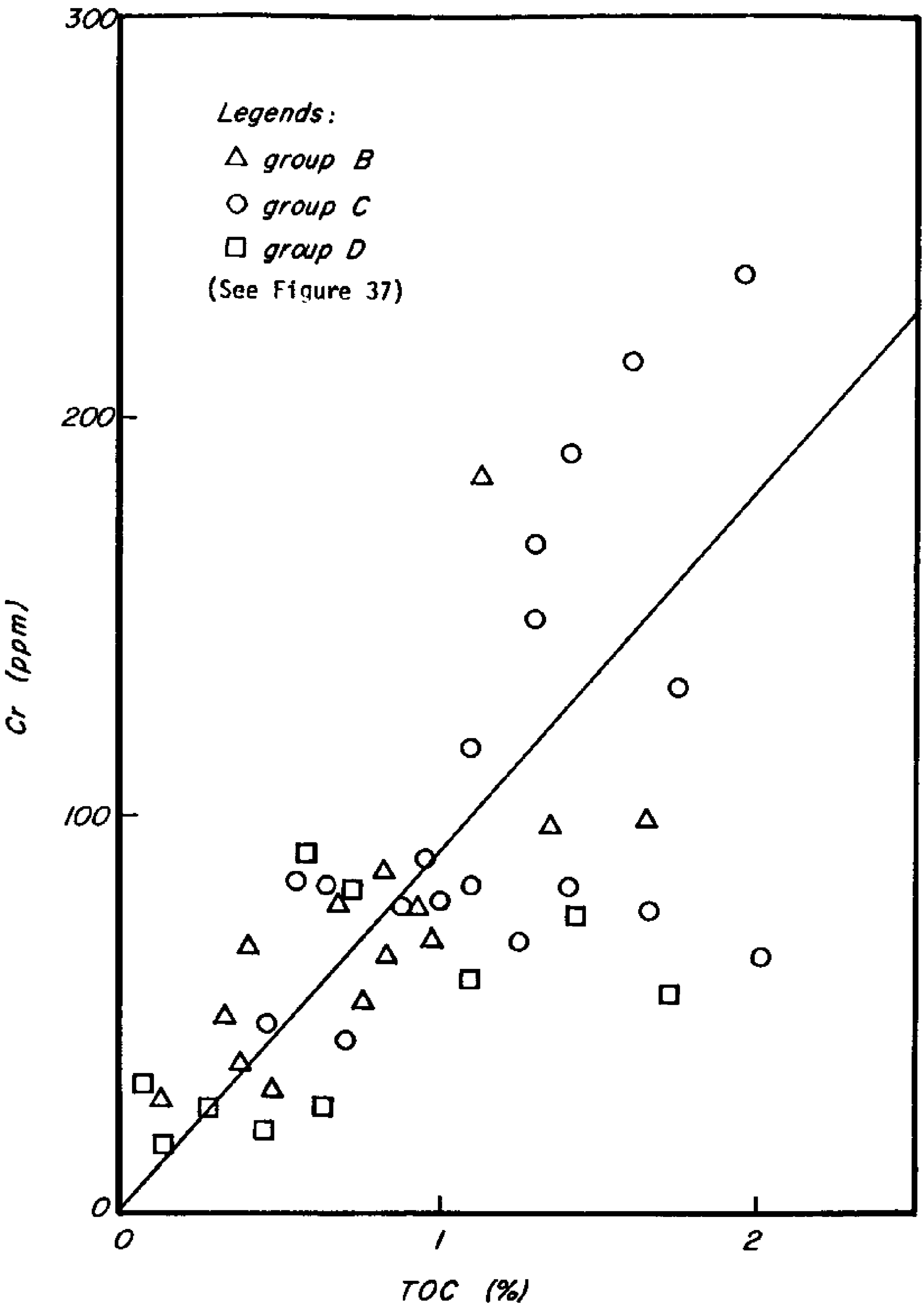


FIGURE 66

Concentration of Chromium vs. Total Organic Carbon in the Surface Sediments of L.A. - L.B. Harbors

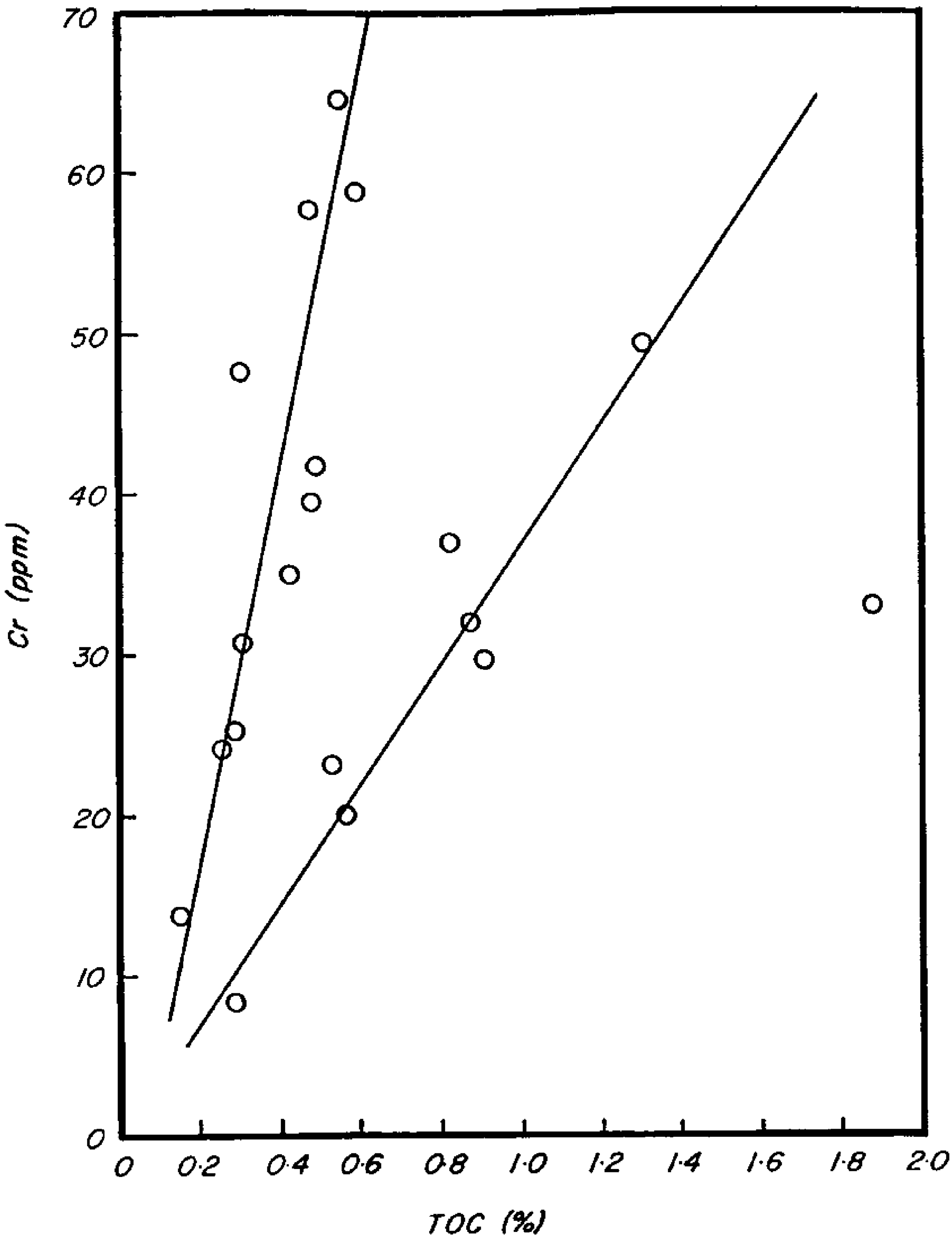


FIGURE 67

Concentration of Chromium vs. Total Organic Carbon in the Sediments of the Proposed LNG Route

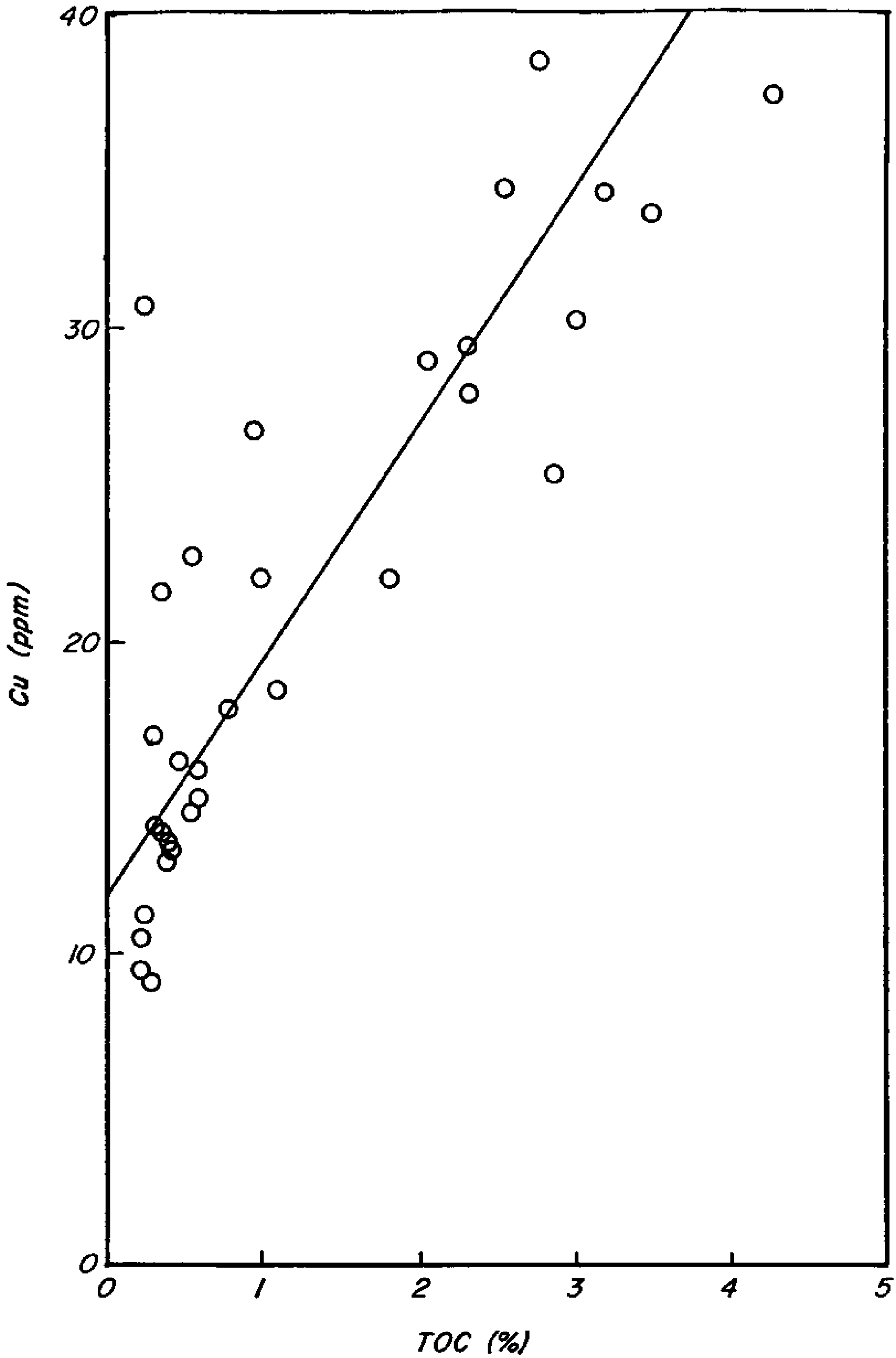


FIGURE 68

Concentration of Copper vs. Total Organic Carbon in the Surface Sediments of San Pedro Basin

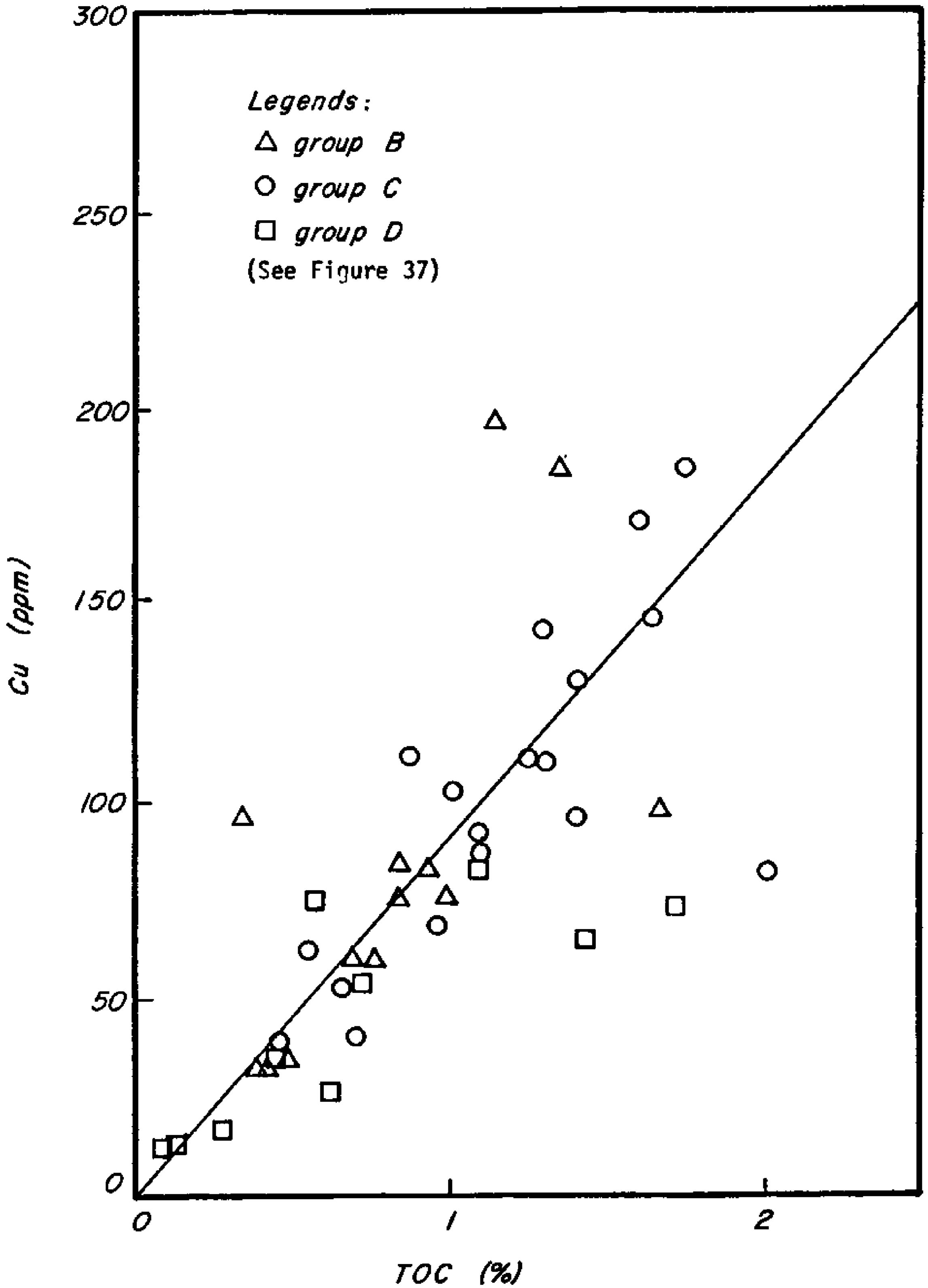


FIGURE 69

Concentration of Copper vs. Total Organic Carbon in the Surface Sediments of L.A. - L.B. Harbors

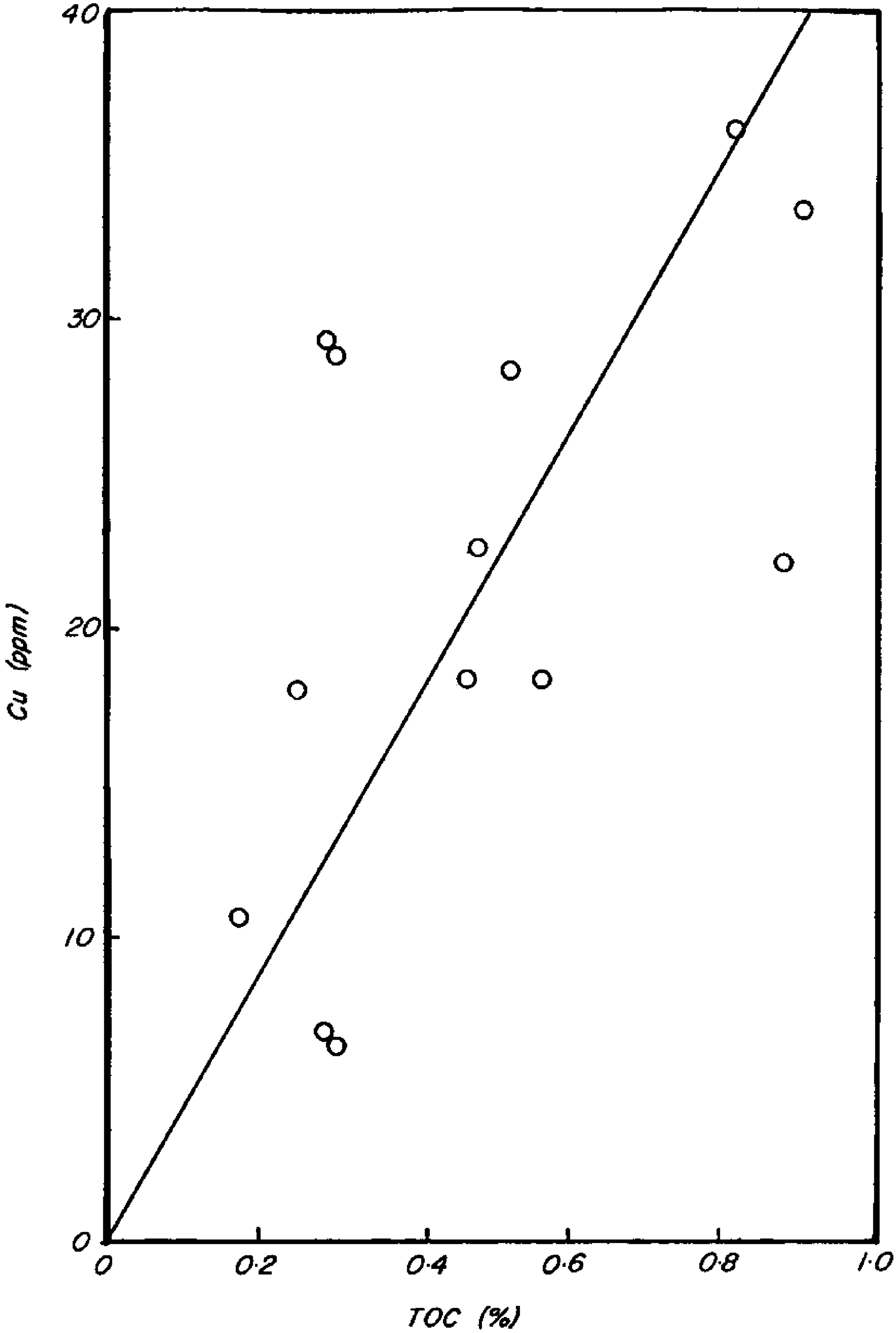


FIGURE 70

Concentration of Copper vs. Total Organic Carbon in the Sediments of the Proposed LNG Route

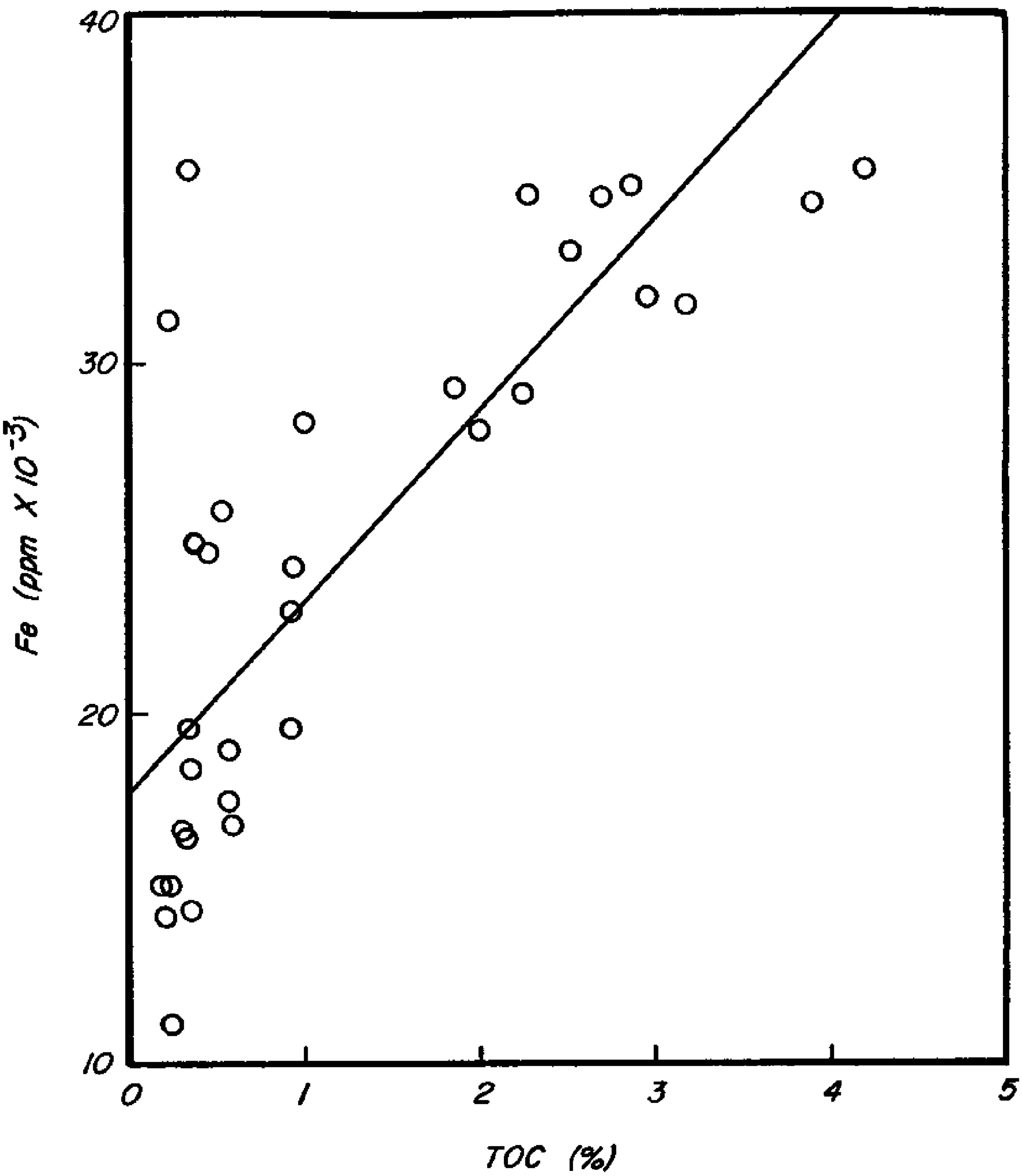


FIGURE 71

Concentration of Iron vs. Total Organic Carbon in the Surface Sediments of San Pedro Basin

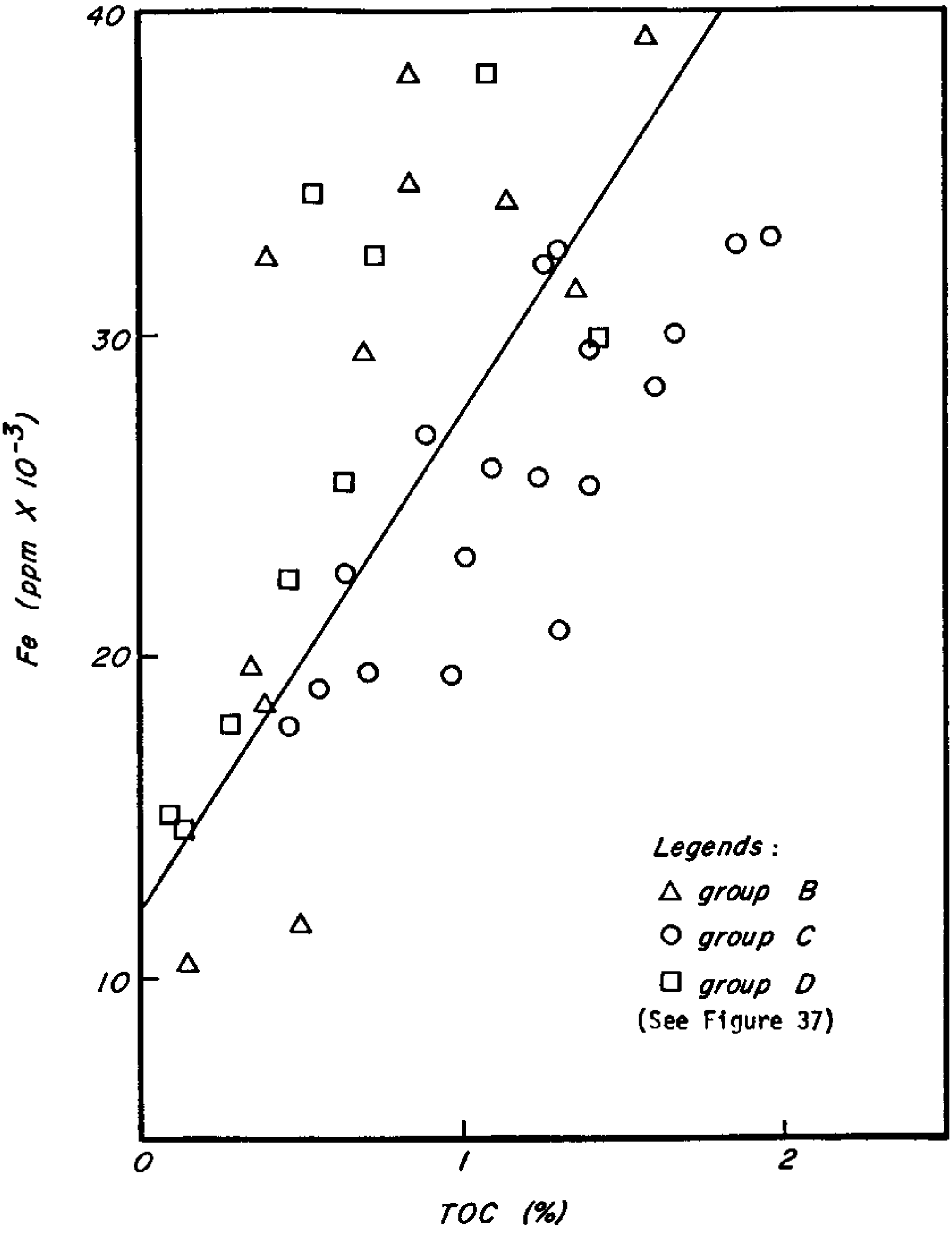


FIGURE 72

Concentration of Iron vs. Total Organic Carbon in the Surface Sediments of L.A.-L.B. Harbors

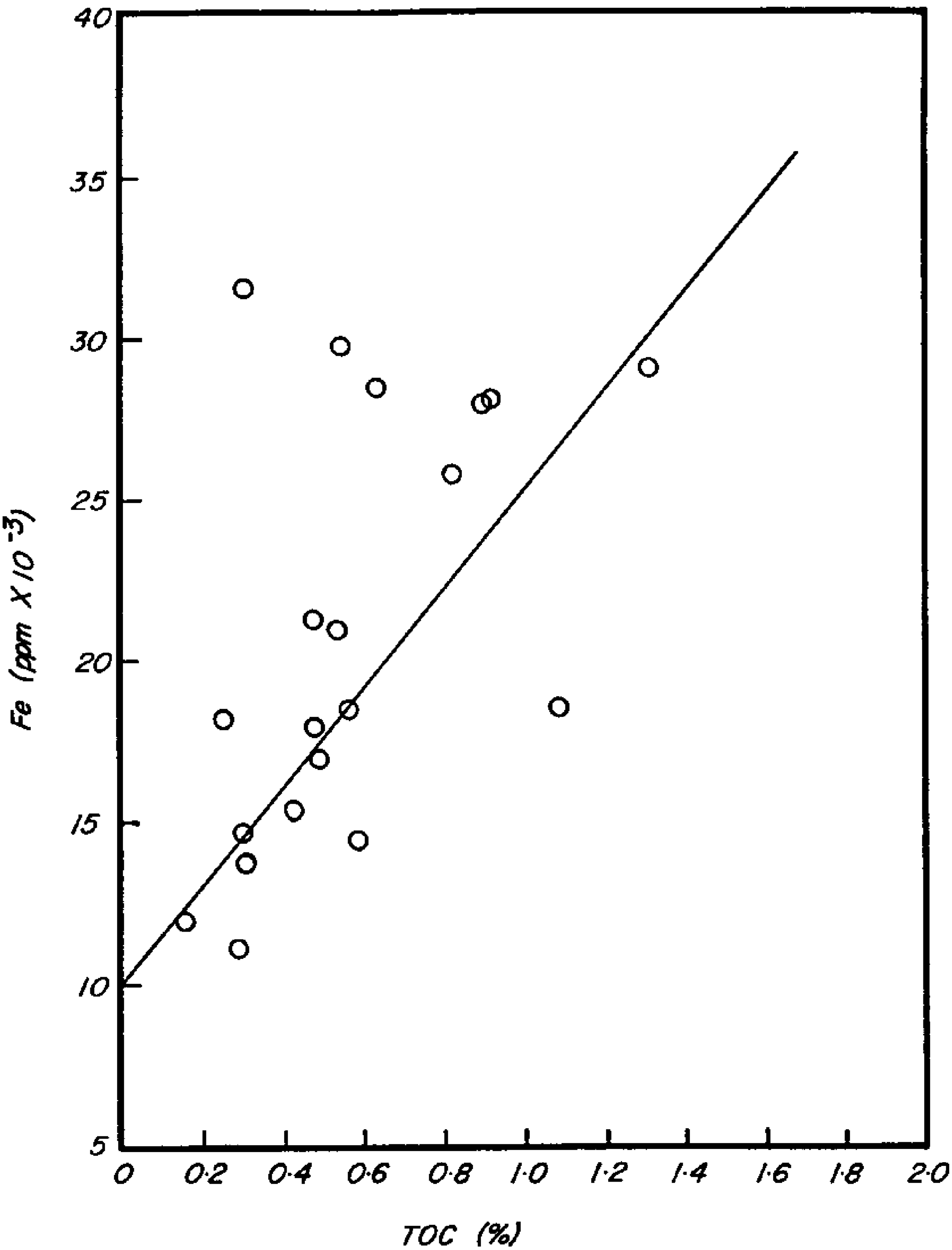


FIGURE 73

Concentration of Iron vs. Total Organic Carbon in the Sediments of the Proposed LNG Route

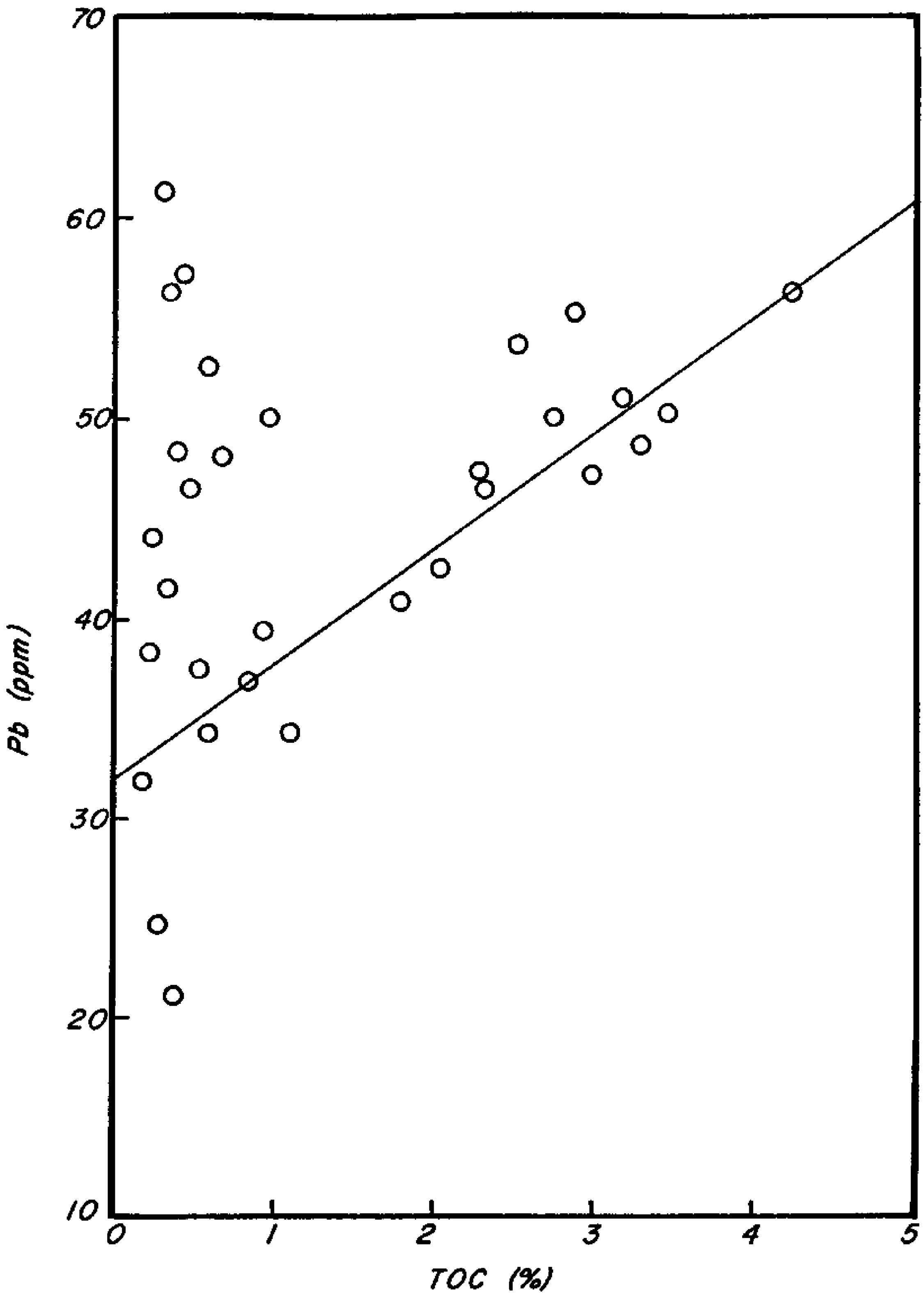


FIGURE 74

Concentration of Lead vs. Total Organic Carbon in the Surface Sediments of San Pedro Basin

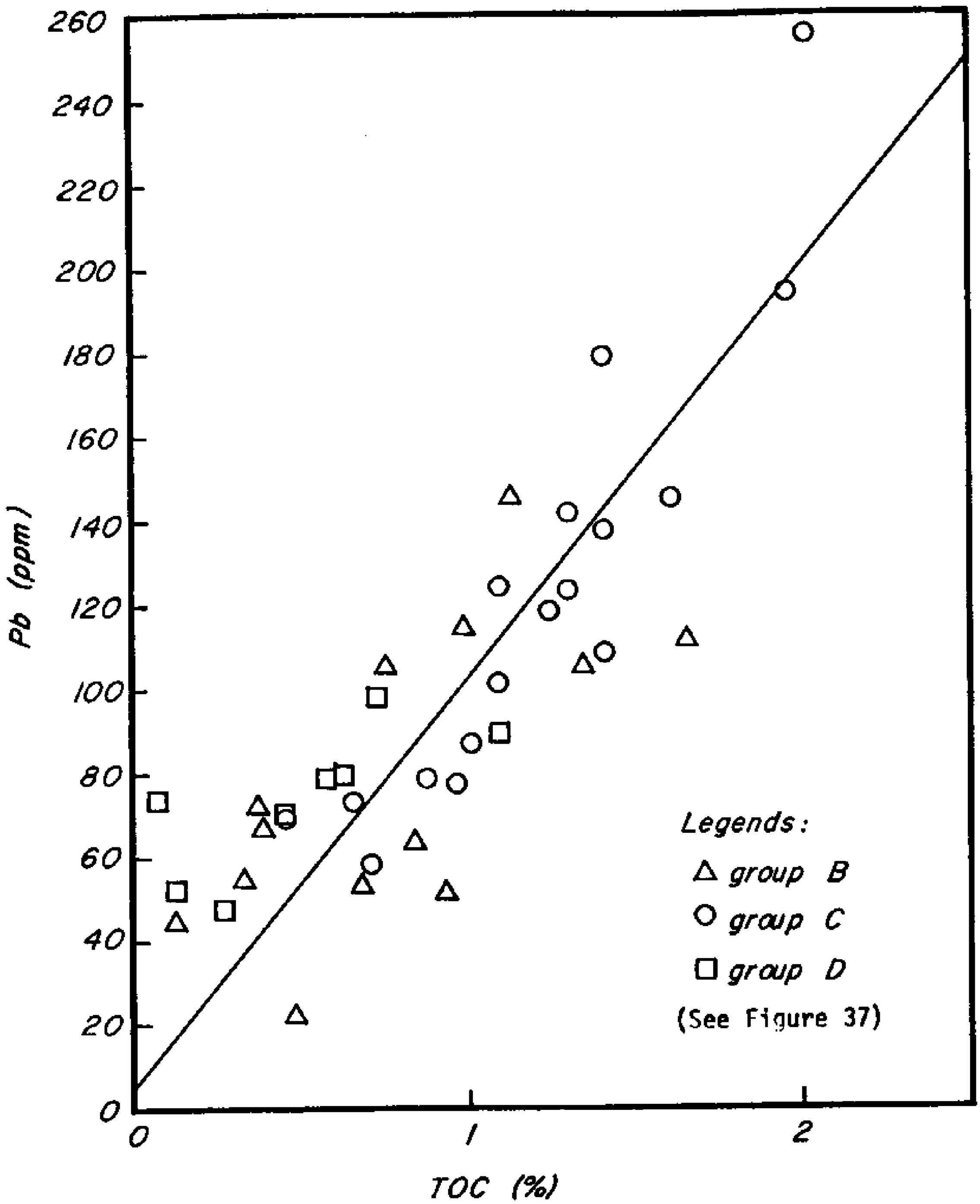


FIGURE 75

Concentration of Lead vs. Total Organic Carbon in the Surface Sediments of L.A.- L.B. Harbors

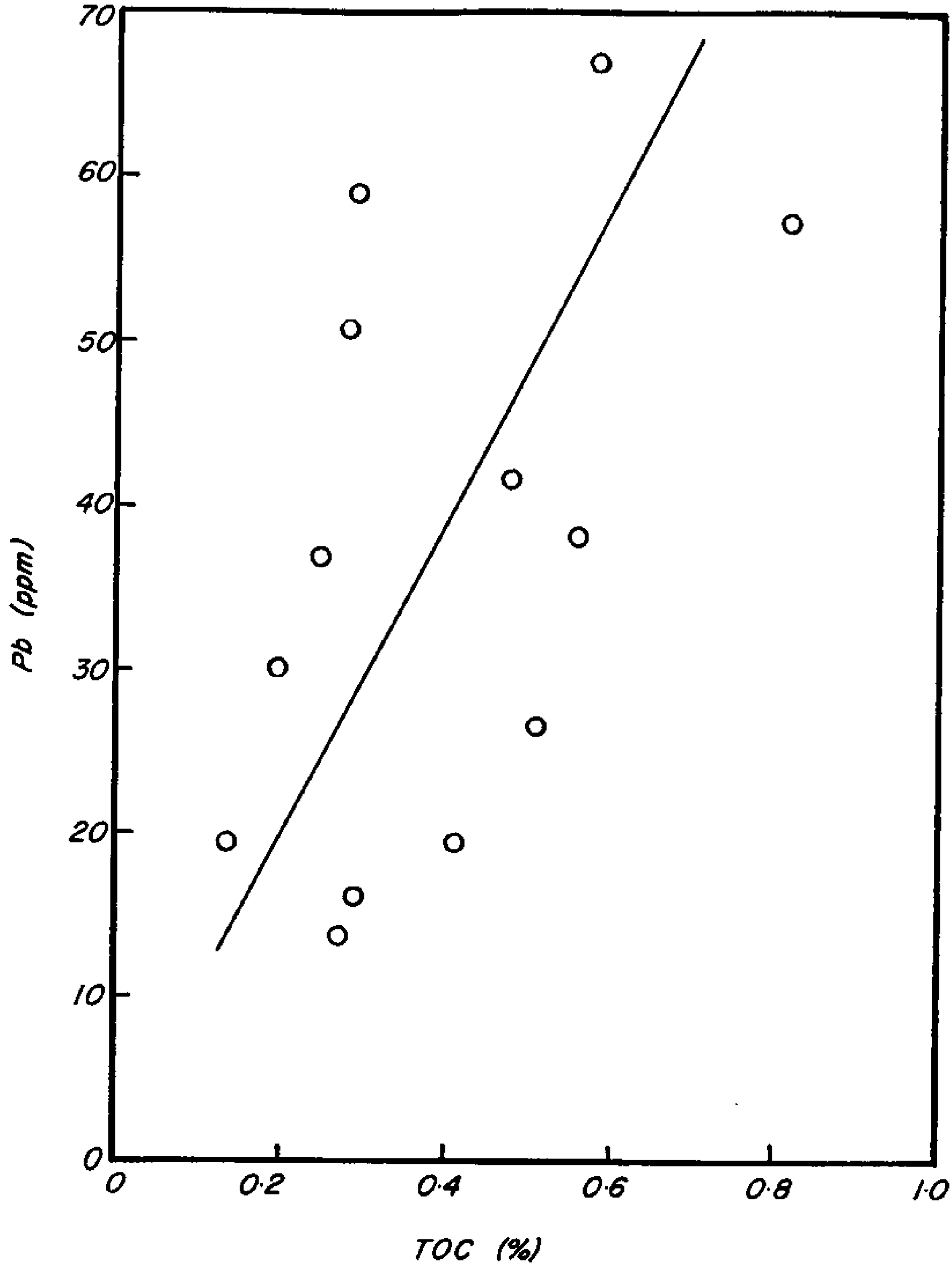


FIGURE 76

Concentration of Lead vs. Total Organic Carbon in the Sediments of the Proposed LNG Route

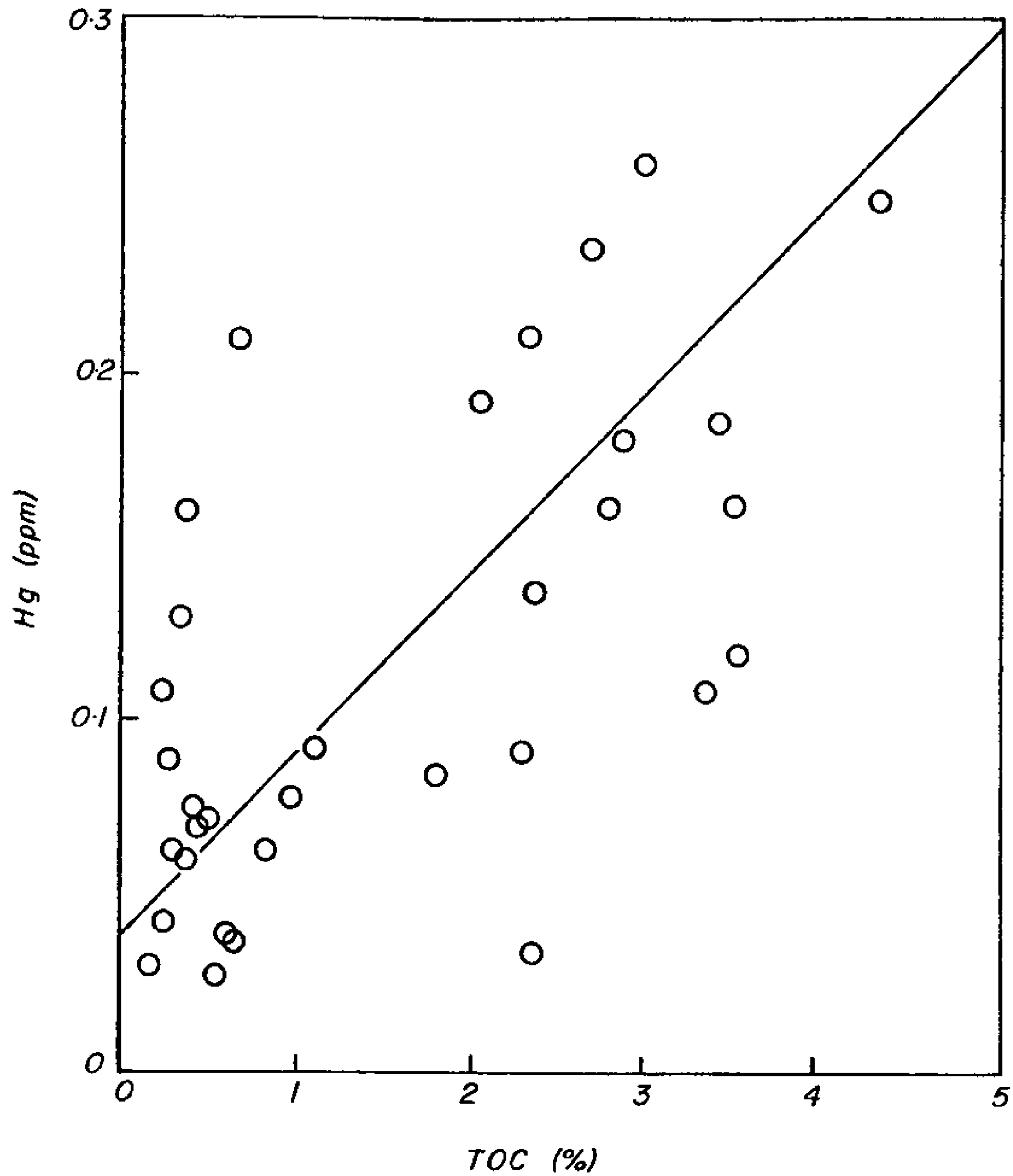


FIGURE 77

Concentration of Mercury vs. Total Organic Carbon in the Surface Sediments of San Pedro Basin

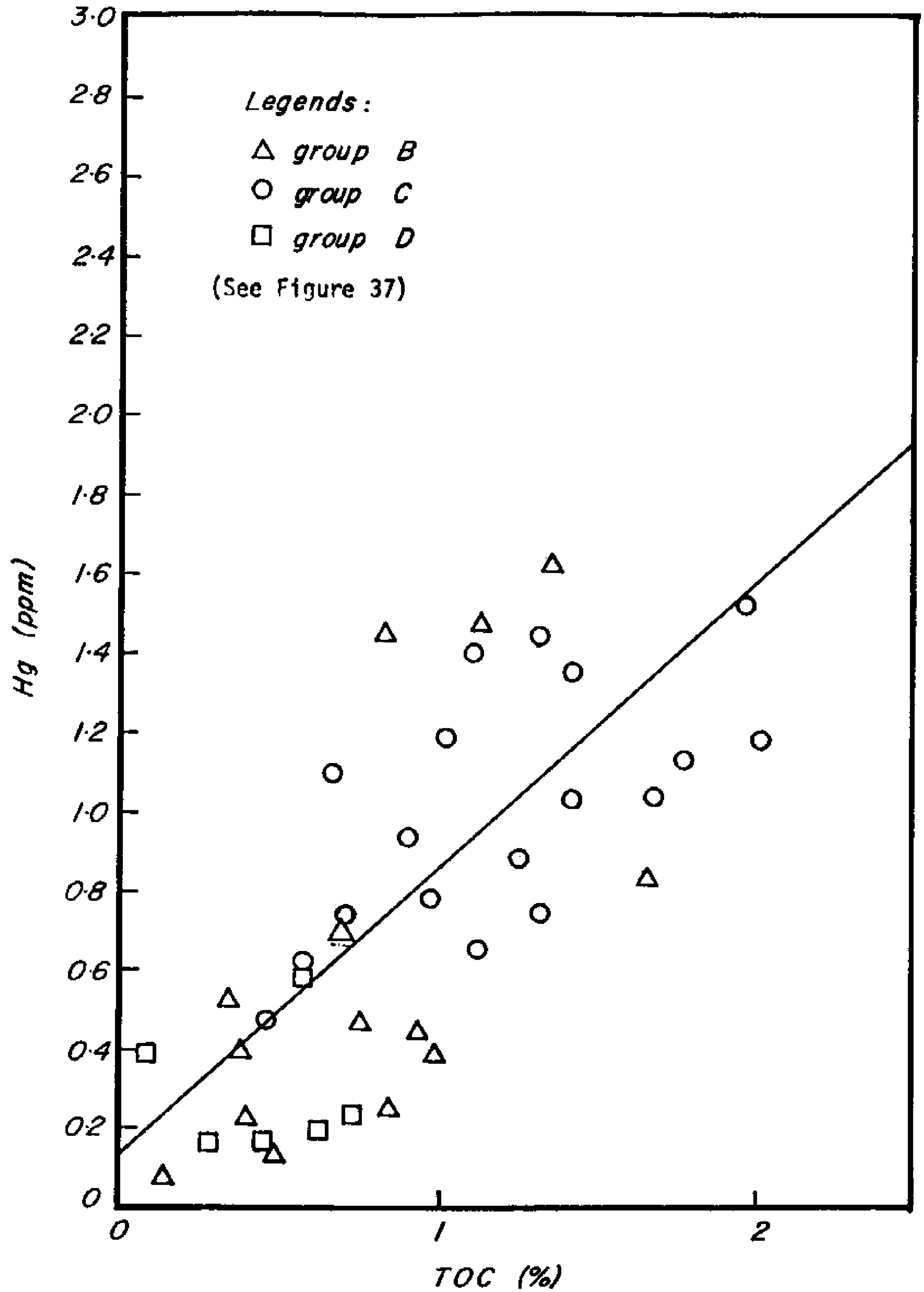


FIGURE 78

Concentration of Mercury vs. Total Organic Carbon in the Surface Sediments of L.A. - L.B. Harbors

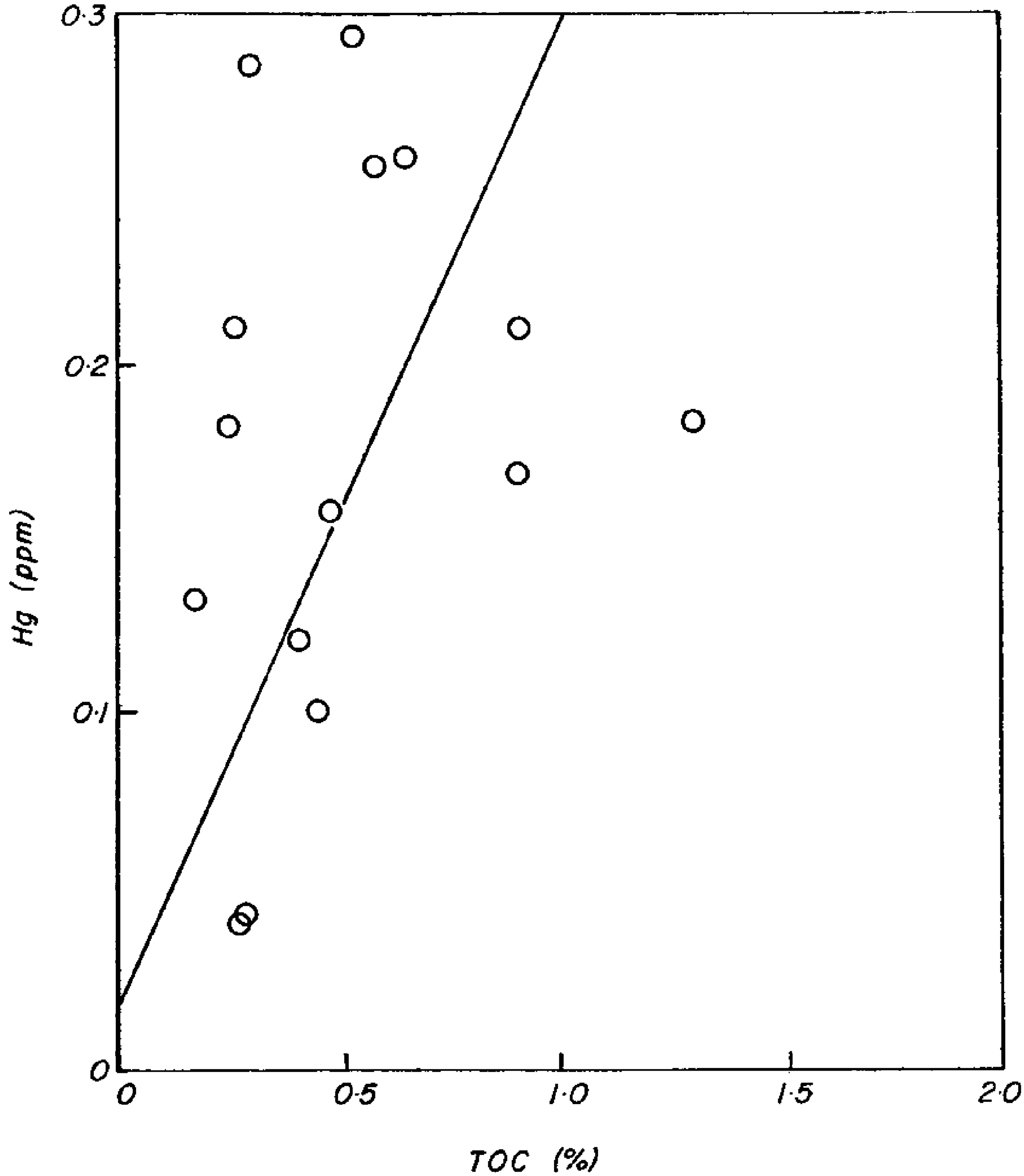


FIGURE 79
Concentration of Mercury vs. Total Organic Carbon in the Sediments of the Proposed LNG Route

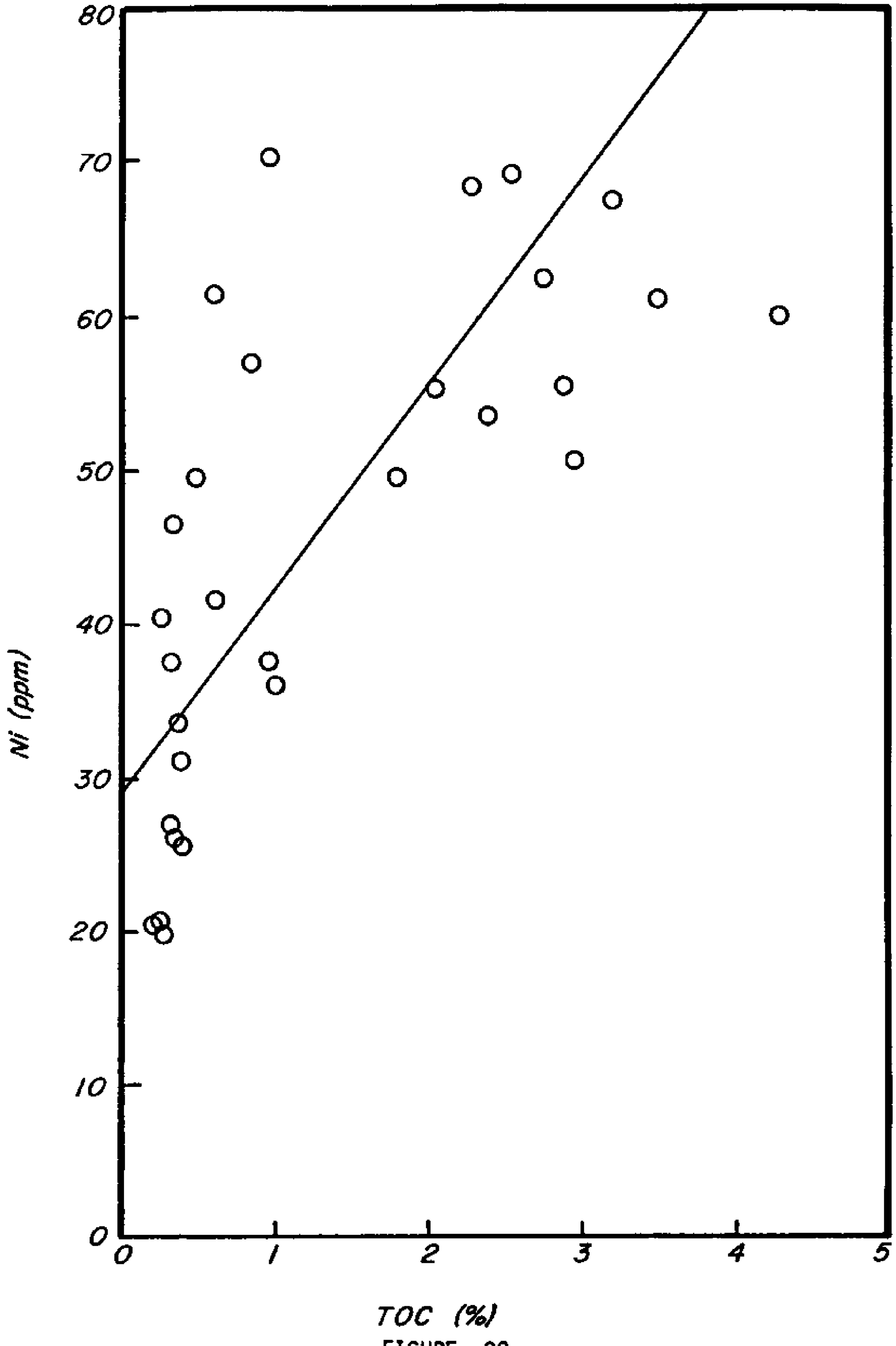


FIGURE 80

Concentration of Nickel vs. Total Organic Carbon in the Surface Sediments of San Pedro Basin

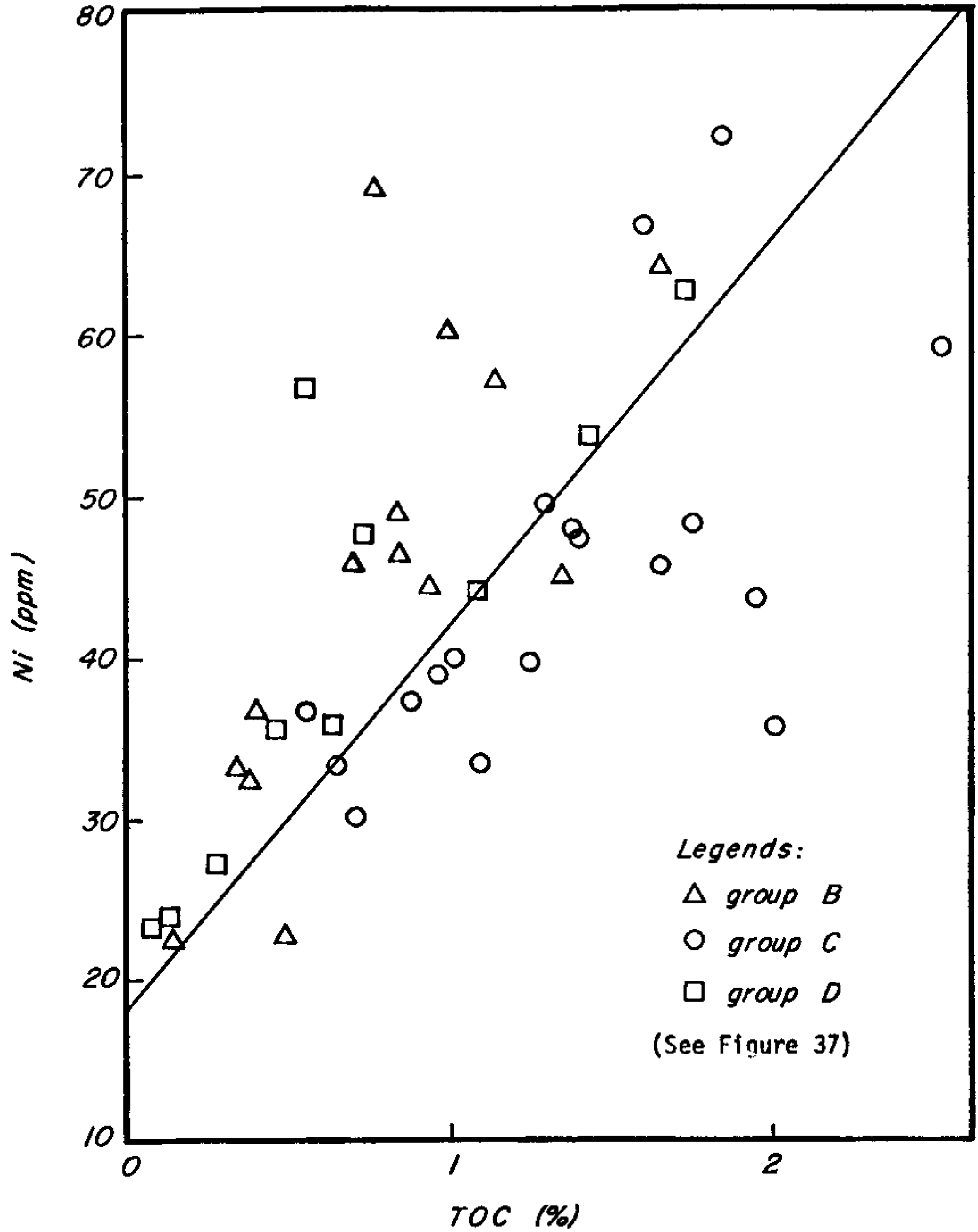


FIGURE 81

Concentration of Nickel vs. Total Organic Carbon in the Surface Sediments of L.A.-L.B. Harbors

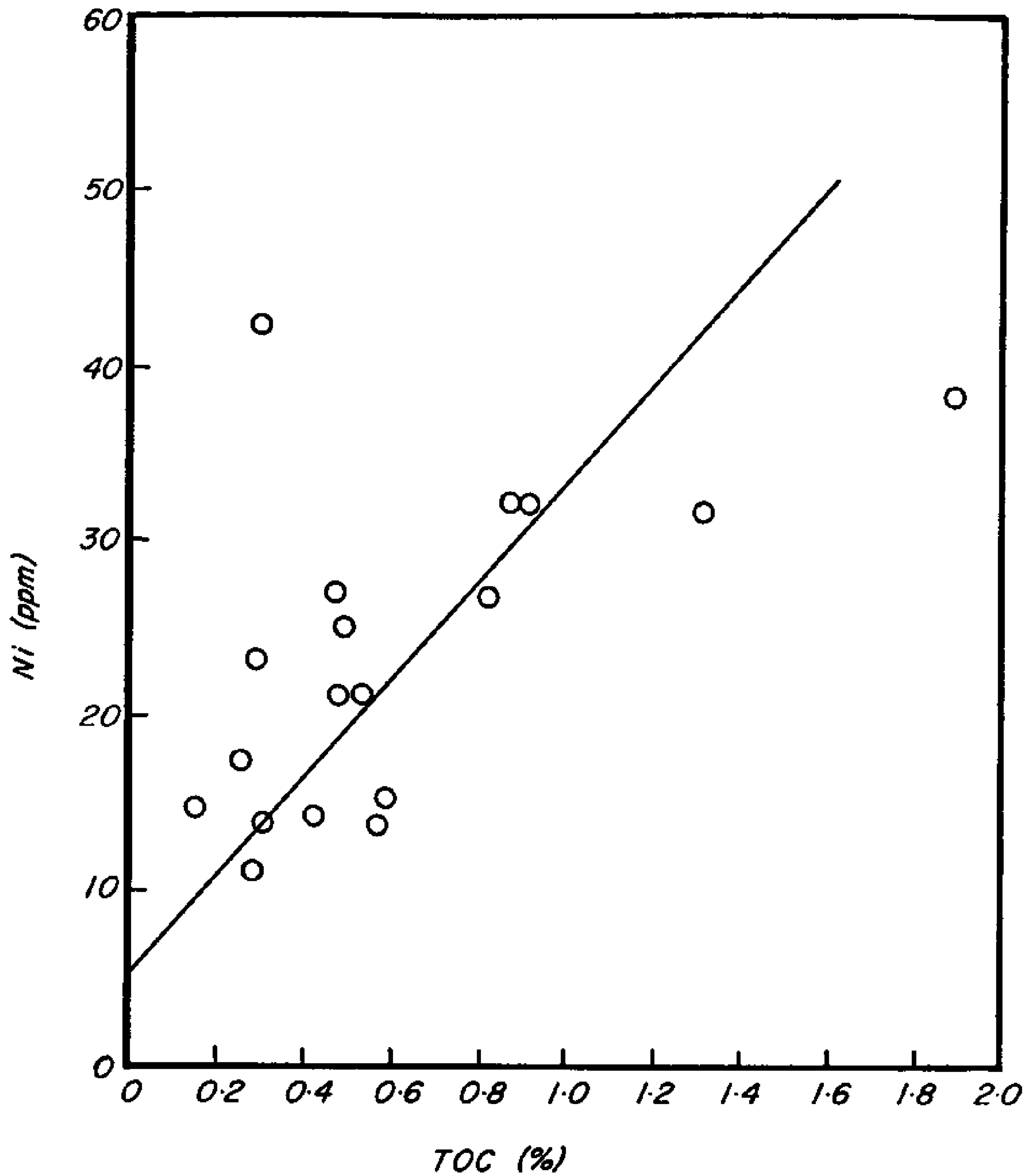


FIGURE 82

Concentration of Nickel vs. Total Organic Carbon
in the Sediments of the Proposed LNG Route

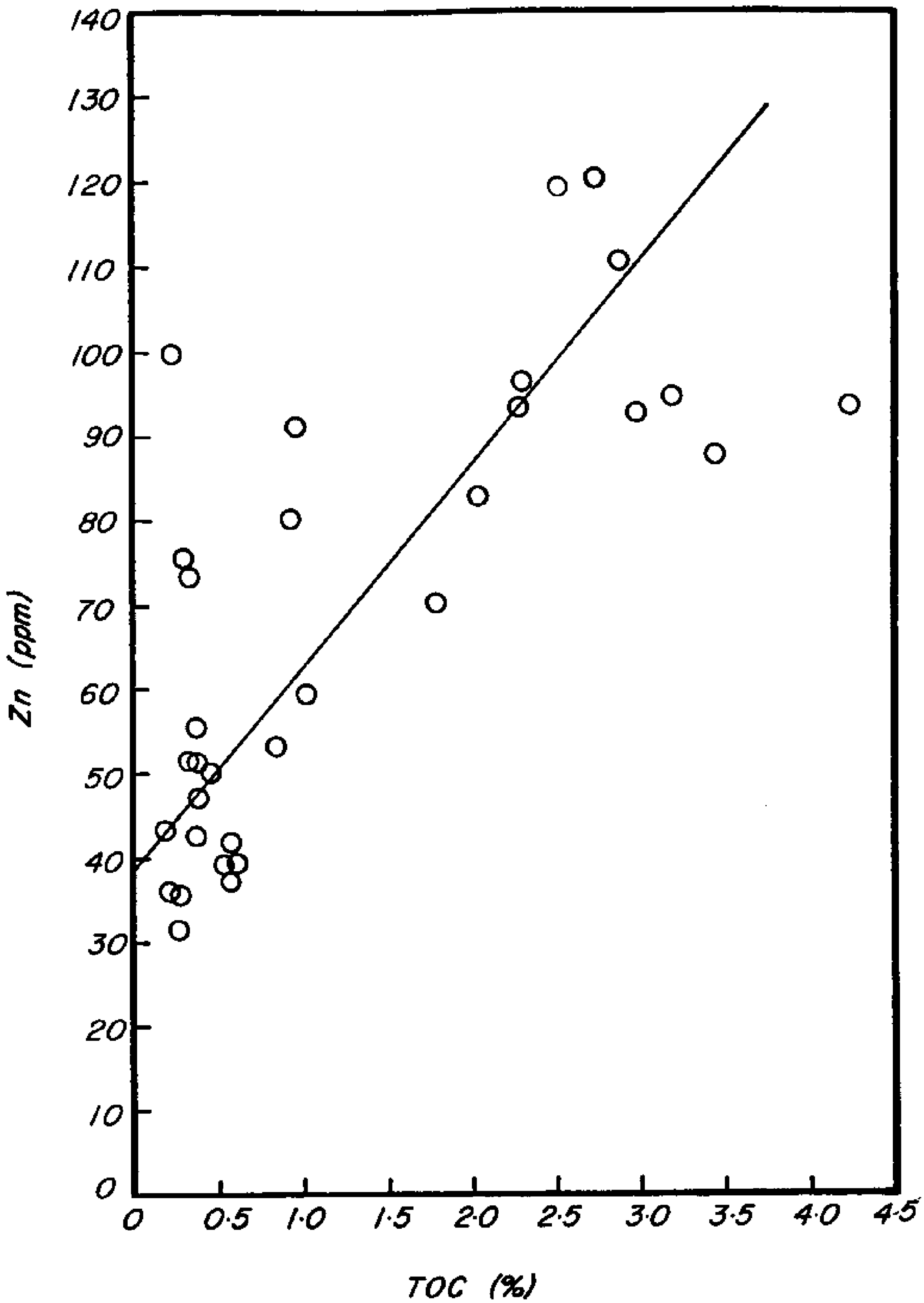


FIGURE 83

Concentration of Zinc vs. Total Organic Carbon in the Surface Sediments of San Pedro Basin

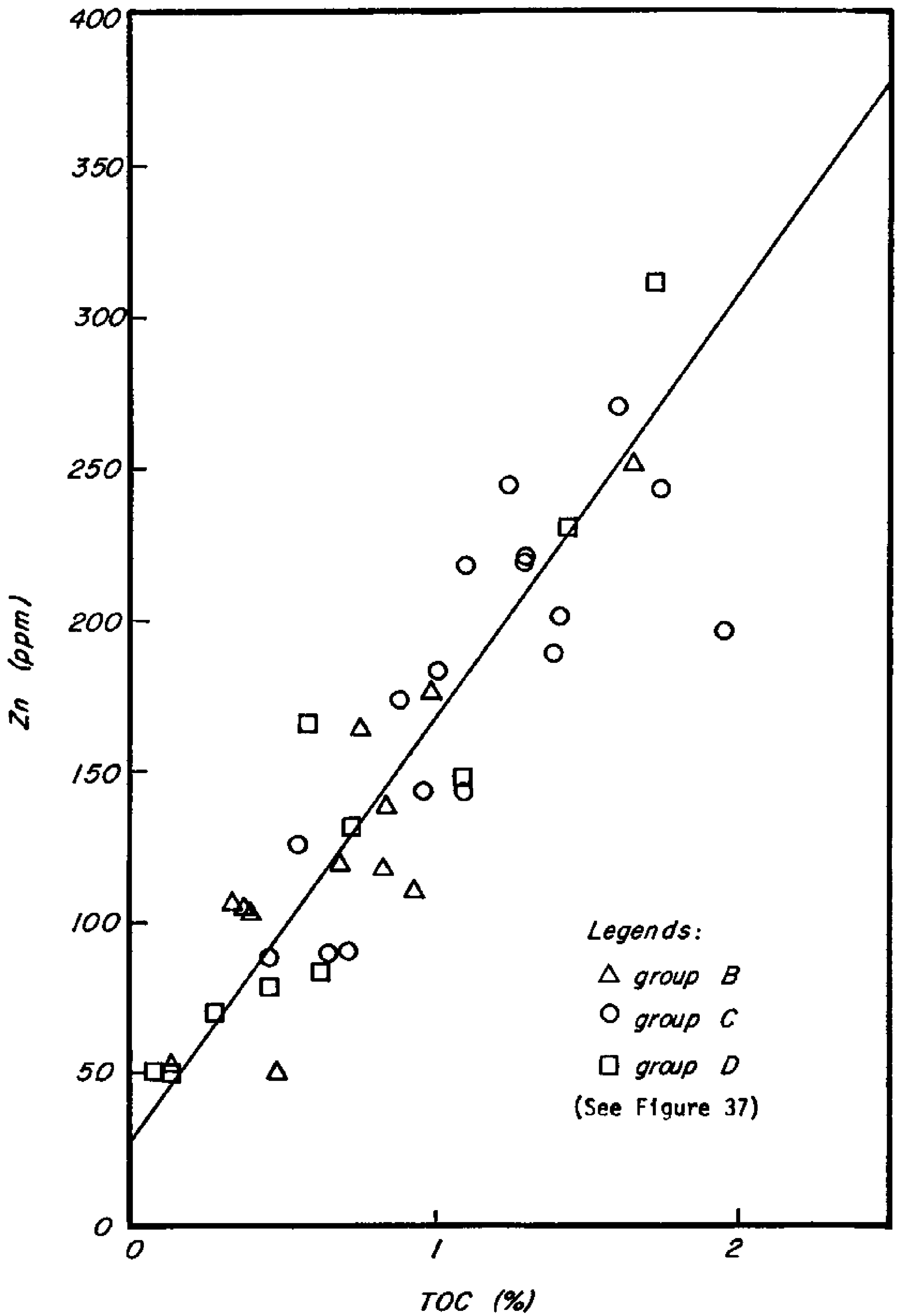


FIGURE 84

Concentration of Zinc vs. Total Organic Carbon in the Surface Sediments of L.A.-L.B. Harbors

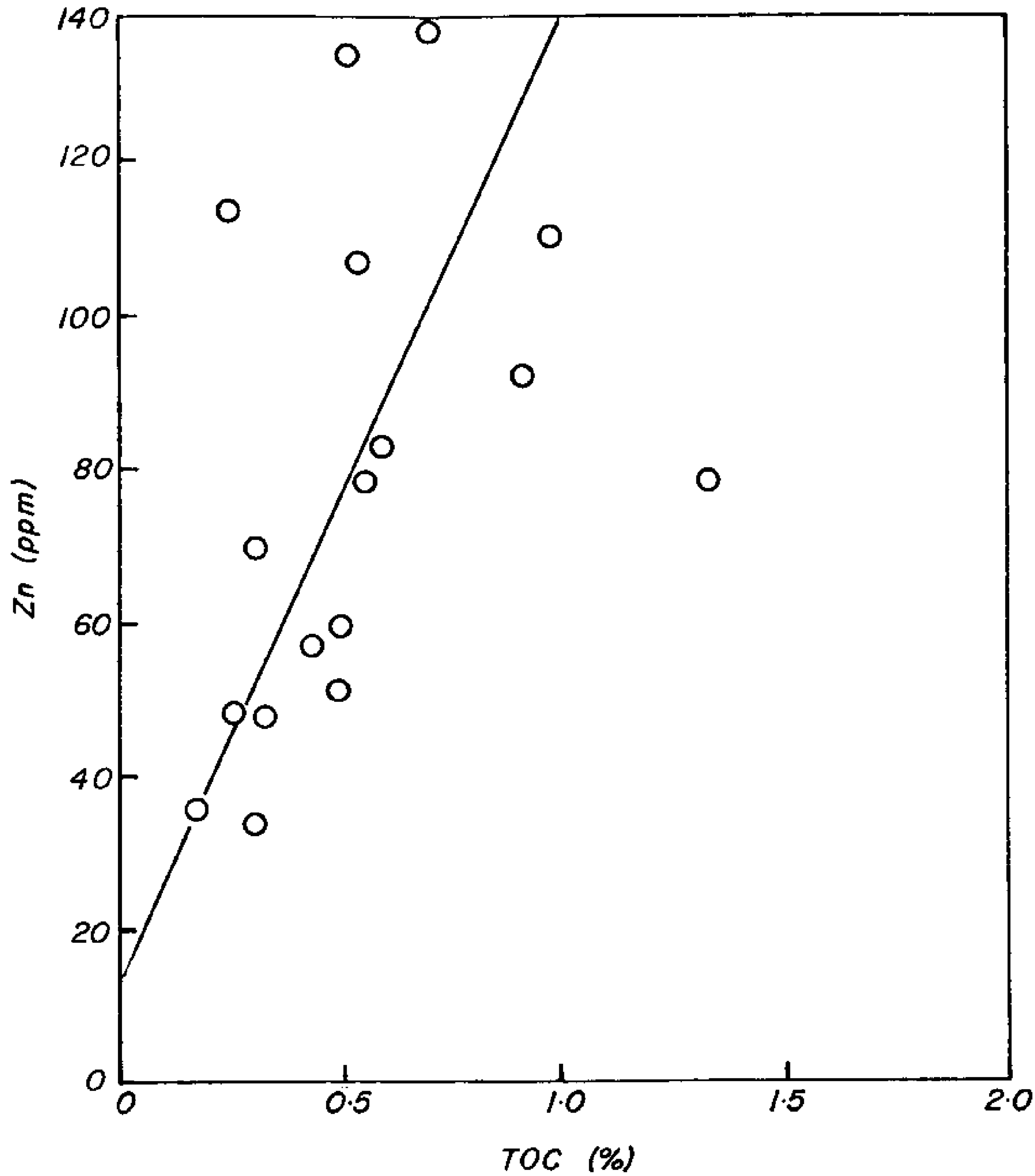


FIGURE 85

Concentration of Zinc vs. Total Organic Carbon in the Sediments of the Proposed LNG Route

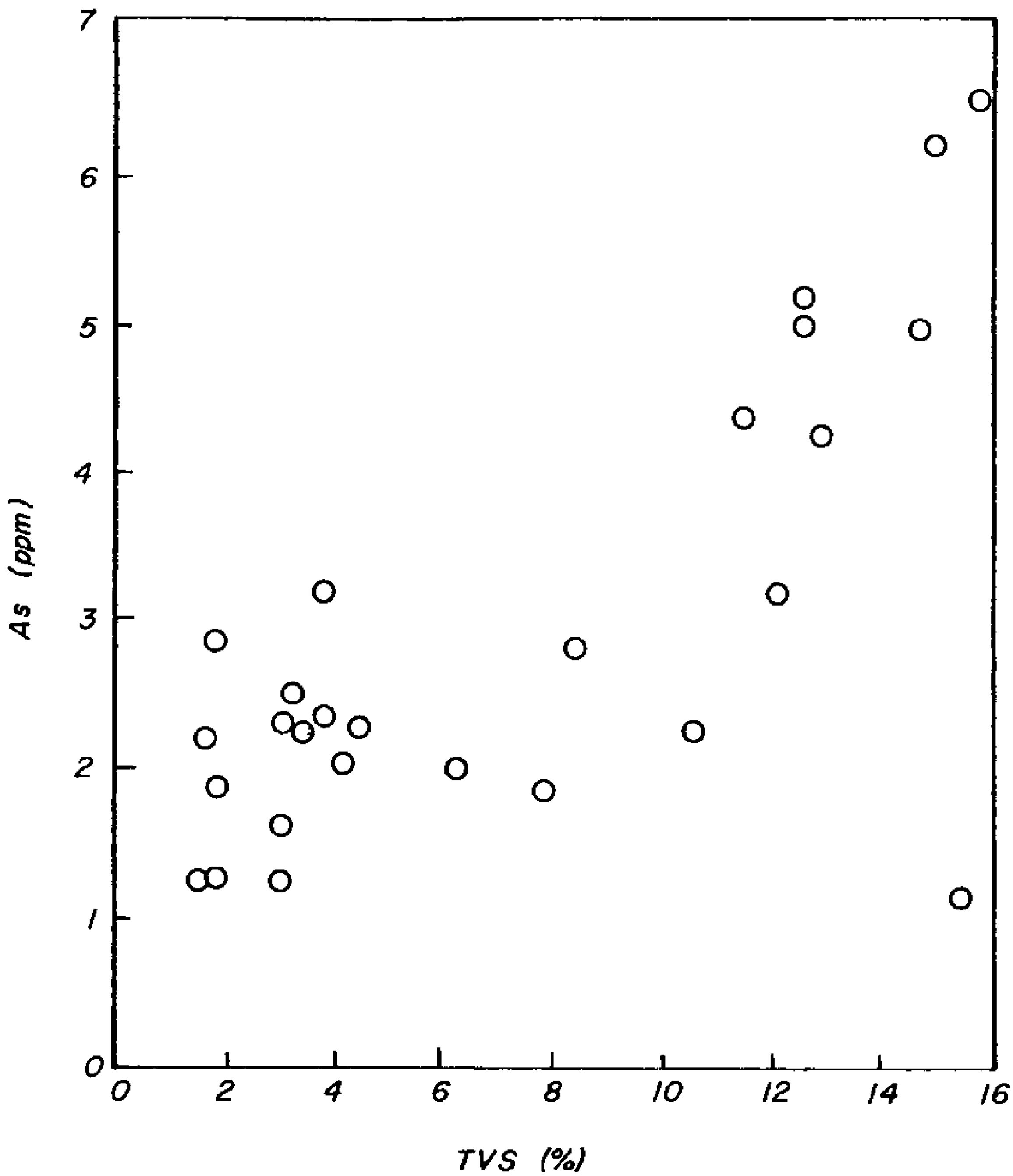


FIGURE 86

Concentration of Arsenic vs. Total Volatile Substances in the Surface Sediments of San Pedro Basin

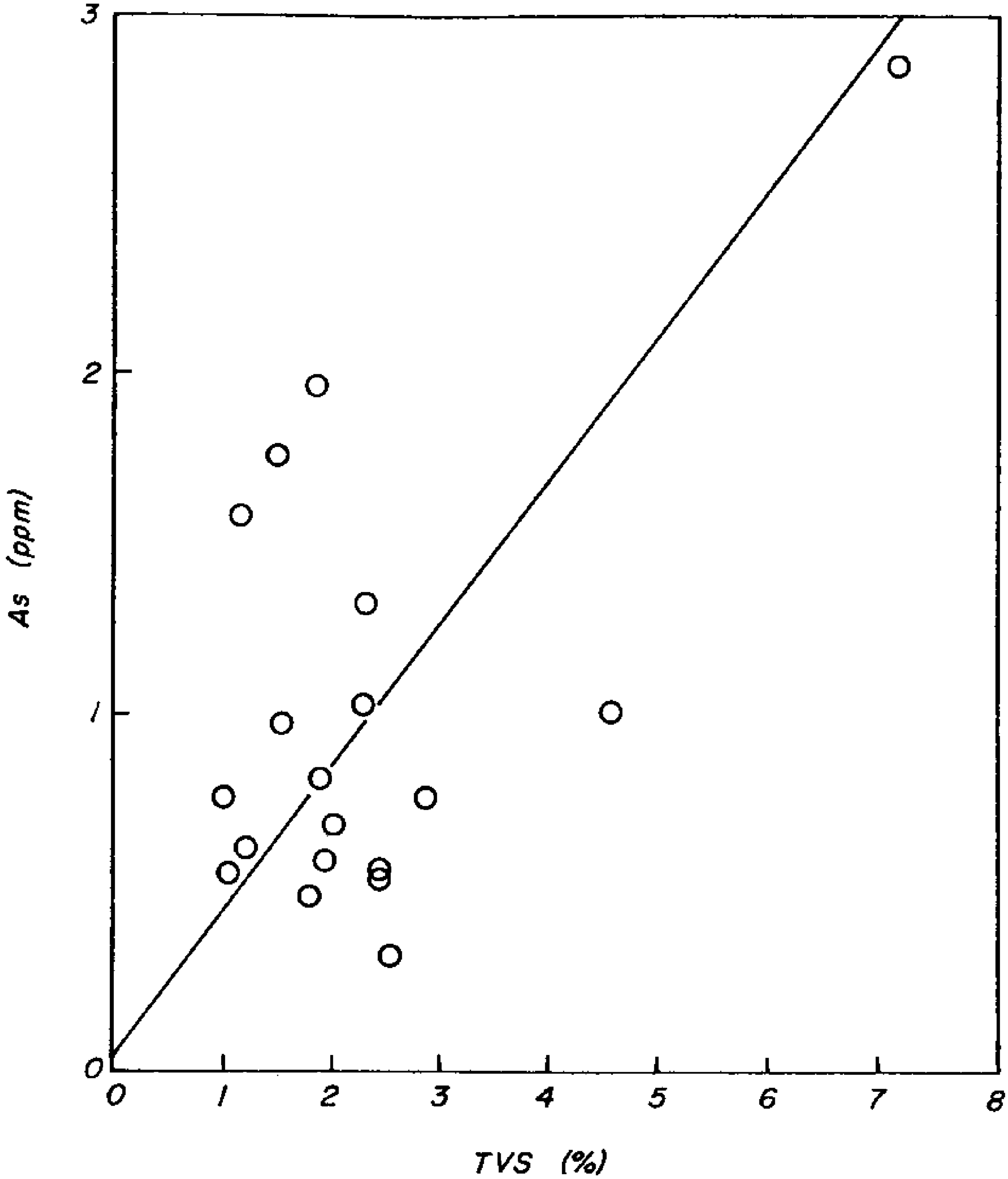


FIGURE 87

Concentration of Arsenic vs. Total Volatile Substances in the Sediments of the Proposed LNG Route

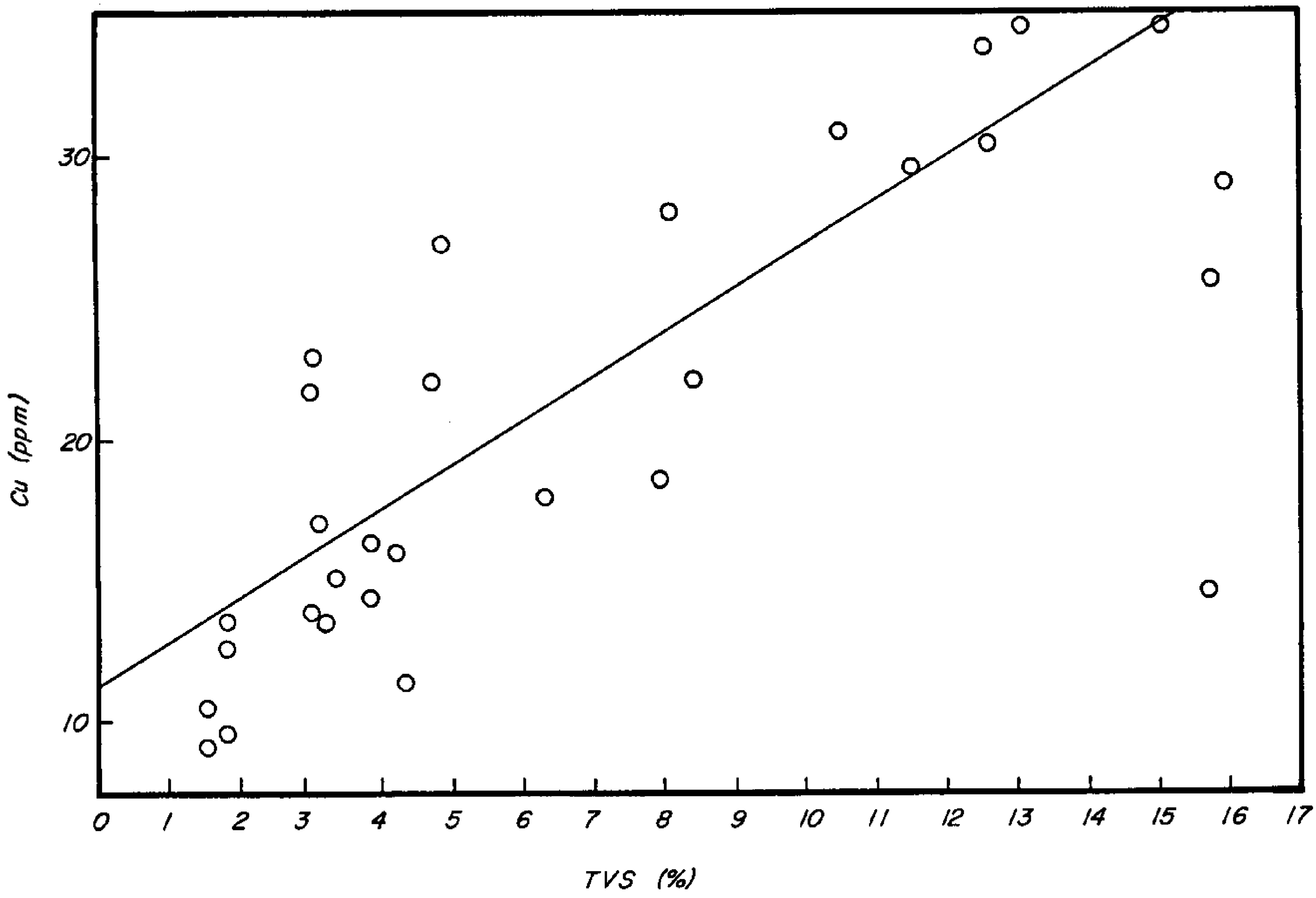


FIGURE 88

Concentration of Copper vs. Total Volatile Substances in the Surface Sediment of San Pedro Basin

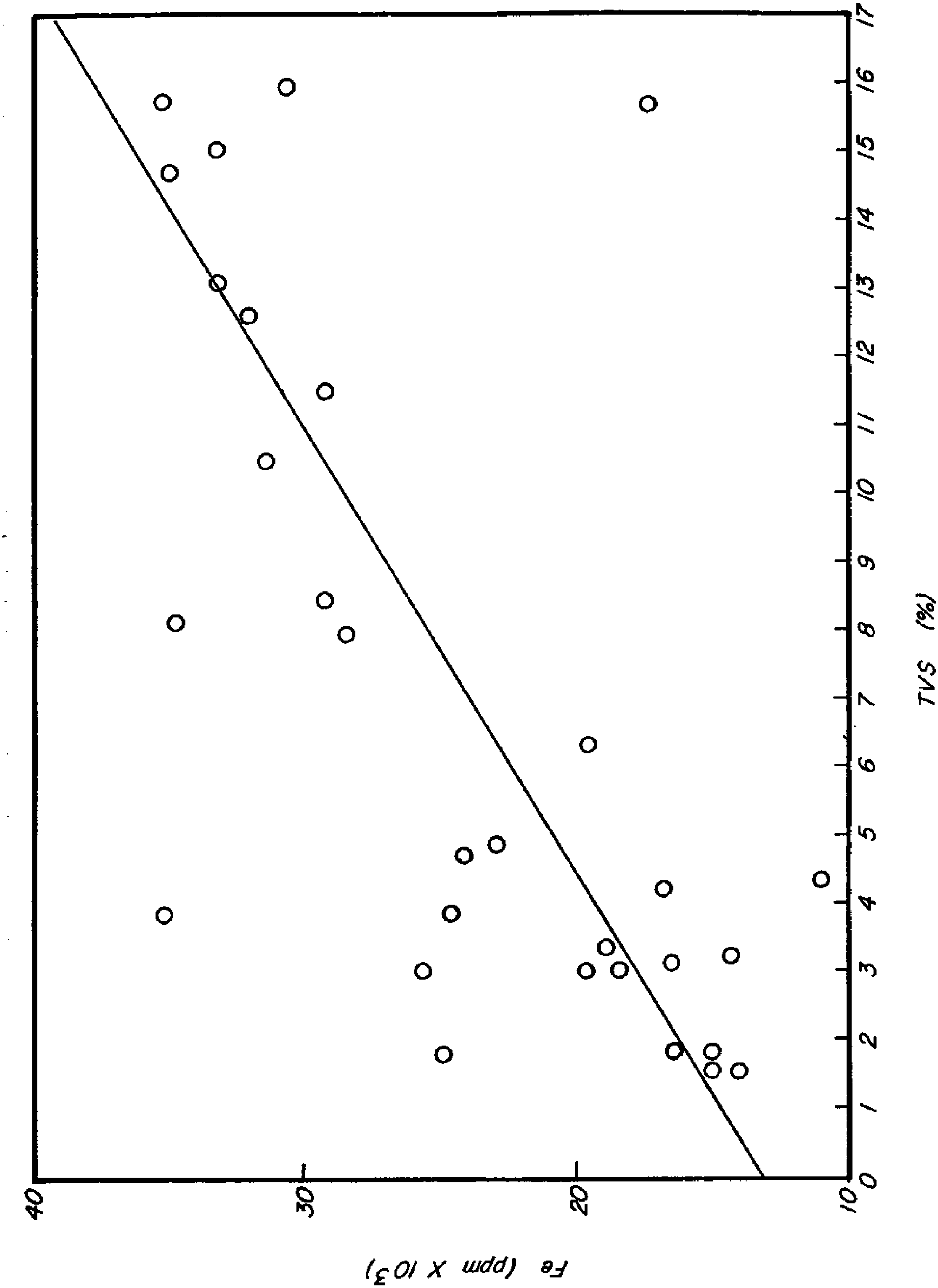


FIGURE 89
Concentration of Iron vs. Total Volatile Substances
in the Surface Sediment of San Pedro Basin

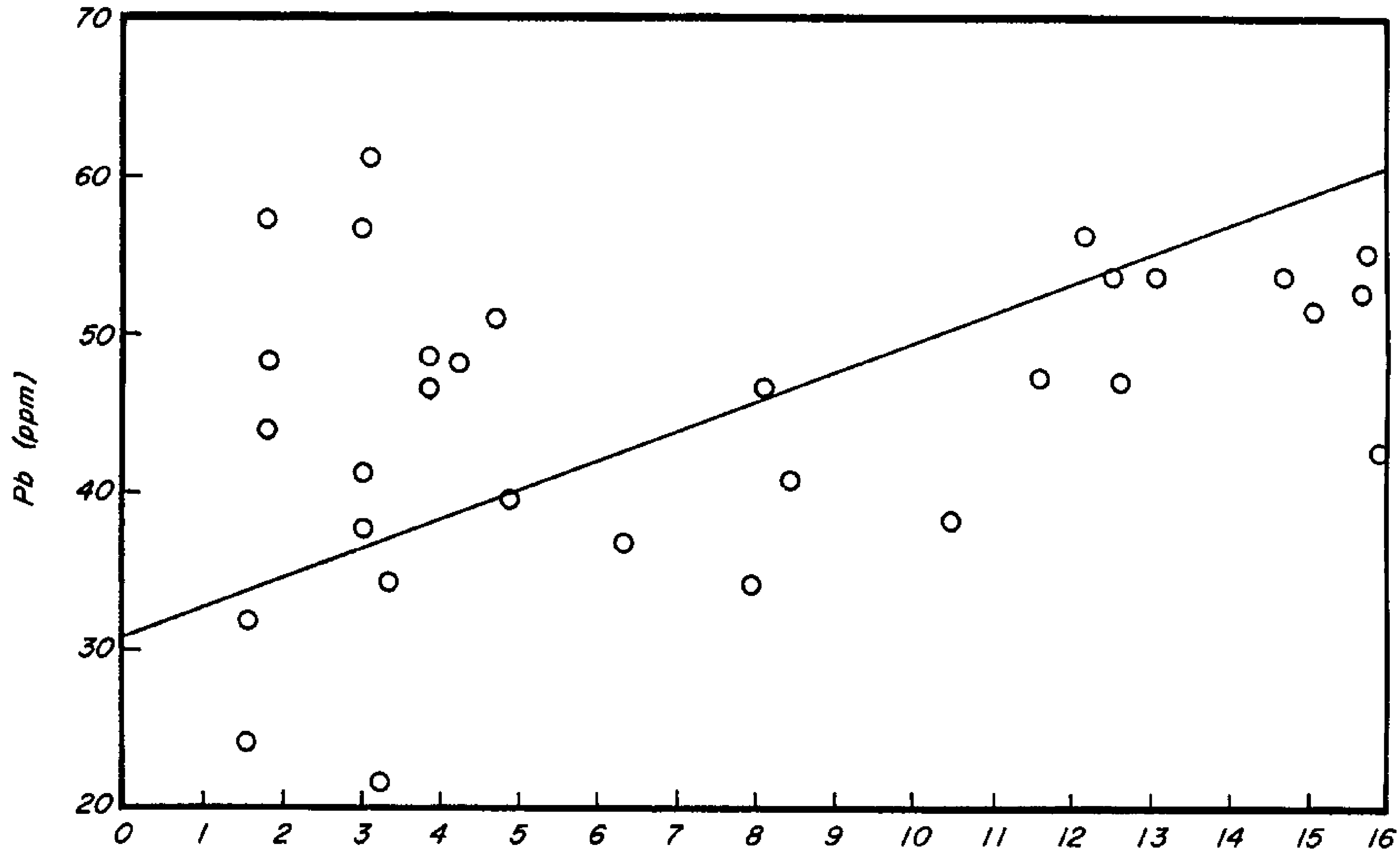


FIGURE 90

Concentration of Lead vs. Total Volatile Substances
in the Surface Sediments of San Pedro Basin

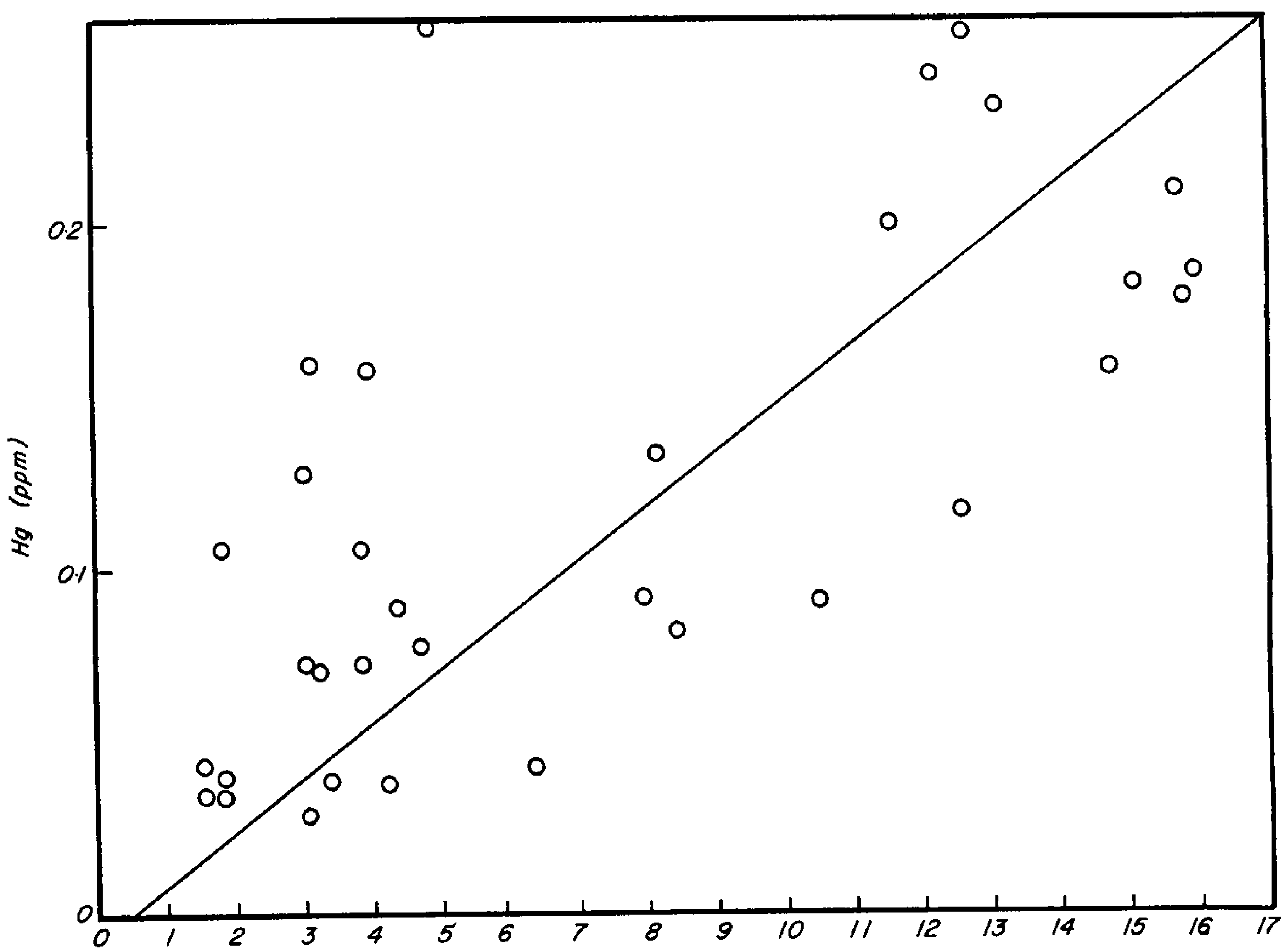


FIGURE 91
Concentration of Mercury vs. Total Volatile Substances
in the Surface Sediments of San Pedro Basin

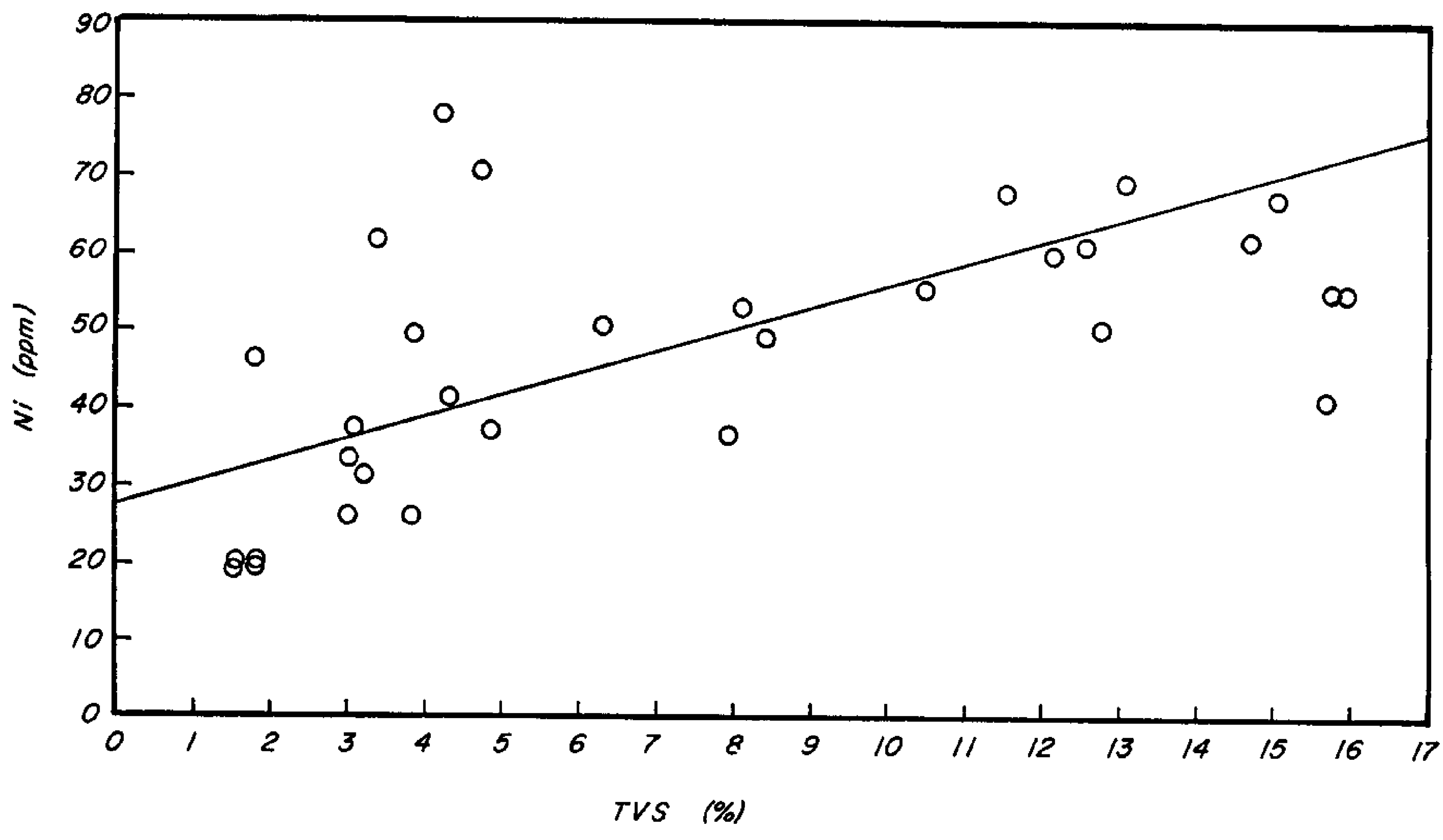


FIGURE 92

Concentration of Nickel vs. Total Volatile Substances in the Surface Sediments of San Pédro Basin

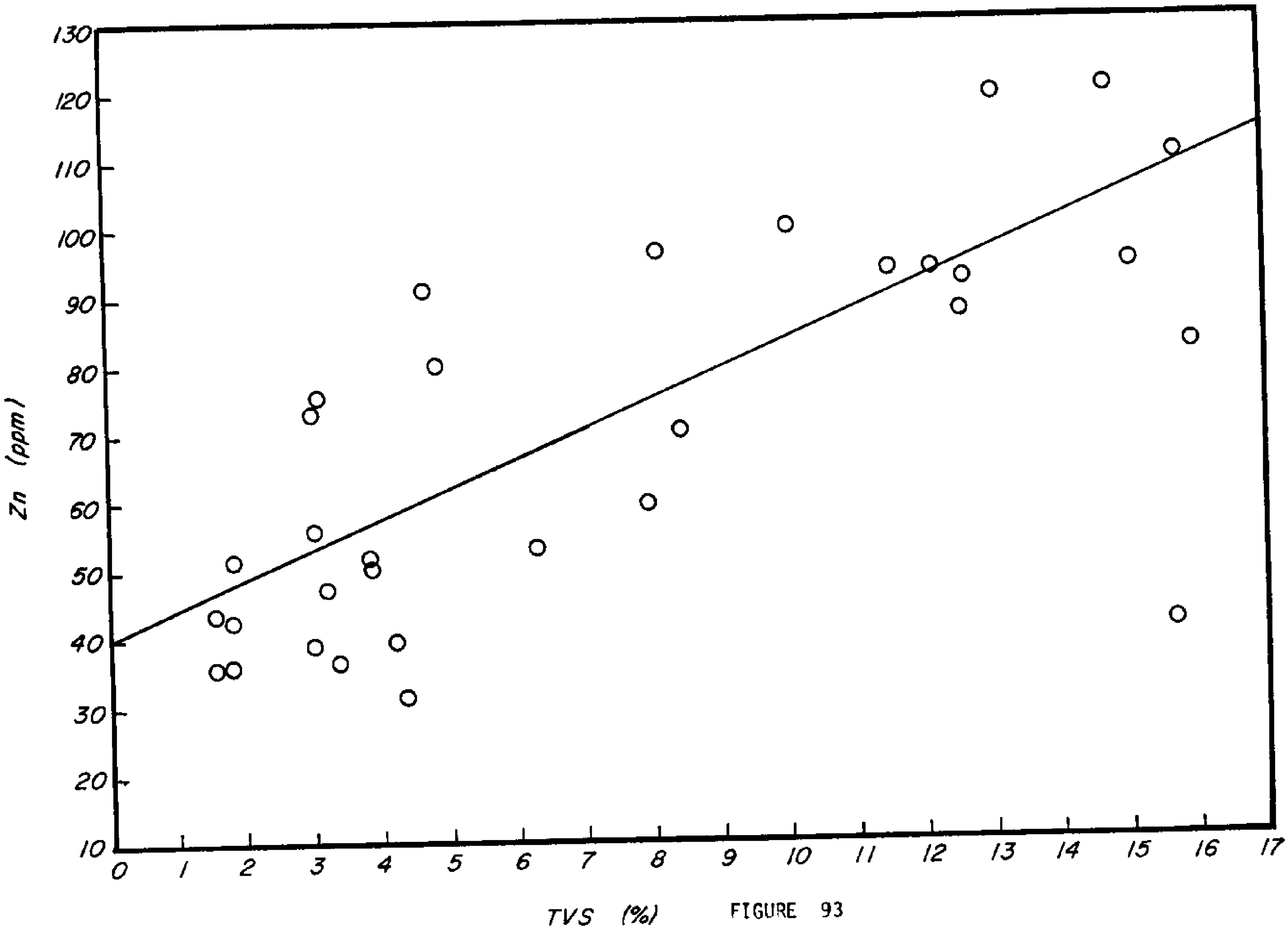


FIGURE 93

Concentration of Zinc vs. Total Volatile Substances
in the Surface Sediments of San Pedro Basin

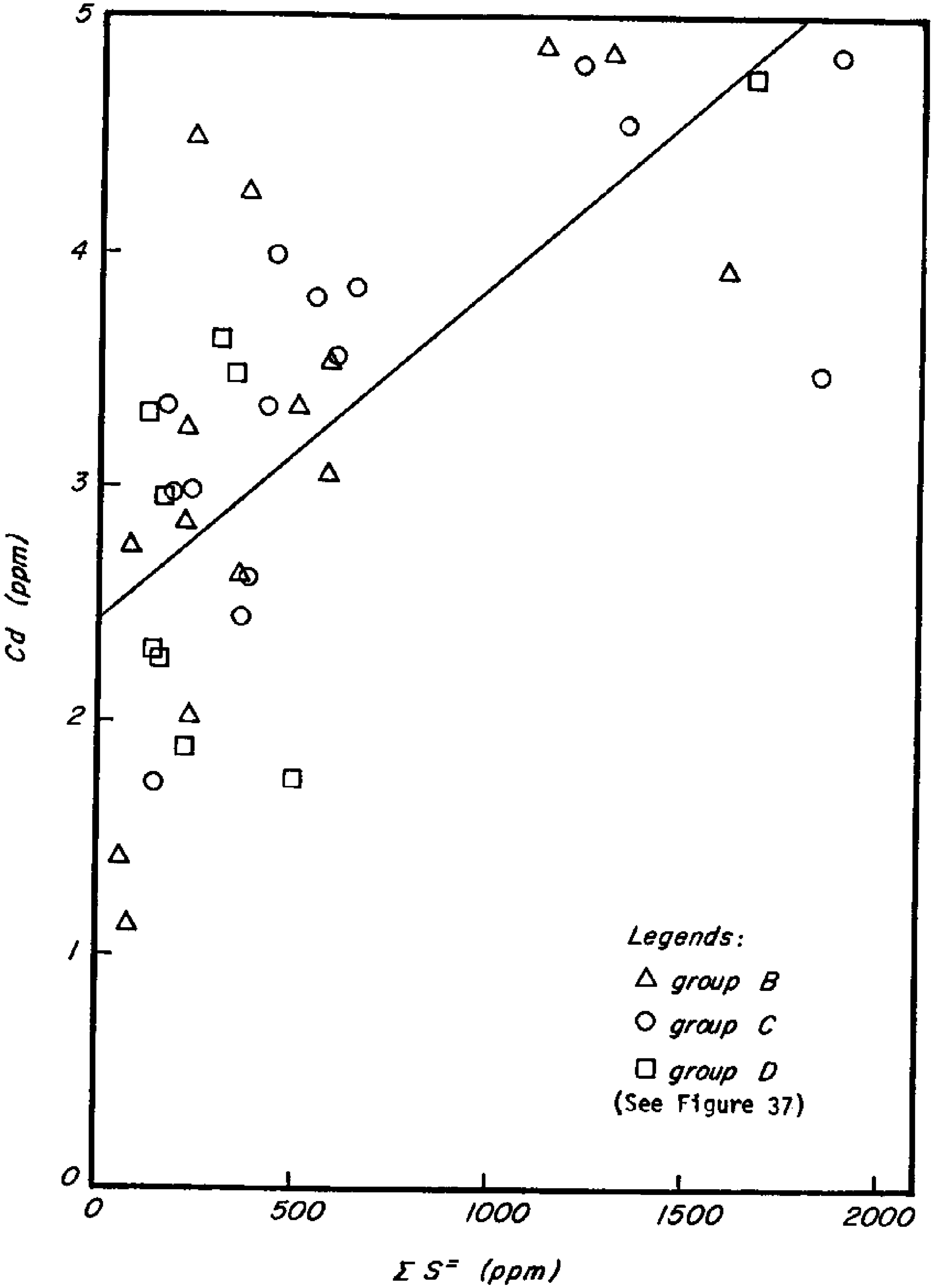


FIGURE 94

Concentration of Cadmium vs. Total Sulfides in the Surface Sediment of L.A. - L.B. Harbors

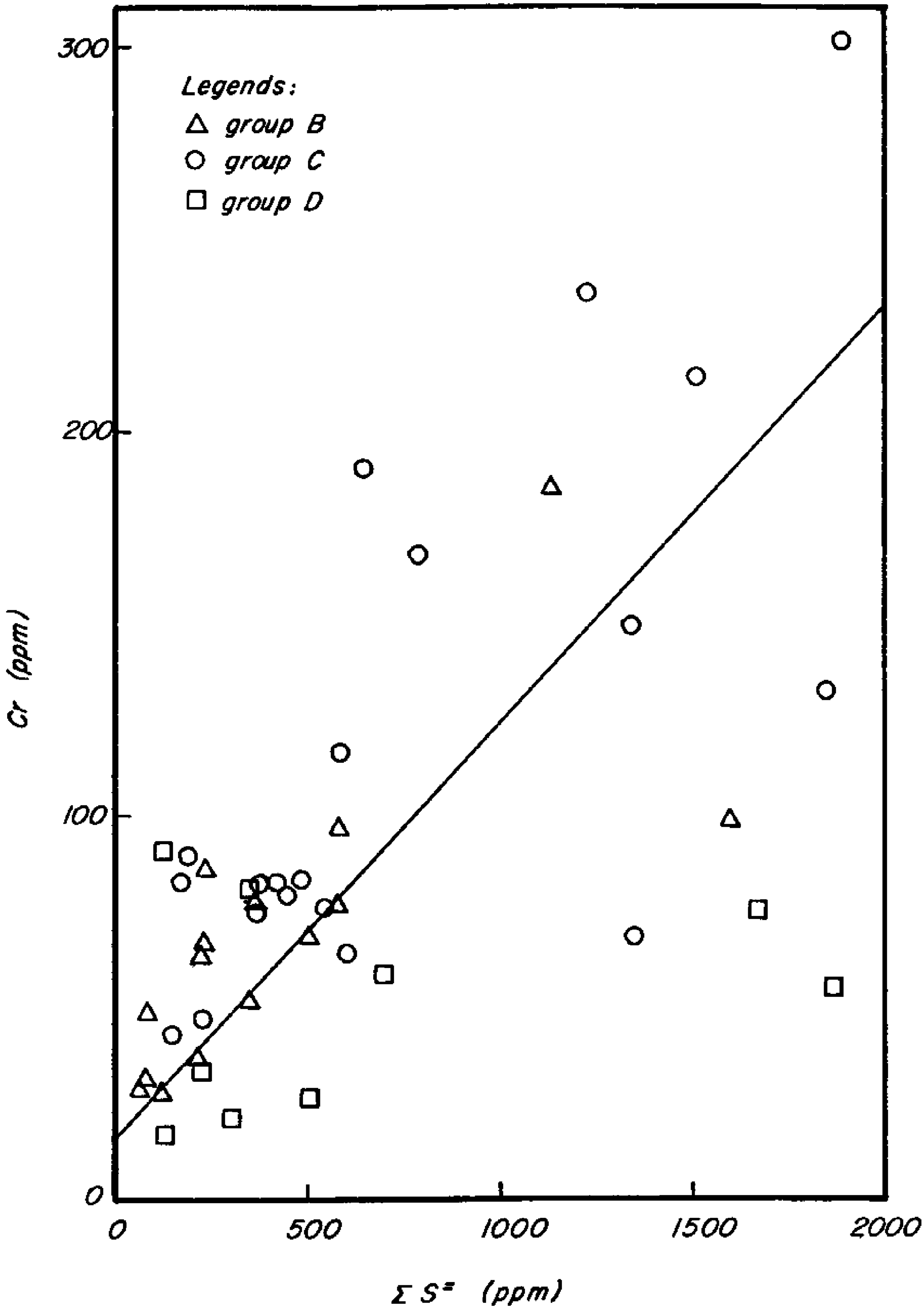


FIGURE 95

Concentration of Chromium vs. Total Sulfides in the Surface Sediment of L.A. - L.B. Harbors

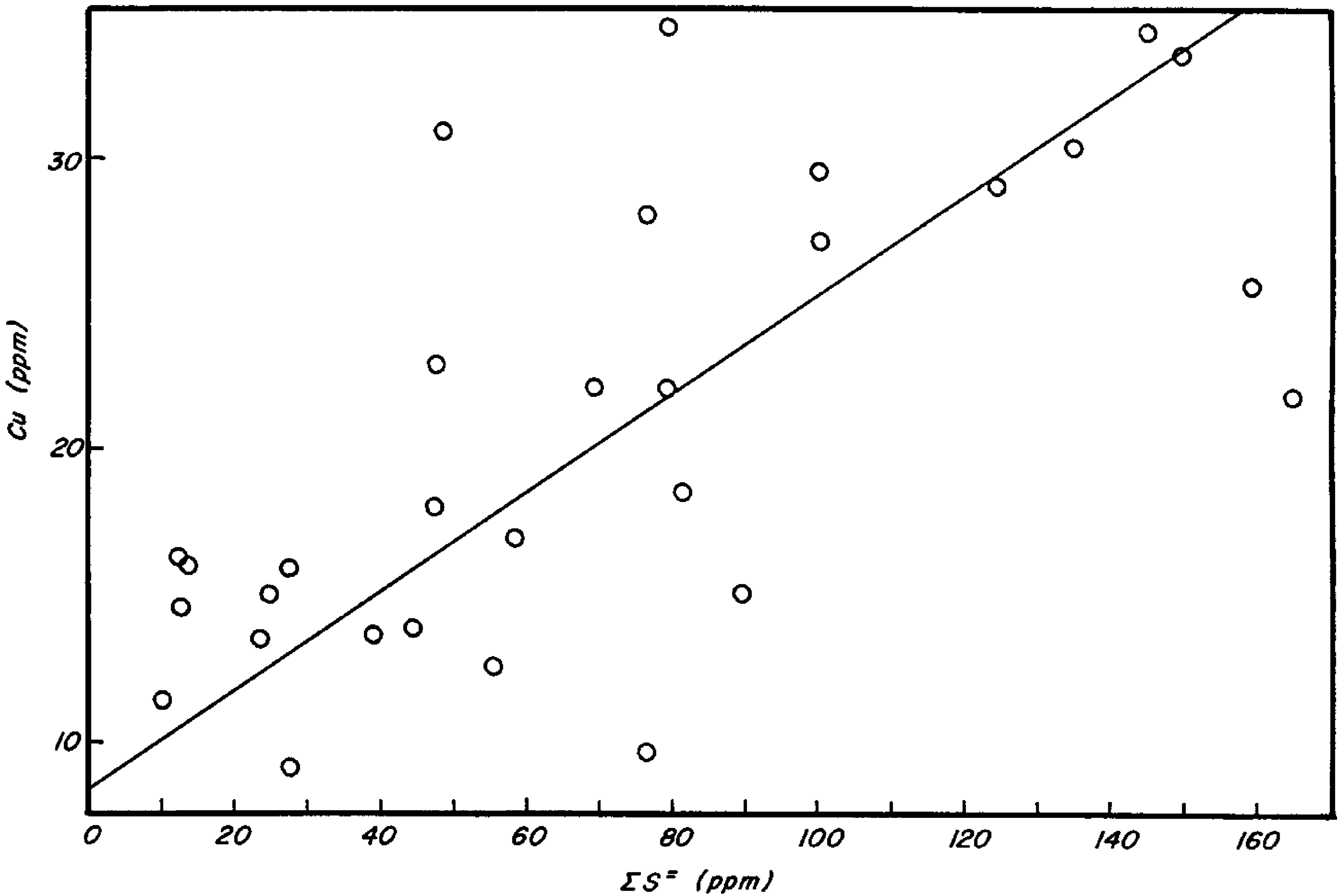


FIGURE 96
Concentration of Copper vs. Total Sulfide
in the Surface Sediments of San Pedro Basin

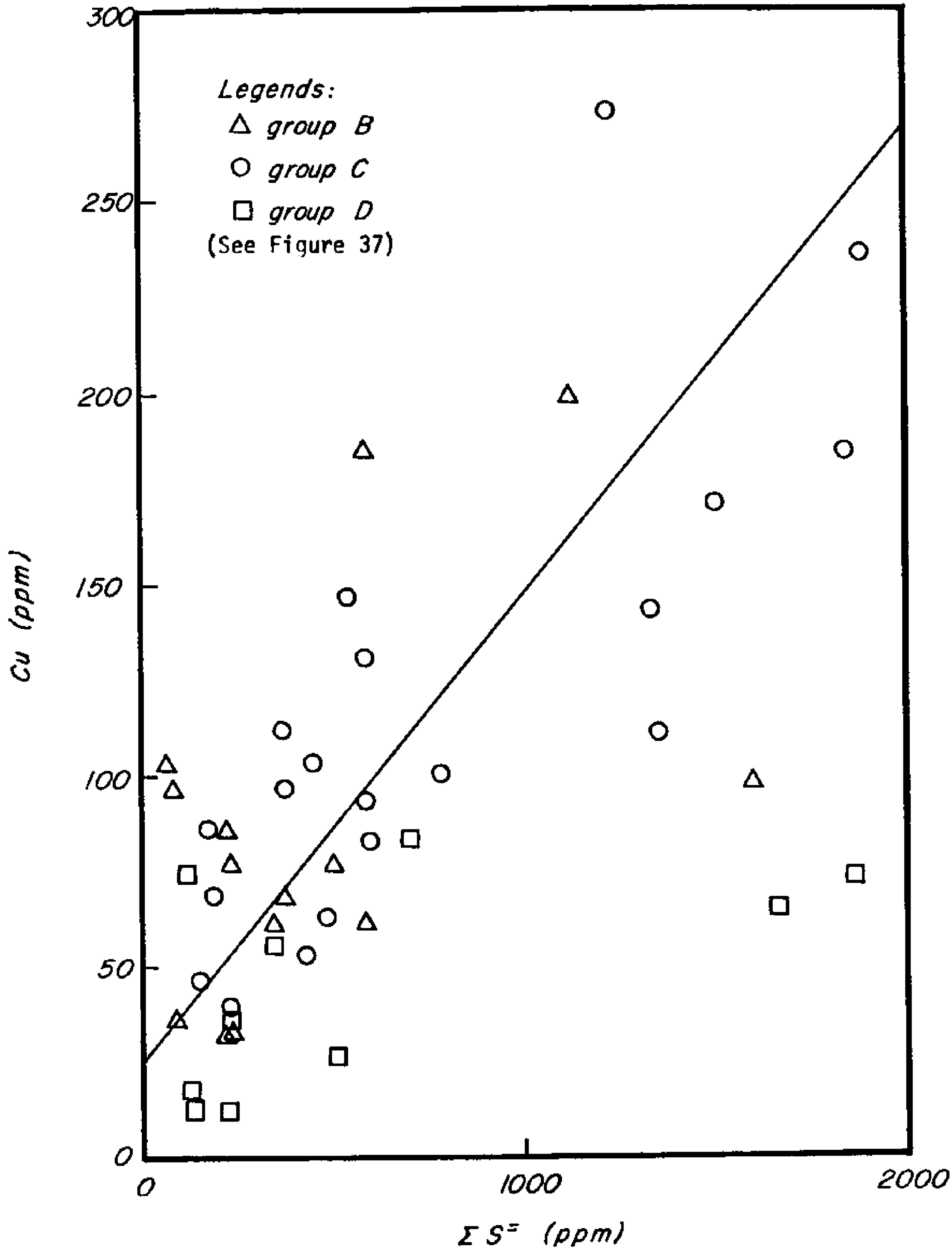


FIGURE 97

Concentration of Copper vs. Total Sulfide
in the Surface Sediments of L.A. - L.B. Harbors

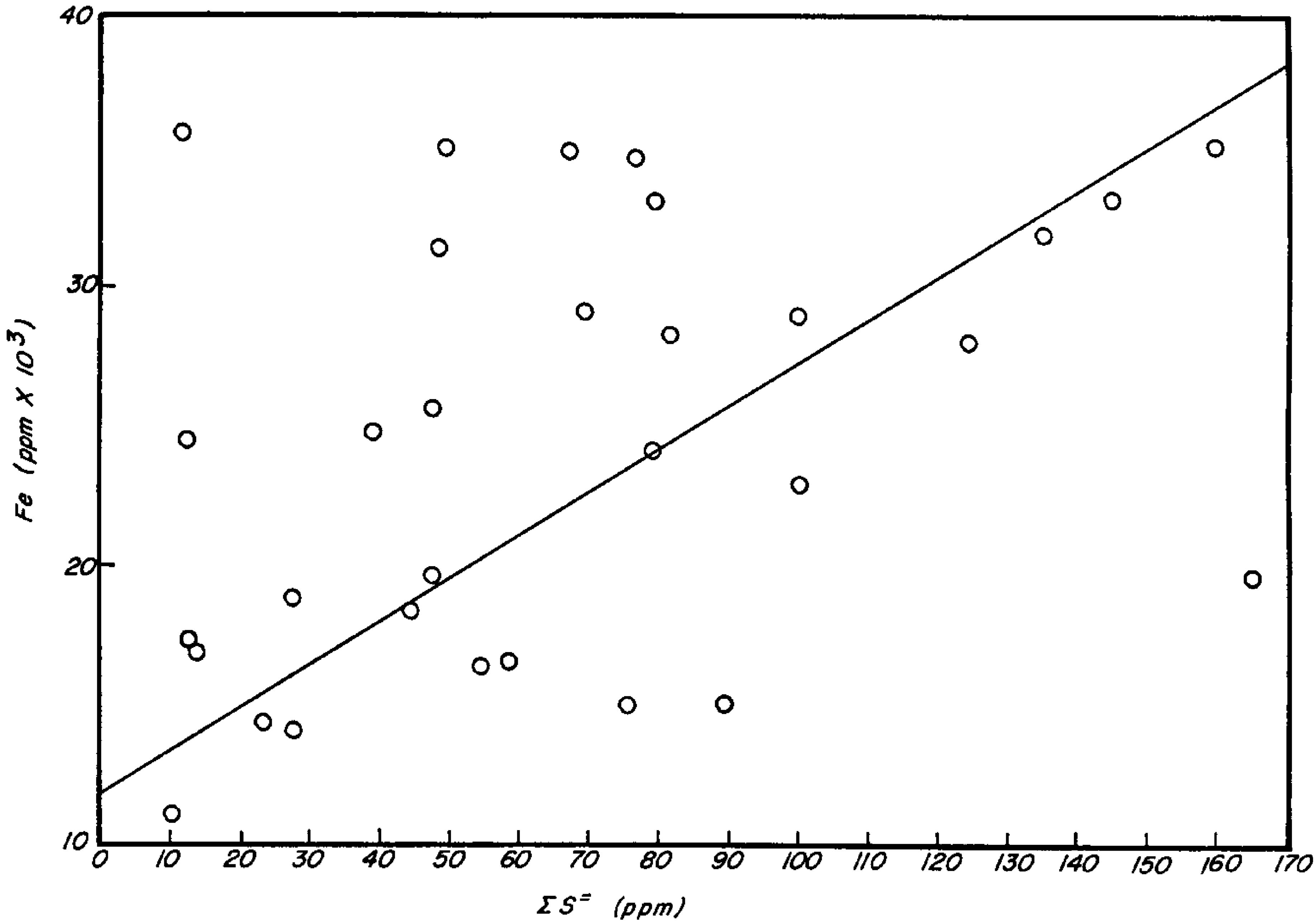


FIGURE 98

Concentration of Iron vs. Total Sulfide
in the Surface Sediments of San Pedro Basin

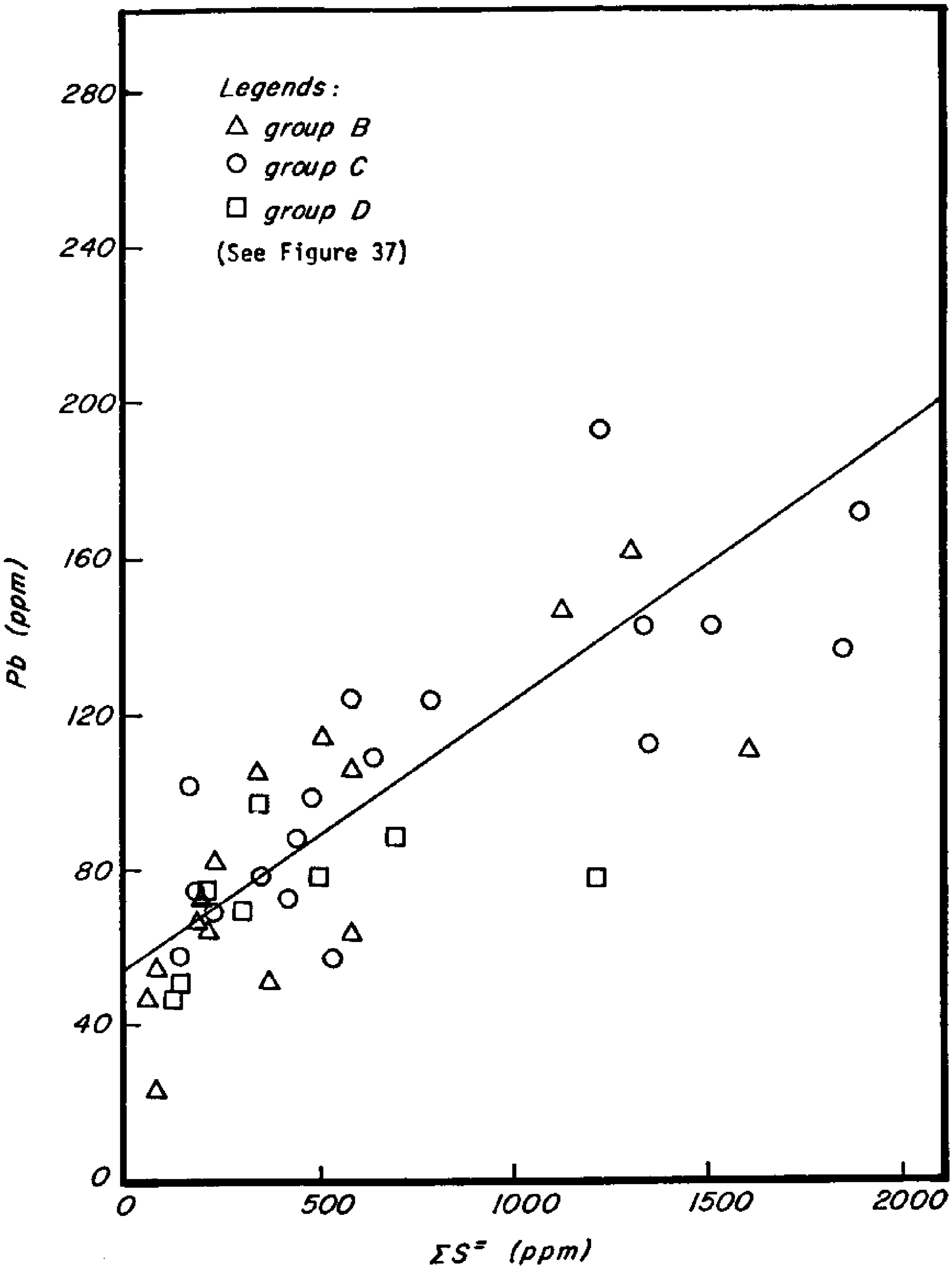


FIGURE 99

Concentration of Lead vs. Total Sulfide
in the Surface Sediments of L.A. - L.B. Harbors

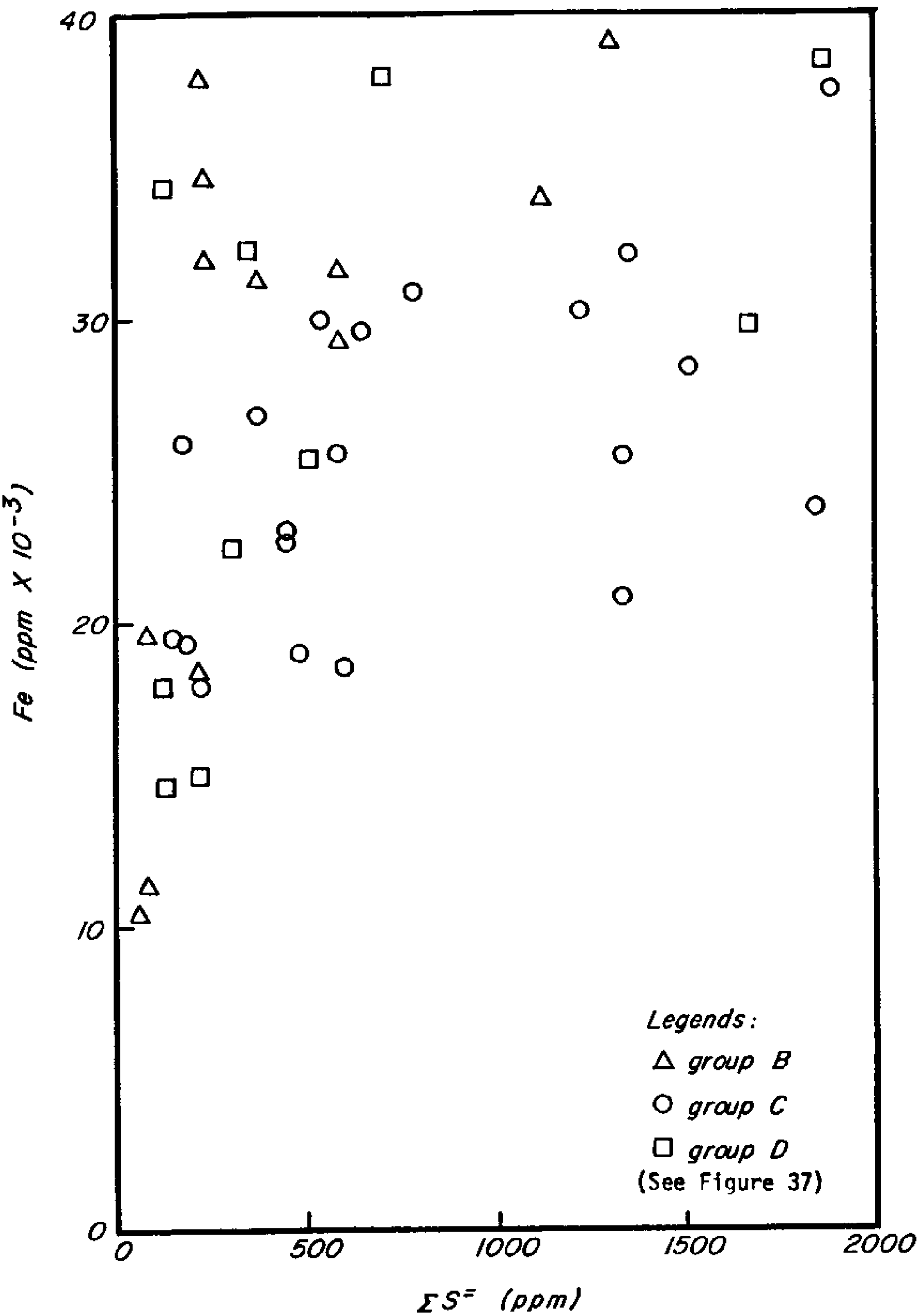


FIGURE 100
Concentration of Iron vs. Total Sulfide in the Surface Sediments of L.A.-L.B. Harbors

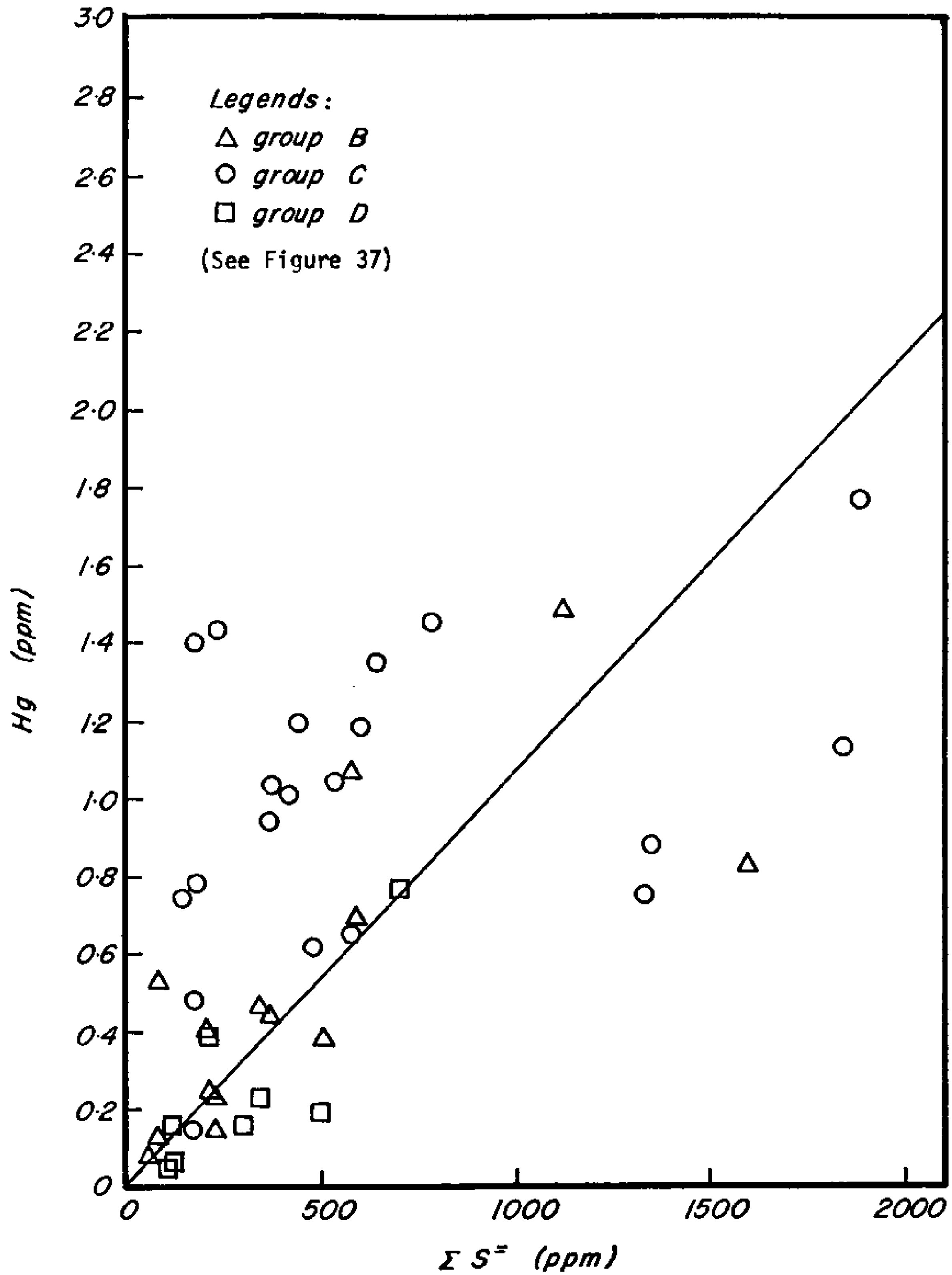


FIGURE 101

Concentration of Mercury vs. Total Sulfide
in the Surface Sediments of L.A. - L.B. Harbors

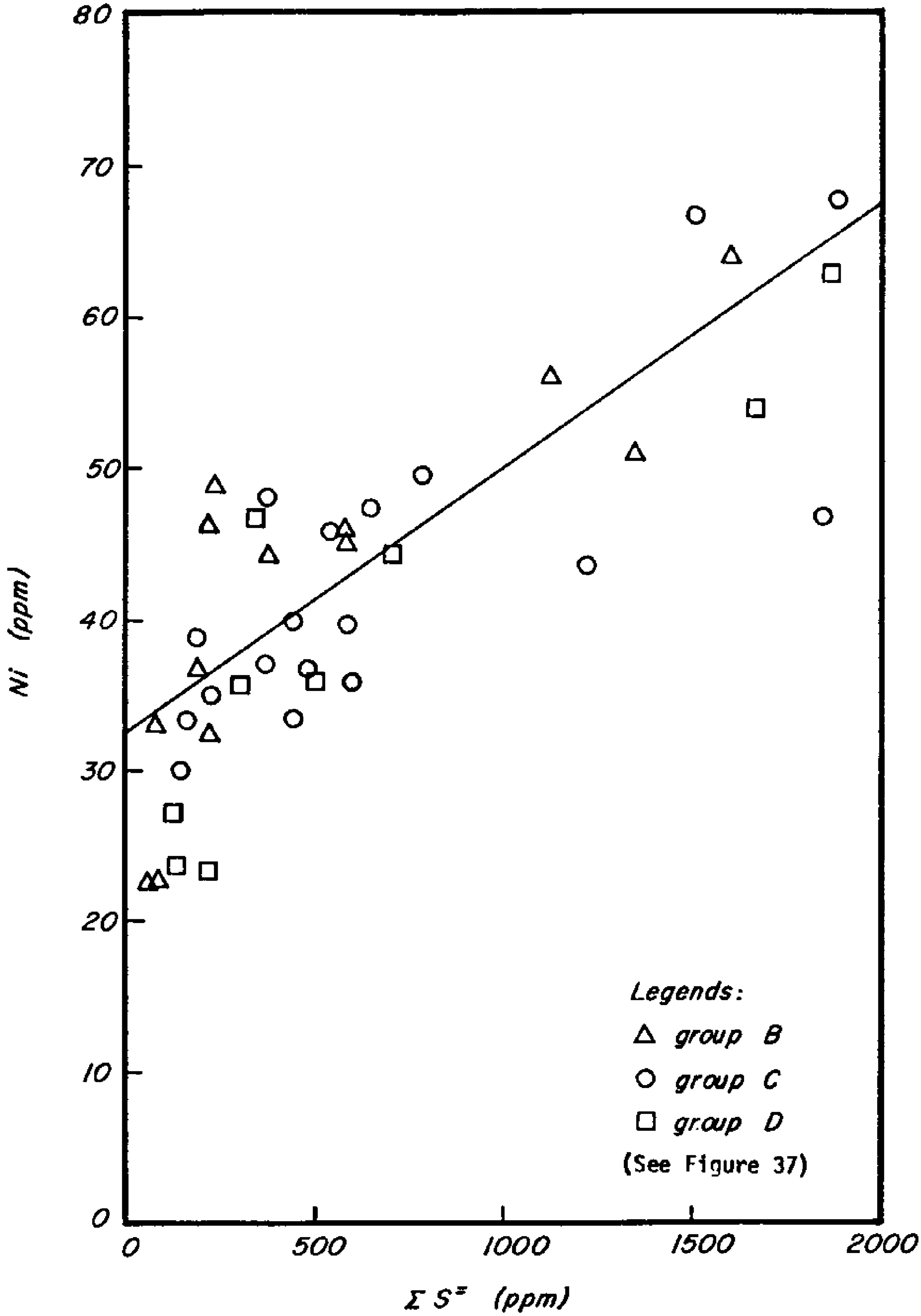


FIGURE 102

Concentration of Nickel vs. Total Sulfide in the Surface Sediments of L.A.-L.B. Harbors

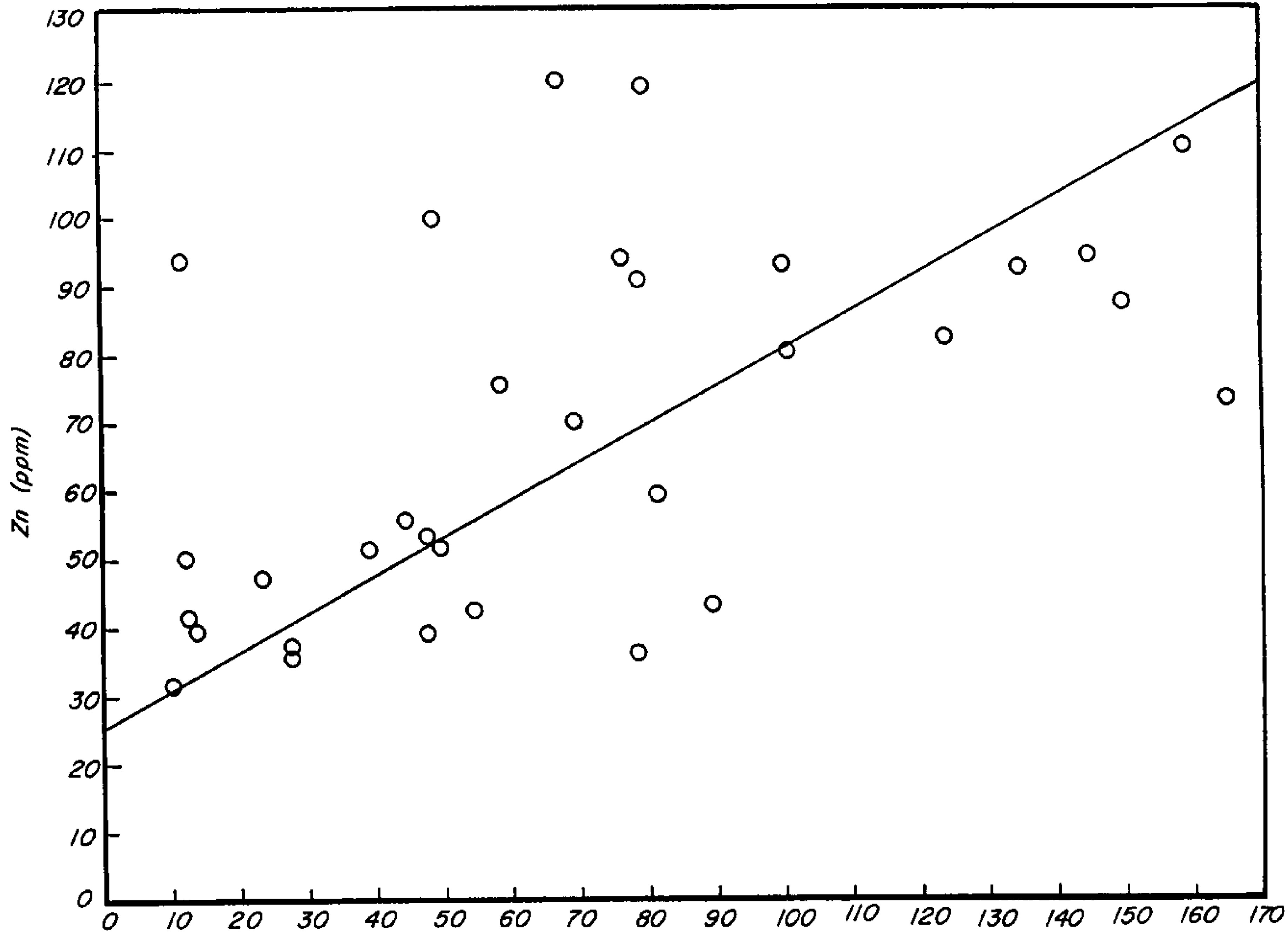


FIGURE 103

Concentration of Zinc vs. Total Sulfide in the Surface Sediments of San Pedro Basin

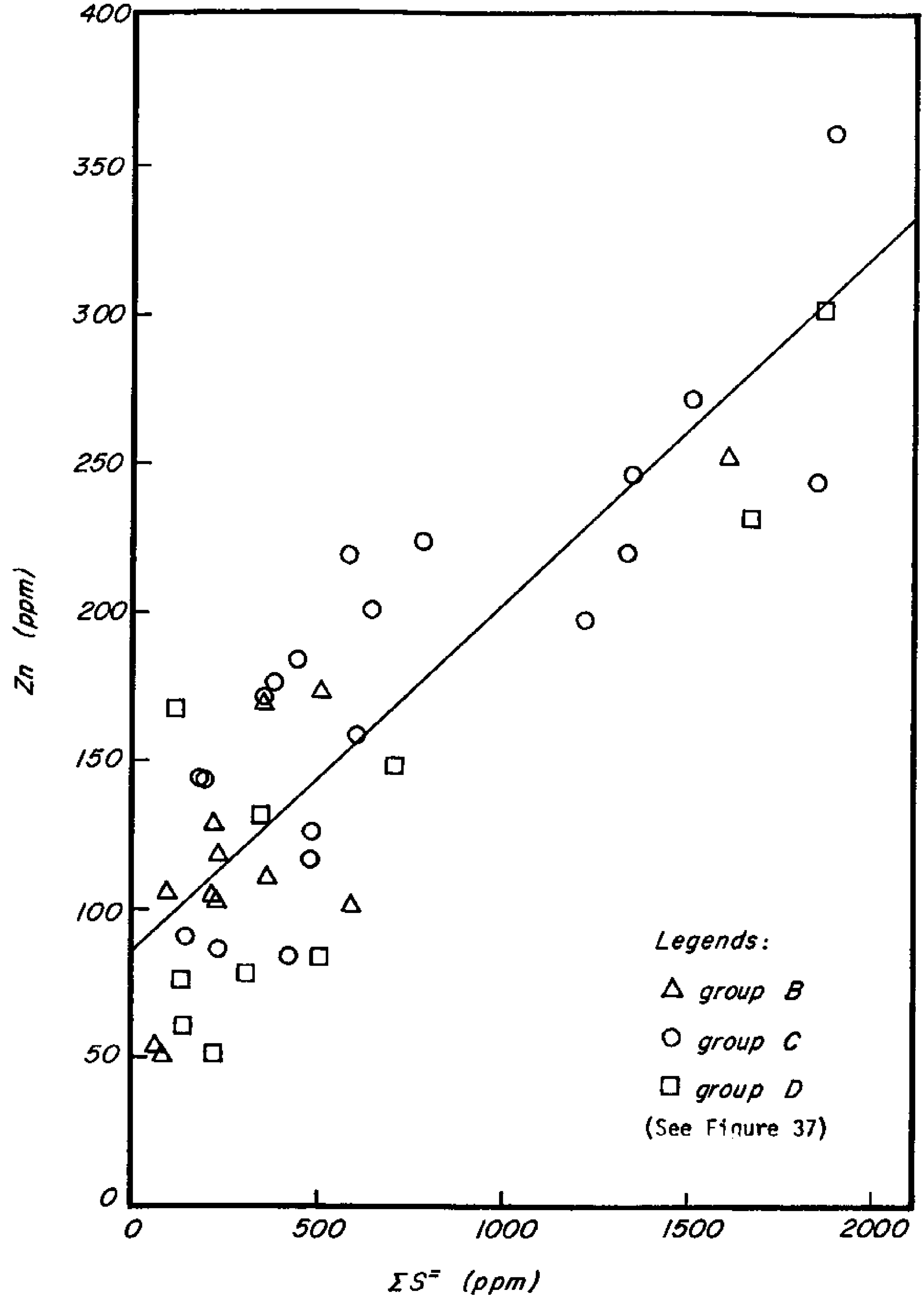


FIGURE 104

Concentration of Zinc vs. Total Sulfide in the Surface Sediments of L.A. - L.B. Harbors

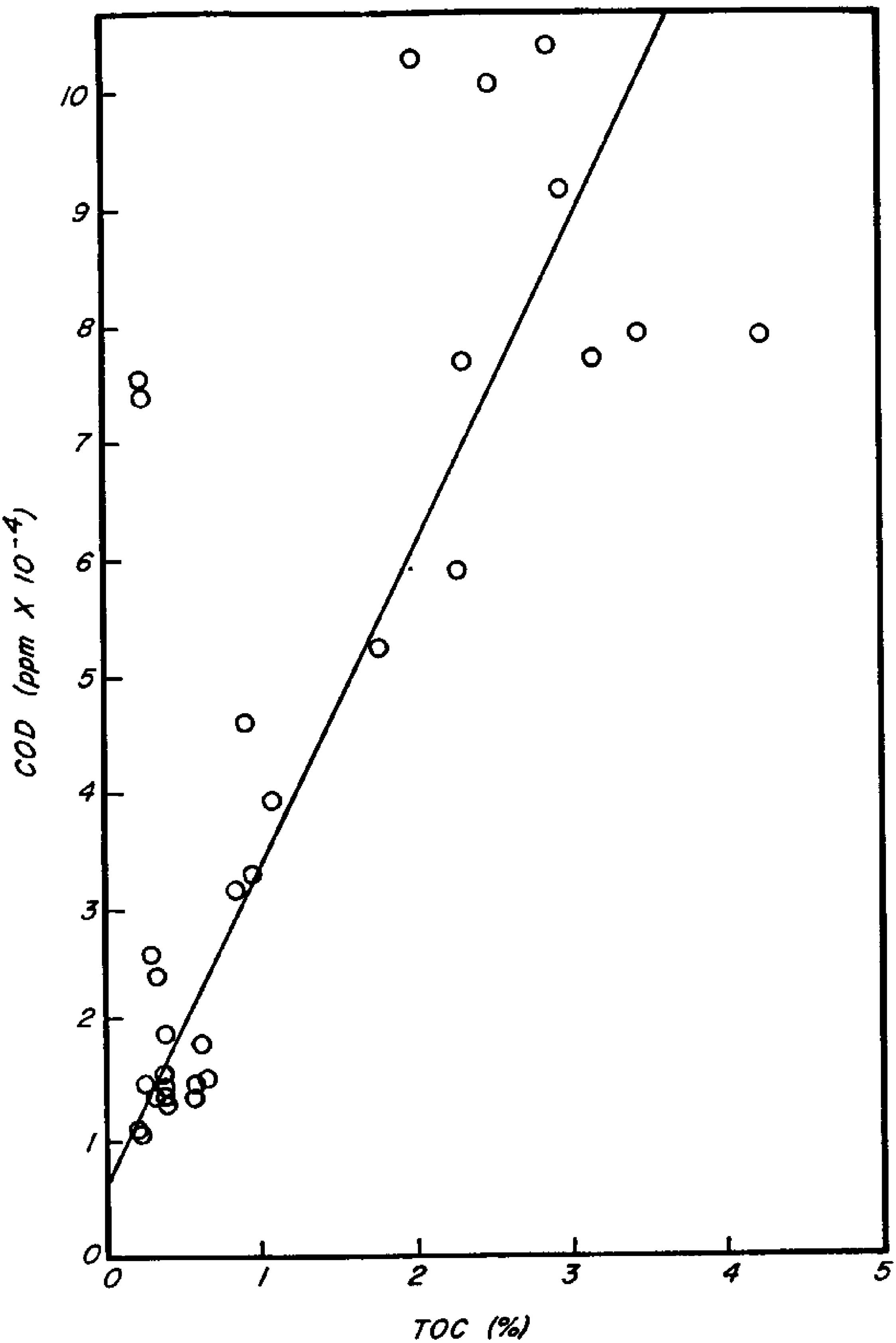


FIGURE 105

TOC vs. COD in the Surface Sediments of San Pedro Basin

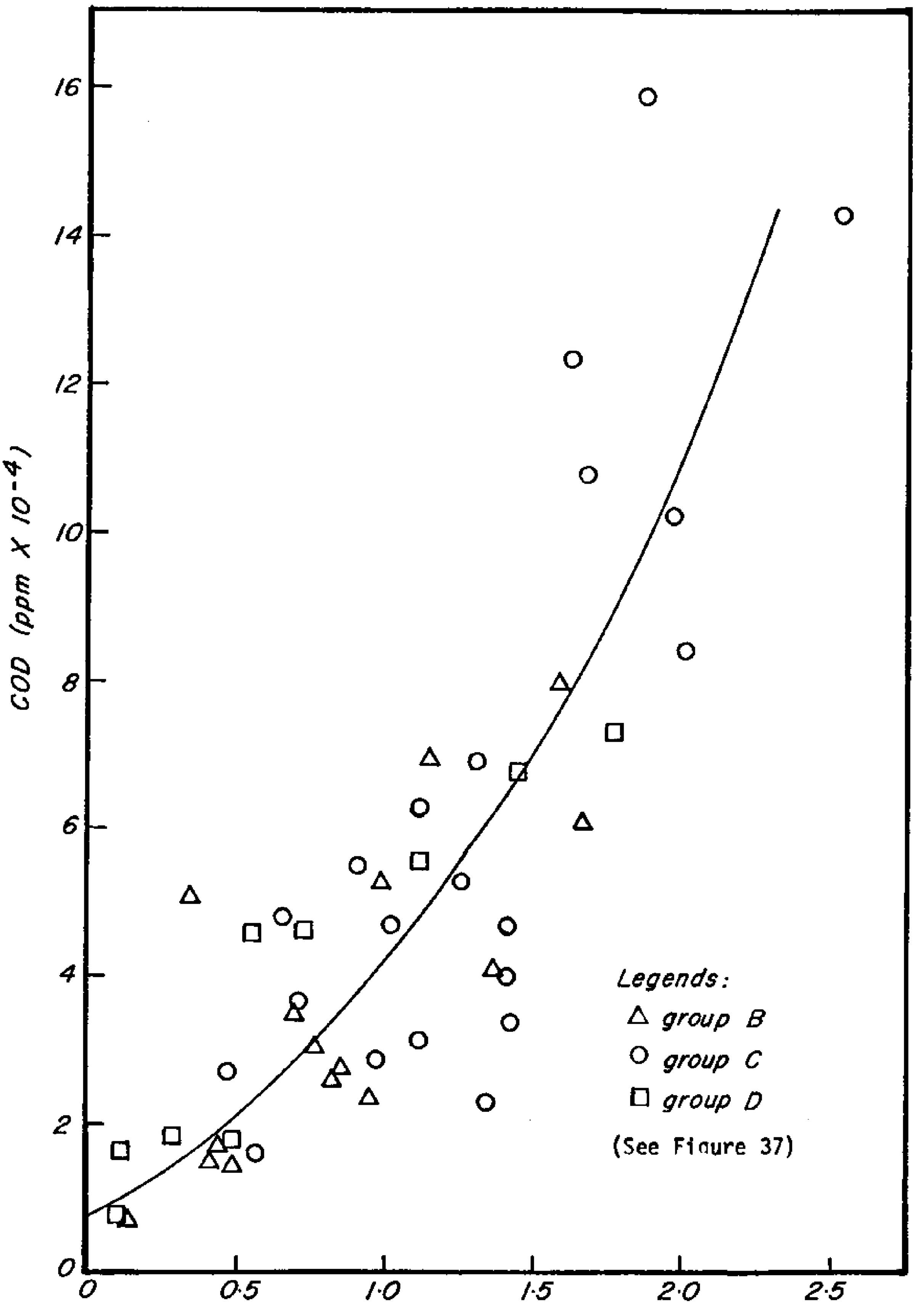


FIGURE 106

TOC vs COD in the Surface Sediments of San Pedro Basin

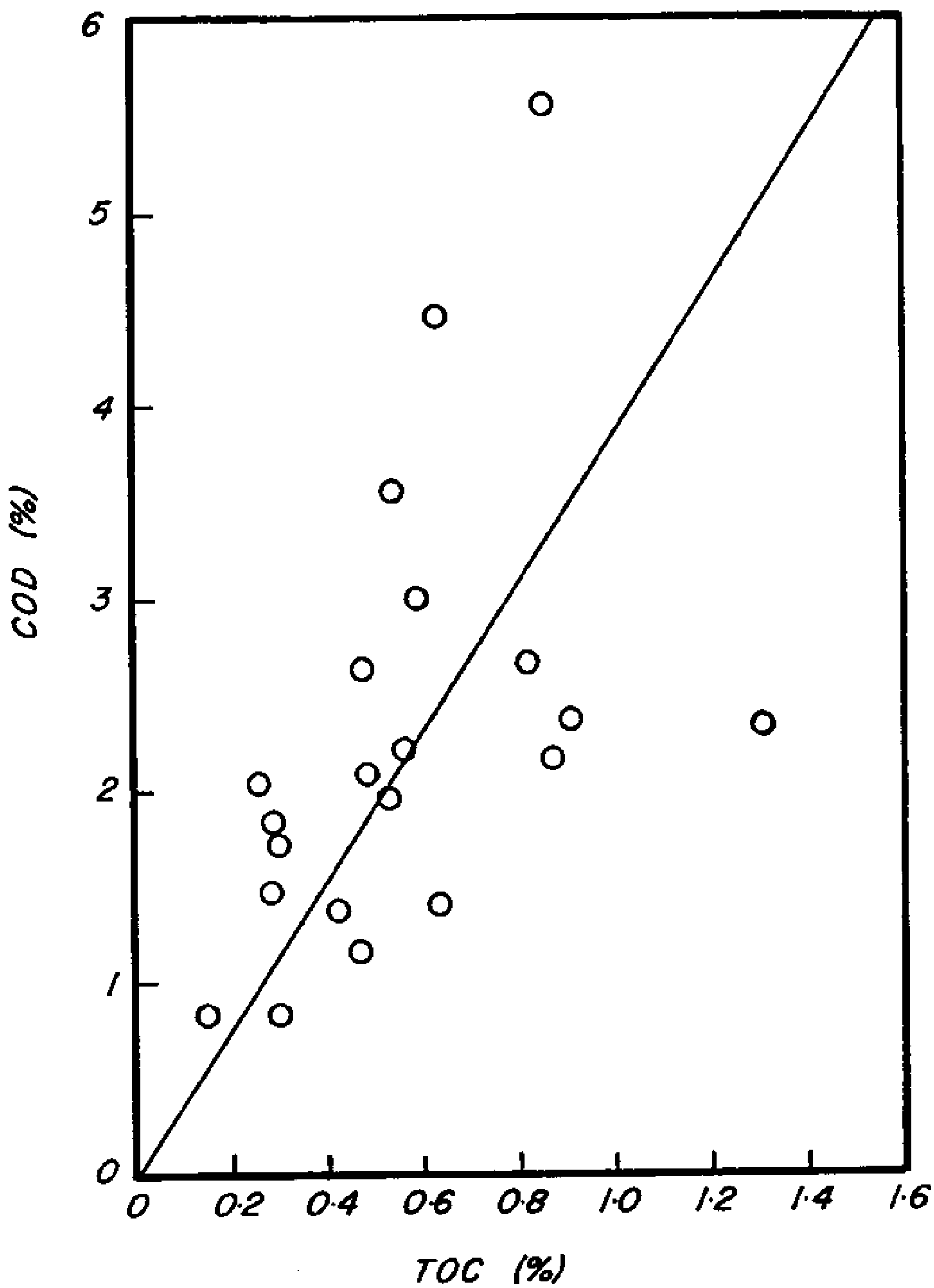


FIGURE 107

TOC vs. COD in the Sediments of the Proposed LNG Route

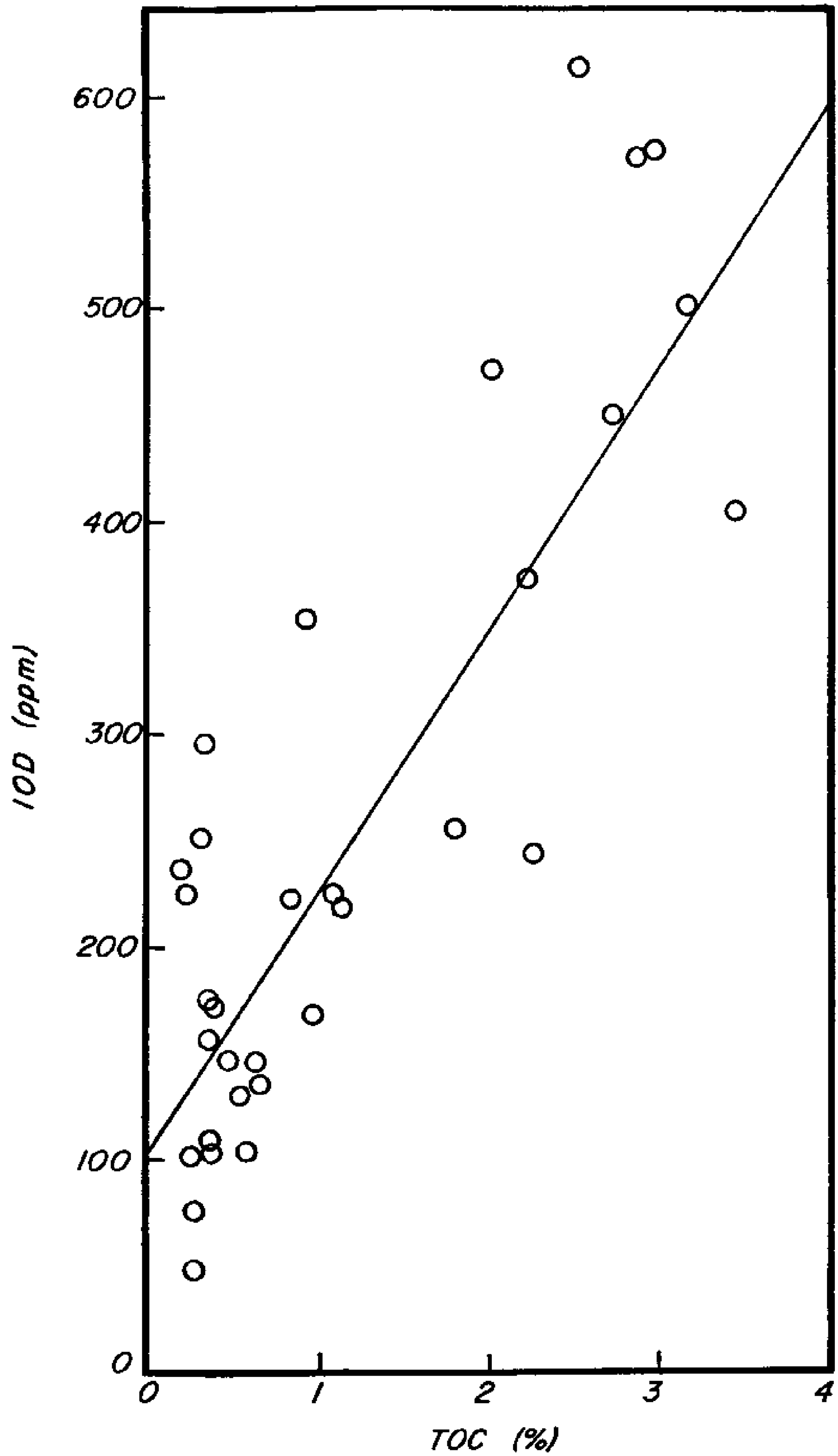


FIGURE 108

TOC vs. IOD in the Surface Sediments of San Pedro Basin

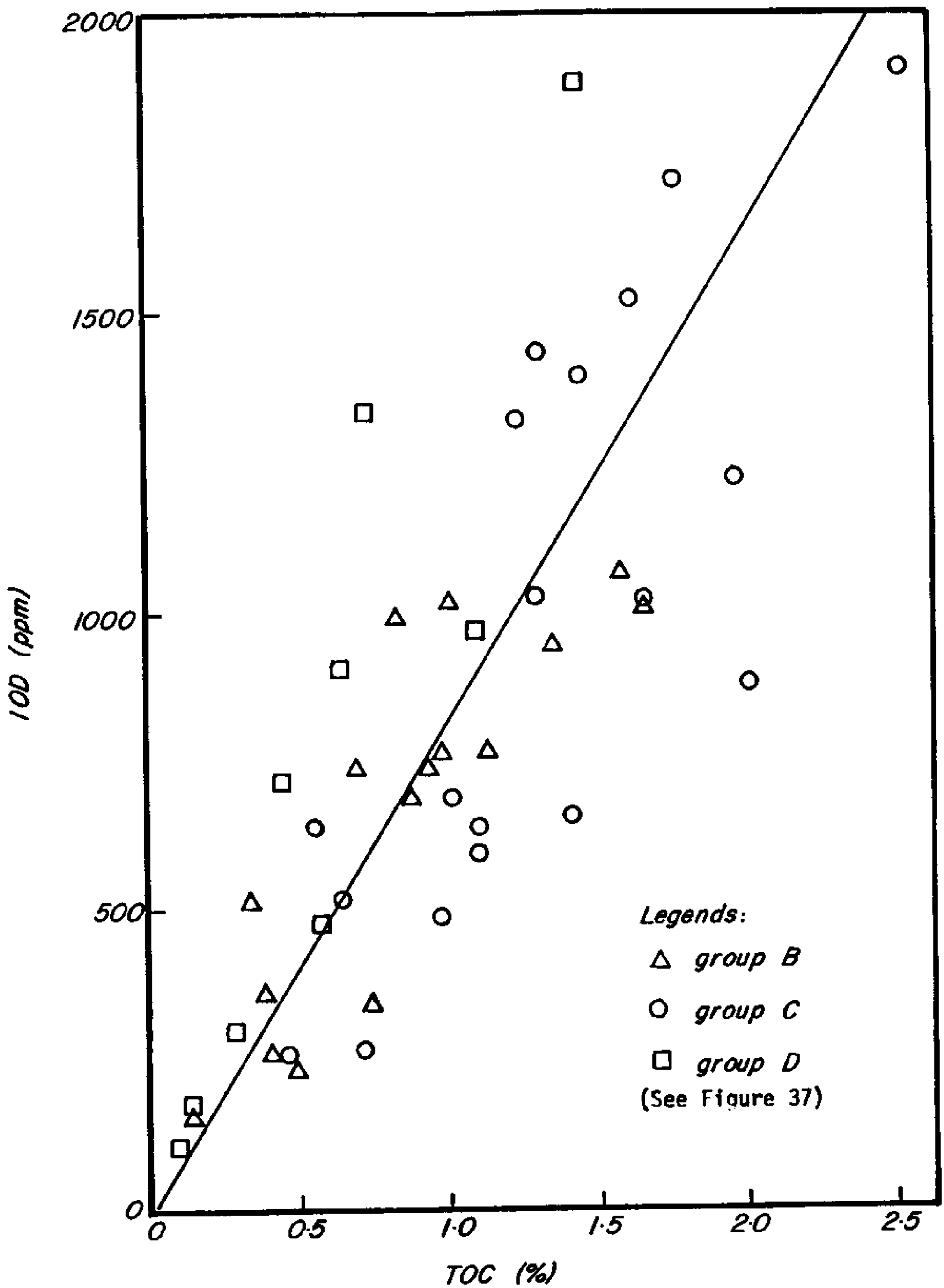


FIGURE 109

TOC vs. IOD in the Surface Sediments of L.A. - L.B. Harbors

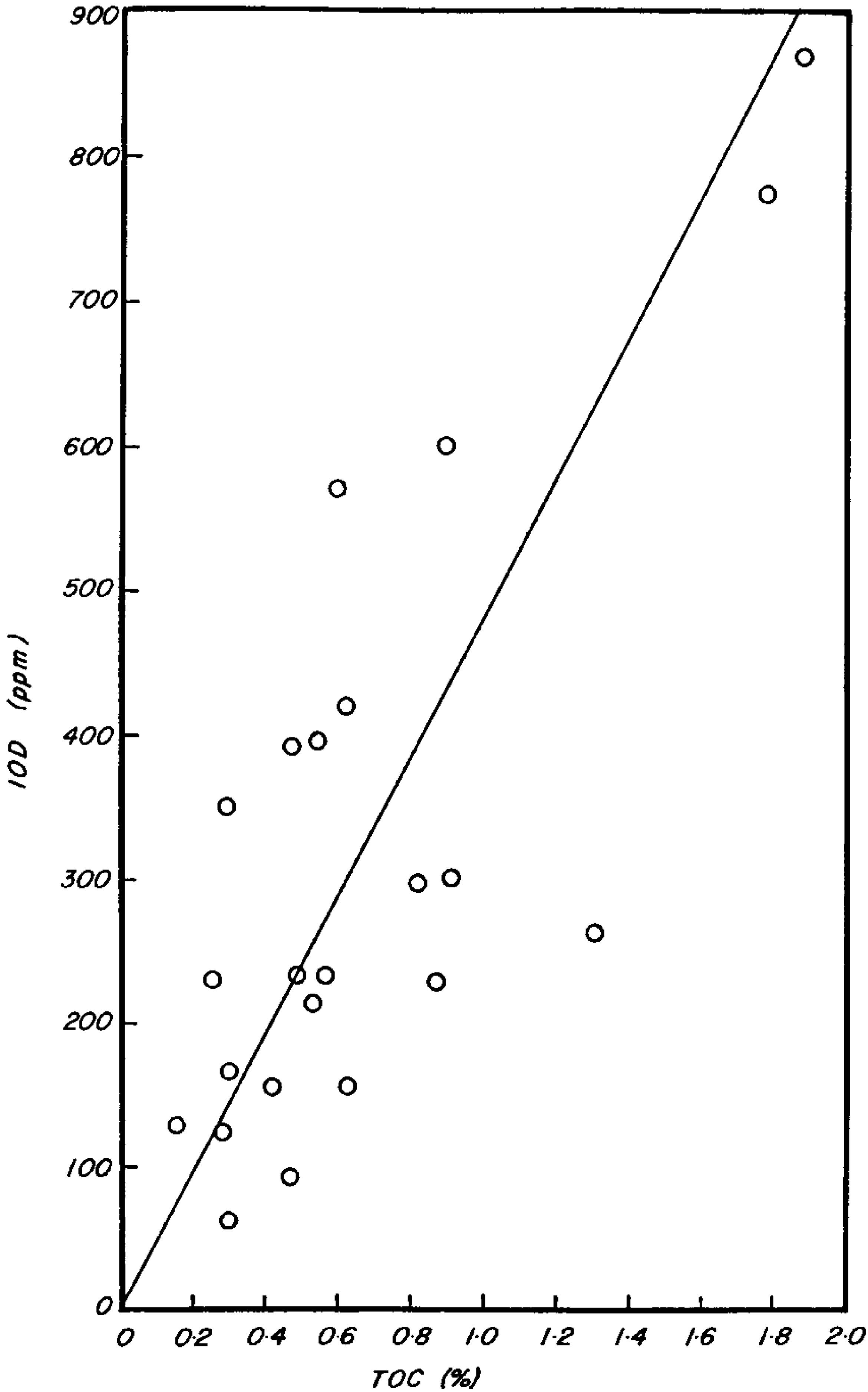


FIGURE 110

TOC vs. IOD in the Sediments of the Proposed LNG Route

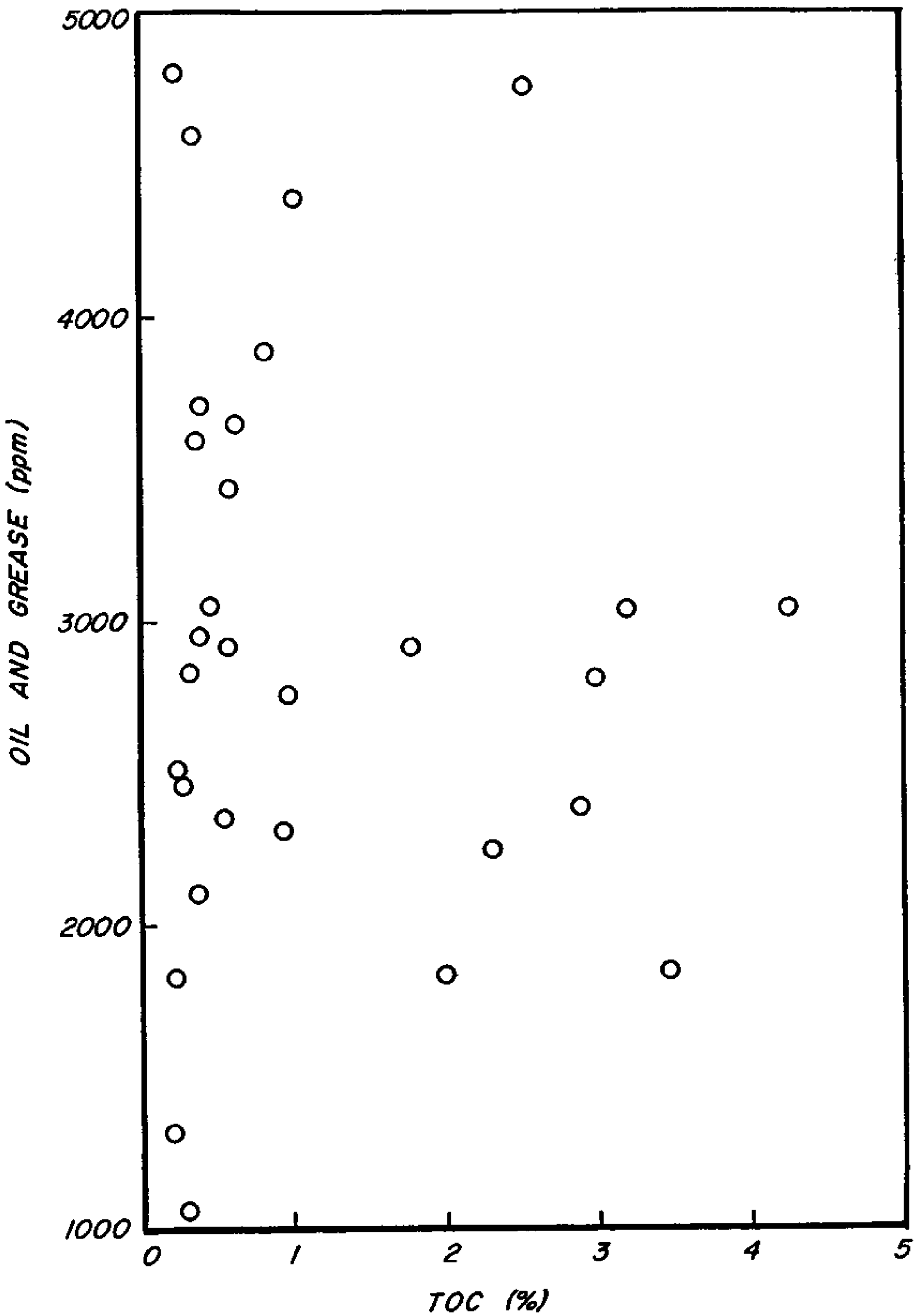


FIGURE 111
TOC vs. Oil and Grease in the Surface Sediments of San Pedro Basin

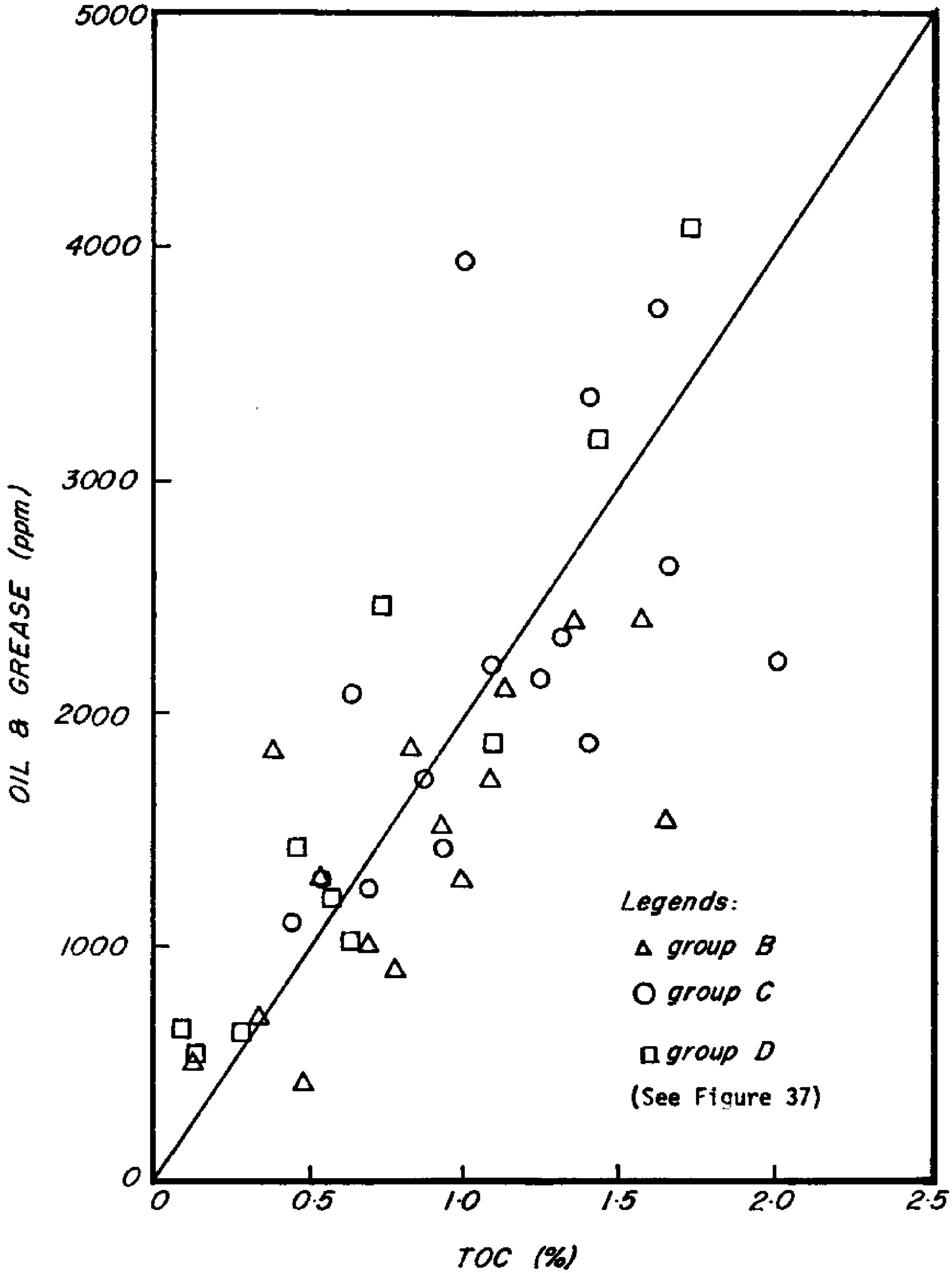


FIGURE 112

TOC vs. Oil and Grease in the Surface Sediments of L.A. - L.B. Harbors

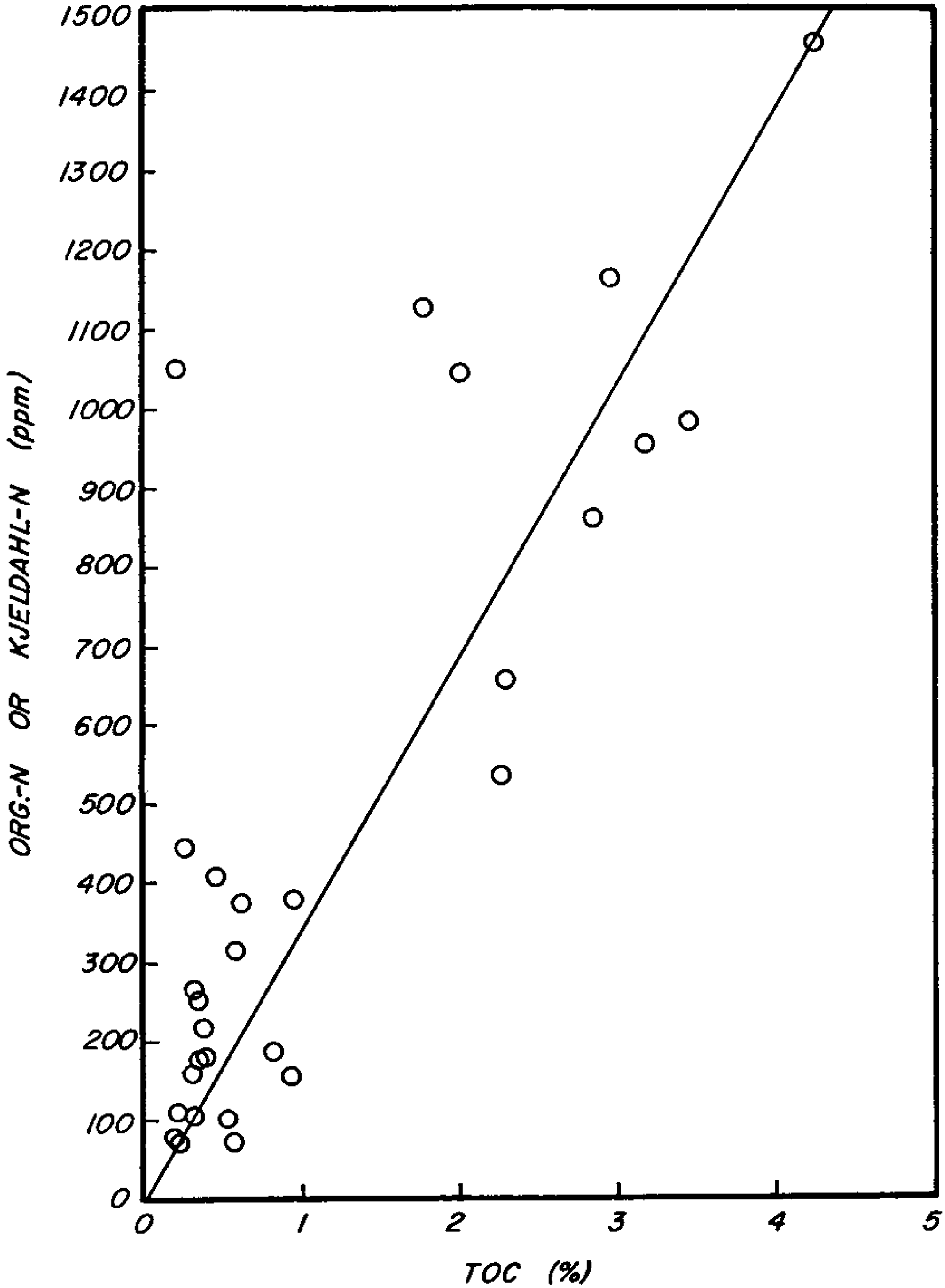


FIGURE 113

TOC vs. Org. N or Kjeldahl N in the
Surface Sediments of San Pedro Basin

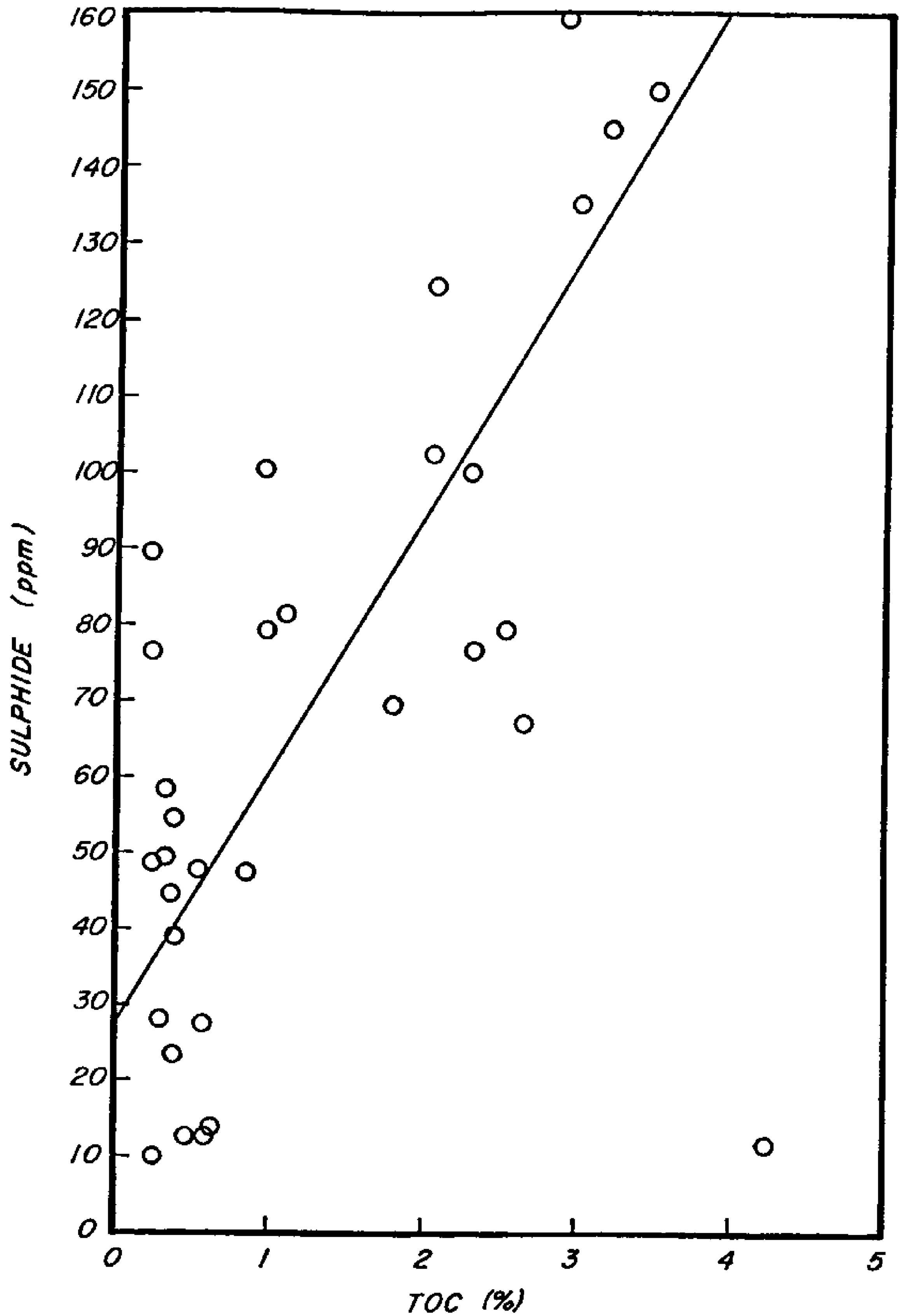


FIGURE 114

TOC vs Sulfide in the Surface Sediments of San Pedro Basin

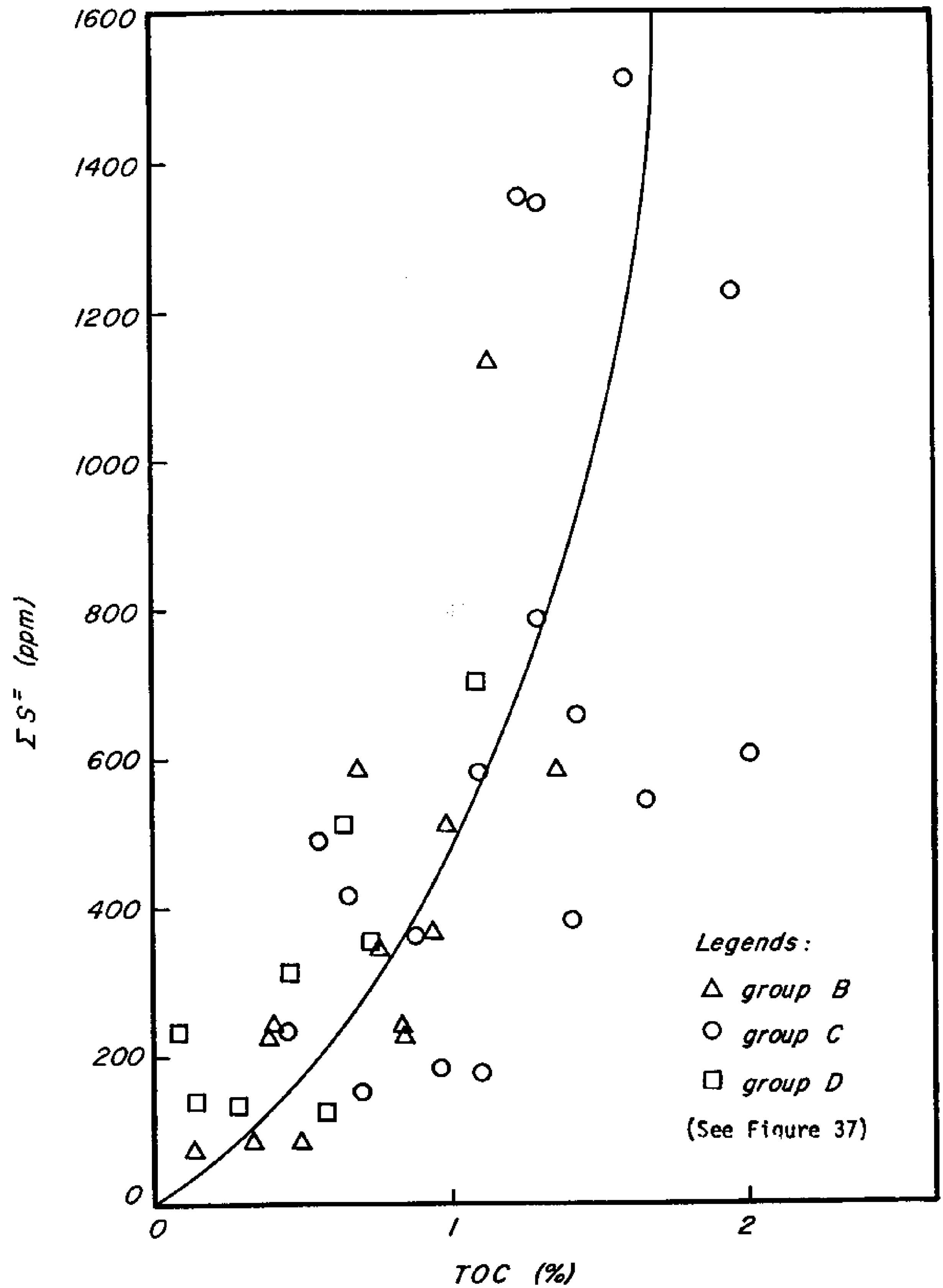


FIGURE 115

TOC vs Sulfide in the Surface Sediments of L.A.-L.B. Harbors

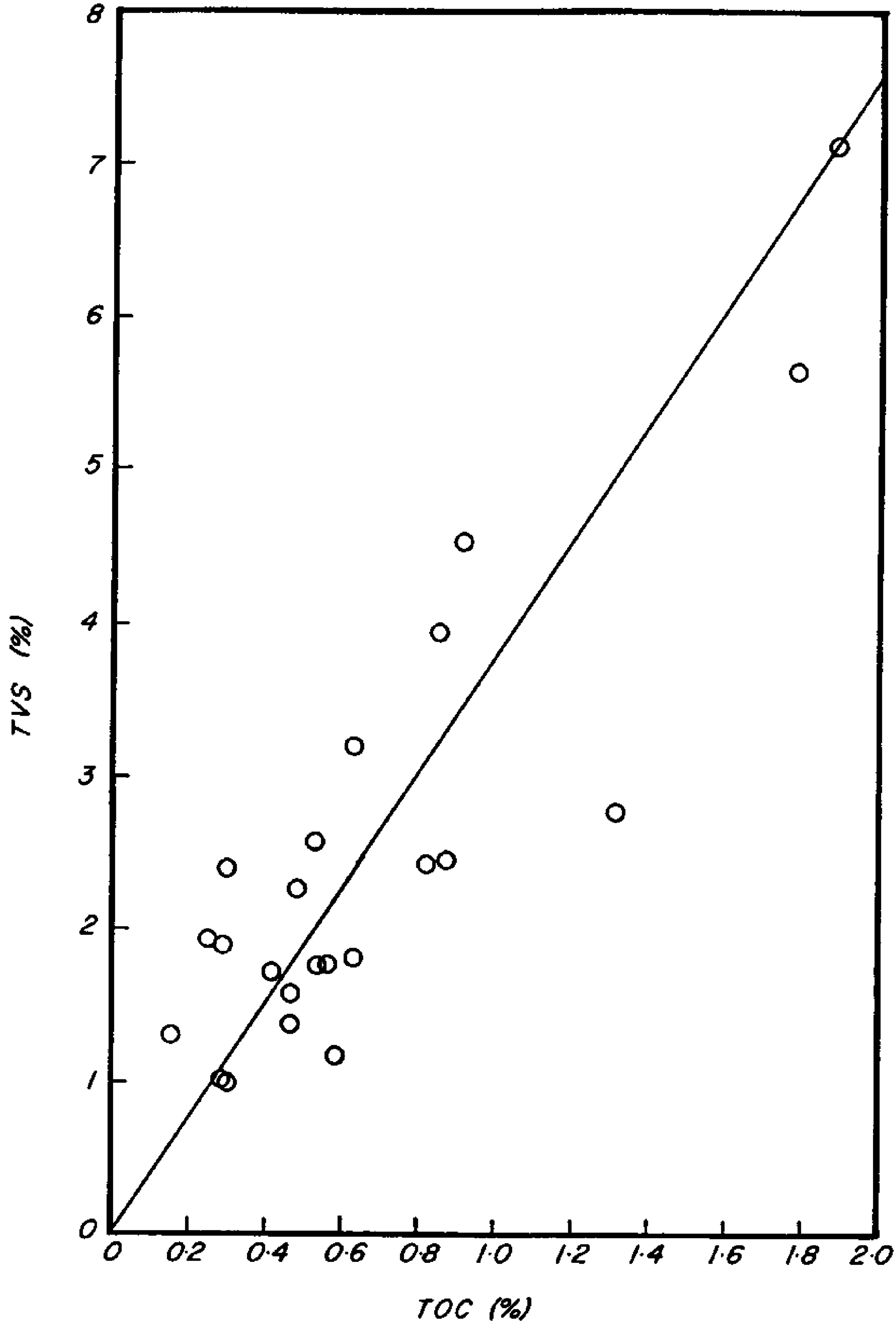


FIGURE 116
TOC vs. TVS in the Surface Sediments
of San Pedro Basin

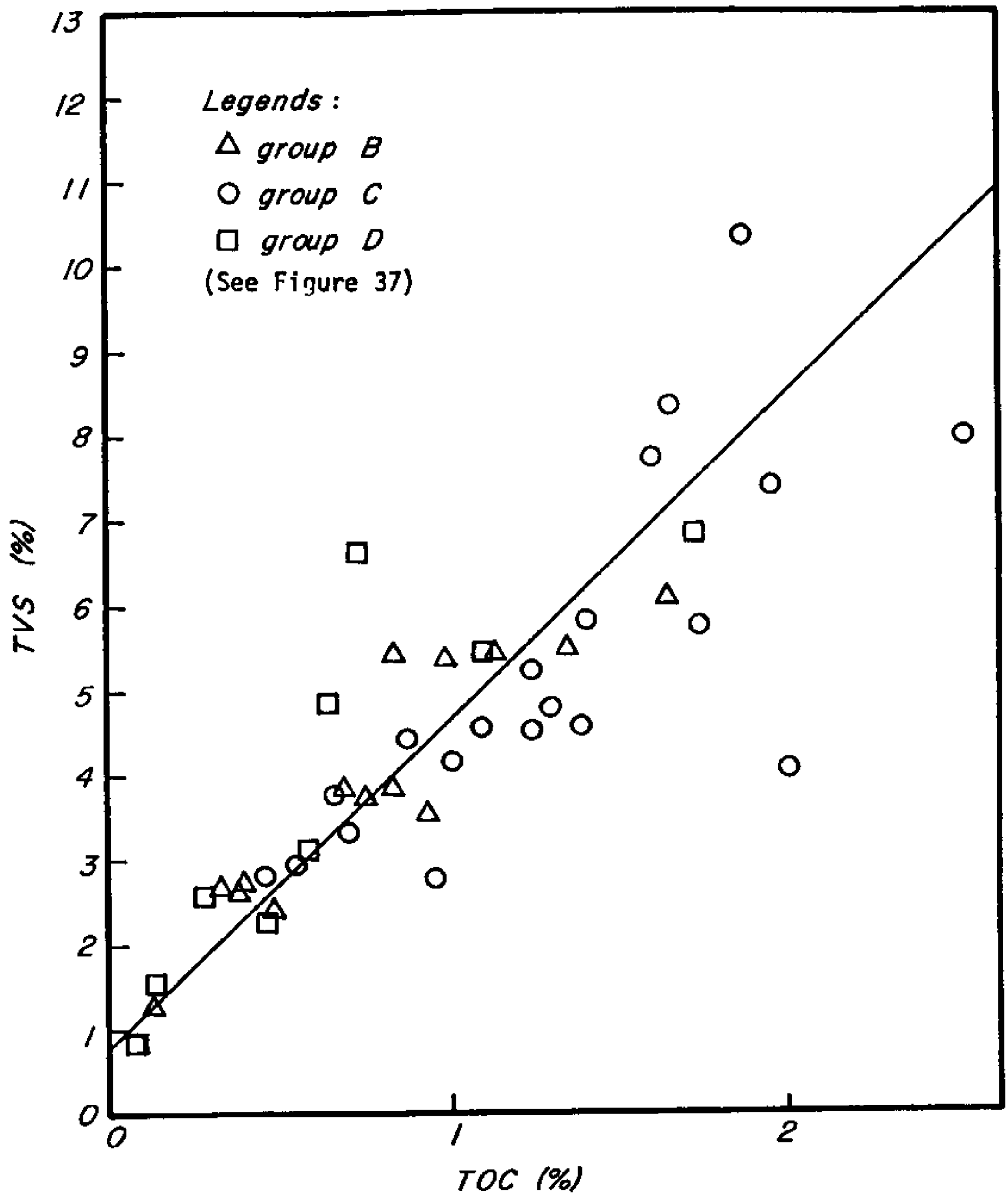


FIGURE 117

TOC vs. TVS in the Surface Sediments of L.A. - L.B. Harbors

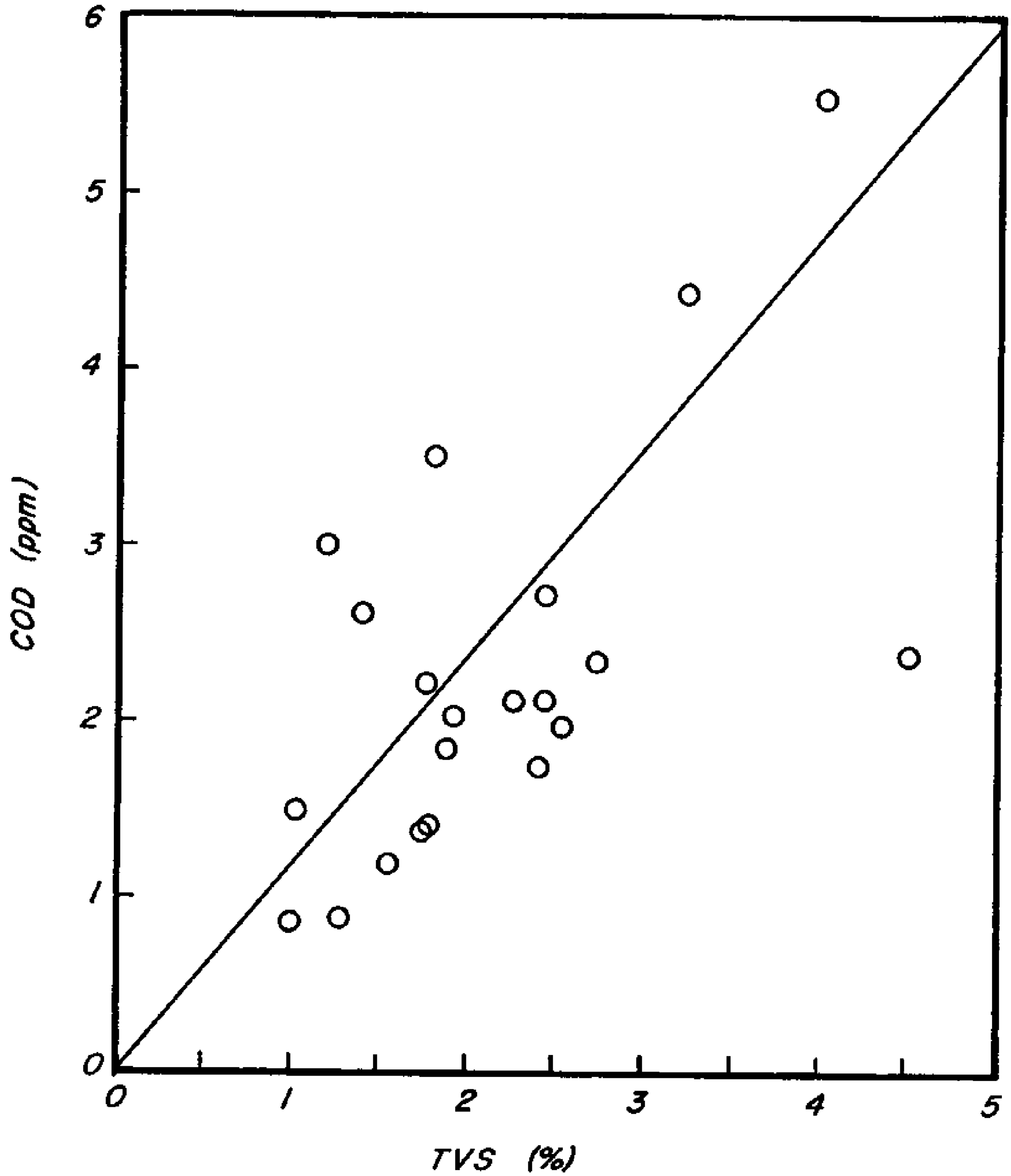


FIGURE 118

TVS vs. COD in the Surface Sediments of San Pedro Basin

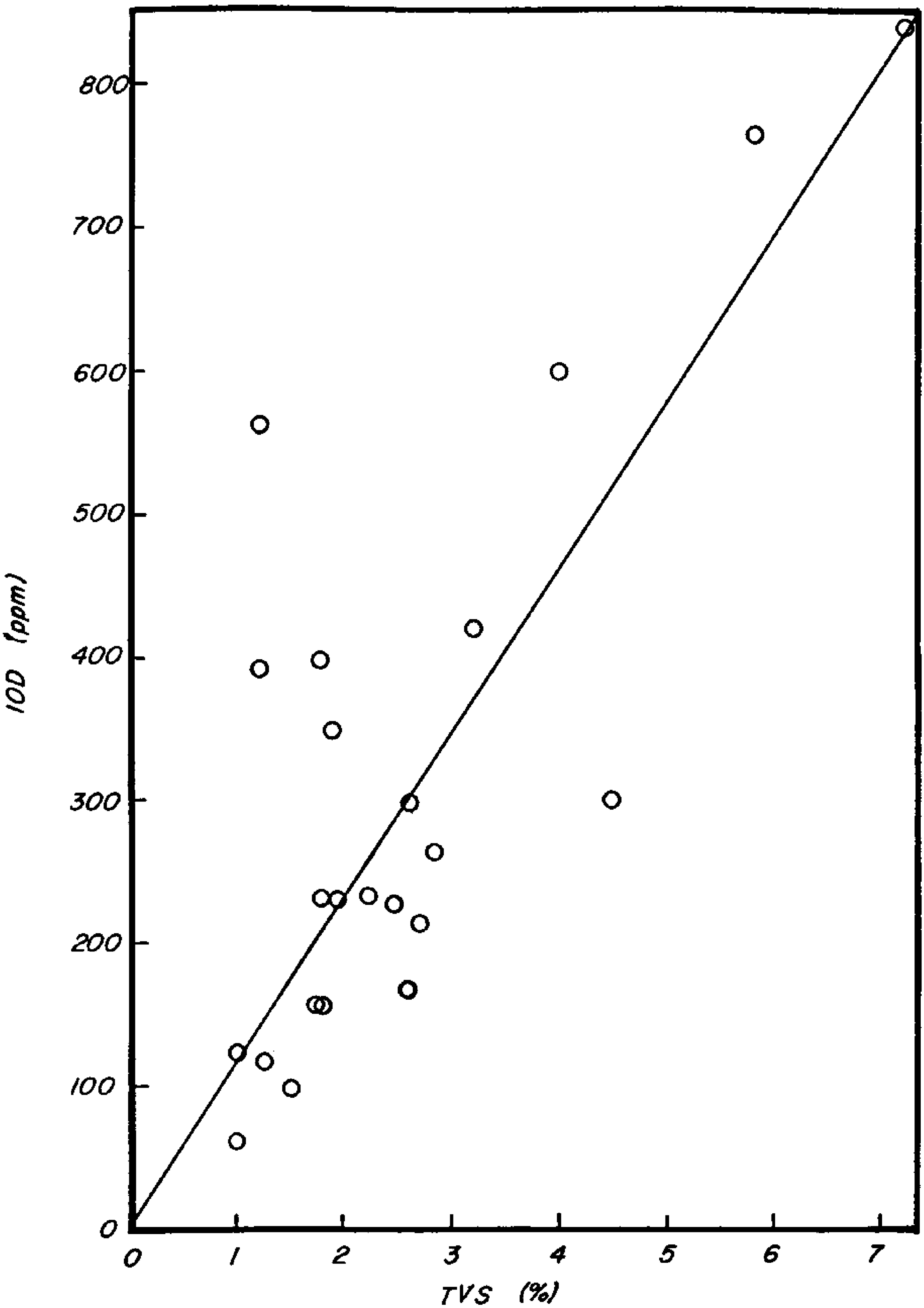


FIGURE 119: TVS vs. IOD in the Surface Sediments of San Pedro Basin

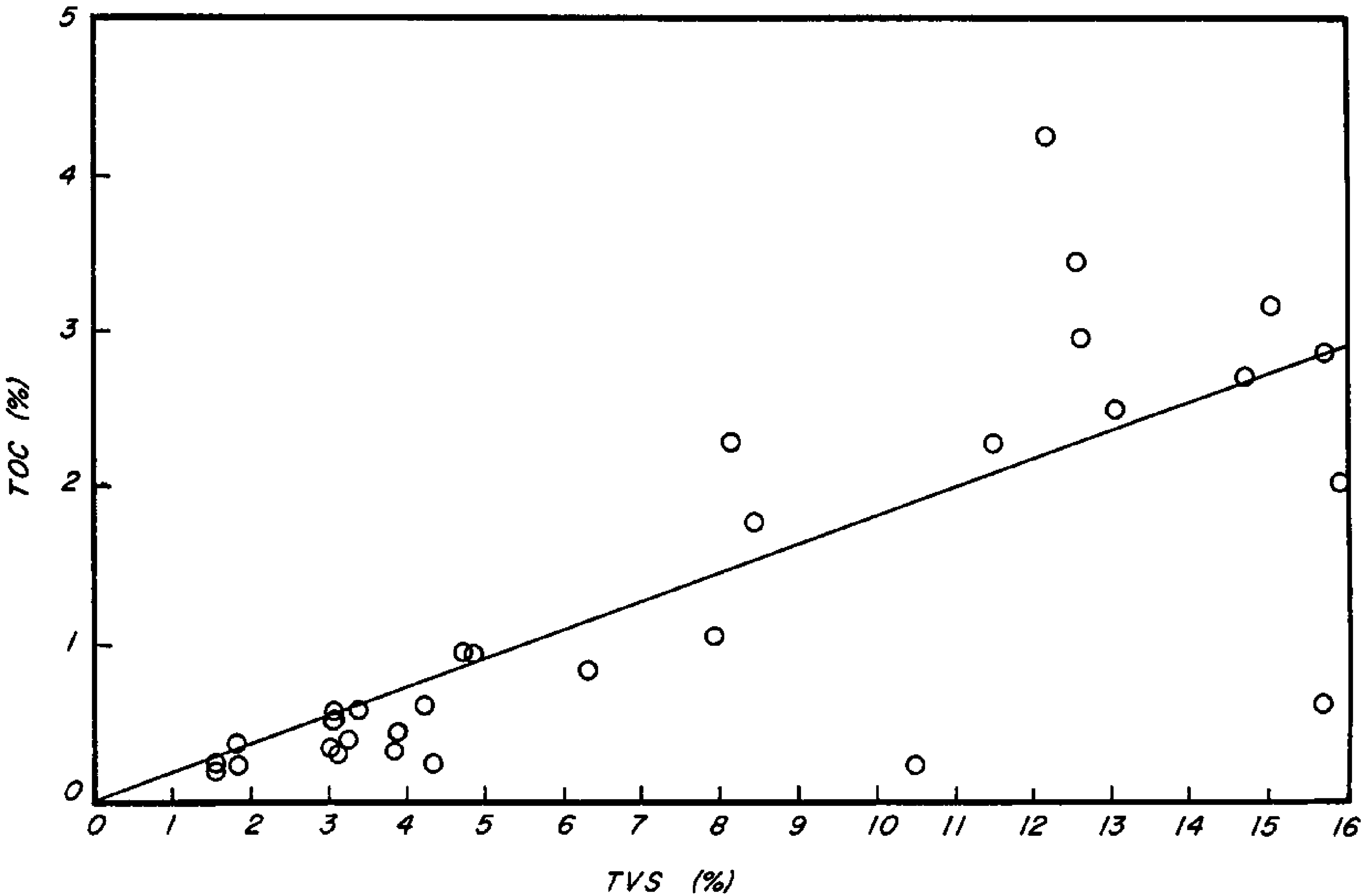


FIGURE 120

TVS vs. TOC in the Surface Sediments of San Pedro Basin

TABLE 2

GENERAL CHARACTERISTICS OF SEDIMENTS IN THE LOS ANGELES HARBOR
(mg/kg dry wt. except for % columns)

Station	Collection Date	MC%	DM%	COD	TOC%*	TVS%*	IOD	Oil & Grease	Kjeldahl N	Organic N	Total P	$\Sigma S^=$
A1	10/20/73	27.0	73.0	23400	0.855	3.70	276	784	73.1	73.1	926	159
A2	"	48.6	51.4	48700	1.629	7.23	398	1373	208.3	208.3	1120	303
A3	"	34.1	65.9	17500	0.329	2.69	286	437	138.7	138.7	818	59
A4	"	49.7	50.3	40400	1.523	5.14	927	1283	400.8	400.8	1666	111
A5	"	54.9	45.1	55800	1.824	6.60	620	1165	193.3	193.3	1260	270
A6	"	53.5	46.5	55500	2.334	6.13	785	2998	616.4	566.8	2253	384
A7	"	36.6	63.4	24400	0.882	3.40	445	1136	215.0	184.3	1453	156
A8	"	51.5	48.5	49400	2.026	7.18	834	1145	356.7	356.7	834	244
A9	"	58.7	41.3	81100	1.406	9.89	1007	1113	457.7	457.7	1592	150
A10	"	50.1	49.9	73600	2.864	8.12	639	582	406.1	406.1	1616	393
A11	"	31.1	68.9	17600	0.534	3.16	410	898	176.0	176.0	1400	84
A12	"	36.2	63.8	21400	0.666	3.34	435	443	214.2	214.2	1417	76

MC% -- moisture content   * % dry weight

TABLE 2, Continued

Station	Collection Date	MC%	DM%	COD	TOC %	TVS %	IOD	Oil & Grease	Kjeldahl N	Organic N	Total P	$\Sigma S^=$
B1	10/14	23.88	76.12	1178	0.219	1.26	89	505	125.4	83.6	989	72
	11/14	22.34	77.66	15100	0.269	2.40	114	630	121.7	118.9	1020	85
B2	10/10	45.84	54.16	30800	1.126	3.78	348	992	586.5	533.9	1580	349
	11/14	43.38	56.62	26400	1.053	5.45	595	5185	365.9	303.2	1309	225
B3	10/10	50.38	49.62	33100	0.784	5.39	763	1296	369.7	333.5	1287	517
	10/14	39.36	60.64	35200	0.793	3.82	721	1101	317.0	303.5	1517	590
B5	10/10	49.14	50.86	61100	1.617	6.08	1003	1571	427.1	340.9	790	1616
	11/14	29.34	70.66	15260	0.773	2.69	359	1841	283.5	242.6	1532	222
B6	10/10	41.70	58.30	69900	1.143	5.43	737	2108	717.1	692.8	1472	1130
	11/14	45.45	54.55	41300	1.359	5.49	954	2423	348.0	300.4	1617	582
	11/21	45.74	54.26	80300	1.584	6.85	1067	2758	308.0	274.6	1297	1311
B7	10/10	32.77	67.23	51600	0.342	2.67	516	690	246.3	163.2	1108	86
B8	10/10	28.92	71.08	17520	0.400	2.72	261	3890	305.0	287.7	995	241
	11/14	44.01	55.99	23750	0.940	3.53	711	1510	443.0	378.2	1892	364
B9	11/14	43.38	56.62	27600	0.829	3.86	995	1882	323.7	250.6	1236	239

TABLE 2, Continued

Station	Collection Date	MC%	DM%	COD	TOC %	TVS %	IOD	Oil & Grease	Kjeldahl N	Organic N	Total P	$\Sigma S^{=}$
C1	10/17	42.25	57.75	47000	1.716	4.17	1013	3950	355.1	343.2	1198	452
	11/21	50.31	49.69	108300	1.661	8.34	1004	3626	386.2	326.0	1354	543
C2	10/17	42.73	57.27	30800	1.403	4.57	655	1896	312.4	274.4	1032	382
	11/21	38.56	61.44	84400	2.079	4.04	876	2221	762.2	760.8	1374	602
C3	10/17	35.77	64.23	40100	0.964	2.73	490	1424	446.9	357.5	1127	187
	11/21	31.21	68.79	36500	0.702	3.31	268	1262	254.5	178.3	1084	154
C4	10/17	44.39	55.61	31200	1.101	3.59	638	1702	397.8	359.1	1082	179
	11/21	26.46	73.54	27200	0.451	2.80	194	1117	116.3	115.0	1105	231
C5	10/17	49.14	50.86	23100	1.304	13.04	1345	2326	909.1	887.0	1467	1342
	11/21	45.02	54.98	52700	1.250	5.20	1322	2155	601.1	587.5	1426	1354
C6	10/17	35.54	64.46	16070	0.743	2.94	635	1291	388.7	381.0	1512	491
	11/21	44.06	55.94	26800	1.256	4.82	1026	5596	402.9	374.5	1402	789
C7	10/17	53.1	46.9	47400	1.746	5.78	1680	4910	530.5	451.0	1121	1854
	11/21	50.43	49.57	102200	1.952	7.40	1212	5120	644.2	617.0	1758	1227
C8	11/21	54.49	45.51	124000	1.931	7.74	1518	3780	973.9	961.0	1950	1518
C9	10/17	47.02	52.98	34500	1.407	5.81	1394	3361	913.5	894.4	1430	653
	11/21	40.25	59.75	63000	1.104	4.53	587	2215	322.8	305.1	1585	580

TABLE 2, Continued

Station	Collection Date	MC%	DM%	COD	TOC %	TVS %	IOD	Oil & Grease	Kjeldahl N	Organic N	Total P	$\Sigma S^{=}$
C10	10/17	37.34	62.66	48470	1.084	3.76	518	2086	555.9	543.3	1338	415
	11/21	41.04	58.96	55040	0.946	4.43	689	2215	516.9	503.5	1962	361
	10/17	48.41	51.59	143210	2.527	8.00	1898	6401	1530.3	1377.3	1056	2770
	11/21	54.43	45.57	159270	1.864	10.39	3125	5500	797.5	720.5	1165	4655
D1	10/31	44.10	55.9	46410	0.740	6.62	1310	2466	727.5	534.9	1158	353
D2	10/31	47.66	52.43	67780	1.441	12.22	1883	3173	837.4	835.5	1112	1677
D3	10/31	51.57	48.43	73990	1.728	6.86	2302	4091	824.7	715.3	1182	1876
D4	10/10	48.04	51.96	55660	0.553	5.44	973	1793	1428.5	1364.5	1228	708
	10/31	37.46	62.54	17670	0.797	2.26	712	1325	288.7	288.7	1405	314
D5	10/31	27.50	72.50	7290	0.099	0.82	96	658	107.3	69.3	1134	231
D7	10/31	42.94	57.06	41300	0.637	4.86	892	1028	723.5	692.9	2480	510
	11/14	35.79	64.21	46170	0.587	3.10	489	1210	338.6	298.4	1715	126
D8	10/31	28.86	71.14	17850	0.299	2.59	304	639	225.6	187.7	1345	137
D9	10/31	25.95	74.05	16510	0.139	1.54	168	532	153.6	140.0	2301	141

TABLE 2, Continued

Station	Collection Date	MC%	DM%	COD	TOC %	TVS%	IOD	Oil & Grease	Kjeldahl N	Organic N	Total P	$\Sigma S^{=}$
K1	5/22/73	48.7	51.3	66200	1.036	6.45	603	4110	1510	1510.0	1229.5	1081
K2-A	6/29	40.7	59.3	51600	1.832	3.97	809	8300	1780	1780.0	448.0	223
K2-B	"	50.6	49.4	88700	2.739	5.36	1386	6720	2470	2470.0	543.2	1739
K2-C	"	42.3	57.7	54800	1.314	5.11	1141	4090	917	911.0	442.6	1453
K3-A	12/7	47.1	52.9	51340	1.224	3.60	1120	744	785.2	773.8	1087.0	494
K3-B	"	49.2	50.0	52330	1.064	3.52	790	1410	847.3	821.6	1279.0	354
K3-C	"	49.5	50.5	54310	1.267	3.78	870	961	528.5	496.7	1235.0	519
K3-D	"	41.9	58.1	42330	1.596	3.15	590	777	604.5	549.2	991.0	515
K3-E	"	41.8	58.2	31200	1.186	3.37	1060	1090	434.2	385.5	922.0	940
K4-A	5/31	38.2	61.8	49500	1.186	4.61	464	3765	1088	1078.0	669.0	228
K4-B	"	31.8	68.2	35950	0.997	3.49	310	2075	730.5	676.5	622.0	59
K4-C	"	31.5	68.5	32200	0.781	2.73	368	3340	952.5	952.5	775.0	156
K5-A	9/25	9.9	90.1	6023	0.175	1.21	114	557.2	76.2	65.2	506.0	28
K5-B	"	8.1	91.9	4950	0.189	1.07	104	172.4	76.6	64.6	543.0	29
K5-C	"	6.6	93.4	2342	0.159	0.89	92	153.1	46.6	40.6	444.0	24

TABLE 3

TRACE METALS IN THE SEDIMENTS OF LOS ANGELES HARBOR
(mg/kg dry weight)

Station	Collection Date	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
A1	10/20/73	9.80	1.81	28.4	26.9	16880	0.461	22.0	56.3	63.6
A2	"	8.76	5.23	88.9	147.1	44250	0.371	39.2	121.0	190.9
A3	"	3.70	0.70	14.0	17.8	12410	0.222	24.8	35.1	42.1
A4	"	6.32	3.52	53.5	94.2	28250	1.248	36.4	103.3	188.3
A5	"	5.25	1.86	37.2	78.2	24870	1.658	33.5	89.3	163.8
A6	"	6.80	2.67	49.5	693.1	18660	2.547	34.3	153.1	294.8
A7	"	4.70	1.76	14.1	29.2	11340	0.761	22.7	50.4	68.0
A8	"	9.75	5.58	82.6	146.4	43480	0.796	51.5	163.0	227.5
A9	"	12.02	4.04	145.9	339.0	31550	1.002	63.1	141.6	222.5
A10	"	3.24	4.76	74.8	251.1	36400	0.562	59.6	96.0	241.6
A11	"	4.25	1.62	37.0	61.4	29560	0.331	32.3	69.3	121.5
A12	"	3.80	1.09	48.4	49.4	31640	0.250	34.6	74.2	116.2

TABLE 3, Continued

Station	Collection Date	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
B1	10/14	2.79	1.41	28.2	132.3	10420	0.079	22.5	45.0	13.5
	11/14	3.05	1.13	31.1	135.0	11310	0.122	22.6	47.6	50.9
B2	10/10	6.99	2.63	52.6	61.3	51270	0.460	69.2	105.2	168.3
	11/14	9.46	2.85	64.1	85.5	38060	0.244	46.3	89.0	137.6
B3	10/10	10.92	3.34	68.6	76.3	56240	0.381	60.1	114.4	176.4
	10/14	9.08	3.06	76.6	61.3	29480	0.692	45.9	103.6	118.7
B5	10/10	13.88	3.93	98.2	98.2	43550	0.834	64.1	111.0	251.9
	11/14	14.95	3.24	36.7	32.4	18720	0.399	32.4	72.0	104.4
B6	10/10	14.16	4.89	185.1	199.7	34070	1.479	57.1	146.7	501.2
	11/14	19.43	3.53	97.0	185.2	31310	1.619	45.0	105.8	498.4
6B	11/21	28.83	4.85	40.42	861.0	39210	9.441	50.9	161.7	561.8
B7	10/10	7.76	2.75	48.1	96.2	19710	0.527	33.0	54.9	106.5
B8	10/10	3.45	2.01	66.8	33.4	32350	0.228	36.8	66.8	103.6
	11/14	3.97	4.27	76.9	68.4	31450	0.436	44.4	51.3	111.1
B9	11/14	12.24	4.49	85.8	76.8	34720	1.445	49.0	81.7	118.5

TABLE 3, Continued

Station	Collection Date	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
C1	10/17	10.3	3.99	79.8	103.8	23140	1.196	39.9	87.8	183.6
	11/21	10.3	3.81	76.3	147.2	30130	1.036	45.8	57.2	196.4
C2	10/17	12.09	6.61	82.6	96.4	25480	1.033	48.2	179.1	176.3
	11/21	11/11	3.56	64.8	82.3	18590	1.178	35.6	255.8	159.3
C3	10/17	6.25	2.98	89.5	68.6	19390	0.784	38.8	74.6	143.2
	11/21	7.11	2.73	82.3	60.6	19540	0.742	30.0	50.8	130.1
C4	10/17	10.93	3.34	83.5	87.7	25900	1.402	33.4	101.9	143.7
	11/21	3.45	2.98	47.7	39.7	17870	0.481	35.1	69.5	86.0
C5	10/17	2.32	4.56	149.9	143.9	30770	0.745	81.1	141.8	291.9
	11/21	2.13	5.32	130.1	111.8	32240	0.878	85.1	111.8	245.9
C6	10/17	11.0	6.86	83.9	62.5	19070	0.62	36.6	99.2	125.9
	11/21	6.18	6.19	168.0	110.5	30950	1.447	49.5	123.8	222.8
C7	10/17	18.24	3.49	132.1	185.0	23780	1.131	47.6	137.4	243.1
	11/21	12.51	4.82	236.3	274.1	33080	2.919	43.5	193.8	196.6
C8	10/17	13.22	4.85	315.5	236.7	37620	1.771	72.8	182.0	364.1
	11/21	20.90	5.71	214.3	171.4	28380	2.619	66.7	142.9	272.4
C9	10/17	19.22	3.84	191.8	131.1	29730	1.350	47.3	108.7	201.4
	11/21	16.41	3.21	156.5	93.2	25620	0.648	39.6	124.2	218.9

TABLE 3, Continued

Station	Collection Date	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
C10	10/17	11.46	3.33	83.3	53.3	22670	1.098	33.3	73.3	84.7
	11/21	8.03	2.45	77.0	57.2	26960	0.937	37.1	78.4	173.0
C11	10/17	5.61	7.18	358.9	179.4	29900	0.712	59.0	334.9	386.0
	11/21	29.43	9.85	361.1	322.8	32820	1.522	72.2	656.5	1914.7
D1	10/31	2.22	3.47	81.5	54.6	32410	0.232	47.7	97.1	137.7
D2	10/31	11.53	4.74	75.3	65.1	29830	0.150	53.9	325.3	230.5
D3	10/31	7.42	5.54	55.4	73.8	38470	0.387	62.7	424.4	317.3
D4	10/10	13.99	2.96	59.2	83.9	38010	0.769	44.4	88.8	148.1
	10/31	12.39	3.63	50.9	34.9	22450	0.162	35.6	69.7	78.1
D5	10/31	0.102	1.87	33.5	12.0	15060	0.395	23.4	73.6	50.2
D7	10/31	4.50	1.75	26.2	26.2	25350	0.190	35.8	78.7	80.4
	11/14	11.49	3.31	91.4	74.0	34380	0.576	56.6	78.3	165.4
D8	10/31	3.28	2.30	26.6	17.3	17980	0.160	27.3	46.6	70.6
D9	10/31	0.04	2.27	16.2	13.6	14560	0.064	23.9	51.1	51.1

TABLE 3, Continued

Station	Collection Date	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
K1	5/22	8.62	1.95	87.7	146.0	43500	1.283	53.2	191.5	289.0
K2-A	6/29	3.25	3.21	91.63	148.9	41410	1.810	46.96	196.4	252.0
K2-B	"	8.89	3.80	65.68	226.0	44940	3.001	47.71	207.4	283.5
K2-C	"	7.65	3.16	48.29	134.1	34160	1.178	37.56	143.1	184.8
K3-A	12/7	11.26	2.83	98.9	93.2	31630	0.849	39.5	203.4	178.0
K3-B	"	11.11	1.93	99.5	62.2	40420	0.961	31.1	152.4	121.3
K3-C	"	8.09	3.91	114.6	151.1	31270	1.155	46.9	216.2	224.1
K3-D	"	7.14	4.85	112.1	142.4	32120	1.397	51.5	363.6	342.2
K3-E	"	11.73	3.11	95.9	121.9	22300	1.933	38.1	274.9	437.2
K4-A	5/31	4.51	1.30	62.4	88.4	22747	0.999	32.42	111.8	286.0
K4-B	"	2.50	0.98	42.3	43.4	16705	0.509	12.3	56.2	97.4
K4-C	"	3.21	1.06	57.8	32.9	12630	0.484	10.06	39.1	68.7
K5-A	9/25	2.16	1.38	13.79	16.55	7241	0.0567	17.93	39.65	36.5
K5-B	"	2.12	1.01	10.0	14.48	5050	0.0641	10.10	47.13	28.3
K5-C	"	2.03	0.68	6.83	10.24	4778	0.0108	9.22	17.06	13.6

TABLE 4

(mg/kg dry weight) CHLORINATED HYDROCARBONS IN THE SEDIMENTS OF LOS ANGELES HARBOR

Station	Collection Date	p,p' DDE	o,p' DDE	p,p' DDD	o,p' DDT	p,p' DDT	Total DDT	PCB 1254	PCB 1260	PCB 1242	Total PCB's	Di-eldrin	Heptachlor-Epoxide
A1	10/20/73	0.325	0.066	0.055	0.009	0.022	0.478	0.068	0.006	0.295	0.371	--	--
A2	"	0.1232	0.228	0.186	0.025	0.077	1.750	0.323	0.32	0.635	0.991	--	--
A3	"	0.126	0.016	0.014	--	--	0.156	0.075	0.007	0.337	0.419	--	--
A4	"	0.301	0.033	0.053	0.005	0.014	0.403	0.277	0.027	0.629	0.935	--	--
A5	"	0.516	0.054	0.064	--	--	0.636	0.267	0.026	0.629	0.923	--	--
A6	"	0.347	0.060	0.071	0.002	0.014	0.497	0.491	0.048	0.652	1.192	--	--
A7	"	0.87	0.010	0.040	--	--	0.138	0.110	0.010	0.138	0.409	--	--
A8	"	0.575	0.112	0.107	0.013	0.029	0.838	0.357	0.035	0.553	0.947	--	--
A9	"	0.711	0.159	0.162	--	--	1.033	0.305	0.030	0.734	1.070	--	--
A10	"	0.279	0.074	0.101	--	--	0.454	0.175	0.017	0.304	0.496	--	--
A11	"	0.74	0.005	0.033	0.003	0.017	0.134	0.045	0.212	0.212	0.471	0.000766	--
A12	"	0.274	0.051	0.039	0.002	0.006	0.375	0.129	0.135	0.013	0.277	--	--

TABLE 4, Continued

Station	Collection Date	p,p' DDE	o,p' DDE	p,p' DDD	o,p' DDT	p,p' DDT	Total DDT	PCB 1254	PCB 1260	PCB 1242	Total PCB's	Di-eldrin	Heptachlor-Epoxide
B1	10/14	0.0687	0.0118	0.0146	--	--	0.0951	0.037	0.003	0.023	0.063	--	--
	11/14	0.1303	0.0225	0.0296	--	--	0.1824	0.055	0.005	0.035	0.095	--	--
B2	10/10	0.0416	0.0082	0.0153	--	--	0.0651	0.055	0.005	0.16	0.22	--	--
	11/14	0.0811	0.0127	0.0304	--	--	0.1242	0.150	0.01	0.06	0.17	--	--
B3	10/10	0.2487	0.1027	0.0616	--	--	0.4130	0.14	0.07	0.29	0.50	--	--
	10/14	0.1786	0.0403	0.0851	--	--	0.3040	0.17	0.02	0.22	0.41	--	--
B5	10/10	0.1772	0.0284	0.0740	--	--	0.2796	0.20	0.14	0.29	0.63	--	--
	11/14	0.0400	0.0069	0.0185	--	--	0.0654	0.08	0.05	0.05	0.18	--	--
B6	10/10	0.1402	0.0112	0.0990	--	--	0.2504	0.54	0.21	0.50	1.25	--	--
	11/14	0.1382	0.0355	0.1057	--	0.15	0.4294	0.56	0.17	0.30	1.03	0.0031	--
	11/21	0.2521	0.0506	0.3138	--	--	0.6165	1.28	0.19	0.56	2.03	0.0034	--
B7	10/10	0.0380	0.0048	0.0181	--	--	0.0609	0.08	0.005	0.14	0.225	--	--
B8	10/10	0.0807	0.0113	0.0166	--	--	0.1086	0.05	0.01	0.15	0.21	--	--
	11/14	0.1972	0.0381	0.0516	--	--	0.2869	0.18	0.03	0.09	0.30	--	--
B9	11/14	0.1744	0.0363	0.0570	--	0.071	0.3387	0.15	0.05	0.10	0.30	0.0023	--

TABLE 4, Continued

Station	Collection Date	p,p' DDE	o,p' DDE	p,p' DDD	o,p' DDT	p,p' DDT	Total DDT	PCB 1254	PCB 1260	PCB 1242	Total PCB's	Di-eldrin	Heptachlor Epoxide
C1	10/17	0.4699	0.0891	0.1316	--	--	0.6906	0.6	0.06	0.13	0.79	0.0032	--
	11/21	0.6650	--	0.1673	--	0.1	0.9323	0.59	0.06	0.19	0.84	0.0061	0.003
C2	10/17	0.44	0.0310	0.1530	--	--	0.6420	0.95	0.11	0.11	1.17	0.0039	--
	11/21	0.3791	--	0.1722	--	0.172	0.7233	0.86	0.11	0.15	1.12	0.0539	0.0191
C3	10/17	0.1562	0.0287	0.0733	--	--	0.2582	0.45	0.07	0.17	0.69	0.0018	--
	11/21	0.0860	--	0.0445	--	--	0.1305	0.28	0.03	0.031	0.342	--	0.0015
C4	10/17	0.2197	0.1908	0.1090	--	--	0.3428	1.18	0.12	0.11	1.41	0.0021	--
	11/21	0.0510	--	0.0246	--	--	0.0756	0.23	0.023	0.033	0.286	--	--
C5	10/17	0.1125	--	0.1390	--	--	0.2515	0.50	0.40	0.24	1.14	0.0178	0.0333
	11/21	0.0552	0.0158	0.1100	0.0076	0.0291	0.2177	0.170	0.050	0.05	0.270	--	0.0330
C6	10/17	0.1024	--	0.0648	--	--	0.1672	1.00	0.14	0.12	1.26	0.0101	0.0035
	11/21	0.2368	0.0230	0.1462	--	--	0.4060	1.95	0.19	0.21	2.35	0.0057	--
C7	10/17	0.2360	--	0.3551	--	0.651	1.2421	1.30	0.14	0.33	1.77	0.0135	--
	11/21	0.2787	0.0360	0.2393	--	0.0800	0.6340	1.15	0.15	0.24	1.54	0.0082	--
C8	10/17	0.6686	--	0.4957	--	--	1.1643	1.40	0.11	0.44	1.95	0.0427	--
	11/21	0.6002	0.0350	0.2855	--	--	0.9207	0.90	0.14	0.35	1.39	0.0306	--
C9	10/17	0.2290	--	0.3470	--	--	0.5760	0.72	0.11	0.4	1.23	0.0062	0.0175
	11/21	0.1669	0.0250	0.3227	0.0060	0.2	0.7236	0.53	0.05	0.35	0.93	0.0112	--

TABLE 4, Continued

Station	Collection Date	p,p' DDE	o,p' DDE	p,p' DDD	o,p' DDT	p,p' DDT	Total DDT	PCB 1254	PCB 1260	PCB 1242	Total PCB's	Di-eldrin	Heptachlor Epoxide
C10	10/17	0.0712	--	0.0937	--	--	0.1649	0.34	0.07	0.13	0.54	0.038	0.0052
	11/21	0.1400	0.0340	0.1140	--	--	0.2887	0.43	0.10	0.15	0.68	0.0055	--
C11	11/21	0.5215	0.0970	1.3608	--	--	1.9785	1.60	0.30	1.30	3.20	0.0611	--
	11/21	0.5101	--	1.3810	--	1.05	2.9411	1.62	0.33	1.8	3.75	0.0565	0.0976
D1	10/31	0.2895	0.0313	0.0590	0.0025	0.0251	0.4074	0.214	0.021	0.096	0.331	--	--
D2	10/31	0.1081	0.0561	0.1318	--	0.0462	0.3422	0.51	0.1	0.723	1.33	0.0113	0.1055
D3	10/31	0.1987	0.1303	0.1363	--	0.0936	0.5589	1.05	0.1	1.54	1.69	--	0.1704
D4	10/10	0.1973	0.0459	0.0645	0.0073	0.0429	0.3578	0.17	0.05	0.075	0.295	--	--
	10/31	0.0369	0.0225	0.0352	--	0.0176	0.1122	0.176	0.018	0.187	0.381	0.0018	0.0132
D5	10/31	0.0040	--	--	--	--	0.0040	0.023	0.002	0.038	0.063	--	--
D7	10/31	0.1546	0.0319	0.0529	--	0.0117	0.2511	0.166	0.016	0.08	0.262	--	--
	11/14	0.0752	0.0148	0.0337	--	--	0.1237	0.13	0.013	0.057	0.200	--	--
D8	10/31	0.0560	0.0096	0.0171	--	--	0.0827	0.089	0.008	0.067	0.164	--	--
D9	10/31	0.0097	--	0.0097	--	--	0.0194	0.08	0.008	0.040	0.128	0.0024	0.0021

TABLE 4, Continued

Station	Collection Date	DDE	p,p' DDD	o,p' DDT	p,p' DDT	Total DDT	PCB 1254	PCB 1260	PCB 1242	Total PCB's	Di-eldrin	Heptachlor Epoxide
K1	5/22	0.208	0.116	--	--	0.324	1.605	0.170	--	--	--	--
K2-A	6/29	0.136	0.120	--	--	0.356	0.719	0.071	--	--	--	--
K2-B	"	0.0445	0.0291	--	0.0225	0.0961	0.1545	0.0155	--	--	--	--
K2-C	"	0.056	0.0413	--	0.0388	0.136	0.273	0.027	--	--	--	--
K3-A	12/7	0.17	0.08	--	--	0.25	1.11	0.11	--	--	0.00035	--
K3-B	"	0.18	0.10	0.05	0.02	0.35	1.20	0.11	--	--	0.00022	--
K3-C	"	0.21	0.09	--	--	0.30	1.25	0.12	--	--	0.00022	--
K3-D	"	0.19	0.07	--	--	0.26	4.13	0.62	--	--	0.00047	--
K3-E	"	0.14	0.09	--	--	0.23	1.30	0.30	--	--	0.00020	--
K4-A	5/31	0.37	0.111	--	--	0.481	0.51	0.05	--	--	--	--
K4-B	"	0.266	0.077	--	--	0.343	0.319	0.033	--	--	--	--
K4-C	5/31	0.267	0.07	0.013	0.066	0.377	0.498	0.05	--	--	--	--
K5-A	9/25	0.0077	0.0127	0.0085	0.022	0.051	--	--	0.1135	--	--	--
K5-B	9/25	0.0122	0.018	0.006	0.023	0.058	--	--	0.096	--	--	--
K5-C	9/25	0.0035	0.0056	0.0127	0.047	0.069	--	--	0.085	--	--	--

TABLE 5

GROUPING OF SURFACE SEDIMENTS BY RELATIVE INTENSITY OF CONTAMINATION

	Parameter / Station	Average Value (ppm, except TOC)									
		TOC %	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
1	C11	2.2	17.5	8.5	360	251	31000	1.12	66	496	1150
2	C7, C8, K2	1.9	11.4	4.1	147	193	35000	2.05	51	173	255
3	A9, A10	2.1	7.6	4.4	110	295	34000	0.78	61	119	232
4	A4, A5, A6, LNG 12	1.9	5.3	9.3	43	240	23000	1.52	36	113	213
5	D2, D3	1.6	9.5	5.1	65	69	34000	0.27	58	375	274
6	B5, B6	1.3	18.3	4.1	92	275	33000	1.08	50	119	384
7	C4, C5, C6, K1, K3	1.1	7.8	3.9	105	93	30000	1.09	48	171	220
8	C1,2,3,9,10;A8;K4	1.2	11.3	3.2	88	86	24000	0.91	36	104	168
9	A2,3,7,11,12;B2,3,8,9; D1; LNG's except 12	0.7	7.2	3.4	72	65	38000	0.51	50	89	133
10	B7;D4,5,7,8	0.5	7.6	2.6	51	41	25000	0.38	37	73	107

TABLE 6

GRAIN SIZE DISTRIBUTION ANALYSES OF SEDIMENT SAMPLES
FROM THE PROPOSED LNG ROUTE

[1]100% passed 80 sieve

[2]100% passed 30 sieve

BORING		1											
SAMPLE		1	2	3	4[1]	5	6	7	8	9	10	11	12
% PASSING SIEVE NO.	¼						100.0		100.0				
	4					100.0	98.5	100.0	98.6			100.0	100.0
	10					96.3	95.0	99.3	94.6	100.0		99.7	99.5
	20					88.0	74.7	97.0	76.9	98.6		99.0	99.4
	40		100.0			73.8	43.3	88.7	56.1	95.0	100.0	94.6	98.0
	60		99.2	100.0	100.0	66.7	34.7	80.1	49.0	90.3	97.9	88.8	87.7
	100	100.0	97.9	95.0	98.9	44.5	24.0	32.1	24.9	51.3	50.7	48.8	39.6
	200	97.5	89.5	70.0	93.5	11.7	9.2	4.1	4.1	3.6	3.5	6.2	8.0

Samples arranged according to core run and depth.

BORING		2							
SAMPLE		13	15	14	16	17	18	19	20
% PASSING SIEVE NO.	¼				100.0		100.0		
	4	100.0			98.2	100.0	95.8	100.0	100.0
	10	99.4	100.0		96.8	99.0	93.2	99.4	98.8
	20	99.4	98.8	100.0	95.4	97.9	91.6	98.8	98.2
	40	98.9	96.4	99.5	93.2	95.8	89.7	97.1	97.0
	60	96.9	94.0	93.4	86.8	78.8	84.4	89.2	88.7
	100	72.3	68.9	32.4	45.6	45.8	51.0	60.0	48.1
	200	17.7	31.8	4.6	9.8	5.7	9.6	11.3	13.0

TABLE 6, Continued

[1] 100% passed 80 sieve
[2] 100% passed 30 sieve

BORING		8				9			
SAMPLE		40	41	42[2]	43	45	46	47	48
% PASSING SIEVE NO.	1/4				100.0				
	4	100.0			99.0		100.0	100.0	
	10	99.1			98.1		99.6	99.6	
	20	96.9		100.0	96.9	100.0	97.6	97.5	
	40	91.4	100.0	99.6	95.6	93.6	91.5	91.4	100.0
	60	86.8	92.3	92.6	86.5	87.2	87.4	89.5	95.3
	100	65.4	42.8	36.0	57.5	61.2	56.0	62.3	57.2
	200	17.7	6.7	5.5	20.5	25.4	9.5	10.3	7.8

Samples arranged according to core run and depth.

BORING		10					
SAMPLE		49	50[2]	56	57	58[2]	59
% PASSING SIEVE NO.	1/4			100.0	100.0		
	4	100.0		96.3	99.3		100.0
	10	99.4		94.1	97.8		98.2
	20	98.9	100.0	92.5	95.2	100.0	97.5
	40	98.2	99.5	89.4	85.5	99.7	96.8
	60	91.9	92.9	84.2	64.5	96.5	94.8
	100	34.1	27.1	59.6	33.7	55.1	82.3
	200	7.2	3.3	6.9	4.0	5.3	61.5

TABLE 6, Continued

[1]100% passed 80 sieve
[2]100% passed 30 sieve

	BORING	3									4	5	
	SAMPLE	21	22	25	26	27	28	29	30	31	23	24	
% PASSING SIEVE NO.	¼			100.0			100.0		100.0				
	4	100.0		98.6	100.0		99.1	100.0	98.9	100.0			
	10	98.2	100.0	97.0	96.7		98.4	98.6	98.1	97.4	100.0		
	20	52.2	96.9	94.8	92.6		97.6	98.2	97.3	97.0	98.6	100.0	
	40	23.9	93.8	89.9	84.0	100.0	92.1	96.8	95.7	95.7	91.3	97.9	
	60	15.1	82.7	83.3	73.2	98.2	83.5	83.2	76.7	78.0	60.5	89.4	
	100	11.6	67.0	59.9	37.9	49.3	46.6	17.7	16.9	22.3	31.5	65.3	
	200	8.1	41.8	34.0	11.2	6.5	6.3	4.4	2.7	6.5	16.5	35.3	

Samples arranged according to core run and depth.

	BORING	6			7								
	SAMPLE	32	38	39	44	33	34	35	36	37			
% PASSING SIEVE NO.	¼	100.0				100.0							
	4	89.0	100.0		100.0	99.0	100.0						
	10	86.4	99.7		98.8	98.0	98.0	100.0					
	20	79.8	99.4	100.0	97.8	96.0	96.4	98.9					
	40	69.7	99.0	99.7	96.8	92.1	90.7	96.2	100.0	100.0			
	60	65.2	97.2	94.8	93.7	89.9	84.7	90.1	95.4	99.1			
	100	48.5	81.5	56.9	67.5	57.4	49.4	53.2	53.9	68.4			
	200	19.5	12.7	12.7	30.4	15.8	11.8	7.1	4.8	18.8			

TABLE 6, Continued

BORING		11						
SAMPLE		51	52	53[2]	54	55	60[2]	61
% PASSING SIEVE NO.	¼	100.0	100.0					
	4	98.1	97.6		100.0	100.0		100.0
	10	95.2	95.2		98.5	99.0		99.6
	20	91.5	93.0	100.0	98.0		100.0	99.3
	40	81.9	76.4	99.2	97.1	97.0	99.3	98.9
	60	67.1	43.3	96.8	91.3	78.8	95.5	95.9
	100	52.2	14.1	58.0	30.8	23.0	60.8	59.7
	200	37.0	3.5	5.0	7.7	6.6	5.3	7.1

Samples arranged according to core run and depth.

BORING		12							
SAMPLE		62	63	64	65	66	67	68	69[2]
% PASSING SIEVE NO.	¼			100.0					
	4			99.0	100.0	100.0			
	10			95.8	99.0	99.1	100.0	100.0	
	20			91.2	96.9	98.5	99.6	99.5	100.0
	40			81.4	91.4	93.9	98.7	99.0	99.3
	60			70.8	84.0	86.1	90.8	91.1	95.3
	100	100,0	100.0	47.2	39.9	32.9	43.0	39.1	60.3
	200	95.4	95.0	22.8	10.4	2.0	5.5	4.9	4.6

[1] 100% passed 80 sieve
[2] 100% passed 30 sieve

TABLE 6, Continued

	BORING	13							14			
	SAMPLE	70	71	72	73	74	75	109	76	77	78	79
% PASSING SIEVE NO.	1/4				100.0			100.0	100.0			
	4		100.0		98.7	100.0	100.0	99.3	99.5		100.0	100.0
	10	100.0	99.2	100.0	96.0	98.3	99.7	98.6	98.4		98.9	98.8
	20	98.4	98.3	99.3	91.5	93.7	96.9	98.1	94.2		93.3	94.5
	40	90.16	94.9	98.8	80.5	82.1	89.4	96.0	84.2	100.0	80.5	86.8
	60	85.4	91.5	91.5	69.4	74.1	82.5	80.6	79.0	97.2	76.9	78.4
	100	66.5	65.1	43.4	19.6	36.3	48.3	28.4	54.1	59.2	46.6	39.0
	200	28.1	9.5	5.3	3.6	3.5	5.1	2.0	13.6	4.4	5.2	12.5

Samples arranged according to core run and depth.

	BORING	15		16			17			
	SAMPLE	80	81	82	83	84	85	86	87	88
% PASSING SIEVE NO.	1/4	100.0			100.0				100.0	
	4	99.0			99.7				97.8	
	10	98.0	100.0		98.5		100.0		97.1	100.0
	20	95.4	99.4		89.7		99.5	100.0	96.4	98.4
	40	91.3	98.0		76.3	100.0	98.4	98.6	95.1	98.4
	60	83.5	67.8		69.6	98.6	96.4	96.3	90.7	95.1
	100	60.4	17.4	100.0	34.9	71.2	90.3	87.2	65.1	73.7
	200	32.9	4.0	94.3	6.8	5.4	46.3	37.2	6.4	6.2

TABLE 6, Continued

BORING		18				19					20		
SAMPLE		89	90	91	92	93	94	95	96	97	98	99	100
% PASSING SIEVE NO.	1/4	100.0	100.0		100.0	100.0							
	4	99.3	98.9	100.0	99.2	97.3		100.0				100.0	
	10	97.9	98.3	99.2	97.7	93.5		98.9		100.0		97.3	
	20	96.7	96.7	96.7	94.4	88.9		98.9		99.7		94.9	
	40	95.0	94.9	84.3	81.3	67.9	100.0	98.0			100.0	93.2	100.0
	60	92.2	92.6	76.4	75.3	32.4	99.0	79.1		91.7	94.2	89.6	98.9
	100	84.6	70.7	53.1	53.7	22.5	95.5	22.9	100.0	69.1	83.0	61.4	91.3
	200	43.8	4.4	6.3	8.2	13.5	86.0	8.5	98.5	46.8	61.4	15.1	60.9

Samples arranged according to core run and depth.

BORING		20		21						22	23		
SAMPLE		101	102	103	104	105	106	107	108	110	111		
% PASSING SIEVE NO.	1/4	100.0											
	4	99.5											
	10	96.7											
	20	93.4	100.0		100.0						100.0		
	40	91.5	90.3	100.0	98.5	100.0		100.0	100.0	100.0	96.6		
	60	88.5	94.2	98.1	95.9	99.2		96.5	97.9	95.7	88.6		
	100	82.0	84.9	92.3	85.4	96.7	100.0	76.0	91.5	80.5	65.2		
	200	72.0	72.5	76.0	68.6	86.2	96.0	46.6	61.9	63.5	53.4		

TABLE 7

GENERAL CHARACTERISTICS OF SURFACE SEDIMENTS (0-3')
FROM THE PROPOSED LNG ROUTE

Core No.	Sample No.	Moisture %	COD %	TOC %	TVS %	IOD ppm	Oil and Grease ppm	Total Organic Nitrogen ppm	Kjeldahl Nitrogen ppm	PO_4-P ppm	Sulfide ppm
1	1	30.9	1.40	0.63	1.81	157	5650	69.9	93.0	1014	138
2	15	26.4	1.96	0.532	2.56	214	2690	89.5	102.0	904	216
3	21	17.9	3.01	0.589	1.17	572	3350	173.0	173.0	313	985
4	23	24.4	2.09	0.482	2.26	233	2720	114.0	114.0	812	236
5	24	28.6	2.33	1.31	2.76	264	4100	120.0	120.0	1020	253
6	32	22.6	1.36	0.421	1.76	156	2050	74.7	74.7	861	151
7	33	24.4	1.16	0.472	1.58	94	1940	64.3	64.3	950	104
8	40	24.7	0.838	0.302	1.01	64	1700	48.0	48.0	808	72.8
9	45	26.2	2.04	0.253	1.93	230	3020	112.0	112.0	981	79.8
10	49	24.4	0.846	0.157	1.30	128	1850	33.1	33.1	647	49.1
11	51	22.4	1.83	0.288	1.89	350	2450	122.0	142.0	890	366
12	62	52.5	9.53	1.88	7.14	872	6000	669.0	1070.0	1600	1135
13	70	24.8	2.22	0.563	1.78	234	3850	122.0	122.0	1370	110
14	76	20.8	1.48	0.283	1.02	124	1400	51.5	51.5	890	37.3
15	80	26.0	2.67	0.820	2.44	299	2160	152.0	159.0	1222	438
16	82	26.1	1.73	0.30	2.41	167	1880	169.0	169.0	1250	185
17	85	27.4	2.38	0.912	4.53	302	1510	157.0	157.0	1805	108.5
18	89	27.0	2.16	0.877	2.46	229	2560	117.0	117.0	1658	201.2
19	93	25.3	2.64	0.470	1.38	394	1810	117.0	117.0	740	320
20	98	39.5	5.59	0.854	3.94	602	6100	192.0	192.0	1241	804
21	103	45.2	10.2	1.785	5.78	778	9400	251.0	292.0	1347	1189
22	110	33.3	3.52	0.54	1.76	396	1420	174.0	198.0	1106	458
23	111	31.7	4.45	0.625	3.20	421	2600	187.0	281.3	1220	744

TABLE 8

METAL CONTENTS OF SURFACE SEDIMENTS (0-3')
FROM THE PROPOSED LNG ROUTE

Core No.	Sample No.	Hg ppm	Pb ppm	Zn ppm	As ppm	Cd ppm	Ni ppm	Cu ppm	Fe ppm	Cr ppm
1	1	0.261	190	137	0.48	3.94	54.8	43.8	38000	109.5
2	15	0.294	26.8	77	0.312	1.22	21.2	28.4	21100	23.2
3	21	6.05	66.5	368	1.53	1.71	15.2	78	14450	59
4	23	0.16	41.8	57.5	1.02	2.09	25.1	22.6	17150	41.8
5	24	0.183	49.5	77.7	0.778	2.03	31.5	24.8	29050	49.5
6	32	0.120	19.3	56.7	1.12	1.29	14.2	41.3	15460	35.1
7	33	0.100	36.7	50.8	0.98	1.41	21.2	18.35	18050	39.6
8	40	0.042	16.2	47.7	0.77	0.88	13.7	6.45	13800	30.9
9	45	0.182	36.7	47.8	0.70	0.96	17.3	18.2	18220	24.3
10	49	0.132	19.4	35.6	0.63	0.86	14.6	10.7	11970	13.9
11	51	0.286	50.9	68.9	0.82	1.71	23.1	29.3	14680	25.2
12	62	0.61	107	205	2.86	29.0	38.1	95.1	18700	33.3
13	70	0.26	38.2	81.2	0.59	1.273	13.7	30.5	18450	20.1
14	76	0.04	13.9	34.6	0.55	0.55	11.1	6.93	11210	8.3
15	80	1.23	57.0	96.8	0.99	1.73	26.6	36.0	25950	37.0
16	82	0.259	58.8	113.6	1.27	1.85	42.4	28.9	31600	47.6
17	85	0.213	55.0	108.7	0.99	1.59	32.1	33.6	28100	29.9
18	89	0.170	54.6	89.9	0.55	1.99	32.4	22.5	28100	32.0
19	93	0.727	95.2	134.8	1.70	1.435	27.0	58.6	21300	57.8
20	98	1.334	173.3	279.5	1.22	3.64	53.1	185	39400	156.5
21	103	1.723	215.4	326.5	4.88	5.07	79.92	157	47990	178
22	110	0.522	85.1	106.3	1.95	2.13	55.3	44.7	29800	64.8
23	111	1.304	133.7	180	3.86	3.48	58.1	107.4	28430	92

TABLE 9

CHLORINATED HYDROCARBONS IN SURFACE SEDIMENTS (0-3')
FROM THE PROPOSED LNG ROUTE

Core No.	Sample No.	PCB (ppm)			ORGANOCHLORINE PESTICIDES (ppm)					
		Aroclor 1242	Aroclor 1254	Aroclor 1260	DDE	DDD	O.P[1] DDT	P.P[1] DDT	Chlordane	Dieldrin
1	1	-	-	-	0.0573	0.0122	-	-	-	-
2	15	-	-	-	0.1316	0.0125	-	-	-	-
3	21	-	0.520	0.465	0.0444	-	-	-	-	-
4	23	-	0.1991	-	0.6248	0.1005	0.0168	0.0506	-	-
5	24	-	0.139	-	0.7062	0.1190	0.0189	0.089	-	-
6	32	-	0.0514	-	0.3181	0.0340	0.0069	0.0196	-	-
7	33	-	0.0360	-	0.1439	0.0122	0.0001	0.0033	-	-
8	40	-	-	-	0.0322	0.0037	-	-	-	-
9	45	-	0.1160	-	0.3436	0.0515	-	-	-	-
10	49	-	0.0262	-	0.0311	0.0054	-	-	-	-
11	51	-	0.1435	-	0.1083	0.0230	-	-	-	-
12	62	-	0.594	-	0.596	0.193	-	-	-	-
13	70	-	0.0707	-	0.0790	0.0185	-	-	-	-
14	76	-	-	-	0.0868	0.0123	0.0125	0.033	-	-
15	80	-	0.121	0.0225	0.1008	0.0210	-	-	-	-
16	82	-	-	0.0160	0.0179	0.0057	-	-	-	-
17	85	-	-	0.0600	0.0704	0.0213	-	-	-	-
18	89	-	-	0.0200	0.0404	0.0123	-	-	-	-
19	93	-	-	0.069	-	-	-	-	-	-
20	98	-	-	0.1345	0.0362	0.1225	-	-	0.0597	-
21	103	-	-	0.2270	0.0512	0.1455	-	-	0.1270	0.0041
22	110	-	0.21	0.0136	0.155	0.040	-	-	-	0.0009
23	111	-	0.91	0.091	0.224	0.0932	-	-	-	0.0020